An analysis of the Transactive Memory System construct and corresponding empirical research from a multi-level perspective

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Volker Peter Wagner

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Prüfungskommission:

Vorsitzender: Prof. Dr. Markus Nöth

Erstgutachterin: Prof. Dr. Dorothea Alewell

Zweitgutachter: Prof. Dr. Rick Vogel

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cmc	computer-mediated-communication
ftf	face-to-face
e.g.	exempli gratia (example given)
et al.	et alii (and others)
HRM	Human Resource Management
ibid.	ibidem (in the same place)
IMOI	Input Mediator Output Input
I-P-O	Input-Process-Output
IT	Information technology
SMM	Shared Mental Model
TM	Transactive Memory
TMM	Team Mental Model
TMS	Transactive Memory System

1 Introduction

The importance of managing knowledge in an organization is regarded as one of the most critical organizational challenges of our time (Nonaka 1994; Nonaka, Takeuchi 1995; Schreyögg, Geiger 2003; Salas, Fiore 2004b). Organizations must be able to quickly adapt to ever faster changing environments and to develop the dynamic capabilities to transform and utilize their knowledge-based resources in order to gain a lasting competitive advantage and to survive (Argote, Ren 2012; Vogel, Güttel 2013). However, the question of how these knowledge-based resources are utilized by members of an organization is still not thoroughly answered by research (Salas 2005). One answer that is applied in actual organizational contexts is to use teams consisting of individuals to cope with the increased cognitive workload interdependently and to find solutions to existing and prospective problems by combining and integrating existing and novel knowledge-based resources within the organization (Salas et al. 2008; Goodwin et al. 2009). According to this perspective, knowledge embedded within human minds is seen as the basic unit of organizational analysis and the "most important source of their international competitiveness" (Nonaka, Takeuchi 1995, p. viii).

While there is much research and an underlying understanding of the individual team member characteristics and their influence on the efficiency and effectiveness on the exchange and coordination within teamwork (Mount et al. 1998), research still lacks behind regarding the actual development and functioning of cognitive structures at the individual- and team-levels (Salas, Fiore 2004b; Cleveland, Murphy 2012). Of particular interest here is how these expertise structures shape and develop based on the organizational context and team composition, and how these structures influence the interactive processes that are assumed to influence team performance in problem-solving, decision-making, or product-development tasks. In team research, it is proposed that "to accomplish the common goal of solving the problem, each team member has to behave or act in a way that supports the functioning of the team" (Hung 2013, p. 372). If we could get an insight into this behavior and actual cognitive structures and processes within a team, we can infer further valuable answers and propositions as to how training and development, staffing, or task structuring within organizations can influence the effectiveness of knowledge-worker teams.

1.1 Research problem and objective

One central research field that combines and organizes theories related to these knowledge-based structures and processes at the individual- and team-levels is the field of Team

Cognition, which aims to explain "how teams respond to complex challenges that require the skills and inputs of multiple members" (Cleveland et al. 2012, p. xiii). In this research field, researchers are concerned with the prediction and understanding of cognitive activities of teams (Cooke et al. 2009, p. 157) and the influence of shared cognitive processes on team performance (Salas et al. 2012a, p. 3). Within this context, there is one explicit theory in which both the cognitive structures and interactive and coordinative processes of cognitive teamwork are supposedly explained and utilized, especially with regard to the use of teams for the cognitive division of labor and the knowledge differentiation that is proposed to be necessary for a team to provide a contribution to novel and complex tasks. This particular theory is called Transactive Memory System (TMS) theory (Wegner et al. 1985). While a multitude of other theoretical approaches to Team Cognition are currently discussed (for an overview, see Salas et al. 2012b), it is argued throughout the course of this work that TMS theory is unique in its approach of integrating both static (cognitive structures) and dynamic (processes) perspectives of Team Cognition (as will be further discussed in section 2.1). The core of the TMS concept is based on the assumption that teams develop a system for group information processing that offers utility beyond the apparent value of their division of labor (Wegner et al. 1985). On this account, a TMS as the representation of or metaphor for this system is defined in terms of two separate but connected components: "(1) an organized store of knowledge that is contained entirely in the individual memory systems of the group members, and (2) a set of knowledge-relevant transactive processes that occur among group members" (ibid., p. 256).

While originally developed to explain the cognitive interdependence in close dyads (Wegner et al. 1985; Wegner 1987; Wegner et al. 1991), TMS theory has since been applied and expanded to groups in laboratory settings (e.g., Liang et al. 1995; Moreland et al. 1996; Moreland 1999) and a multitude of organizational settings (e.g., Faraj, Sproull 2000; Lewis 2003; Austin 2003). However, the contribution of TMS theory to Team Cognition research is still hindered by issues in conceptual clarity and empirical measurement. This will be further discussed in the following paragraphs, in which the current status of the research field and the objective of this work are outlined.

As discussed above, research on TMSs is proposed to potentially contribute to our understanding of the cognitive division of labor within a team. However, the related literature is disorganized and – even after three decades of research – there is still no conceptual clarity about how to specify the components of a working TMS, how to measure the cognitive content and behavioral indicators of a working TMS, and how to integrate existing individual and group research into the theoretical framework (see Peltokorpi 2008, 2012; Lewis, Herndon 2011; Ren, Argote 2011, for recent reviews). On this account, it is necessary to structure and discuss these crucial issues in conceptual development and empirical measurement in order to infer a differentiated research strategy for the analysis of the TMS construct and existing empirical research.

Discrepancies in defining the components of a TMS

According to Lewis & Herndon (2011, p. 1255), the definition of a TMS has been somewhat simplified in many studies to "a shared understanding of who knows what" while the terms TMS and Transactive Memory (TM) have however often been used interchangeably. The authors make a legitimate argument by calling this simplification deficient, because important aspects of the original TMS theory are neglected, which in turn limits the explanatory power of empirical and conceptual research. The notion of a shared understanding of who knows what is very similar to the concept of a Shared Mental Model of the expertise distribution within the team (e.g., Cannon-Bowers et al. 1993). This latter definition does not incorporate the process dimension of team members sharing information and specializing in different fields of expertise. TM is an emergent structural property of individual team members, but the term TMS describes the system of individual TMs working together – and thus the aforementioned integration of both static and dynamic perspectives of Team Cognition.

Although Ren & Argote (2011, p. 193) also refer to the original distinction between structural and procedural dimensions of a TMS and the conceptual simplification of the concept in TMS research, they follow Walsh & Ungson's (1991, p. 63) argumentation concerning individuals as potential storage for organizational memory. Therefore, they outline a TMS as an organizational retention bin or knowledge repository. This emergent structural understanding differs from the original TMS concept (which will be further discussed in section 3) insofar as that it mixes levels of explanation and analysis. The notion of a TMS as an organizational knowledge repository is indeed compatible with the notion of an organizational TMS (e.g., Peltokorpi 2012), but I propose that a distinction between team- and organizational-level TMSs is needed. In this regard, I further argue that the original notion of TMSs as group information processing systems is more fitting at the team-level of analysis, because the notion of an organizational-level TMS does not integrate the dynamic perspective of Team Cognition.

Related to these conceptual issues of defining TMS components and processes, existing empirical TMS research still lacks agreed upon methods for the measurement and interpretation of cognitive structures and interactive processes. Measurement problems clearly reflect the conceptual ambiguity in the research field. Lewis & Herndon (2011) stress this issue with regard to the use of Lewis' (2003) composite TMS scale. This scale is applied to infer but not to directly observe that a TMS is working within a team. It has been originally developed to transfer the experimental direct measurement method developed by Liang et al. (1995) to organizational settings. While these authors analyzed the cognitive structures within a laboratory group, they also directly measured behavioral indicators of a working TMS through observations. Since TMSs were originally thought to enhance a group's information processing and knowledge utilization, Liang et al. (1995) observed the group's behavior in the knowledge relevant dimensions of memory differentiation (which was later called specialization by Lewis), task coordination, and task credibility. In many subsequent studies, however, the measurement of these indirect indicators of the social interaction processes in a working group has been interpreted as direct reflections of structural TMS dimensions (e.g., Akgün et al. 2005; see also Lewis, Herndon 2011).

From these discrepancies in the definition and measurement in TMS research follows that – in its current state – it is not possible to analyze the theoretical and empirical contributions of TMS research by focusing on the relationship between all constructs that are defined as representations of TMSs and their relationship to team performance. This implies that – as will be discussed in section 4 – different TMS research strategies regarding the measurement of cognitive structures and interactive processes have to be accounted for in order to evaluate the contribution of the existing empirical research to our understanding of TMSs (Wildman et al. 2014, p. 931).

The integration of predictors and interrelations into the study of TMSs

The discussion about conceptual clarity in TMS research further relates to the questions of what kind of input variables or antecedents influence the development and functioning of a TMS and how the different components (dynamic and structural) are interrelated with each other and the input variables. For example, Ren & Argote (2011, pp. 190–191) argue that despite the increase in organizational TMS studies, our understanding of what contributes to the development and functioning of a TMS remains deficient. According to the authors, the same input variables (e.g., trust) are sometimes studied either as antecedent, component, or moderator, which is supposed to hinder the generalization of results to further contexts. In this connection, more clarity is needed with regard to what constitutes input, moderator, and output variables in the study of TMSs.

Next to these issues that concern the definition of predictors for the development and functioning of a TMS, the positive and negative interrelations between predictors and components and between different components of a TMS are still not thoroughly explained. For example, in current TMS research, a positive relationship between a differentiated TM structure and group performance is proposed (Lewis, Herndon 2011; Ren, Argote 2011). The logic behind this proposition is related to the cognitive division of labor within a team in which team members specialize in different fields of expertise.

As originally argued by Wegner (1987), this differentiation of knowledge within the team is proposed to increase the individuals' access to information and is therefore proposed to lead to a greater amount of knowledge stored and utilized by the team within a task. While this proposition has been widely tested with regard to dyads and groups performing memory recall (e.g., Hollingshead 1998a) or radio assembly tasks (e.g., Liang et al. 1995; Moreland et al. 1996; Moreland et al. 1998), there are not nearly as many studies in organizational settings in which this relationship has been tested explicitly and directly. Contrary to the proposed relationship above, group knowledge stock (Austin 2003), initial expertise distribution (Lewis 2004), the organization of the group's knowledge (Palazzolo 2005), and expertise composition (Rau 2005; Rau 2006) – as representations of a differentiated TM structure – have been directly measured and found to have no persistent relationship with the team's performance. Furthermore, recent TMS studies suggest that tasks in organizational settings – which depend on group discussions and problem-solving – might benefit from an integrated TM structure (see section 3), in which knowledge is shared between all group members (e.g., Gupta, Hollingshead 2010; see also Lewis, Herndon 2011). In this context, there is still no conceptual clarity about the influence of differentiated and integrated team knowledge structures on team performance in organizational settings. Moreover, in many studies in which a positive relationship is implicated by the results, the components of a TMS are not directly measured. As discussed above, these studies use Lewis' (2003) aggregated composite TMS scale with a focus on behavioral indicators and do not directly measure TMS components or the group's knowledge structures.

Supporting this, negative implications of a developing – or existing – knowledge differentiation in teams have been largely neglected in TMS research. Although knowledge specialization is assumed to have beneficial effects on team performance (as discussed above), group research has provided evidence for the proposition that knowledge diversity in an organizational setting can lead to the discussion of already shared information (which is thus known to all team members) in favor of new or unique information. Thereby, knowledge diversity may prevent unshared and perhaps more relevant information (which is potentially known only to few team members) to be used in the discussion (e.g., Stasser et al. 1989). This favoring of shared information could thus have a negative influence on creativity and group decision-making.

Another possible negative effect of knowledge diversity is the potential influence on trust and the psychological safety within a team (Edmondson, Roloff 2009). Psychological safety is defined as a team's property that "facilitates the appropriate conditions to release individual knowledge, ultimately stimulating learning behavior" (ibid., p. 201). When a safety climate is absent, knowledge diversity is proposed to lead to issues in sharing this knowledge because team members would not trust each other's intentions (Edmondson 1999). Although Liang et al. (1995) and Lewis (2003) integrate credibility of the knowledge source as a behavioral indicator for an efficiently working TMS into their TMS measurement methods, potential negative effects of knowledge diversity should be further integrated into the conceptual TMS model.

Assumptions about the unconditional willingness of team members to share their expertise

Similar to the simplistic assumption that knowledge diversity or differentiated knowledge structures are positively related to team performance, another assumption of the original research context of Wegner's (1985; 1987; 1991) early studies has been transferred to the organizational context without further discussion: individuals in teams are assumed to be unconditionally willing to share their expertise on the basis of similar individual-level and team-level goals. While this assumption is based on the intimate relationship context of these studies, by regarding team members as individuals with their own agenda, possible issues in the sharing behavior (e.g., withholding expertise) have to be accounted for in the study of cognitive division of labor. As will be argued in the course of this work, factors influencing the alignment of individual-level and team-level goals and, furthermore, factors promoting the motivation of individuals to share have to be integrated into the study of TMSs in order to transfer the theoretical model to an organizational context (e.g., Hollingshead 2001; Yuan et al. 2010b; Beersma et al. 2013).

Neglecting the organizational and task context in the study of TMSs

Related to the transfer of assumptions about individual sharing behavior, other issues with respect to the integration of organizational and task contexts into the study of TMSs have to be discussed. While there seems to be a consensus about the importance of considering and specifying the task type and task context in recent TMS research (e.g., Peltokorpi 2008; Baumann, Bonner 2011; Lewis, Herndon 2011), it is relevant to note that the integration of shared task representations is a rarely discussed topic in the conceptual TMS development. To be more precise, there is some ambiguity about the integration of this perspective. Although researchers mostly agree about the role of task types in moderating the relationship between TMSs and team performance (e.g., Ren, Argote 2011; Lewis, Herndon 2011), there are only few studies in which the roles of shared task representations and perceived cognitive interdependence have actually been directly measured and analyzed (e.g., Zhang et al. 2007; Yuan et al. 2010b).

In this context, Ren & Argote (2011, pp. 192–193) argue that TMSs do not include shared mental representations of the task and the team, because TMSs would be "narrower in content coverage" than related concepts. The concept of a shared understanding about the task and the team is very similar to the notion of Shared Mental Models (SMM) or Team Mental Models (TMM) in group and team research (e.g., Cannon-Bowers et al. 1993; Mohammed et al. 2010). SMMs are defined as "knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task" (Cannon-Bowers et al. 1993, p. 228). Research on SMMs of the task and the team has focused so far on analyzing the positive relationship between accuracy and agreement measures of these types of SMMs and team performance (Mohammed et al. 2010). TMMs are furthermore defined as "emergent characteristics of the group which reflect organized knowledge and the tendency of individuals to categorize what they "know"" (Klimoski, Mohammed 1994, p. 417). They represent a shared understanding about important aspects of the team and the task which are considered to be beneficial to team performance. Ren & Argote (2011, p. 193) further argue in this context that, since the construct of TMSs is focused on knowledge differentiation, notions of shared representations of task and team characteristics are not compatible with and thus different from this original construct. In contrast to this proposition and based on the conceptual TMS development of Brandon & Hollingshead (2004), it is argued throughout this work that it is necessary to integrate these representations and characteristics into the TMS construct to account for the differences between the original dyadic context of TMS research (see section 3.1) and organizational contexts.

In this regard, another issue in transferring the TMS concept to organizational settings needs to be considered. As elaborated above, in current TMS research, an approach is being discussed that transfers the concept of TMSs from a team-level construct of cognitive division of labor with both static and dynamic dimension to an organizational-level construct of TMS that consists of static knowledge repositories (e.g., Ren, Argote 2011; Peltokorpi 2012). However, the explicit integration of the individual-level and team-level sub-constructs in TMS theory into organizational settings with further proposed organizational-level (e.g., HRM systems, organizational culture and routines) and contextual-level (e.g., market turbulence) influences is missing in this discussion. In empirical TMS research, only few studies in organizational settings exist in which some of these higher-level influences have been accounted for (e.g., Akgün et al. 2006; Jarvenpaa, Majchrzak 2008; Lee et al. 2014).

On this account, I propose that an explicit conceptual integration of these possible level-dependent influences into the TMS concept in form of a multi-level TMS model for organizational research contexts is needed. Although this integration of different levels of analysis and their respective interrelations increases the complexity of the TMS theory and thus decreases the level of abstraction – in other words the foundation of theories and their ability to reduce complex problems to their basic structural relations –, I argue that the aforementioned issues justify this conceptual integration since our current understanding of TMSs hinders our ability to capture the phenomenon of interest (Kozlowski, Klein 2000, p. 12; Kozlowski 2012, p. 262) – the cognitive division of labor in a team.

Main objectives of this work

Taking into account the presented issues in current TMS research, the first main objective of this work is defined as follows. To evaluate the possible contribution of existing conceptual development and empirical research in the field of TMS research to our understanding of Team Cognition in an organizational setting, I propose that it is necessary to reformulate the original TMS construct based on a multi-level framework that enables the analysis of interrelations between different levels of analysis. Here, possible issues of transferring existing assumptions to organizational contexts have to be discussed.

On this basis, the second objective of this work is to analyze existing empirical TMS research and the originally proposed relationships between cognitive structures, interactive processes, and team performance from this particular multi-level perspective. As discussed above, it is therefore necessary to account for the different research strategies in TMS research in order to discuss the question of "what is actually being captured" (Kozlowski, Bell 2013, p. 37) by the different research approaches and measurement methods in the study of TMSs.

Building on this analysis, the third objective of this work is to integrate the structured findings in empirical TMS research into an adapted multi-level TMS model that is proposed to capture the value of the cognitive division of labor in a team by integrating individual-, team-, and organizational-/contextual-levels and their interrelations into the study of TMSs. Next to the presentation of an adapted TMS model, propositions that can be tested as hypotheses in empirical research have to be inferred. These propositions are crucial in order to advance our understanding of TMSs beyond the general notion that TMSs positively influence team performance (e.g., Ren, Argote 2011, p. 223). Furthermore, such propositions are necessary to make predictions in organizational contexts regarding TMSs and the proposed sub-constructs possible – and thus to advance our understanding of TMSs beyond the sole description of the studied social phenomenon of cognitive division of labor (Godfrey-Smith 2003, p. 6).

On the basis of these three objectives – first, the development of a framework for analysis, second, the explicit analysis of empirical TMS research differentiated into the specific research approaches, and third, the proposition of an adapted multi-level TMS model – the final objective of this work is to evaluate the contribution of the differentiated approach advanced in this work to the analysis of Team Cognition and specifically the TMS concept.

1.2 The structure of this work

The structure of this work is based on the discussion of current issues in TMS research and the objectives that have been inferred from these issues, as illustrated above. Following this introduction (section 1) is the development of a multi-level framework (section 2) for the analysis of the original TMS theory (section 3) and corresponding empirical research (section 4). Here, TMS research is further embedded into the field of Team Cognition (2.1) to discuss possible contributions of an adapted TMS model to this research field. Subsequently, the unit of analysis of this work – teams in organizational settings and their cognitive division of labor – are discussed and defined (2.2) for the application in the following sections. This definition is a first step in enabling the transfer of the original TMS propositions to an organizational context, because it specifies and clarifies the context of TMS research. Directly related to this discussion – since knowledge is regarded as the foundation for the development of a TMS in teams – is the analysis of different approaches to the concept of knowledge (2.3) that enables the definition of the following terms that are applied throughout this work: information, knowledge, expertise, and cognitive structures. Next to the content of expertise sharing, the discussion of motivational aspects of expertise sharing within teams (2.4) further allows for the transfer of the TMS concept to organizational contexts which – next to team-level goals – are shaped by individual agents and their individual-level goals. After discussing and defining these components of the cognitive division of labor, the functional approach of applying an Input-Process-Output (I-P-O) model that is used in the majority of empirical TMS and Team Cognition settings is analyzed and transferred to a dynamic Input Mediator Output Input

(IMOI) model in the following section (2.5). This dynamic model enables the study of cyclical non-linear development in the cognitive division of labor concerning interrelations between different components, levels, and inputs in the subsequently developed TMS model (section 5). The second section closes with the elaboration of a multi-level concept of emergence and its fit for the study of existing and developing higher-level cognitive structures and expertise sharing processes (2.6).

On the basis of this developed framework, section 3 transfers the original TMS concept and its assumptions to a multi-level perspective. Here, special emphasis is put on the differences between the early research context of Wegner's TMS studies and the organizational context that is applied in this work (3.1). Following this, the transferred TMS multi-level concept, the proposed cognitive structures at the individual-level and team-level of analysis (individual and Transactive Memory), and the emergent transactive processes that are proposed to link these levels bottom-up and top-down are discussed (3.2). Further emphasis is put on the development of such a proposed system and the path dependencies that are assumed to shape and constrain the development of TMSs (3.3). The last subsection (3.4) transfers the proposed multi-level model into the IMOI context that is applied in this work and discusses the further need for adapting this model in order to fit organizational settings and research.

The focus of section 4 is the specific analysis of empirical TMS research by applying the developed multi-level lens. Prior to the analysis of particular findings, the different conceptualizations and measurement strategies in TMS research are accounted for (4.1). Thus, special attention is paid to how cognitive structures, interaction, and TMSs as latent constructs have been defined and measured in existing empirical TMS research. After discussing these strategies, findings in empirical TMS research are analyzed (4.2) in relation to these strategies and the different TMS research settings – dyadic, group, and organizational. The findings are then summarized and interpreted in terms of the propositions within current TMS research and the original TMS concept (4.3).

In section 5, an adapted multi-level TMS model for organizational contexts is proposed and presented. This adapted model integrates solutions to the mentioned conceptual issues and is based on a) the theoretical framework developed in section 2, b) the empirical results analyzed in section 4, and c) further interdisciplinary research. On this account, propositions are inferred for the following aspects: the adapted core of the TMS concept, input and output variables, the development of such a proposed system, and the influence of organizational and contextual factors on this development and functioning of a TMS (5.1). Based on these propositions, the contributions of the adapted multi-level TMS model to Team Cognition and

TMS research – especially with respect to the current issues in conceptual development and measurement – are discussed. Finally, this work closes with section 6, in which the overall contribution of this work concerning its objectives and limitations with regard to its explanatory value as well as possible future research objectives are discussed.

2 Developing a framework for the analysis of Transactive Memory System theory and research

In this section, the framework for the analysis of the construct of Transactive Memory Systems (TMSs) is developed. First, TMS research will be embedded into the broader field of Team Cognition in order to emphasize possible contributions of a differentiated construct of TMSs in this research field. Subsequently, teams are defined and discussed as the unit of analysis in this work. This supports inferences for an extended team TMS concept by understanding teams as complex, adaptive, and dynamic systems. It also allows for the differentiation between the early research context in TMS research (see section 3.1) and the organizational context that is applied in this work. This is followed by a discussion of different approaches to the concepts of information and knowledge that have been used in team and knowledge research. Here, a discursive approach is applied to define information and knowledge for the utilization and analysis in the TMS context. As explained in the introduction, information and knowledge are commonly understood as the basis for a working TMS, so it is essential to clarify the ambiguous definitions that these concepts entail. Furthermore, a discussion of the primary functional research approach of information processing in TMS research is needed to analyze potential shortcomings in the study of teams as complex systems and to extend this approach to a model that incorporates potential non-linear relationships, emergent states, and feedback loops into team cognitive life. To conclude the theoretical embedding, a multi-level concept of emergence that is used to reformulate the concept of TMSs in the third section is explained. On this account, this explanation includes the discussion of the concepts of emergence and interrelations between different components in a multi-level construct.

2.1 Embedding TMS research into the field of Team Cognition

When studying the cross-literature on teams and TMSs, one encounters the construct of TMSs in a multitude of varying research themes regarding shared information processing and team or group learning. Examples for these themes are Macrocognition (Fiore et al. 2010; Kozlowski, Chao 2012), Social Cognition (Nye, Brower 1996), Shared Cognition (Patterson, Stephens 2012), Distributed Cognition (King 1998), Metacognition (Hinsz 2004), and Group Cognition (Theiner 2009; Lewis et al. 2007) (for an overview, see Fiore et al. 2010).

One overarching research field in the study of teams that seeks to bring these themes together is the study of Team Cognition (Salas, Fiore 2004a; Salas et al. 2012b). Team Cognition researchers are concerned with the prediction and understanding of cognitive activities of teams (Cooke et al. 2009, p. 157) and the influence of shared cognitive processes on team performance (Salas et al. 2012a, p. 3). As Salas et al. (2012a, p. 3) explain, it combines the aforementioned themes by the common notion that shared cognition of team members produces both individual- and team-level outcomes (e.g., Levine et al. 1993, p. 588), and that a functional equivalence[1] is thought to exist between the encoding, storage, and retrieval of information at both the individual- and team-level (Hinsz et al. 1997; Larson et al. 1996; Cooke et al. 2004). Furthermore, researchers in the field of Team Cognition propose that knowledge representations and the cognitive processing of these representations exist in both the individual mind and between individuals and their environment (Fiore et al. 2010, p. 204).

Two distinct perspectives on Team Cognition

According to Wildman et al. (2014, p. 913), current Team Cognition research is divided into two distinct perspectives. The *first* perspective is a rather static perspective that regards Team Cognition as the cognitive representation of emergent team-level knowledge structures that are embedded in the minds of the individual team members. Examples of this perspective are Shared Mental Models (e.g., Cannon-Bowers et al. 1993; Cannon-Bowers, Salas 2001), Team Mental Models (e.g., Mohammed et al. 2000; Mohammed et al. 2010), or Strategic Consensus (e.g., Kellermanns et al. 2005). As Cooke et al. (2013, p. 258) discuss, this Shared Cognition perspective on Team Cognition is influenced by an information-processing model of individual-level cognition that is based on a functional Input-Process-Output (I-P-O) model (Hackman 1987, p. 316). In contrast to the original focus of the I-P-O model on the processes, Team Cognition has been described as shared knowledge structures or emergent states within this model (a thorough discussion of this model and emergent states will follow in section 2.5).

Furthermore, this first perspective can be seen as divided into two approaches to the concept of shared knowledge structures. While one approach focuses on Shared Cognition in the sense of similar knowledge structures – for example, the construct of Shared Mental Models in the Shared Cognition theme (e.g., Cannon-Bowers, Salas 2001; Cannon-Bowers et al. 1993) is focused on similar mental models or mental representations of important aspects (e.g., team, task) among team members – the other approach focuses on differentiated knowledge structures or the distribution of knowledge (and expertise) between different team members and knowledge repositories. An example of this second approach is the research on Distributed Cognition (e.g., King 1998; Hutchins 1991). Although Wildman et al. (2014,

[1] The functional equivalence concept will be explained in more detail in the emergence section about general system theory.

p. 913) assign TMS theory to this first static perspective, we will see that this approach takes an exceptional position in Team Cognition research.

In contrast to the static perspective, a *second* and more recent (and thus minor) part of Team Cognition research focuses on an alternative approach (Cooke et al. 2013, p. 255) that considers Team Cognition as dynamic cognitive processes that are constituted by the interaction and communication of team members (Wildman et al. 2014, p. 915). Wildman et al. (2014, p. 915) stress the notion within this second perspective that Team Cognition consists of both the content of cognitive processes in the form of interaction and communication and also (more importantly) the act of communication itself. This understanding leads to a differentiated approach to the measurement of Team Cognition. Based on this approach, communicative acts are not understood in terms of their content that might reflect the structure of Team Cognition but rather as an act of Team Cognition. According to Cooke et al. (2013, p. 256), forms of these cognitive processes include team learning, planning, reasoning, decision-making, problem-solving, remembering, designing, and assessing situations.

If we compare these two distinct approaches, it becomes clear that again – similar to the issues in TMS research discussed in the introduction – there is still no conceptual clarity as to what exactly constitutes the construct of Team Cognition: similar and/or distributed cognitive structures and/or cognitive processes. This makes the differentiation and comparison of different constructs within Team Cognition a complex endeavor. However, what most of the Team Cognition research has in common is the position that Team Cognition is more than the sum of its parts (Cooke et al. 2004, p. 85) and that it emerges from collaborative cognition and communication among team members. From this follows, that it is not adequate to measure and analyze Team Cognition on either the micro, meso, or macro level of analysis independently. Fiore et al. (2010, p. 203) argue that understanding these shared cognitive activities at their respective level is necessary to develop sociotechnical systems and to develop methods for training team members to work effectively together. On this account, the dynamic Input Mediator Output Input (IMOI) model of team interaction (Ilgen et al. 2005) and a model of social emergence that considers both similar and distributed cognitive structures as well as cognitive processes (Kozlowski, Klein 2000) will be introduced in sections 2.5 and 2.6 to reformulate the concept of TMSs from a dynamic and multi-level perspective in section 3.

The call for a combined Team Cognition perspective and the potential role of TMS theory

Recognizing the distinct perspectives in Team Cognition research, several researchers are calling for an integration of both cognitive structures and processes into a common Team Cognition construct (e.g., Cooke et al. 2009; Cooke et al. 2013; Wildman et al. 2012; Wildman et al. 2014). According to Cooke et al. (2009, p. 177), both perspectives represent different research questions at different levels of analysis (individual- and team-levels) regarding a more complex construct. Wildman et al. (2012, p. 85) argue for an integrated understanding of Team Cognition in order to understand and study both the process of cognitive teamwork and the development of shared cognitive structures. Furthermore, they discuss that such an integrated approach is mainly unexplored in Team Cognition research (ibid., p. 104). This call for an integration of both static and dynamic approaches to Team Cognition is supported by a recent meta-analysis by DeChurch & Mesmer-Magnus (2010). Following the static understanding of Team Cognition, the authors found evidence for a positive interaction between both Team Mental Models and Transactive Memory Systems with interactive and communicative processes in teamwork for predicting team performance (ibid., p. 40). These results substantiate the perspective that both the content and the process of Team Cognition are relevant in the study of teamwork.

As stated in the above, there is some support in Team Cognition research for the understanding of TMSs as a part of the static perspective on Team Cognition – that might be justified by the ambiguous definitions of the construct as discussed in the introduction. In contrast to this understanding, this work instead uses the original TMS definition of the construct as a foundation for evaluating its value for the analysis of cognitive teamwork. To recall this definition, a TMS has been defined as a system for the division of cognitive labor that contains both cognitive structures in the form of similar representations of expertise – as well as the actual distributed expertise (and with this the two forms of cognitive structures of the static perspective on Team Cognition) – and cognitive transactive processes of team interaction that contribute to the encoding, storage, and retrieval of knowledge and information (Wegner et al. 1985, p. 256). Based on this definition, by integrating both static and dynamic perspectives of Team Cognition, the original TMS theory takes in a potentially exceptional position in this research field.

In contrast to only emphasizing the shared aspect of knowledge and understanding in for example Shared Mental Model theory, TMS theory integrates the actual knowledge distribution and processes of knowledge sharing within groups and teams (Wildman et al. 2014) and thus integrates the research on Distributed Cognition (King 1998; Hutchins 1991).

Furthermore, in contrast to the static perspective on Team Cognition and for example economic approaches of team theory (e.g., Marschak, Radner 1972), the focus in TMS theory does not only lie on the optimal distribution of information and knowledge, but also on the social processes of Team Cognition (Wegner et al. 1985). In summary, TMS theory emphasizes the social organization of cognitive diversity by theoretically integrating the connections between individual minds and their communication (Wegner 1987).

It is important to note here, that – as with other constructs in the field of Team Cognition – the construct of TMSs can be seen as a metaphor for an existing social phenomenon (Klimoski, Mohammed 1994). This implies that the construct of TMSs represents only an approximation of the interrelations and components of the cognitive division of labor within a team. The definitions and proposed relationships between components are nonetheless beneficial for understanding cognitive team processes, because they render the study of the underlying processes that influence a team's performance possible.

2.2 Defining teams as complex systems

In the history of small group and team research, various definitions for teams[2] have been in existence (e.g., Levine, Moreland 2012, 1998; Moreland et al. 1994; Mathieu et al. 2008). Since the end of the 20th century, team research has – although at a very slow pace (Cronin et al. 2011, p. 573) – collectively shifted from the study of small ad-hoc groups without much context to the analysis and understanding of existing teams in organizations as complex, adaptive, and dynamic systems (e.g., McGrath et al. 2000, p. 95; Hollingshead et al. 2005, p. 48).[3] Following this differentiated understanding, teams can be defined as: a) structured entities that emerge from the interdependent interaction of the individual team members (McGrath et al. 2000, p. 95), b) embedded within an organizational context in which multiple, bidirectional, and nonlinear causal relations exist (ibid., p. 98), c) dynamic systems that have an inherent time lifecycle in which the team's processes are dependent on former and future events (McGrath et al. 2000, p. 98; Ilgen et al. 2005, p. 519), and d) open and complex systems without explicitly defined boundaries that interact with smaller systems in the form of its individual members and larger systems in the form of organizations, communities, or other teams; the complexity of these interactions changes the smaller and larger systems in manners that cannot be operationalized by simple cause and effect models (McGrath et al. 2000, p. 98;

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[2] Following the use of the term "team" in the definition and naming of the research field of Team Cognition (e.g., Fiore et al. 2010; Fiore, Salas 2004), this term will be used for both work groups and teams in the following sections of this work for consistency reasons. This implies no preference of terms as the author regards teams and work groups as interchangeable terms for the same systems.

[3] For an overview of existing definitions of team types as complex systems in organizational science, see table 1 in Hollenbeck, Beersma, and Schouten (2012, p. 85).

Ilgen et al. 2005, p. 519). It is this definition of teams that is employed in this work because it supports the analysis of possible interrelations between different TMS processes and components and the team's environment in a differentiated Input Mediator Output Input (IMOI) model.

Regarding the interdependence of the team's interactions, it is important to note that according to this understanding, two levels of goals exist simultaneously within teams: shared team-level goals (e.g., task goals) and individual member-level goals (e.g., career advancement, social goals) (McGrath et al. 2000, p. 98). This perspective reflects the understanding of teams as complex systems consisting of *individual* team members with their own characteristics or agenda and will be further discussed in section 2.4. From this understanding of teams as nested systems within the organizational context also follows the necessity to study these systems at the respective levels of analysis. As Cronin et al. (2011, p. 572) discuss, these levels consist of at least the individual-, team-, and organizational-/contextual-levels, leading to a multi-level understanding and study of teams (see section 2.6.1).

To conclude this perspective of teams, the issue of the existence of informal teams and non-definable boundaries between systems has to be discussed. According to the definition employed in this work, boundaries between teams and other systems are permeable. Therefore, a possible objection to the definition of teams as outlined above – and thus the study of such teams – is that individuals can be members of multiple organizational teams and that informal networks between organizational entities can exist that are not reflected by this definition. This in turn would complicate the definition of individual teams as the unit of analysis in this work. In response to this objection, teams are understood as actively maintaining and managing boundaries to other systems (Kozlowski, Bell 2003, p. 334) and to be embedded within a hierarchical organizational structure. From this follows that – in combination with the measurement of communication networks – team specific patterns emerge when analyzing these communication networks that can be linked to a specific team and task. Accordingly, it is possible to define and distinguish individual teams as the unit of analysis. On this account, the aforementioned definition of teams will be used in this work.

2.3 What do teams share – Different approaches to the concept of knowledge

After the previous discussion and definition of the term teams, this section is focused on the specific content of cognitive team interaction: the question of what is actually shared between individual team members. Reviewing the original studies by Wegner et al. (Wegner et al. 1985; Wegner 1987; Wegner et al. 1991) and more recent articles (Ren, Argote 2011; Lewis, Herndon 2011; Peltokorpi 2008, 2012) that have been published more than 20 years after the first mention of the term TMS, it becomes clear that there is no agreement on the content of cognitive team interaction and its definition. In this literature, for example, both knowledge and information can be processed, stored, shared, updated, remembered, and accessed. Both can be parts of individual and collective memory, be structured in this memory, stored next to each other or as part of the other. In fact, both can be encoded, stored and retrieved (to describe it in terms of the processing that is supposed to happen within a TMS or individual mind). This is illustrated by the following example: "For ease of representation, we use knowledge sharing and knowledge distribution to refer inclusively to data, information, and knowledge" (Hollingshead et al. 2002, p. 335). This statement exemplifies, that while TMS researchers might be aware of the differences and potential issues of sharing the different types of content (ibid., p. 336), most of the time, these differences are actually not mentioned or elaborated.

What is missing in this discussion are specific definitions of information and knowledge as distinct variables in order to describe what constitutes the content of the cognitive division of labor in a team which is central to the TMS concept. This issue of misspecification or non-specification of important variables within a theory leads to the possibility of trivial or generic conclusions that do not contribute to the theoretical development of a research field (Kozlowski, Klein 2000, p. 12). From this follows, that to evaluate the possible contributions of TMS theory to team research in this work, specific definitions and classifications of the terms are needed.[4]

In the following, two distinct approaches that are frequently used in organizational research to define the terms of information and knowledge will be discussed: the hierarchy of knowledge (Ackoff 1989) and the distinction between explicit and tacit knowledge (Polanyi 1966; Nonaka 1994). Based on this discussion, a discursive approach to the classification of

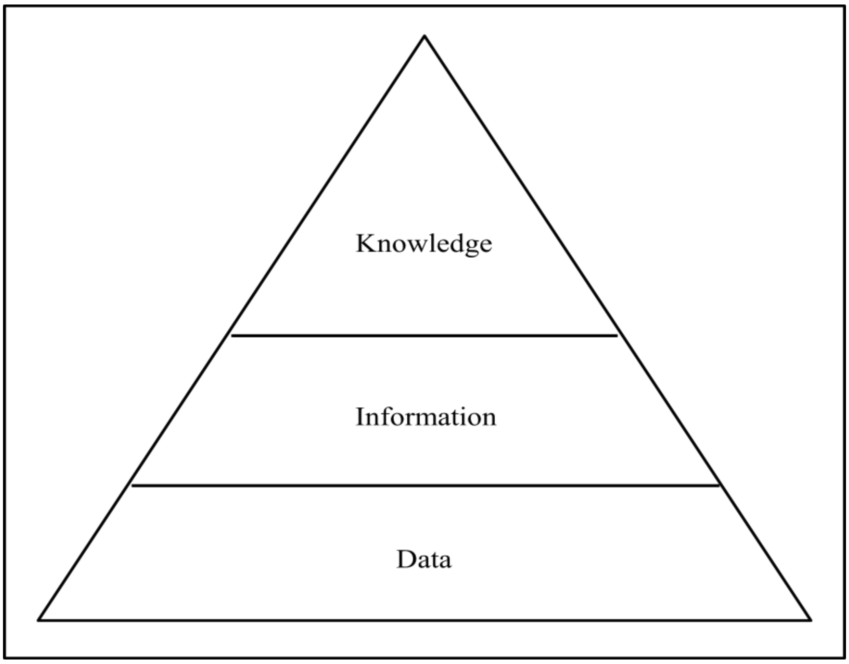
[4] This discussion about the definition of knowledge and information is by no means novel. In fact, most researchers that focus on this topic base their study on the philosophical discussions in the classical Greek era (e.g., Alavi, Leidner 2001, p. 108; Nonaka 1994, p. 15).

knowledge (Schreyögg, Geiger 2003) will be presented that lays the foundation for the definition of knowledge advanced in this work.

2.3.1 The hierarchy of knowledge

The hierarchy of knowledge is used in numerous studies in the fields of information management, knowledge management, and organizational management (Rowley 2007, p. 166). According to Rowley (2007, p. 166), most researchers using the hierarchy of knowledge base their assumptions on the work of Ackoff (1989), who is often cited as the founder of this hierarchy. Although minor variants of the exact form and definition of the hierarchy exist, Alavi & Leidner (2001, p. 109) as well as Rowley (2007, p. 166) recognize that there is a broad agreement on the differentiation between data, information, and knowledge in the aforementioned fields. One basic form of this knowledge hierarchy is presented in figure 1 and will be explained in detail below.[5]

Figure 1: Basic representation of the hierarchy of knowledge



Author's illustration based on (Alavi, Leidner 2001; Rowley 2007)

The hierarchical structure in the hierarchy of knowledge implies a progression between the meaningfulness and usefulness of data, information, and knowledge for organizational

[5] For researchers familiar with this topic, a difference of the presented model in respect to others is the exclusion of categories such as symbols below data or wisdom above knowledge. This exclusion is intentional here, since a further discussion of such categories would not advance the differentiation between the use of information and knowledge in TMS research. Data is included, because it is essential for the understanding of the term information in the view of the hierarchy of knowledge.

purposes (Rowley 2007, p. 164). Here, *data* is most often defined as objective facts or observations in an unprocessed form (ibid., p. 170) or raw numbers (Alavi, Leidner 2001, p. 109), whereas *information* is defined as data enriched with some meaning (Rowley 2007, p. 171) or as processed or structured data (Alavi, Leidner 2001, p. 109).

Although there is some agreement on the aforementioned definitions of data and information, the term *knowledge*, however, is defined in ambiguous ways. According to Rowley (2007, p. 174), knowledge is either described as a combination of "information, understanding, capability, experience, skills and values"[6] and is thus understood as an "elusive concept." It is also often described with reference to information or the process of converting information that is defined and filled with meaning consistent with the specific research context (ibid., p. 173). Following Schreyögg & Geiger (2003, p. 9), this understanding of the concepts of information and knowledge does not help us in defining the quality and differences between the two concepts, since knowledge in this context has been transformed into a vague notion that renders the classification of information and knowledge impossible.

Alavi & Leidner (2001, p. 109), however, describe a more recent understanding of knowledge in the hierarchy as authenticated information. They argue that a differentiation between knowledge and information cannot be found in the specific organizational or research context, but rather in the definition of knowledge as information that is stored in the minds of individuals, as "personalized information."

Taking the argument by Alavi & Leidner (2001) into account, knowledge in this context is understood as not to be found outside of the human mind. Information is thus transformed to knowledge and transferred into the individual mind by actively processing it and this knowledge is then retransformed into information for the purpose of sharing or external storage. Furthermore, the authors state that for individuals to come to an identical understanding they have to share the same knowledge base (ibid., p. 109). If this knowledge base as per definition is not observable or measureable, how would one infer the differences and quality between the concepts of information and knowledge? In statistical terms, knowledge is here understood as a latent variable that can neither be observed nor measured (Bortz, Schuster 2010, p. 338), so that researchers can only infer the existence of knowledge by measuring the content and flow of information. Therefore, even though this argumentation integrates personal variables into the definition of knowledge, it helps us just as little in determining the differences in meaning and quality between the concepts of information and knowledge used in TMS research. On this account, another frequently used theory in

[6] For a further overview on concepts of knowledge used in the information systems, knowledge management, and organizational management literature, see table 1 in Alavi and Leidner (2001, p. 111).

organizational research that could potentially be applied to infer differences in quality between information and knowledge is discussed in the next subsection.

2.3.2 The dynamic theory of organizational knowledge creation

One similarity between the understanding of knowledge in the hierarchy of knowledge discussed by Alavi & Leidner (2001) and Polanyi's (1966) differentiation between explicit and tacit knowledge is the distinction between an observable and a latent dimension. However, whereas Alavi & Leidner (2001) imply that knowledge has only unobservable aspects, Polanyi (1966, p. 6) integrates the concept of unconscious and tacit thoughts, which – while not observable or conscious – are able to influence our ability to express and draw conclusions from our explicit and codifiable knowledge. Polanyi (1966, p. 20) argues that the importance of tacit knowledge is far greater than that of explicit knowledge and that this tacit knowledge cannot be replaced or substituted by the integration of explicit knowledge. This is considered to be the meaning of the often cited expression that "I shall reconsider human knowledge by starting from the fact that we can know more than we can tell" (ibid., p. 4). Although the concept by Polanyi (1966) in this form does not directly contribute to the determination of the quality of knowledge or the differentiation between knowledge and information, the work that is done on its premises may be of some assistance.

Drawing on the research of Polanyi and breaking with the concept of an absolutely unobservable dimension, Nonaka (1994) integrates both concepts of explicit and tacit knowledge in the dynamic theory of organizational knowledge creation. According to the author, a major task for the organization in our information society is to manage its knowledge resources efficiently in an uncertain environment (ibid., p. 14). Nonaka further argues that a shift from a passive understanding of knowledge in the functional input-process-output perspective (see section 2.5) to an active understanding of knowledge creation is needed. According to this understanding, the organization would not only use its currently held knowledge to make decisions or find solutions to relevant problems, but would also use its organizational members to actively change and distribute existing knowledge to create new knowledge (Nonaka, Takeuchi 1995, p. 6).

To differentiate between knowledge and information, Nonaka (1994, p. 16) defines information as a "flow of messages" and to consist of both semantic (meaning) and syntactic (volume) aspects. Knowledge, on the other hand, is understood as the organization of the flow of information, as embedded in the commitment and beliefs of the individuals, and is further specified as justified true belief (Nonaka, Takeuchi 1995, p. 58). Whereas Nonaka further differentiates knowledge in an ontological and epistemological dimension, only the epistemological differentiation between explicit and tacit knowledge will be discussed in this work.[7]

Explicit knowledge, according to Nonaka (1994, p. 16), is considered to be only "the tip of the iceberg" of existing knowledge, and is defined as codified knowledge that is transferrable in a formal, systematic language. *Tacit knowledge*, on the other hand, is considered to be grounded in "action, commitment, and involvement in a specific context" (ibid., p. 16). Individuals are proposed to acquire tacit knowledge through experience in different tasks (Nonaka, Takeuchi 1995, p. 60). Two elements of tacit knowledge are considered here: cognitive and technical elements. Whereas cognitive elements are understood to be mental models or schemata that enable a certain perspective on the perception of context, technical elements, on the other hand, describe "know-how, crafts, and skills that apply to specific contexts" (Nonaka 1994, p. 16). As mentioned above, Nonaka does not understand explicit and tacit knowledge as exclusively observable and unobservable dimensions. In fact, the sharing of tacit knowledge is explicitly mentioned in the theory of organizational knowledge creation for the purpose of building a shared understanding between individuals (Nonaka 1994, p. 16; Nonaka, Takeuchi 1995, p. 61). Accordingly, tacit knowledge – which is considered to be difficult to articulate – should be regularly expressed and codified in a process of individual externalization to share this knowledge with other team members.

As Schreyögg & Geiger (2003, p. 14) discuss, this understanding stands in conflict with the differentiation between explicit and tacit knowledge as understood by Polanyi (1966). If individuals are able to codify tacit knowledge for the purpose of sharing, tacit knowledge cannot be understood as tacit but only as not yet codified explicit knowledge, which – as discussed above – is defined as codified knowledge. Such an understanding is therefore rejected here.

In contrast to Alavi & Leidner (2001), Nonaka (1994, p. 26) specifically discusses how the quality of knowledge could be evaluated. According to this discussion, a process of organizational convergence represents the final step in knowledge creation, in which the created concepts or ideas are justified. This organizational justification thus determines the quality of knowledge. How this justification process is specifically applied to determine the quality of knowledge – next to the evaluation of the return on investment of different ideas and the decision of the top management (Nonaka, Takeuchi 1995, pp. 86–87) – or which criteria for the differentiation of information and knowledge should be used in this process is

[7] This restriction is made in order to avoid repetition in this work. The ontological dimension in the form of the level of knowledge creation through social interaction will, however, be implicitly discussed in sections 2.6 and 3, where the different levels of emergence and the basic model of TMS will be presented.

not further specified. On this account, a discursive approach to the concept of knowledge that forms the foundation for the definition of knowledge in this work is discussed in the next subsection.

2.3.3 A discursive approach to the concept of knowledge

As discussed in sections 2.3.1 and 2.3.2, both the hierarchy of knowledge and the dynamic theory of organizational knowledge creation do not directly support the specific differentiation between the terms of information and knowledge. Furthermore, only the latter theory mentions the evaluation of knowledge quality, however, without presenting distinct criteria for evaluating knowledge. To take these issues into account, a discursive approach to the concept of knowledge will be presented in this section (e.g., Schreyögg, Geiger 2003; Schreyögg, Geiger 2007a; Schreyögg, Geiger 2007b; Geiger, Schreyögg 2009).

Schreyögg & Geiger (2007a, p. 78) argue that – despite the broad agreement that knowledge is a concept with an ever growing importance in our so called information society – the discussion about the definition of the term knowledge itself is lacking behind in terms of theoretical development in organizational research. The authors (Schreyögg, Geiger 2003, p. 9) criticize not only the absence of a differentiated classification between knowledge and non-knowledge in the hierarchy of knowledge, but also the understanding of knowledge as a "superordinate" concept in the compilative-pragmatic view that represents the basis for the distinction between explicit and tacit knowledge. Accordingly, the conceptual problems in the development of a classification system based on a philosophical discussion do not absolve us as researchers from the obligation to classify knowledge (Schreyögg, Geiger 2007b, p. 603). In fact, organizations have an urgent need to "select and distinguish useful from useless knowledge" if knowledge is an ever-growing competitive resource (Geiger, Schreyögg 2009, p. 477). Schreyögg & Geiger (2007a, p. 80) argue that knowledge and skills should thus be separated and that it is necessary to develop a framework for the differentiation between knowledge and non-knowledge.

Based on the general process of knowledge validation in scientific research and the philosophy of science (ibid., p. 82), the authors thus propose that a validation process is needed to represent the concept of knowledge as a source for competitive advantage in organizations. This proposition is similar to the notion by Nonaka (1994), but distinguishes itself by including specific metacriteria for the evaluation of knowledge (Schreyögg, Geiger 2003, p. 12) that are presented below:

1. Knowledge consists of a statement

Schreyögg & Geiger (2003, p. 12) state that the fundamental criterion for a differentiation between knowledge and non-knowledge is that knowledge has to contain some kind of statement. From this follows that knowledge is understood as communicative or discursive in nature, implying that it is thus constructed by individuals and cannot exist without communication (Schreyögg, Geiger 2007a, p. 86). In contrast to the understanding of Polanyi (1966), tacit skills and abilities are therefore not to be defined as types of knowledge since they are not codifiable as statements (Schreyögg, Geiger 2003, p. 12). Schreyögg & Geiger (2007a, p. 88) explicitly state that they do not regard the tacit dimension as less important than explicit knowledge, but rather that this distinction is important for a classification between knowledge and non-knowledge in an organizational context.

2. Reasons have to be given to justify the claim

The communicative nature of knowledge alone is not sufficient to classify a statement as knowledge. Thus, reasons have to be given to justify the claim made in the statement (Schreyögg, Geiger 2003, p. 13). From this follows that the reasons and claims in the statement have to be expressed in a way that enables their evaluation. Without including reasons and claims, it is therefore not possible for knowledge to exist (Schreyögg, Geiger 2007a, p. 87).

3. A method for validation or testing procedure is needed to validate the statement

Similar to the process of validation in scientific research, knowledge is validated within the organization by reaching a consensus about the reasons for the claim. This validation procedure consists of a discourse in which the acceptability of the statement is evaluated (Schreyögg, Geiger 2003, p. 13). In other words, the reasons for the claim have to be acceptable reasons that have been evaluated in an internal discourse in the organization (Schreyögg, Geiger 2007a, p. 87). The authors do not specify explicit criteria for the validation, but constitute that the criteria would correspond to the specific field or context of the organization. Therefore, knowledge is not understood as a singular concept, but rather as a multitude of approaches for different fields of organizations and discourses (ibid., p. 87). Different concepts of knowledge are thus able to coexist in different organizations or within organizations as much as the discourses in the organizations differ from each other.

2.3.4 Definition of knowledge, information, and non-knowledge in this work

What does the discursive understanding discussed above imply for the differentiation between information and knowledge in the field of TMS research? First, by using the approach proposed by Schreyögg and Geiger, it is possible to classify knowledge and non-knowledge. Following this, knowledge is defined as communicative in nature (and thus codifiable and measurable) and consisting of statements that are substantiated by claims that have been validated in a specific organizational discourse. Since non-knowledge can be both tacit and explicit (if it is yet to be validated), the explicit form of non-knowledge is furthermore defined as information. This enables the differentiation between explicit and measurable forms of communication insofar as that information can be understood as both facts (or raw codified objects) and not or not yet validated statements, whereas knowledge is understood as the validated form of these statements. Following Schreyögg & Geiger (2003; 2007b), the tacit form of non-knowledge is thus defined as skills and abilities of individuals (see table 1). These skills and abilities are assumed to be not directly codifiable and bound to the individual that possesses them (Schreyögg, Geiger 2003, p. 14). In contrast to Nonaka's (1994) understanding of tacit knowledge as not yet codified explicit knowledge (see section 2.3.2), this definition thus acknowledges differences in individual characteristics between team members that can be attributed to their different skills and abilities.

Table 1: Definition of knowledge, information, and tacit forms of non-knowledge

Classification	Definition
Knowledge	Statement consisting of claims and reasons that has been validated in an organizational discourse
Information (Explicit non-knowledge)	Can be either a statement as above that has not been validated in an organizational discourse or codifiable facts that are not (or not yet) supported by reasons in a context
Tacit non-knowledge	An individual's skills and abilities

Author's representation based on Schreyögg & Geiger (2003; 2007b)

Following these definitions, an expert in a specific field is understood as an individual that possesses the ability to express a certain amount of statements that have been validated in the organization's discourse and to use this knowledge constructively in a specific task. In such a discourse, it is possible to come to an agreement on the acceptance of specific signals – e.g., university degrees, certificates, working experience, etc. – that can be used as a validation of expertise or knowledge. Furthermore, information can be validated in a discourse within the organization (e.g., in a team) and transformed into knowledge that is embedded within a subsystem or into codifiable routines and/or external storage repositories for knowledge sharing. It can also be understood as codified facts (or raw codified objects) that can be purposefully shared between individuals or transformed into statements. As discussed above and following Schreyögg & Geiger, tacit non-knowledge is understood as an individual's skills and abilities.

It is important to integrate this tacit non-knowledge dimension, since, in combination with the explicit dimension, this integration creates the possibility to put the research on Human Capital into context with this definition (which is used in Input-Process-Output models that are part of the discussion in section 2.5). Human Capital can be broadly defined as specific knowledge, skills, and abilities that an individual possesses (Becker 1993, p. 16). Thus, next to the knowledge and information an expert in a specific field possesses, he or she also possesses tacit non-knowledge, which is inseparable from his or her person. Furthermore, considering the discussion in Team Cognition research about the terms of shared cognitive or knowledge structures (see section 2.1), a reformulation of terms has to be made here. In place of the term shared knowledge structures, the term shared cognitive structures will be used in this work to describe the structural component of Shared Cognition and Team Cognition. The rationale behind this reformulation follows the definition of knowledge and non-knowledge as discussed above. Shared cognitive structures can thus contain both shared knowledge structures as well as shared information structures. Furthermore, teams can contain both shared cognitive structures and tacit non-knowledge. An example of a shared information structure would be a shared understanding about a novel idea, whose purposefulness is yet to be validated. With these definitions, it is thus possible to discuss the content dimension of team interaction and sharing in Team Cognition research in general and specifically in the context of TMS research.

2.4 Why do teams share – Cognitive interdependence and motivation

Early studies in the field of TMSs are characterized by the context of the cognitive interdependence in close couple relationships (e.g., Wegner et al. 1985; Wegner 1987; Wegner et al. 1991). As further outlined in section 3.1 of this work, Wegner et al. (1985, p. 253) regarded this interdependence in close relationships as the defining variable for intimacy.

However, organizational contexts differ from this intimate context in several ways. First, team membership and group composition are not absolutely fixed over the same period of time as in the intimate context. Teams, defined as complex adaptive systems, can (as is often the norm) consist of more than two individuals and these individuals are likely to change in the lifecycle of the team (e.g., Levine, Choi 2004; Rao, Argote 2006). Therefore, the underlying questions are: why do team members engage in the sharing of their knowledge and information and what constitutes interdependence in a team?

Teams have to accomplish complex tasks where knowledge matching the specific task – such as problem-solving, decision-making, new product development, or simpler administrative tasks – is needed (e.g., Akgün et al. 2006; Lewis, Herndon 2011; Tang et al. 2014). In these contexts, it is assumed that individual team members are not able to cope with the increased amount of knowledge and information on their own (Yuan et al. 2007, p. 131). Following this, teams in such cognitive task contexts frequently consist of team members with heterogeneous expertise (or more broadly put, Human Capital) to increase the pool of information and knowledge available in the team (Wittenbaum, Stasser 1996, p. 15).

Although this explanation matches the first part of the definition of teams regarding team-level goals, it is not sufficient to explain the alignment of individual-level goals in teams, which is necessary for the functioning of a team. Sharing information about one's own expertise and specifically sharing this expertise can be regarded as a transaction that implicates certain costs on the sender's side (e.g., Alewell, Martin 2006, p. 284). Furthermore, since expertise – at least in our information society – can be understood as one of the bases of personal power (e.g., Mechanic 1962, p. 357; Schein 1977, p. 65; Whetten, Cameron 2011, p. 288) – and thus as a potential to influence another individual's behavior in one's favor (e.g., Schein 1977, p. 65; Whetten, Cameron 2011, p. 283) – granting access to the sender's expertise can be regarded as weakening one's base of personal power by the sender. Equally, the power base of the receiver is strengthened by receiving information and knowledge. Therefore, the questions regarding organizational contexts are here formulated as follows: why does the sender give access to his or her power base and what motivates knowledge and information sharing behavior of individuals? Since individuals in teams are regarded to be at least partially rational, the costs of sharing have to be lower than the benefit of sharing their expertise (e.g., Alewell, Hackert 1998, pp. 33–34). Following this, the task and reward structure needs to be structured insofar as to motivate individuals and to link individual-level and team-level goals, next to the interdependence of goals at the team-level (e.g., Hollingshead 2001; Yuan et al. 2010b; Beersma et al. 2013).

Another approach to this concept relates to the utilization of team members as external storage facilities (next to nonhuman external storage) for the individual team member (Wegner 1987, p. 187). From a functional point of view, another approach to TMS theory could thus be to analyze how individuals secure their property right of usage for their human external storage facilities. What kind of psychological or explicit contracts would team members have to commit to in order to efficiently coordinate their expertise (e.g., Alewell 2002; Hauff 2007)? Furthermore, how would a task have to be structured to encourage this commitment? And how would access to the external storage be secured and what kind of consequences would the refusal of granting access to one's own storage entail? If we regard a team as a purposeful social system (see definition of teams in section 2.2) consisting of individual actors that are at least partially rational in the motivation to achieve their individual-level goals, we need to integrate these interrelations into the theoretical TMS discussion.[8]

How these questions have been integrated into the TMS concept and empirical research will be further discussed in the following chapters 3 and 4, where the original construct and empirical research regarding TMSs are discussed and organized. What should have become clear in this section, is that both the *What* (content) and the *Why* (interdependence) of Team Cognition are aspects that are fundamental to the analysis and development of the TMS construct.

2.5 From the functional perspective of information processing to a dynamic approach

In this section, the shift in Team Cognition and TMS research from the functional Input-Process-Output (I-P-O) paradigm to a dynamic Input Mediator Output Input (IMOI) approach is discussed.[9] This discussion is necessary, since, according to the definition advanced in this work, teams are no longer understood as single-level entities but complex multi-level systems. To begin with, the functional I-P-O paradigm that has been used in many studies in the fields of Team Cognition and TMSs (see Hinsz et al. 1997) will be explained and discussed in the following subsection. Here, potential issues of this paradigm will be highlighted and embedded within the team context. Following this, the revised IMOI approach that

[8] The author is aware that this brief discussion displays only a fraction of the implications of a true discussion of interdependence in organizational contexts. However, the focus of this work is to analyze the TMS concept itself. Here, it is important to remind researchers that these problems exist within the organizational research context.

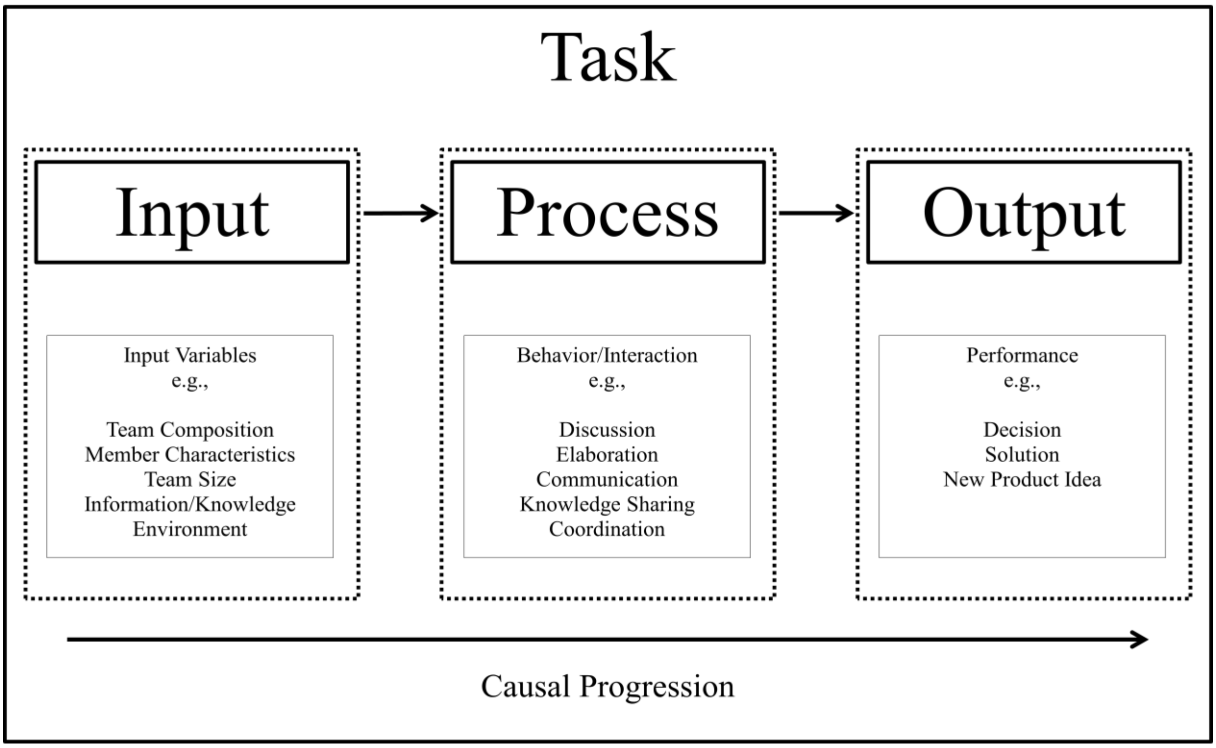
[9] Following Ilgen et al. (2005, p. 520), the hyphens between I-P-O have been removed for the IMOI approach. This removal represents the understanding that the causal links within the IMOI model are understood to be not exclusively (or even) linear, but also rather nonlinear or conditional in nature.

incorporates the solutions to the discussed issues is outlined in more detail with a particular focus on the team processes and the development of emergent states. The latter will then be a main topic of the subsequent section (2.6) that presents the multi-level concept of social emergence developed by Kozlowski & Klein (2000). This concept – in an integrated model – is used to reframe the original definition of the TMS construct from a multi-level perspective in section 3. This connection of the IMOI model and the multi-level framework supports the analysis and classification of existing TMS literature and research that follows in section 4.

2.5.1 The functional Input-Process-Output (I-P-O) perspective

Most of the early research in both Team Cognition and TMSs has been guided by the functional I-P-O perspective (Hackman 1987, p. 316). As explained in the introduction, some of the issues in TMS research might be related to this single-level and static view. To address these issues, the basics of the functional perspective of teams inherent to the I-P-O paradigm will be briefly explained in the following.

Figure 2: A functional Input-Process-Output model



Author's illustration based on Hollingshead et al. (2005) and Ilgen et al. (2005)

According to Hollingshead et al. (2005, p. 22), the functional perspective is defined "as a normative approach to describing and predicting group behavior and performance that focuses on the functions of inputs and/or processes" (as seen in figure 2). There are four core assumptions that guide research using this perspective (ibid., p. 22):

1. Teams are goal oriented

Compatible with the definition of teams in section 2.2, the functional perspective describes teams to pursue certain goals. With regards to the shared information processing paradigm in Team Cognition, these goals mostly consist of the effective processing of information to finish a task such as decision-making, problem-solving, or new product development. Although teams may have other sub-goals such as social or personal goals, research following the functional approach primarily focuses on the task-related goals and outputs.

2. Team behavior and performance varies in quality and quantity and can be evaluated

The most essential assumption according to the functional perspective states that behavior and performance of teams varies between groups and can be measured. Regarding the Team Cognition literature, this implies that the interaction and output in form of decision-making, problem-solving, or new product development can be evaluated and compared to each other in other teams or within the same team in different tasks. If the output is less than requested, the input dimension (in form of team member characteristics) or the process dimension (in form of team behavior) can be regulated through training and development.

3. Interaction processes have utility and can be regulated

The third assumption of the functional perspective states that team performance is primarily influenced by certain interaction processes in team behavior. Furthermore, these interaction processes have different utility for the team's task completion and can be controlled and regulated. Regarding the Team Cognition literature, most of these interaction processes are described as information and knowledge sharing as well as communicative acts between different team members. Supporting the interaction processes, the functional perspective argues that team activities – that constructively maintain the interaction processes – are needed for teams to achieve their task goals. In Team Cognition research, these activities are found in the literature on the explicit and implicit coordination (e.g., Fisher et al. 2012; Rico et al. 2008) and organizational routines (e.g., Feldman, Pentland 2003; Miller et al. 2012).

Concerning the regulation of the interaction processes, the functional perspective states that certain organizational interventions are possibilities to enhance team performance. Examples of such interventions are the development of organizational rules for knowledge sharing, the use or implementation of specific communication technologies, or the restructuring of the task.

4. Internal and external factors influence team behavior and performance via interaction

The fourth assumption relates to the internal and external factors of team interaction. Team factors such as composition and team size in combination with external factors such as time pressure and organizational competition are thought to influence team behavior and performance. This influence is described as a causal relationship insofar as that the input factors mediated by the interaction processes influence team performance. Of importance here is the assumption that this causal influence is described as a sequential, causal string, in which the input factors influence the interaction processes and behavior, which in turn influence team performance (as depicted in figure 2 above). This causal explanation has been widely used in Team Cognition research and specifically in TMS research to describe the relationship between shared information processing and team outcomes (see for example the TMS model described by Ren and Argote 2011, p. 196).

In conclusion, the strengths of the functional perspective on teams are based on its focus on causal relationships between specified inputs and processes on the one hand, and measureable and definable outcomes on the other hand.

2.5.2 Conceptual issues of the functional I-P-O paradigm

While the functional perspective can be effectively used to study inputs, processes, and outputs that are in a direct causal relationship, it shows certain weaknesses regarding the analysis of teams as complex, adaptive, and dynamic systems, which are discussed in this section. Next to this discussion, the issues of using this perspective to understand the cyclic development of such systems will be elaborated.[10]

Although the reduction in complexity in the I-P-O approach may be necessary and appropriate for the inference of propositions and relationships in other team research contexts, I argue that it should not be applied in TMS research (as has been discussed regarding the multi-level nature of TMSs in section 1.1). As expressed above, the evaluation of studies in TMS

[10] Another possible issue is the accurate and distinct measurement of team performance as a specific output variable (e.g., Hollingshead et al. 2005, p. 48). Since this issue is not exclusive to the research of TMS, it will not be explicitly addressed here. It will, however, be reflected in the discussion of what constitutes output variables (performance, development of emergent states, refinement of team processes) in the following sections.

research in which a single-level and functional approach has been applied (see section 4) can be supported by the analysis of conceptual issues in the I-P-O approach. This is because certain conceptual issues in the functional approach might explain deficiencies within these TMS research approaches.

Issues in the definition of teams and research settings

According to Hollingshead et al. (2005, p. 47), the functional approach should not be used to study dynamic causal relationships in teams, because it is limited to the study of direct linear causal relationships. As the authors argue, due to the approach's limitation on "group outcomes as the linear function of inputs and processes, it cannot explain cyclical, nonlinear group dynamics, or reverse causality" (ibid., p. 48). Similar to this, Ilgen et al. (2005, p. 519) argue that the functional perspective in team research – that is related to early contributions (e.g., Steiner 1972; McGrath 1984; Hackman 1987) – regards team performance as a linear progression from input to process to output. Thus, it fails to "capture the emerging consensus about teams as complex, adaptive systems" (Ilgen et al. 2005, p. 519). Supporting this conclusion, McGrath et al. (2000, p. 96) elaborate that the field of team research consists of a variety of settings in which the functional approach has been used. According to the authors, this positivistic approach has led (to some extent) to the study of groups in experimental settings that have only been established for the particular purpose of experimental tasks. In field settings, however, many studies have been focused on groups as "isolated entities and for only a short amount of time" (ibid., p. 96). This has also been the case in parts of TMS research, as will be discussed in more detail in section 4.

Causal and cyclical issues in the study of teams

Regarding the assumption of linear causal progression in the functional I-P-O perspective, Ilgen et al. (2005, p. 519) argue that this assumption cannot be kept up if the understanding of teams as complex, dynamic, and adaptive systems is considered in the study of team performance. According to the authors, knowledge, attitudes, and behavior should be seen as both inputs and processes in the cyclical nature of teamwork. Furthermore, team performance itself can be considered as both output and input dependent on the specific point of time in the task cycle. This argument is supported by Hollingshead et al. (2005, p. 48) in their discussion on the cyclical contribution of inputs and processes to outcomes. McGrath et al. (2000, p. 100) also argue that from the complexity view on teams follows a reconsideration of the nature of causality in team research: "The very idea of complex systems carries with it the implication that the causal connections (at the level of local dynamics) are multivariate, bidirectional, and nonlinear relations." In light of such problems of assumed singular causality, another issue of the functional I-P-O perspective has to be considered. Related to what has been discussed in the introduction of this work (e.g., Lewis, Herndon 2011), most of the studies in Team Cognition and TMS research that follow the functional perspective cannot accurately explain cyclic development or cyclic team performance, since it restricts causality to a "single-cycle linear path" in which processes do not influence inputs or outcomes influence further processes (Ilgen et al. 2005, p. 520).

The issue of conceptual clarity: Processes vs. emergent states

Another issue existing in team research following the functional I-P-O perspective is the conceptual clarity in the process dimension. As Marks et al. (2001, p. 357) state, the diversity in concepts that have been used in the process dimension has hindered the theoretical development in this research field. An example of this issue in Team Cognition research would be the use of shared cognitive structures as processes between inputs and outcomes without conceptual clarity about the integration of interactive components in a latent model (e.g., Akgün et al. 2005, p. 1110). According to Marks et al. (2001, p. 357), some of these concepts that are understood as processes are in fact not processes but emergent states: "constructs that characterize properties of the team that are typically dynamic in nature and vary as a function of team context, inputs, processes, and outcomes." Emergent states are in fact understood as the consequences of team experiences such as processes and – later on in the team life cycle – are seen as further inputs to processes and outcomes (ibid., p. 358). Accordingly, emergent states do not constitute interactive processes but influence and are influenced by those interactive processes. This between-level influence is further defined as emergence (as will be discussed in section 2.6).

The distinction between interactive processes and emergent states is thus important, because in team research studies, the concept of emergent states is mixed up with process indicators (e.g., for knowledge sharing or coordination), "which results in serious construct contamination" (ibid., p. 358). To improve the conceptual clarity in theoretical and empirical team research, emergent states and processes should therefore be studied in their own terms and at their distinct levels (Hackman 2012, p. 440).

The issue of the level of analysis – Individual- or team-level

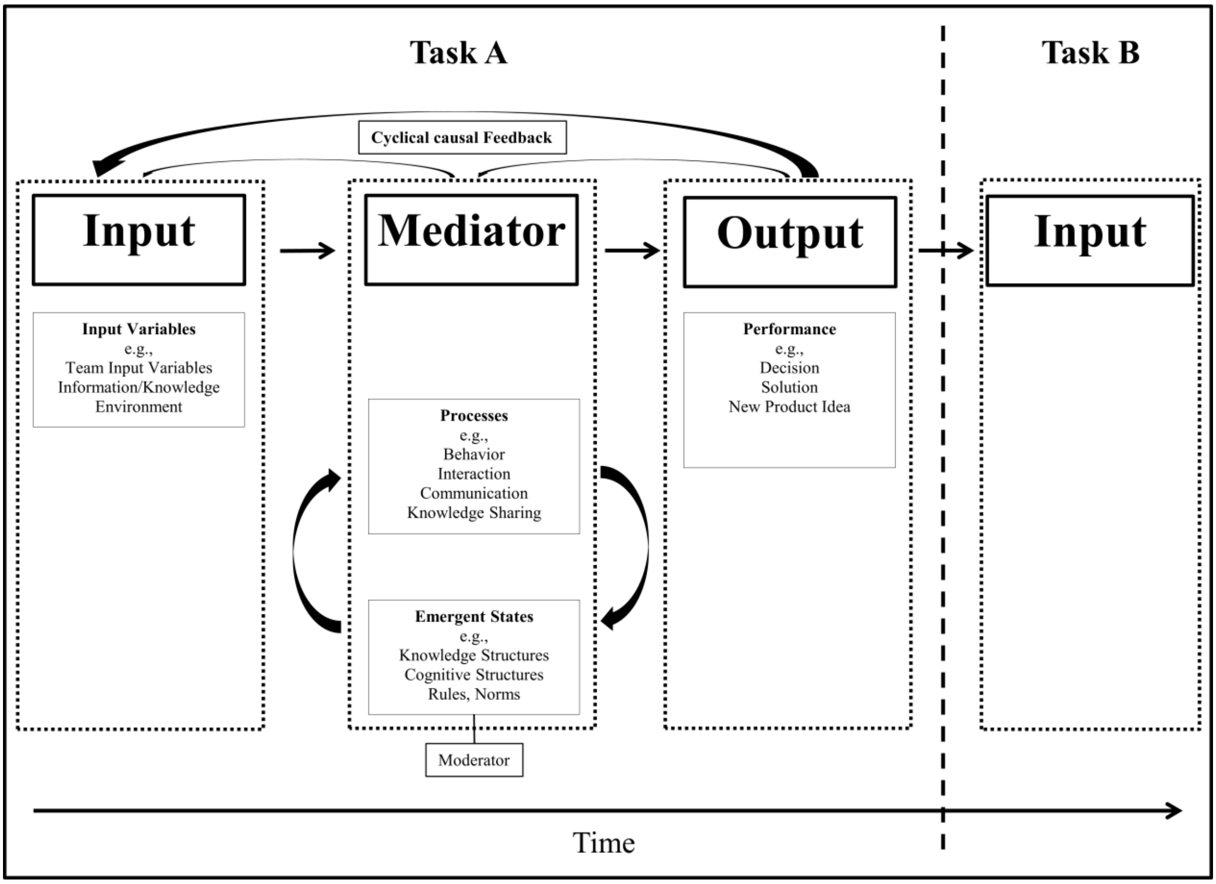
A fourth issue in the use of the functional I-P-O perspective in the study of teams is discussed by Cooke et al. (2009; 2013). According to the authors, since the I-P-O model focuses on information processing within individual minds, the focus in the functional approach is set on the individual-level of analysis (Cooke et al. 2009, pp. 159–160). Therefore, the I-P-O paradigm cannot be used to explain outcomes and emergent states of team interaction at the team-level of analysis, which is the focus of cognition in Team Cognition research (Cooke et al. 2013, p. 256). The authors argue that a revised model should be used to study and measure Team Cognition at both the individual- and team-level of analysis.

In summary, these issues legitimate a revision of the functional I-P-O perspective to study team TMSs and Team Cognition in complex organizational settings at the respective levels of analysis. Reflecting on the problems in general team research discussed above, in relation to the TMS research issues discussed in the introduction, it appears that the issues in TMS research are not unique to this specific construct. Rather, they reflect an underlying research approach that relates to the understanding of teams as rather simple entities as well as a functional I-P-O perspective of information processing. Considering the issues of applying such a functional approach for the study of multi-level cognitive constructs, the extended IMOI model developed by Ilgen et al. (2005) will thus be discussed in the next subsection.

2.5.3 The Input Mediator Output Input (IMOI) model

Taking the issues of the functional I-P-O perspective into account, the Input Mediator Output Input (IMOI) model has been developed to integrate the understanding of teams as complex, adaptive, and dynamic systems (as explained in section 2.1) into a dynamic framework that is not limited to a linear progression from inputs to processes to outputs (Ilgen et al. 2005, p. 520). The specific differences compared to the I-P-O model are the change of the process dimension to a mediator dimension (and integrating emergent states as moderators) and the integration of cyclical causal feedback between the different dimensions (see figure 3).

Figure 3: An Input Mediator Output Input model



Author's illustration based on Ilgen et al. (2005)

Mediator Dimension

As discussed in section 2.5.2, there is an ongoing discussion as to what constitutes processes in team research. The process dimension in the I-P-O model has thus been transformed to a mediator dimension in the IMOI model in order to reflect the understanding that emergent states in combination with interactive team processes mediate the relationship between input and output variables. A mediator is defined in this work as a variable that establishes the relationship between an independent and dependent variable (Bortz, Schuster 2010, p. 441). A basic example in team research would be that team processes in the form of information and knowledge sharing behavior establish the relationship between input in the form of team composition and information and output in the form of decision-making performance of the team. In other words, the independent variable influences the dependent variable through a third mediating variable (Bühner, Ziegler 2009, p. 690). Since an emergent state (e.g., in the form of cognitive structures) according to the definition in this work cannot represent a process, the emergent states can only indirectly influence the relationship between input and output through their direct influence on the interactive team variables. Therefore, in the IMOI model, they moderate the relationship between input, mediator, and output. Moderator variables are defined as variables that influence the relationship between two correlated variables (Bortz, Schuster 2010, p. 357). Here, a direct relationship between the two correlated variables exists and the extent of their correlation is influenced by the moderator (Bühner, Ziegler 2009, p. 690). Another basic example would be that emergent states in the form of team cognitive structures as moderators influence the relationship between information and knowledge sharing as process and decision-making performance as output.

The arrows between the emergent states and processes in the mediator dimension reflect another difference from the I-P-O approach. Within the mediation dimension, it is possible for emergent states to influence processes as well as for processes to influence emergent states. Within our Team Cognition example, this would be explained by the interactive processes of information and knowledge sharing that change and/or refine the cognitive structures at the same time as the cognitive structures influence the efficiency of information and knowledge sharing. Thus, the arrows in the IMOI model reflect the dynamic and nonlinear interplay between different levels in the form of emergent states and interactive processes in teamwork.

Cyclical causal feedback

To integrate the possibility of nonlinear progression within the IMOI model, Ilgen et al. (2005, p. 520) add feedback loops between the input, mediator, and output dimensions. Accordingly, it is possible for outputs or mediators of subtasks to transform into further inputs or mediators in the same task or generally to transform into inputs for the subsequent task (as depicted in figure 3 in the added input dimension in task B). For example, a team decision or solution to a sub-problem can transform into information or knowledge that is used in the subsequent sharing or discussion phase. This change in perspective is also reflected by the replacement of causal progression in the I-P-O model with time in the IMOI model. This is important regarding the development of specific research questions in team research. Here, it is important to specify a) the dimensions of the model that are studied and b) the point of time in the team lifecycle in which the team is studied (as will be further discussed in terms of the TMS development in section 3.3). For a view on teamwork and the cognitive structures that considers development, this in turn leads to the development of longitudinal studies in which teams are observed not only at a specific point in time but over longer periods of time, as has been discussed by Lewis & Herndon (2011) regarding issues in TMS research.

Putting the moderation between emergent states and team processes as well as the cyclical causal feedback into perspective of the knowledge creation approaches discussed by Nonaka

(1994) and Schreyögg & Geiger (2003; 2007b; 2007a), the integration of such moderation partially enables the analysis of knowledge creation within a team. Since team processes in form of an internal discourse in the IMOI model are able to validate novel information and existing knowledge by using for example an established routine, they are also able to change the shared cognitive structures of the team that contain specific knowledge. These changed cognitive structures can then be regarded as further inputs for the next task or subtask. The differentiation between emergent states and team processes also supports the operationalization of different levels (individual- and team-level) as discussed by Cooke et al. (2009; 2013) with regards to the issues of the I-P-O model.

To further differentiate this perspective on emergent states and shared cognitive structures, the concept of emergence will be discussed in the next section. This discussion clarifies the types of emergence that are proposed to lead to different emergent states (e.g., shared or differentiated cognitive structures) that – next to the interactive processes of knowledge and information sharing – lie at the heart of the TMS theory.

2.6 Emergence in social systems – A multi-level team approach

Based on the discussion about the integration of emergent states in the I-P-O as well as the IMOI model in sections 2.5.2 and 2.5.3, a differentiated multi-level framework of emergence in social systems based on Kozlowski & Klein (2000) is presented in this section. The aim of this discussion is to link existing Team Cognition and specifically TMS studies to the concept of emergence and to identify issues regarding the multi-level design of Team Cognition constructs (namely the TMS construct that is presented in section 3 of this work). According to Kozlowski & Klein (2000, p. 26), these issues (as argued in the introduction of this work) are grounded in the lack of conceptual clarity and misalignment within the representation of their potentially multi-level nature. As discussed in the prior sections, teams are not represented as dynamic systems consisting of lower-level systems (members) and as being embedded within a higher-level system (organization). Existing research therefore "slices" the organization into the respective levels of their own research disciplines, theories, and methodologies (Kozlowski, Klein 2000, p. 3). Although these issues have been identified almost two decades ago, current research still has a long way to go in this regard, as Cronin et al. (2011, pp. 586–592) summarize in their review of team research up to the year 2010. As discussed in the introduction, these issues do not only exist in the broader context of team research, but specifically in the TMS context. Therefore, it is important to a) define what constitutes emergence and emergent states that are represented in the process and mediator dimensions of the aforementioned models, b) clarify in which direction and at what level (individual, team, organization) emergent constructs can influence other variables, c) define what shape emergence can take (regarding the shared or distributed cognitive structures in Team Cognition), and d) how the temporal dynamics influence emergent processes within the team.

The framework by Kozlowski & Klein (2000) supports the study of dynamic multi-level constructs at their respective levels. In this regard, it fits this work's purpose for two reasons: a) it fits my theoretical lens on TMS theory to explain team performance, since it regards teams as complex, dynamic systems and integrates team processes at different levels of analysis, and b) this perspective is already comprehensibly utilized in existing Team Cognition research (e.g., Fiore et al. 2010).

In the following subsections, the framework will be further discussed with an emphasis on the need to clarify the levels of analysis in TMS research. Subsequently, the concept of emergence in social systems is discussed – including bottom-up and top-down emergent processes. The final subsection is focused on temporal dynamics and path dependencies in emergent processes.

2.6.1 The construct of interest – Determining the levels of analysis

Prior to understanding and utilizing the concept of emergence, it is important to specifically explain what phenomenon of interest is analyzed in this work. This explanation defines the levels that are necessary to be integrated into the constructs that are applied for the study of this phenomenon (Kozlowski, Klein 2000, p. 12). The phenomena analyzed in this work – teams and the emergent cognitive structures – that are considered to exist in the cognitive division of labor are conceptually represented as constructs consisting of multiple levels of interest (Kozlowski 2012, p. 260). As discussed in section 2.1, Team Cognition research is concerned with the cognitive activities of teams and their influence on team performance. Furthermore, researchers in this field explicitly state that these activities exist at both the individual- and team-level and that the individual and shared representations of team members influence the cognitive activities of the team. In summary, for the transfer of the TMS construct to a multi-level model, it is necessary to account for these concerns by integrating both individual- and team-levels next to the organizational-level (see table 2). The integration of the organizational-level results from the definition of teams nested in the larger system of the organization (e.g., Bell, Kozlowski 2012, p. 45).

Not specifying and integrating these levels into Team Cognition research would, according to Kozlowski & Klein (2000, p. 12), lead to "incomplete or misspecified models" that are unable to capture the phenomenon of interest. Furthermore, the misspecification of such multi-level models would hinder their evaluation since not clarifying the levels of analysis would lead to ambiguity in developing measurement methods (Kozlowski 2012, p. 262). This issue of misspecification is clearly noticeable in Team Cognition and TMS research following the functional I-P-O model of information processing, as discussed above.

Table 2: Levels of analysis in team research

Level of analysis	In team research context
Micro	Individual-level (Team member)
Macro	Team-level
Contextual	Organizational-level (context and/or compared to team-level units and constructs at hierarchically higher levels)

Author's illustration based on House et al. (1995)

In addition to the need for level and phenomenon specification, it is necessary to specify how the constructs at different levels influence and are influenced by each other. This explanation and specification of the combination of different levels are what House et al. (1995) define as the meso perspective.[11] They define meso as "the simultaneous study of at least two levels of analysis" that are thought to be linked by processes that enable micro-level constructs to influence macro-level constructs and vice versa (ibid., p. 73). In the framework by Kozlowski & Klein (2000), this meso perspective is integrated into the concept of emergence, given that the latter can be seen as a link between the individual-level and the team-level. How emergence is proposed to function in social systems will be further outlined in the following.

[11] This debate about links and processes between micro and macro perspectives is not unique to team research. For example, it is frequently referred to in organizational sciences regarding the link between individual human capital and behavior on the micro-level and the collective capabilities of an organization at the macro-level as levels of research in the study of Human Resource Management systems (e.g., Alewell, Hansen 2011, p. 95; Hansen, Alewell 2013, p. 2136).

2.6.2 Bottom-up and top-down emergent processes

The concept of emergence is used to explain how two constructs at different levels of analysis are linked. According to Kozlowski & Klein (2000, p. 55), a "phenomenon is emergent when it originates in the cognition, affect, behaviors, or other characteristics of individuals, is amplified by their interactions, and manifests as a higher-level, collective phenomenon." In an organizational context, emergent processes are thought to amplify, combine, and crystallize the individual-level learning and changes to form an emergent team-level phenomenon (Kozlowski et al. 2011, p. 370). For example, in Team Cognition research, Shared Mental Models or Team Mental Models – defined as the shared representations of key elements in a team's task that are shared by the team members – can be defined as such emergent phenomena (e.g., Cannon-Bowers et al. 1993; Mohammed et al. 2010). They originate in the cognition of individual team members and manifest themselves as shared higher-level, collective cognitive structures. In the following, first, bottom-up and top-down processes of emergence are discussed in order to detail how interaction at the individual-level can potentially lead to an emergent phenomenon bottom-up and how these emergent phenomena are proposed to influence the individual-level units top-down. Furthermore, contextual factors and temporal dynamics are integrated into the framework.

2.6.2.1 Bottom-up emergence

Drawing on the discussion of a static perspective of emergence based on isomorphism in General System theory (e.g., Bertalanffy 1968, p. 80) and the actual differentiated structure within organizations due to the division of labor, Kozlowski & Klein (2000, p. 16) differentiate between two types of bottom-up emergence: emergence based on compositional and emergence based on compilational processes at the individual-level (see table 3). This differentiation between two distinct types of bottom-up emergent processes is expedient for the purpose of this work to study TMSs from a multi-level perspective, because it considers both the content of the emergent phenomenon itself and the processes that are proposed to lead to its emergence.

Table 3: Two types of bottom-up emergence

Process types	Compositional	Compilational
Emergent phenomena	Shared unit properties	Configural unit properties
Individual contribution to the emergent phenomenon	Similar (e.g., mental models)	Dissimilar (e.g., diverse expertise)

Author's illustration based on Kozlowski and Klein (2000)

Compositional emergence

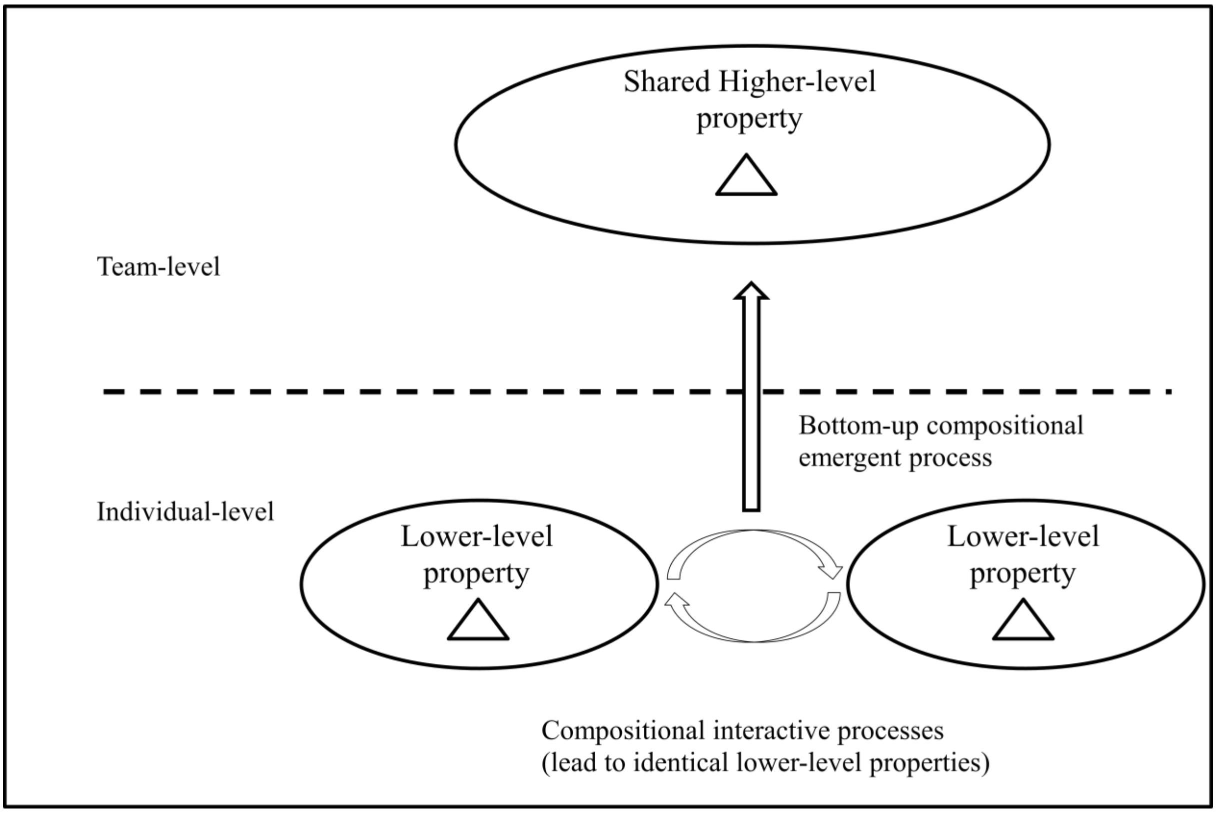
Compositional emergence is based on the isomorphic understanding of emergence applied in General System theory (e.g., Bertalanffy 1968, p. 80). This type of emergence is used to refer to phenomena that emerge "through linear, convergent processes" (Bell, Kozlowski 2012, p. 46).[12] Accordingly, composition processes are understood to lead to identical lower-level properties (Kozlowski, Klein 2000, p. 16). These identical properties consist of for example mental models at the individual-level that form a team-level Shared Mental Model which is identical to the individual mental models (e.g., Cannon-Bowers et al. 1993). At both the individual-level and the team-level the content of the mental model is identical, thus isomorphic (see figure 4).

One objection to the emergent nature of these shared higher-level properties relates to the identical content at both the individual- and team-level and thus the possibility of not regarding the team-level properties as emergent. However, there are two possible responses to this objection. First, as stated above, interactive processes are proposed to lead to identical lower-level properties, implying that, for example, similar models of the task can be developed through the interaction of the team members. Second, as Cronin et al. (2011, p. 575) argue, the shared higher-level property (in this example the Shared Mental Model) does not exist without team members a) sharing its content and b) being aware of this sharedness. Based on this, the awareness of shared cognitive structures is regarded as the basis for compositional emergence in this work (as will be further discussed in sections 3 and 5 of this work).

[12] The assumptions of linear, convergent processes that lead to compositional emergence and compilation processes that in turn lead to compilational emergence are expressed by Kozlowski & Klein (2000, p. 16) as idealistic assumptions that are used to exemplify different types of emergence. The authors (ibid., p. 59) recognize that emergent collective phenomena "may emerge in different ways under different contextual constraints and patterns of interaction." In this section, these assumptions are applied to clarify the possible differences between shared and configural cognitive structures in Team Cognition research.

As seen in figure 4, compositional bottom-up emergence is proposed to lead to higher-level constructs that are shared by each team member. Kozlowski & Klein (2000, p. 30) refer to these constructs as *shared unit properties* that are thought to emerge as a "consensual, collective aspect of the unit as a whole." Individual- and team-level constructs are thus proposed to share the same content and meaning. On this account, in section 3.2, special attention will be paid to how the interactive processes at the lower-level are proposed to lead to the emergence of shared higher-level unit properties in the original concept of TMSs.

Figure 4: Idealistic representation of compositional bottom-up emergence

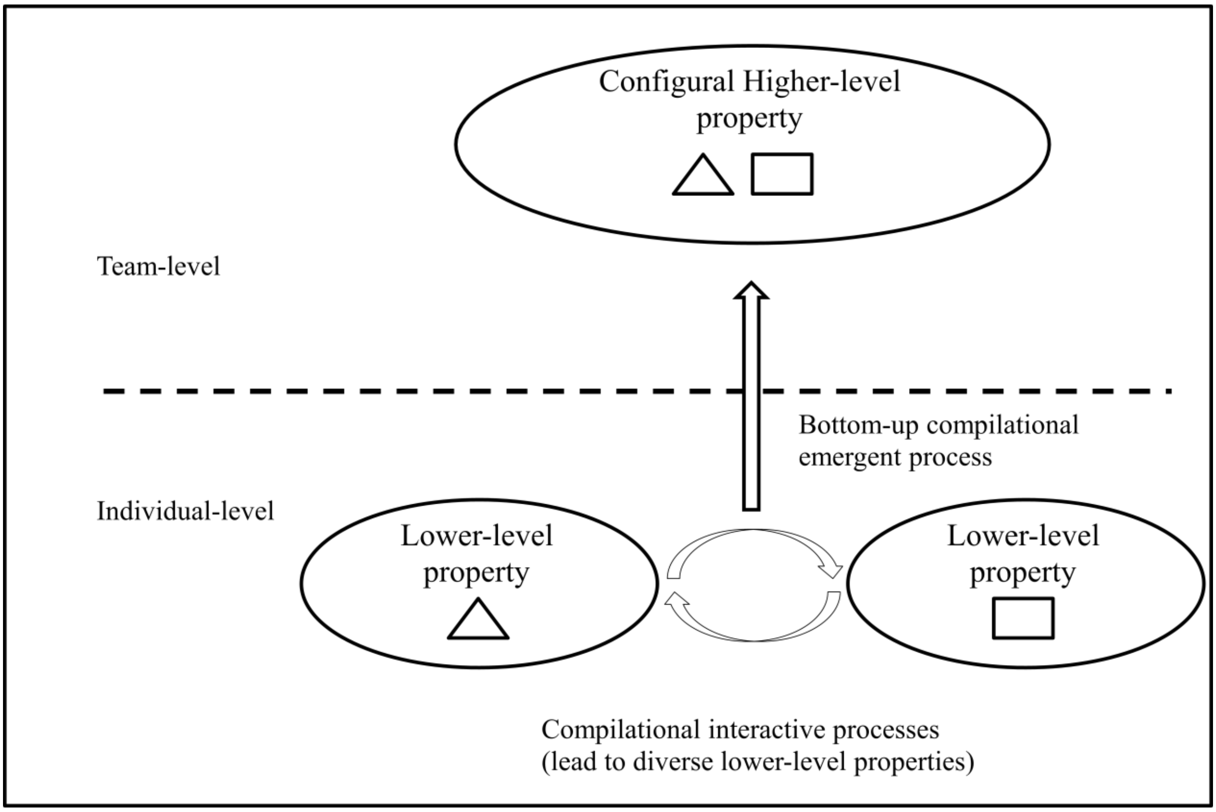


Author's illustration based on Kozlowski and Klein (2000)

Compilational emergence

Compilational emergence is based on the assumption that higher-level constructs such as team performance can emerge from diverse contributions of individual team members (Kozlowski et al. 2011, p. 372). Here, lower-level properties that differ in meaning and content are proposed to possibly lead to a higher-level configural property that is functionally equivalent to the lower-level properties, but is patterned to contain the differences between lower-level properties (Bell, Kozlowski 2012, p. 46). An example in Team Cognition research is the expertise possessed by each individual team member that, in combination, form the team's expertise as a whole (e.g., King 1998). Accordingly, the content of each individual team member's expertise and the team's expertise as a whole is proposed to differ (see figure 5). As Bell & Kozlowski (2012, p. 46) discuss, due to the patterned nature of these compilational processes and the complex nature of their theoretical and empirical study, these processes have been underrepresented in team research compared to compositional processes.

Figure 5: Idealistic representation of compilational bottom-up emergence



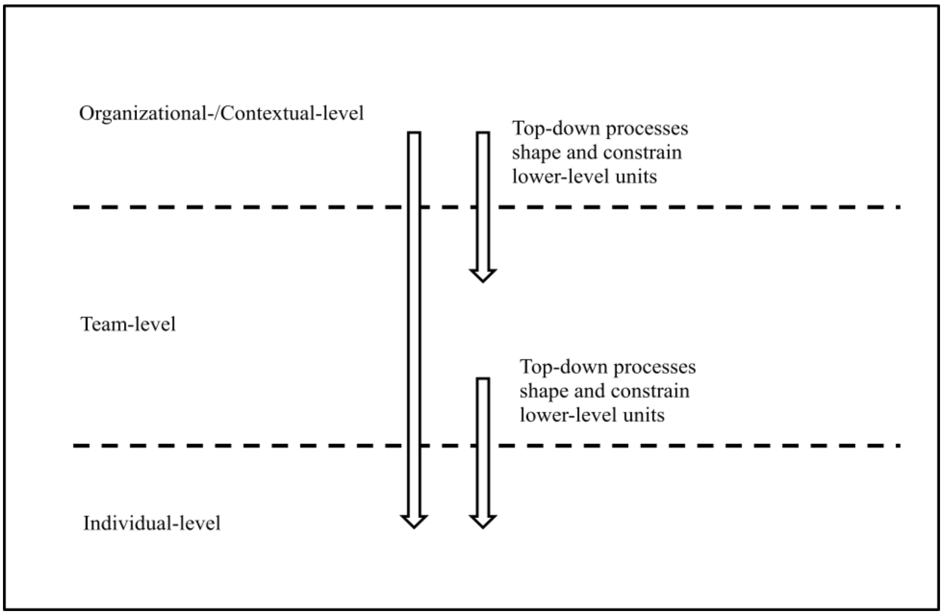
Author's illustration based on Kozlowski and Klein (2000)

As figure 5 shows, compilational bottom-up emergence is proposed to lead to higher-level constructs that are different in content from the lower-level constructs. Kozlowski & Klein (2000, p. 16) refer to these constructs that emerge from compilational processes as *configural unit properties*. In contrast to shared unit properties, configural unit properties do not emerge from processes that promote isomorphism but are rather proposed to emerge from processes that promote differences in content. Although configural unit properties are proposed to emerge from dissimilar properties of lower-level constructs, they can nonetheless entirely represent the unit in form of a team (ibid., p. 17). Again, the example of team expertise can be used in this regard. One cannot infer individual-level expertise from the configural team-level property of team expertise. Nonetheless, it represents the team's expertise through the pattern or configuration that is represented. Similar to the analysis of interactive processes that are proposed to lead to shared cognitive structures, it is therefore necessary to analyze how the interactive processes at the lower-level are proposed to lead to the emergence of configural higher-level unit properties in the original concept of TMSs (see section 3.2). As will be discussed in this context, emergent team-level constructs are not bound to a single type of emergent process. Rather, depending on the assumed underlying interactive processes, the emergent construct may be both shared and configural in nature.

2.6.2.2 Top-Down processes: Contextual influences

Teams understood as social systems are not isolated from other systems in the organizational context. Rather, these other systems and the organizational context in its entirety shape and constrain the emergent processes and interactions of individual team members (Bell, Kozlowski 2012, p. 45). For example, the information technology used within a firm to document expertise, workflow, and correspondences potentially shapes the form in which information and knowledge can be shared (e.g., Bazarova, Yuan 2013; Choi et al. 2010) or how trust and stress develop within a team (e.g., Barley et al. 2011; Bos et al. 2002) and how this in return influences the formation of a higher-level construct. In the example of the information technology used within an organization, cognitive structures held by the individuals of a team have to be aligned with the technology in so far as to enable individuals to use this technology for information and knowledge sharing purposes (Kozlowski et al. 2011, p. 370).

Figure 6: Top-down emergent processes



Author's illustration based on Kozlowski and Klein (2000)

According to Kozlowski & Klein (2000, p. 14), such contextual and higher-level influences or top-down processes have to be integrated into the multi-level model in order to capture interrelations between the different constructs (see figure 6).

The influence a specific higher-level unit can potentially exert on a lower-level unit is proposed to be of either direct or indirect nature (ibid., p. 14). Direct influence describes an immediate effect on the lower-level unit such as described in the example above. Information technology can directly influence the form of information and knowledge sharing of lower-level units in form of team members if there is an organizational standard procedure to use this technology (e.g., Rao, Argote 2006). Indirect influence describes a moderating influence that a higher-level unit has on the relationships of lower-level units. For example, organizational climate can potentially exert a moderating effect on information and knowledge sharing via the influence on the psychological safety of the team members (e.g., Edmondson 1999; Edmondson, Lei 2014), if psychological safety influences information and knowledge sharing (see the discussion about interdependence in section 2.4). Thus, it is necessary to analyze how the higher-level contextual factors are specified to influence lower-level relationships in the original TMS concept (see section 3.2).

Although Kozlowski & Klein (2000, pp. 14–15) explicitly discuss the top-down processes at the meso-level between the organizational-/contextual-level and the team-level, there is an essential top-down meso-level that has to be integrated. Referring to the discussion in section 2.5, it has been elaborated that emergent states themselves do not mediate between inputs and outputs in the IMOI model. Instead, they are assumed to moderate the relationship between inputs, interactive processes, and outputs via their influence on the interactive processes. Translated to the multi-level emergence framework by Kozlowski & Klein (2000), these team-level emergent phenomena influence the emergent and interactive processes top-down at the individual-level (see figure 6). If it is assumed that top-down processes at higher levels in the organizational structure exist, it is unreasonable to assume that the emergent phenomena would not themselves influence the lower-level units. An example of this proposed influence in Team Cognition literature is the influence that Shared Mental Models exert on the coordination and decision-making processes of the team members (e.g., Cannon-Bowers et al. 1993; Espinosa et al. 2007; Stout et al. 1999).

Thus, if emergent team-level phenomena in the original TMS concept are proposed to originate at the individual-level in the affect, cognition, and behavior of team members (Kozlowski et al. 2013, p. 588), it is necessary to analyze how these emergent phenomena are specified to influence the individual-level units top-down in their affect, cognition, and behavior (see section 3.2). Without this specification, any possible moderation effect of the emergent phenomena on the interactive processes cannot be analyzed.

2.6.3 Temporal dynamics and path dependencies in emergent processes

Time is a complex subject in the study of teams. Most of the studied team phenomena are influenced by time constraints and a varying pace of interaction at the specific levels of analysis (Bell, Kozlowski 2012, p. 46). When integrating the concept of time into a multi-level construct, one has to be aware of the consequences this integration entails. Thus, the concepts of temporal dynamics and path dependencies in emergence are discussed next in order to consider these consequences.

Temporal dynamics

When considering the direction that emergent processes may include (bottom-up or top-down), it is also necessary to consider the temporal dynamics within the multi-level emergence framework (Kozlowski, Klein 2000, p. 21). Although researchers in the field of Team Cognition have started to integrate time and development cycles within their studied constructs (e.g., Brandon, Hollingshead 2004; Lewis et al. 2005), the difference in temporal dynamics between bottom-up and top-down emergent processes has to be considered in developing multi-level constructs (Kozlowski, Klein 2000, p. 23). For example, a higher-level organizational routine for information sharing is possibly able to change the pattern of individual-level cognitive structures top-down rather fast, once it has been established in the organization (regardless of a possible resistance to change in organizational contexts). In contrast to this, due to such possible difference in temporal dynamics on the higher-level, bottom-up emergent processes may need a longer time-frame to establish a change in the higher-level phenomenon. In the example above, discursive processes at a lower-level (team-level) – in most cases – are not able to directly change an established interaction pattern (organizational routine) on a higher-level. Therefore, it is necessary to analyze how temporal dynamics have been integrated into the original TMS concept (see sections 3.2 and 3.3).

Path dependencies

Next to the definition of bottom-up and top-down processes, it is also essential to integrate time specific path dependencies into the framework of multi-level emergence. In this regard, it is necessary to analyze how the points of time in the team's lifecycle are specified in the original TMS concept (Kozlowski, Klein 2000, p. 23), which will be done in section 3.3. Again, taking the aforementioned IMOI model into account, the emergent constructs and processes are proposed to influence each other within and between each IMO cycle to become new inputs and outputs in the lifecycle of the team and the task. Cronin et al. (2011, p. 579) discuss this dynamic cycle regarding the construct of team knowledge – specified as group memory or memory repository with reference to TMSs (Wilson et al. 2007, p. 1047). In this context, the authors argue that, by integrating dynamic cycles and multiple levels of analysis into the study of team knowledge, path dependencies could potentially be introduced into a multi-level IMOI model. Accordingly, path dependence refers to the possibility that one emergent phenomenon can exert different influences on other phenomena and interactive processes dependent on the point of time in the team's lifecycle in which this phenomenon is observed. Furthermore, due to the cyclic nature of the IMOI model, the influence a phenomenon exerts at point A in the team's lifecycle changes the influence it can possibly exert in point B (see figure 7, where to exemplify this, the influence of contextual factors is assumed to be constant between points A and B in time). As represented in figure 7, path dependencies are assumed to possibly exist within and between different levels in this model. This is exactly the reason why a single-cycle linear analysis of teamwork in a functional I-P-O model is limited in explanatory power for the analysis of the TMS construct in this work. It cannot be used to incorporate the interrelations within a team's assumed multi-level emergent constructs and processes.

Related to the construct of team knowledge mentioned above (Cronin et al. 2011), the following example helps to clarify this path dependence. The influence of a team's configural cognitive structure (see section 2.6.2) on the information and knowledge sharing behavior is observed in point A in the team's lifecycle. This influence can possibly lead to a change in the information and knowledge sharing behavior in so far as the structure can channel the behavior into a specific direction. Furthermore, this changed behavior in turn can influence the cognitive structure in so far as it may lead to a more differentiated or integrated cognitive structure (as is one assumption in the TMS theory that is the subject of section 3). At point B in the team's lifecycle, this changed cognitive structure may thus exert a different influence on the information and knowledge sharing behavior at lower levels. Therefore, observing this assumed multi-level construct of emergent states and processes in point A or B alone is not sufficient for the analysis of emergence within the team's lifecycle.

However logical this inference might be, it is seldom applied in Team Cognition research (Kozlowski 2015, p. 273). Due to the potential path dependencies within the IMOI model, it is important to analyze the team at multiple points in the team's lifecycle to understand the underlying emergent processes and their directions.

Figure 7: Possibilities for path dependence in multi-level emergence

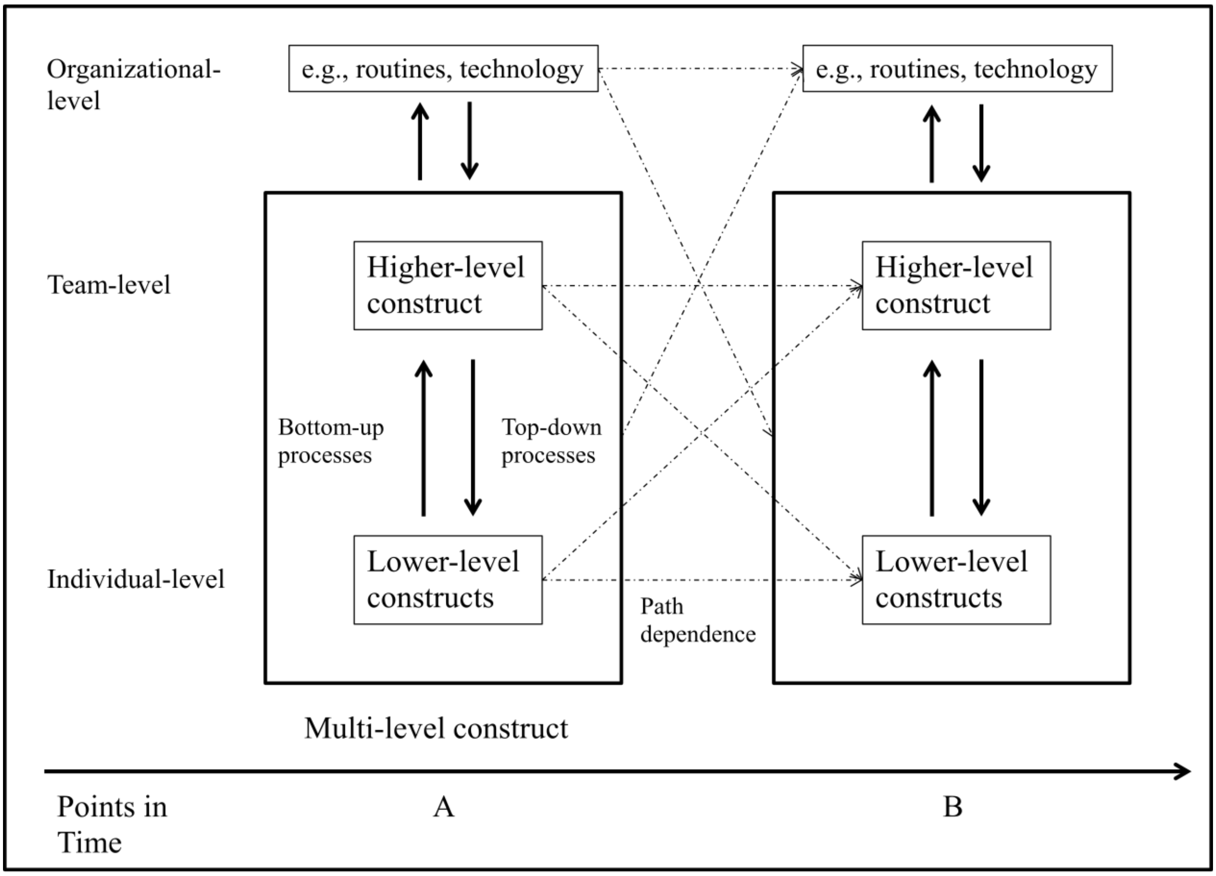


Illustration adapted from Cronin et al. (2011, p. 581)

Based on the development of a multi-level IMOI framework which has been the focus of this section, it is now possible to reformulate Wegner's original TMS concept from a multi-level perspective within an organizational context. This is the topic of the following section (3) of this work. Subsequent to this reformulation, current TMS research is analyzed from this particular perspective in section 4 in order to assess how empirical TMS research integrates the multi-level issues and temporal dynamics into the specific models and measurement methods.

3 Transferring the concept of Transactive Memory Systems to a multi-level perspective

In this section, the original concept of Transactive Memory Systems (TMSs) developed by Wegner et al. (1985) will be integrated into the multi-level framework developed by Kozlowski and Klein (2000) and, moreover, into the IMOI model presented by Ilgen et al. (2005) that both have been the focus of section 2 of this work.[13] This integration is important for the analysis of TMS research which follows in section 4, since it specifies interrelations and influences between different levels within the multi-level construct of TMSs and thus considers one main issue in TMS research: the misspecification of the multi-level nature of the TMS construct (see the introduction). On this account, the underlying propositions of the original TMS concept concerning individual-level and team-level constructs and their interrelations are discussed and evaluated regarding their specificity. Based on this evaluation, this section lays the foundation for the adapted model of TMSs that will be presented in section 5.

Regarding the use of terms such as teams and knowledge, all respective terms in the original TMS articles have been rephrased in this section to fit into the theoretical background presented in the previous section. To relate this reformulation to the original research, the section begins with an overview of the early TMS research context. Following this overview is an integration of the TMS construct into the multi-level framework. Here, both the emerging team-level cognitive structures as well as the bottom-up and top-down emergent transactive processes are elaborated. In order to integrate the notion of team lifecycle into the proposed framework, the development of a working TMS and possible path dependencies are discussed.

Finally, the multi-level TMS model is combined with the IMOI model to support the analysis of current TMS research from this perspective (see section 4). In this context, the particular role of the original TMS construct within Team Cognition research and its potential contributions are discussed. This discussion also clarifies the differences between dyadic and organizational research contexts that have to be included in organizational TMS research.

[13] The author is aware of one work that reformulates TMS theory into a multi-level framework (Yuan 2004, pp. 38–42) that is the foundation for studies on TM and expertise exchange (Yuan et al. 2010b), TM and social capital (Yuan et al. 2005), and awareness and expertise retrieval (Yuan et al. 2010a). But whereas the work presented here integrates the original TMS theory by the use of Kozlowski and Klein's (2000) multi-level framework into the dynamic IMOI model presented by Ilgen et al. (2005), Yuan uses the static perspective of TM to define TMS as a shared unit property emerging through compositional processes. Therefore, Yuan's perspective is similar to the notion of Shared Mental Models (e.g., Cannon-Bowers, Salas et al. 1993). As will be seen in this section, this perspective on its own does not contribute to our understanding of the concept of TMS as a differentiated construct next to Shared Mental Model research.

3.1 The early TMS research context

Research on Transactive Memory Systems (TMSs) is focused on the prediction of individual and team behavior through “an understanding of the manner in which groups process and structure information” (Wegner 1987, p. 185). The concept of TMSs was first mentioned by Wegner et al. (1985, p. 253) to describe shared cognitive processes at a dyadic-level as opposed to cognitive processes at the individual-level. The focus of Wegner's early studies (Wegner et al. 1985; Wegner 1987; Wegner et al. 1991) was the cognitive interdependence as it appears in close relationships. He examined this interdependence to identify how and why people in close relationships depend on each other to acquire, remember, and generate knowledge. Wegner describes the interdependence in a close relationship as “hallmark of intimacy” and characterized this relationship as “intertwined to the extreme” (Wegner et al. 1985, p. 253). This interdependence would “produce” a knowledge holding system in which individuals depend on communication for the enhancement of their individual storage capability (Wegner 1987, p. 189). Thus, the main concern of early TMS research was to study how "knowledge enters the dyad, is organized within it, and is made available for subsequent use by it" (Wegner et al. 1985, p. 256).

Wegner et al. (1985, p. 254) envisioned the concept of TMSs as "more clearly definable and, ultimately, more useful than kindred concepts that populate the history of social psychology," referring in particular to the concept of group mind. The main purpose of this definition is to define TMSs as the coordinated cognitive division of labor in a dyad and to define the processes that enable a TMS to work as a combined memory system in an observable way – in contrast to former conceptualizations of the group mind.[14]

According to Wegner et al. (1985, p. 255), early group mind research contained two conceptual issues that have led to misspecification and a lack of clarity in empirical research. The first issue relates to the lack of differentiation between individual-level and higher-level mental processes. This misspecification is assumed to lead to problems in identifying interactive processes at the specific level of mental operation. The second issue concerns the disregarding of communicative processes among individuals. Wegner et al. (1985, p. 256) regard these processes to be the distinctive characteristic of cognitive processes in these dyads. In response to these issues, the construct of TMSs has been developed. It is proposed to link emergent cognitive states to cognitive communicative processes that in turn link these

[14] For a further discussion of the history of group mind research, see Wegner et al. (1985, pp. 254–256). According to Wegner et al. (ibid., p. 254), one "idea worth preserving" of the group mind research is the "emphasis on the difference between group and individual mental processes."

emergent states to the individual-level constructs, as will be further elaborated in the following section.

3.2 The original TMS concept reformulated from a multi-level perspective

Wegner et al. (1985, p. 256) define Transactive Memory Systems (TMSs)[15] in terms of two separate but connected components: "(1) an organized store of knowledge that is contained entirely in the individual memory systems of the group members, and (2) a set of knowledge-relevant transactive processes that occur among group members." The authors furthermore argue that communication would not only be used to transfer information and knowledge between the individuals, but also to promote "the construction of a knowledge-acquiring, knowledge-holding, and knowledge-using system that is greater than the sum of its individual member systems" (ibid., p. 256). In short, they propose that communication promotes the development of a Transactive Memory System (TMS), as it was called in subsequent studies (Wegner 1987, p. 186). This proposition is not further specified regarding the specific role of the frequency of communicative acts or the content of these individual acts. Although it is reasonable to assume that communicative acts can support the development of an organized store of knowledge within a team, the requirements and conditions under which these communicative acts support this development are not elaborated in this context. On these grounds, this proposition will be further discussed in section 3.2.2.

Reconsidering the multi-level framework developed in section 2, Wegner et al. (1985) propose a multi-level construct spanning from the individual-level to the team-level. According to this definition, the store of knowledge can be reformulated as a cognitive structure at the team-level (called TM) that emerges from the cognitive structures of individual team members at the individual-level. Furthermore, the authors propose interactive processes between team members which will be further explained in the following sections (see figure 8 for an illustration of such early propositions).

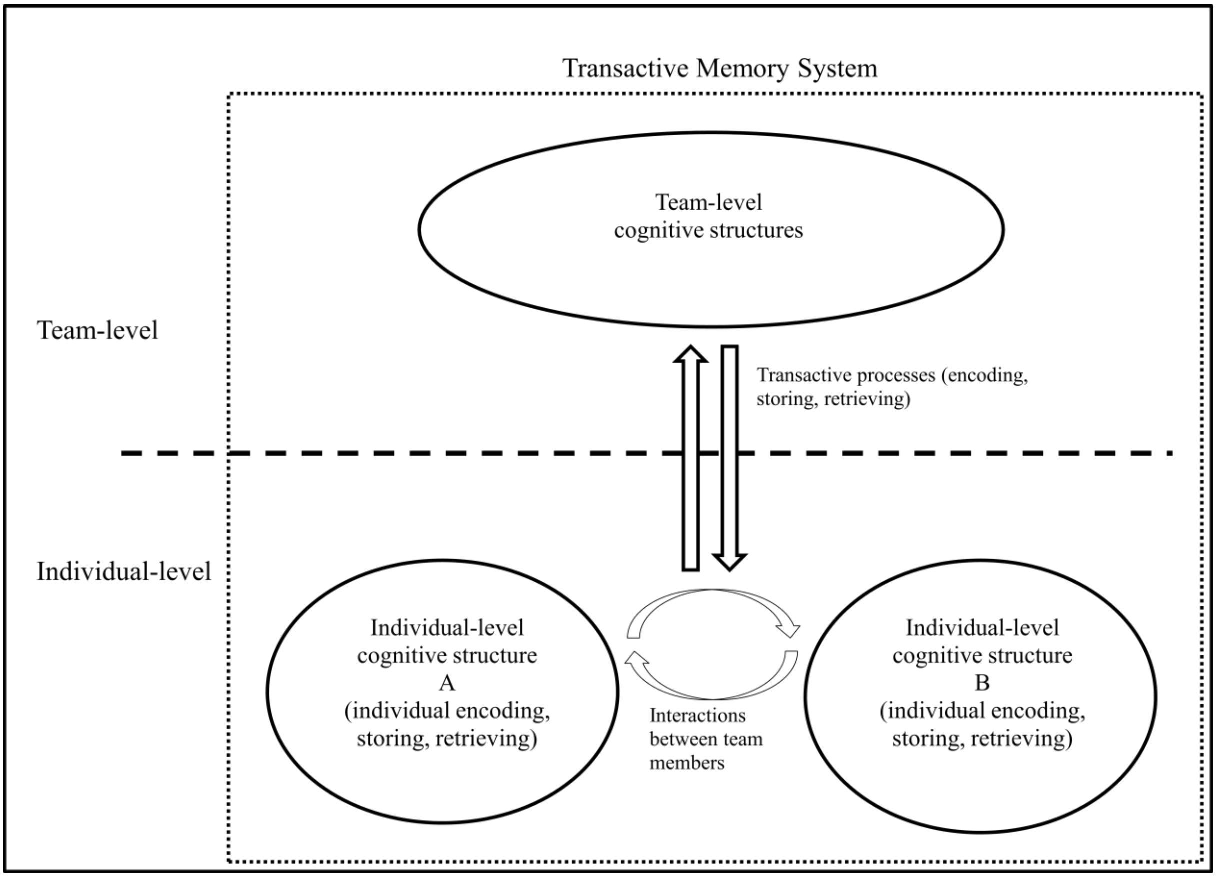
Similar to Kozlowski & Klein (2000), Wegner et al. (1985) propose a functional equivalence between individual-level and team-level cognition based on the assumption in General System Theory that both individuals and teams as systems would be comparable in their respective modes of operation (Bertalanffy 1968).[16] In this context, functional equivalence implies that both individual memory systems and TMSs are proposed to store information and knowledge

[15] In this context, Wegner et al. (1985, p. 256) initially used the term Transactive Memory (TM) that would lead to a system combining multiple individual memories. In the following studies, TMS has then been used to refer to the multi-level construct that consists of both emergent states and processes. TM in turn has been used to refer to the static team-level cognitive structure (the combined individual memories).

[16] See chapters 5 and 8 in van Bertalanffy (1968) "General System Theory" for a thorough discussion of both individual open systems and open systems in the social sciences.

that can be applied in a specific task. According to Wegner et al. (1985, p. 256), "at this broad level of definition," the concepts of individual memory and TM are therefore comparable. Thus, it is assumed that at both levels within the construct, information would be encoded, stored, and retrieved. But whereas this processing of information at the individual-level is assumed to occur within the minds of the individual team members, at the team-level, transactions are proposed to exist between individual team members to collectively encode, store, and retrieve information. This transfer of information is conceived as the basis for the differences between the information processing stages in an individual memory system compared to a TMS (ibid., p. 258).

Figure 8: Wegner's initial Transactive Memory System model



Author's illustration based on Wegner et al. (1985, p. 256)

In the following sections, the components of a TMS (namely the TM structures and transactive processes) will be explained in more detail. Furthermore, the meso-level between both individual-level and team-level is discussed in order to explain how both structures and processes are proposed to influence each other in the original TMS concept.

3.2.1 Individual- and team-level cognitive structures – Transactive Memory

One of the most intriguing questions of TMS theory is how the actual items of information and knowledge are organized within the team's cognitive structures. Wegner (1987) starts from the idea that people frequently use external memory aids to store their information and knowledge (e.g., Harris 1980, p. 38). In this context, and due to limitations of the individual memory capacity, the central storage location for large amounts of information is thus considered to be external storage (Wegner, 1987, p. 187).[17]

Transferring this idea to a team-level memory system, Wegner et al. (1985, p. 264) introduce three types of meta-information called *higher-order information*, *lower-order information*, and *location information* that are used to identify and store some explicit item of information or knowledge within the TMS. *Higher-order information* is described as a general topic and label of the information (e.g., fruit or vegetable as topic and tomato as label). To support this proposition, the authors refer to what cognitive psychologists call schema or semantic network of information for their description of higher-order information (e.g., Mandl, Spada 1988). In short, this refers to the concept that individuals store information as connected sets. Considering the example above, this implies that vegetable and tomato are proposed to be stored in combination with each other as a connected set. *Lower-order information* is seen as the explicit content of the piece of information (e.g., the specific color, taste, and nutritional information of a tomato). *Location information* is defined as information about the storage location of higher-order or lower-order information (Wegner et al. 1985, p. 264). All three types of meta-information are supposed to be transferrable within the team through communicative acts.

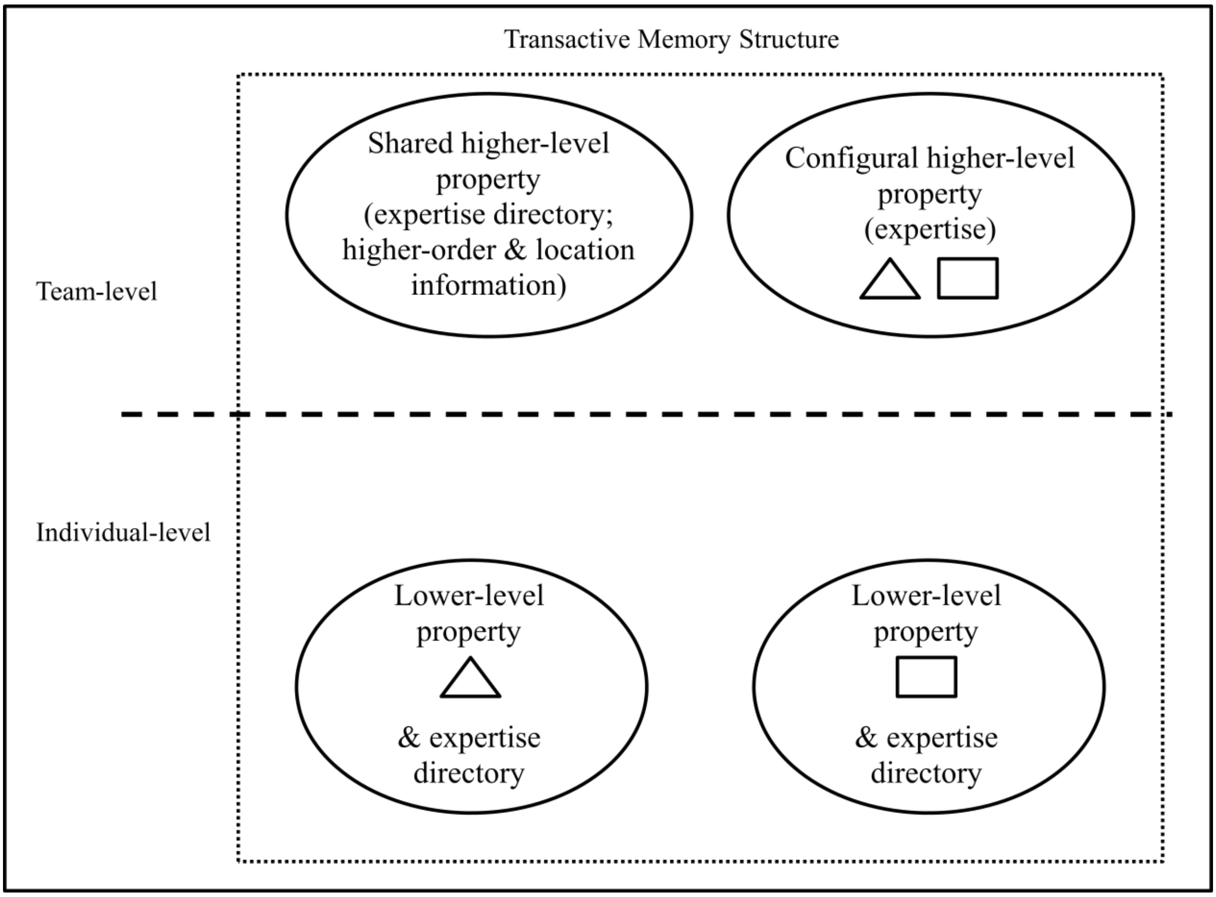
Given that efficient retrieval of specific items of information stored in an external storage location is proposed to be possible only if the individual possesses information about the topic and the location of these items, Wegner et al. (1985, p. 265) propose that a stored item needs at least higher-order and location information as the general requirements for external storage within a TM. Without these two types of information, the efficient retrieval of the items is proposed to be severely hindered. In this context, the authors introduce the term expertise directory for each individual's information about the expertise distribution in human external knowledge repositories.

Reformulated into a multi-level framework, Wegner thus proposes the idealistic structure of a developed TM as follows (see figure 9). Within the multi-level construct of TMSs, two separate higher-order cognitive structures exist. The first cognitive structure is proposed as a

[17] It is important to point out that in TMS theory team members are proposed to not only use other people as external memory aids but also other analog and digital knowledge repositories.

shared team-level property consisting of a shared understanding or Shared Mental Model of the team's expertise that is identical in content (higher-order and location-information) and function (expertise directory) on both the individual-level and the team-level. The second cognitive structure is proposed as a configural higher-level property that represents the pattern of expertise distribution of the team. Here, the content (lower-order information) in the higher-level property and the individual-level properties is not shared but differentiated (to some degree, as will be discussed in the next paragraphs). Although the specific content at different levels is proposed to differ, a functional equivalence in terms of the type of content (information and knowledge items) is supposed to exist between higher-level and lower-level cognitive structures. Therefore, the configural higher-level property represents the team's expertise as a whole but cannot be used to identify individual-level expertise. Rather, this is the purpose of the shared higher-level property. The underlying assumptions (e.g., acceptance of expertise responsibility, expertise differentiation) for the development of this proposed TM structure will be further discussed in section 3.3.

Figure 9: Wegner's initial Transactive Memory Structure proposition



Author's illustration based on (Wegner et al. 1985; Wegner 1987; Wegner et al. 1991)

Referring to the configural higher-level construct in the TM structure, Wegner discusses two possible endpoints of the configuration that are proposed to exist. These are the differentiated and integrated types of expertise distribution within the configural higher-level construct that are discussed next.

Differentiated structure

An idealistic differentiated TM structure or configuration of the configural higher-level property within a TMS refers to a structure in which expertise at the individual-level is entirely differentiated, implicating that only higher-order information and location information are proposed to be shared between individuals within the team. Here, it is important to refer to the underlying assumption for this proposed sharedness of higher-order information and location information. It is based on the early dyadic TMS research context (Wegner et al. 1985) in which only two close individuals are proposed to share their knowledge. This assumption has been transferred to organizational contexts by Wegner (1987, p. 204) without any modifications and has since been applied in TMS research (see Lewis, Herndon 2011; Ren, Argote 2011). Whether expertise directories have to be completely shared for an efficiently working TMS is not discussed in this context. On these grounds, it is necessary to analyze empirical TMS research in section 4 considering this assumption with regard to organizational teams consisting of more than two individuals.

In a differentiated TM structure, every individual is proposed to be an expert in a field that is not shared by any other individual within the team. Thus, each individual would have to gain access to the other individual's expertise for the retrieval of an item of information or knowledge not held by the former individual. Access and transfer of this item is proposed to occur via communication within the team. However, how and why individuals are motivated to share their expertise (see the discussion in section 2.4) is not specifically discussed in the original TMS concept, since individuals in an intimate relationship are supposed to implicitly trust each other and to be willing to share their expertise (Wegner et al. 1985). On this account, it is necessary to analyze empirical TMS research regarding this assumption in organizational contexts (see section 4).

An example of this differentiated structure would be the configural higher-level property consisting of expertise in the fields of tax accounting and controlling, whereas team member A only holds expertise in tax accounting and team member B only holds expertise in controlling. In this differentiated TM structure, the shared higher-level property or expertise directory would contain higher-level and location information of both tax accounting and controlling at both the individual-level and the team-level.

Following from this explanation, Wegner et al. (1985, p. 265) propose that a differentiated organization of knowledge would be preferable and efficient in situations where information is needed for the team as a whole – but not by each individual in the TMS. The cognitive load in terms of actual amount of knowledge that has to be stored by each individual is therefore proposed to be lowered, since each individual in a differentiated TM structure is proposed to possess only specialized lower-order information. The authors further propose that the differentiated organization of expertise in a team can potentially lead to an efficient TMS (in terms of information and knowledge retrieval) in which lower-order information is only communicated when needed for a specific task.

Next to the possible contribution to retrieval efficiency, potential drawbacks might exist in a differentiated TM structure. Due to the proposed retrieval efficiency of a working TMS, team members could potentially become too confident in their TMS and individuals could thus develop a false "feeling of knowing" (Hart 1967, p. 685) for their individual and combined expertise (note though that Hart only tested this proposition on impromptu pairs and not couples in a real relationship). An individual could falsely think that another individual in the team has more actual lower-order information about an information or knowledge item than he or she actually possesses, given that mostly higher-order information is shared within discussions. Because of this potential drawback, Wegner et al. (1985, p. 266) propose that a TM structure should always be partially integrated, as to be discussed next.

Integrated structure

Wegner et al. (1985, p. 267) propose that individuals in teams are not satisfied with discussing only higher-order information, so that there would always exist a certain pressure to develop the TM structure into a more integrated way. In contrast to a differentiated TM structure, individual-level and team-level expertise are equivalent in content and function in an idealistic integrated TM structure. Here, both higher-order and lower-order information of items are shared between all individuals within a completely integrated TM structure. An integrated item within the team's TM structure therefore refers to an item of which both the higher-order and lower-order information are shared between all members. In conclusion, the more expertise items are thoroughly shared between all members, the more integrated a TM is structured.

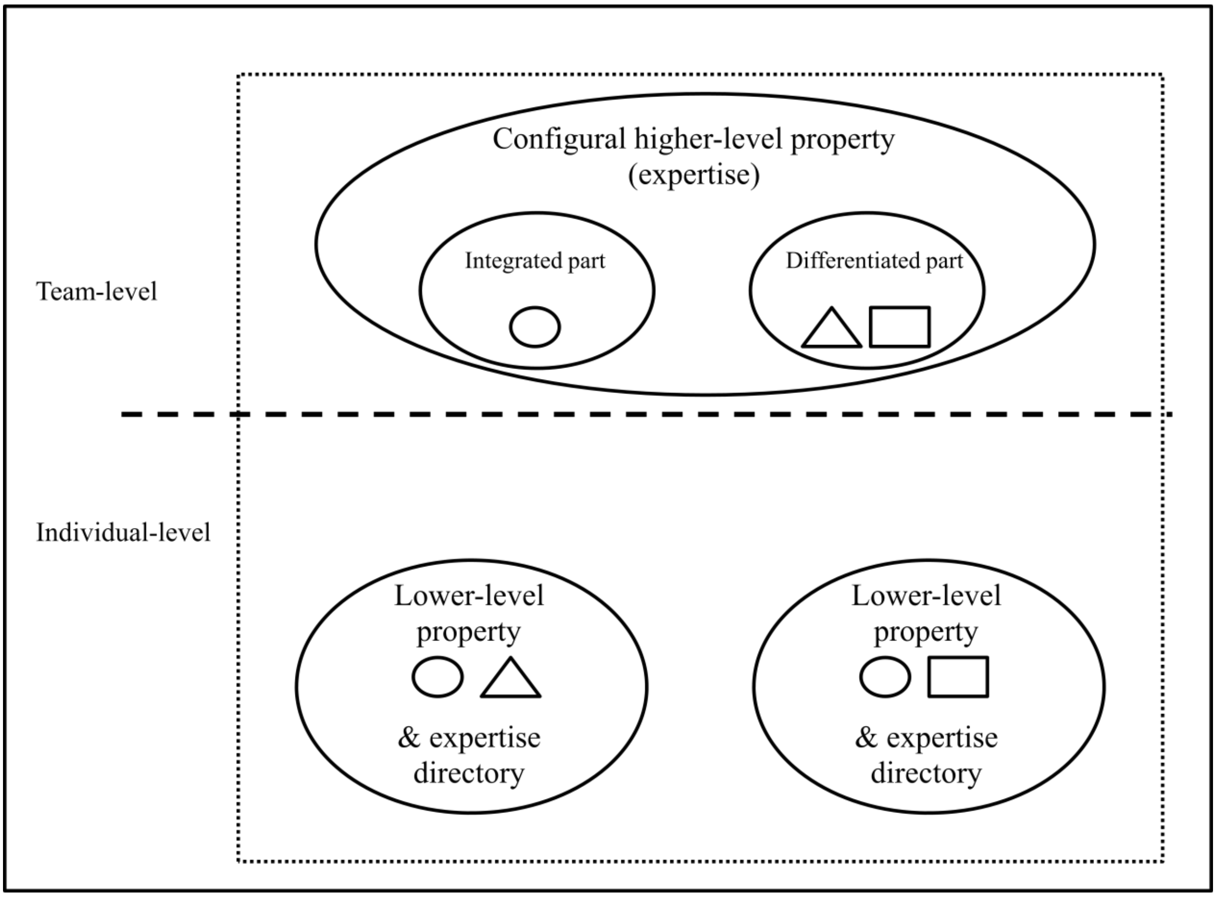
In this context, the authors argue that the tendency of individuals to share and discuss lower-order information "leads to new knowledge for both partners" (Wegner et al. 1985, p. 267), indicating that new information can be created through the discussion of different information and points of view. This explanation is similar to the concept of creating new knowledge in organizational discourses (e.g., Schreyögg, Geiger 2003; Schreyögg, Geiger 2007a). One possible advantage of sharing and integrating lower-order information about a specific topic would thus be that this integration through communication and discussion can possibly lead to the generation of new knowledge items and new forms of interpreting and utilizing the same knowledge items in a specific task.

The foundation of this proposition is based on experiments by Hayes-Roth & Thorndyke (1979, p. 91), who discuss this tendency of knowledge integration as "a fundamental component of the acquisition process" of individuals, as well as Giuliano and Wegner's (1983) own research on close couples during problem-solving. The latter call this newly generated information an "integrated understanding" or "shared higher-order conception" for a specific piece of information (Wegner et al. 1985, p. 267).

The content of the configural team-level properties – Compilational and compositional?

Wegner et al. (1985, p. 266) describe the pattern of the configural team-level property within TMSs as a combination of integrated and differentiated expertise. The following example that draws on the expertise fields of tax accounting and controlling as well as software development helps to clarify this description (see figure 10). In the example used above, team member A has been an expert in the field of tax accounting and team member B has been an expert in the field of controlling. In this example, both of them additionally share the same expertise on software development. Due to this extension of the example, the configural higher-level property in TM contains both shared and differentiated parts of expertise. Though it is still configural – since the pattern represents the team as a whole but cannot be reduced to individual team members – it emerges from a different nature of social-psychological interactions and lower-level properties (Kozlowski, Klein 2000, p. 18). From this follows that the TM structure Wegner et al. (1985) describe is compatible to the multi-level framework Kozlowski & Klein (2000) propose.

Figure 10: Combination of integrated and differentiated expertise structures in a configural higher-level property



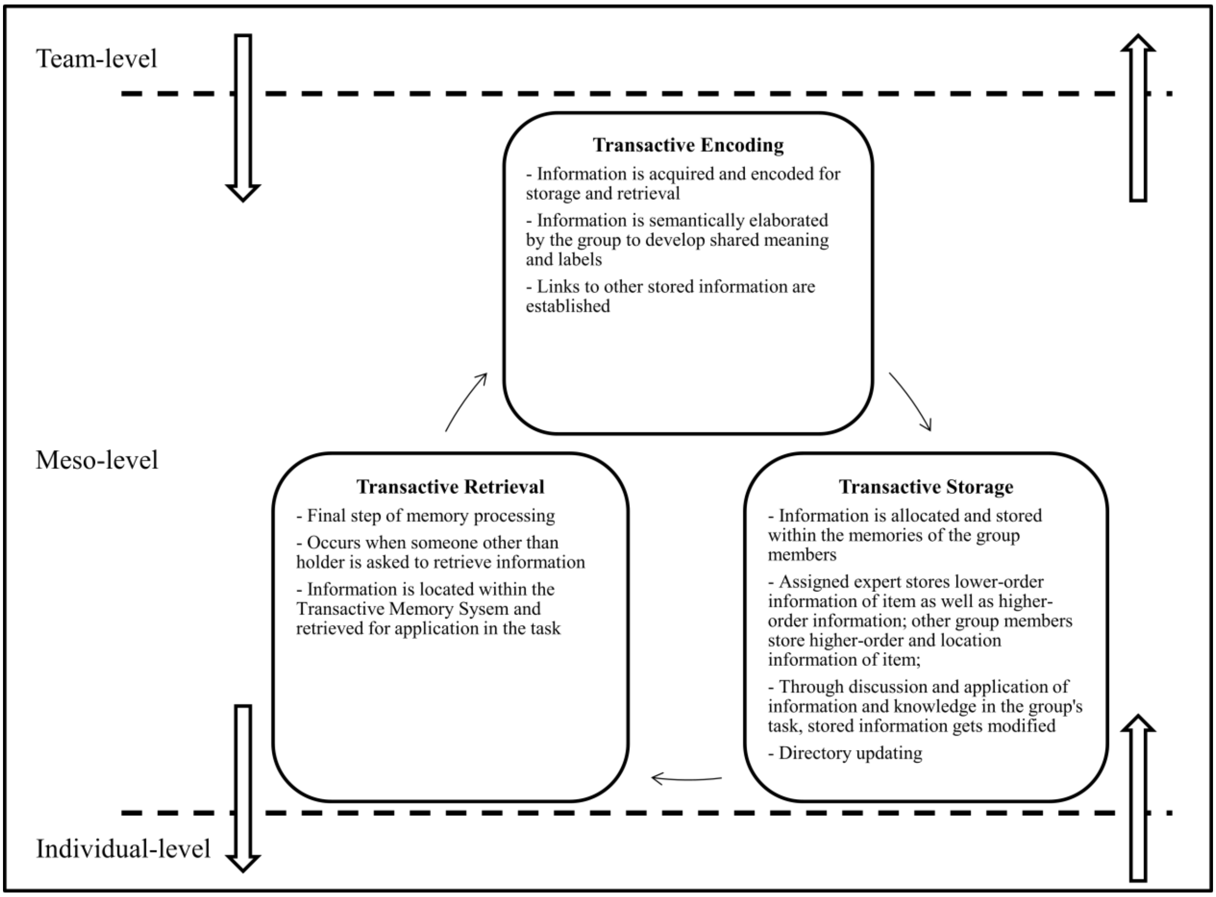
Author's illustration based on Wegner et al. (1985)

This is an important proposition in the construct of TMSs as it enables the derived models of TMSs to capture the structure of expertise distribution within an actual team more accurately.
In the following sections, the interactive and observable transactive processes that are assumed to bridge the individual-level and the team-level at the meso-level are discussed (3.2.2). Furthermore, the top-down influences of the developed shared and configural team-level properties on individual-level units and their interaction are elaborated (3.2.3).

3.2.2 Emergent bottom-up transactive processes

Communication within a TMS is seen as the foundation for both transferring information and knowledge within the system and developing the TMS, thus compatible to both perspectives on Team Cognition that have been explained in section 2.1. Since Wegner et al. (1985, p. 256) consider a functional equivalence between individual-level and team-level cognition, they base their process approach on the phases of information processing occurring within individual memory according to cognitive psychology (see section 2.6.1). These phases are considered to be the encoding, storage, and retrieval of information within individual cognition. Proposing that a TMS consists of multiple individual memories, these processes are called transactive within a TMS, because a transaction is needed to connect the individual memories and collectively process information (Wegner et al. 1985, p. 258). The transactive processes of encoding, storage, and retrieval are each discussed in more detail in the following (see figure 11).

Figure 11: Transactive Processes in a Transactive Memory System



Author's illustration based on (Wegner et al. 1985; Wegner 1987; Wegner et al. 1991)

Transactive encoding

Transactive encoding refers to the encoding of information when it enters the collective memory through, for example, discussions, e-mail, or news. While information does not have to be discussed to be encoded for storage in the collective memory – since one team member can encounter an item of information alone – Wegner et al. (1985, p. 259) focus on this interactive encoding of information. This particular focus is based on the assumption that information encoded interactively and thus considered to be generated information (since it has been given new meaning) is beneficial for the efficiency of the combined memory system. Slamecka & Graf (1978, p. 601) call this experimentally established phenomenon the "generation effect." According to this proposed effect, information that is altered and generated is better remembered than when it is not, e.g., through calculating the numbers for the result versus just memorizing the result of a calculation.

Members of the team are able to discuss such information reaching the team; this discussion might then lead to an alteration of the information to fit into the team's perspective (giving individual items shared labels and translating them into the team and organizational language). This aspect of the collective processing of information in transactive encoding can potentially lead to “idiosyncratic and private ways” of interpreting information in a team (Wegner et al., 1985, p. 260). While this may enhance the common understanding within the team, it may also complicate the information transfer to an individual outside of the team. This is what other researchers have discussed as meaning-making that leads to differences in organizational culture (e.g., Markus et al. 1996, p. 864). The main goal of the encoding process is proposed to facilitate an efficient “filing system” for the following transactive storage phase (Wegner, 1987, p.186). Since the discussion of new or existing information can be considered to happen frequently, it is assumed that the process of transactive encoding can occur at any phase of the collective information processing.

In terms of the proposed multi-level construct of TMSs, transactive encoding is supposed to serve an important function: transactive encoding translates new information into the existing concepts in the individual-level and team-level cognitive structures and thus enables the combination of new and existing information and knowledge as well as the identification of the expert within the team (which is hindered without a shared label). Next to this integrative function, transactive encoding also serves as an interactive step in combining expertise within discussions to apply this expertise to a changing task structure.

Transactive storage

Transactive storage refers to the dynamic way in which information and knowledge is stored within the TMS. Wegner et al. (1985, p. 260) stress the importance of the dynamic nature of TM, since information and knowledge "apparently can be modified, even as it resides in memory." This assumption is based on experimental research regarding individual memory processing. In this context, the change in individual memory has been discussed in combination with the exposure to subsequent information (Hertel 1982, p. 528). This subsequent exposure to information is assumed to alter existing representations of information within the individual memory (Lofthus et al. 1978, p. 30). Wegner et al. (1985) transfer this experimental research to the change in an individual's cognitive structure within a TMS.

Accordingly, they see TM as a dynamic information and knowledge repository, since errors in storage or the modification of existing information through newly encoded information can occur. Wegner et al. (1985, p. 261) regard this modification as "an inevitable part of communication," given that information has to be frequently decoded and re-encoded to be transferred from one individual to another and restored within the TMS. Furthermore, items of information within the individuals' minds in the TMS should be stored "as connected sets" (Wegner 1987, p. 186), which enable the subsequent connected transactive retrieval for application in a specific task context. This suggestion alters the original definition of TMSs insofar as it adds another type of higher-order information to the stored items within the shared individual-level and team-level cognitive structures. This type of higher-order information is supposed to contain information about the usefulness of items for specific task contexts.

In this regard, Wegner et al. (1985, p. 260) propose that such a dynamic nature of stored information "could be quite a bit more complicated (and interesting) because of iterative effects that occur in the course of dyadic communication." But, since members of the team react to subsequent events, it is only logical that both individual memories would be modified if the members are exposed to different stimuli (and also have independent histories). Otherwise, the semantic elaboration (ibid., p. 259) and taking each other's point of view would be unnecessary. This argument leads to another alteration of the original definition of TMSs, since a process has to be added into the multi-level construct to bridge the micro and macro levels between individual-level and team-level shared cognitive structures.

In a comparison between human memory and computer memory networks, Wegner (1995, p. 324) adds this process which he termed directory updating in this context. Directory updating is regarded as the equivalent compositional process that leads to identical shared cognitive structures at the individual-level and team-level within a TMS. Wegner assumes that this directory updating can occur on its own and in combination with the transactive processes, since it is possible for individuals to share information about their shared cognitive structures without exchanging explicit lower-level information.

To summarize transactive storage in terms of the multi-level construct, this process is supposed to serve different purposes. First, since newly encoded information is allocated to individual team members (which is proposed to lead to a differentiated or integrated TM structure),[18] this process shapes the pattern of the configural team-level property by changing the individual expertise of the TMS's team members. Second, in a separate process of

[18] This assumption about the acceptance of expertise responsibility will be discussed in section 3.3 that deals with the development of a functioning TMS.

directory updating, it synchronizes the individual-level and team-level shared properties by exchanging information about the changed pattern of the configural team-level property.

Transactive retrieval

Wegner et al. (1985, p. 262) consider transactive retrieval as the "final step of memory processing" in which the quality of the aforementioned processes influences the successful retrieval of required information – or in which effective and ineffective collective memory systems can be distinguished when stored information is needed for utilization. In contrast to individual memory retrieval, transactive retrieval is proposed to occur when someone other than the knowledge holder is asked to retrieve a specific item and has to determine the location and the connection to other required items (Wegner 1987, p. 190). Therefore, transactive retrieval is proposed to consist of both search processes and individual retrieval processes. Individuals in teams may search in their own cognitive structures for individual retrieval or cue their team members for transactive retrieval. This process is considered to be transactive, since, even at this stage, information can be differently encoded and restored which in turn may lead to different retrieval results (Wegner et al. 1985, p. 262).

Referring to the multi-level construct, transactive retrieval is considered to occur when a team member does not hold information or knowledge that is required to work on his or her current sub-task or problem. Furthermore, it is supposed to happen in discussions where multiple individuals holding diverse expertise work together in solving a specific problem. Here, the individual team member in need of additional information or knowledge is proposed to use his or her expertise directory to channel the search for this particular item within the team's configural higher-level property. If the item-holder is found, the individuals exchange information or knowledge in which the receiver retrieves the specific item from the item-holder. However, the original TMS concept is not specific with regard to transactive retrieval processes in teams with partially integrated TM structures. In this context, it is necessary to consider the added complexity of retrieval from more than one possible source for a specific knowledge item.

3.2.3 Top-down influences of team-level cognitive structures

Next to the bottom-up processes that lead to the development and functioning of a working TMS, possible top-down influences that the two proposed team-level cognitive structures (shared and configural) are supposed to exert on the individual team members and transactive processes have to be discussed. The shared team-level cognitive structure (expertise directory) is supposed to influence the retrieval and allocation processes within the team. Due to the shared expertise directory, the time it takes an individual to assess who in the team is responsible for a certain expertise item is supposed to be reduced (Wegner 1987, p. 197). Furthermore, since information about the task, expertise distribution (with a shared language that is used for higher-order and lower-order information), and team members is supposed to be stored within the shared team-level cognitive structure (see section 3.2.2 above for specifics on transactive storage), the efficiency of detecting required and missing expertise for a task is proposed to be influenced (Wegner et al. 1991, p. 926).

Another implication of the shared team-level cognitive structure is the influence on the cognitive load on each individual team member. Since information about the expertise distribution is proposed to be readily known and encoded into the shared language of the team, this cognitive structure is supposed to free individual-level cognitive capacities that can be utilized for further problem-solving activities. However, at the same time Wegner (1987, p. 197) proposes that the cognitive load can be increased due to the effort it takes to frequently maintain the shared team-level cognitive structure and to store an ever increasing complexity within this directory. This argument is based on the change in the actual patterned team-level cognitive structure (team's expertise), since links between tasks, members, and expertise are proposed to be frequently established within the transactive processes. Therefore, the structure of TM may be constrained by the individual mental capabilities.

In combination, the two team-level cognitive structures (explicit expertise and expertise directory) are proposed to influence the actual amount of expertise that the team can efficiently store (e.g., Wegner 1987, p. 197; Wegner 1995, p. 336). Since team members within a working TMS are assumed to focus on their assigned expertise, each expert is supposed to get more efficient in storing new information and knowledge in his or her field of expertise, which in turn influences the team-level properties bottom-up. Next to the amount of information and knowledge, both team-level cognitive structures are proposed to influence the ability of team members to infer connections between different fields of expertise relating to the task, since an expert is supposed to store the information of the distribution of other task-relevant expertise at the individual-level.

In situations of team member turnover, an existing cognitive TM structure may hinder the development of an adapted structure since the efficiency of the transactive processes could be influenced by the existing cognitive team-level structures (Wegner et al. 1991, p. 924). This argument is based on the assumption that existing implicit expertise assignments (expertise directories) that are possessed by the remaining team members may interfere with the newly assigned explicit expertise assignments after a new team member has been added. As explained in section 3.2.1, these existing structures could also lead to a false "feeling of knowing" (Hart 1967, p. 685), given that team members could refer to their existing expertise directories for the identification of required knowledge for the task (e.g., Wegner et al. 1985, p. 273; Wegner 1987, p. 198). It is necessary to analyze how this proposition has been tested in empirical research, which will be done in section 4.

3.3 The development of a functioning TMS

In this section, Wegner's initial propositions on the development of a functioning TMS are explained with reference to the discussion on path dependence in the development of a multi-level construct.

Wegner (1987, p. 194) considers the development of a working TMS within a team to be a consequence of Social Cognition that happens in everyday situations. Social Cognition is defined as the process of making sense of and perceiving other individuals (Fiske 1995, p. 151). In this context, perceptions thus refer to the process of individuals observing each other's potential domains of expertise (Wegner 1987, p. 191). At first, such assumptions about the expertise distribution within the team may be based on social categorization, information about the education or work experience of each other, roles within the team, or prior experience of working together in other tasks that lead to the inference of expertise embedded within the team (Wegner et al. 1985, p. 263; Wegner 1987, p. 191; Wegner et al. 1991, p. 924). Based on the multi-level framework of emergence (see section 2.6), it is assumed that these so called default entries of expertise may not be an accurate representation of the configural higher-level property (expertise) of the team. Given that interaction between the individual team members has to occur for the awareness and emergence of a shared higher-level cognitive structure (expertise directory), it is further assumed that, at this stage of the development, the individual-level expertise directories are not identical and thus not shared.

The development of the shared team-level expertise directory is proposed to start when the team members begin to interact with each other in cycles of communication or discussions (Wegner 1987, p. 192). Within this interaction, Wegner suggests that the aforementioned process of directory updating is responsible for aligning the individual expertise directories (Wegner et al. 1991, p. 924; Wegner 1995, p. 327). Here, the default entries are supposed to be altered into negotiated entries, which represent shared views on the expertise distribution within the team (Wegner et al. 1991, p. 924). For example, assignments of expertise responsibility for each team member represent such negotiated entries. Thus, according to the initial domain assignment based on early expertise inferences, a TMS may be path-dependent to some degree.

However, the authors remain unspecific regarding the individual requirements for the acceptance of expertise responsibility at this stage of the TMS development. Again, the underlying assumptions of cognitive interdependence and the acceptance of this interdependence remain unchanged compared to the original intimate context (Wegner et al. 1985). To account for the differences between the intimate context and organizational context, it is necessary to analyze how empirical TMS research has integrated these differences (see section 4 and refer to the discussion about cognitive interdependence in section 2.4).

Based on the discussion of path dependence in section 2.6.3, the shared higher-level cognitive structure that has been established in point A in the team's lifecycle may influence the transactive processes of information and knowledge processing in point B in the team's lifecycle. This change in interaction may in turn lead to a change in the configural higher-level cognitive structure (through a channeling of expertise in point B). In this regard, it is important to specify at which point in the team's lifecycle a TMS in this proposed form is studied. To this effect, it is necessary to clarify the focus of individual research approaches: the development of a TMS or the influence of a developed TMS on team performance. As Wegner (1995, p. 332) discusses, the actual pattern (differentiated or integrated to some degree) of the configural higher-level property is supposed to be dependent on the specific task and expertise requirements. Therefore, no explicit propositions on an optimal distribution are integrated by Wegner into the original TMS model concerning this matter.

After the establishing of an initial TMS, information and knowledge are supposed to be channeled directly to the assigned expert(s) (see the discussion above regarding the acceptance of expertise) for encoding, storage, and later retrieval (Wegner 1987, p. 192). In this context, the author does not specify how this channeling of information and knowledge is ensured in an organizational context consisting of individual actors.

Another possibility of path dependence in the development of a TMS is reached if new information that has not been assigned to an individual is passed to the team. The new assignment of this information to an individual is proposed to change both shared and configural team-level cognitive structures through a reinforcement of this structure in future discussions.

In summary, Wegner proposes that a TMS in this form can be developed, because team members accept the assignments for individual domains of expertise (Wegner 1987, p. 194; Wegner 1995, p. 327). While the development of a TMS can be seen as a dynamic process, the resulting TM structure is regarded by Wegner as an emergent state (compatible to the IMOI model discussion explained in section 2.5.3) and thus as constituting the content dimension of TMSs termed TM consisting of both shared and configural higher-level properties of the team.

3.4 Integrating the multi-level TMS construct into the IMOI context

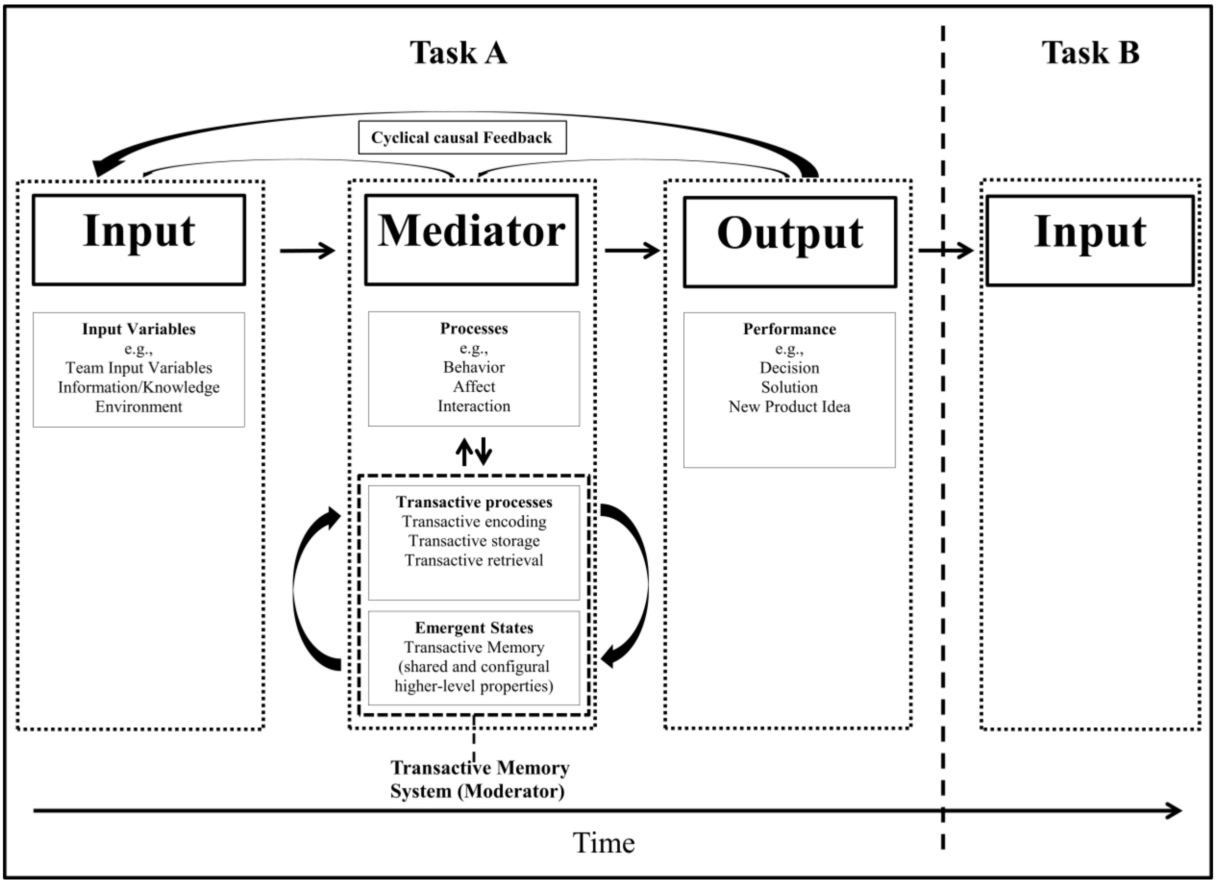
To enable the specification of propositions regarding the influence of TMSs on team performance and interrelations between different TMS components, the multi-level TMS construct will be integrated into the IMOI model developed by Ilgen et al. (2005). Following this integration, the specific role of this multi-level construct within Team Cognition research is discussed with regard to possible contributions of TMS theory to this research discipline. This section ends with a discussion of the differences between the original dyadic research context and underlying assumptions of Wegner's TMS theory and the organizational context applied in this work. It is argued that such differences in research assumptions have to be considered in TMS research – an issue that will be analyzed in detail in section 4 of this work.

3.4.1 The TMS construct within the IMOI model

As discussed in section 2.5.3, the IMOI model developed by Ilgen et al. (2005) is used to render the analysis of non-linear relationships and the proposed moderation of emergent states possible. The integration of the original multi-level TMS construct into the IMOI context is illustrated in figure 12.

As can be inferred from the illustration, the TMS construct has been integrated as a moderator to the interactive processes within the mediator dimension. Both the emergent states and transactive processes are supposed to represent the TMS as a whole, which, as an emergent system, in turn is proposed to influence the behavior, affect, and interaction of individual team members from which it emerges – as elaborated by Kozlowski et al. (2013, p. 588). Given that Wegner et al. (1985) do not specify a direct relationship between transactive processes and team performance, it is suggested that the transactive processes themselves do not constitute the mediating processes on their own. Instead, they are proposed to influence both the emergent states and the task-relevant processes of teamwork. The reason for this differentiation is based on the assumption that information and knowledge sharing does not constitute the direct mediation between input factors and team performance. Particularly, the interactive process of information and knowledge application has to be differentiated from information and knowledge sharing. Both processes are supposed to influence team performance, but the explicit application of information and knowledge to the task is conceived to have a direct influence on team performance, whereas the sharing of information and knowledge (in this model represented by the transactive processes) is proposed to influence team performance through the application of information and knowledge (Alavi, Leidner 2001, p. 114; Alavi, Tiwana 2002, p. 1030; Choi et al. 2010, p. 855). Therefore, it is reasonable to place both the emergent states and transactive processes within the moderator dimension in the IMOI framework.

Figure 12: Wegner's multi-level Transactive Memory System in an Input Mediator Output Input model



Author's illustration based on (Ilgen et al. 2005; Wegner et al. 1985)

The model in figure 12 represents the original TMS construct (including the underlying assumptions) within a team performance model that can be used to analyze and interpret the existing TMS research and propositions from a dynamic multi-level perspective. It serves this purpose by enabling the study of different interrelations and level bridges within the assumed phenomenon of division of cognitive labor.

According to this multi-level perspective, the TMS construct is assumed to represent both static and dynamic perspectives within Team Cognition research, as briefly discussed in section 2.1. This position has been further differentiated by applying both the multi-level theory by Kozlowski & Klein (2000) and the IMOI model by Ilgen et al. (2005). Since the original definition of TMSs focuses neither on static higher-level cognitive structures nor on cognitive processes independently, it appears that the recent call for an integration of both perspectives (Cooke et al. 2009; Cooke et al. 2013; Wildman et al. 2012; Wildman et al. 2014) may have been already answered in theoretical terms by Wegner et al.'s (1985) original work.

However, due to the underlying assumptions of the original research context that have been elaborated in sections 3.1 and 3.2, the explicit contribution of this original multi-level TMS model to Team Cognition research cannot be reliably determined. On this account, the need for a construct adaptation with regard to organizational contexts is discussed in the next section.

3.4.2 The need for a construct adaptation to an organizational context and challenges for current TMS research

As explained in section 3.1, the concept of TMSs has originally not been directly extended to the group or organizational level, because Wegner et al. (1985, p. 257) considered a) the great complexity of explaining interrelations and components at the group- and organizational-level, and b) because in systems other than intimate dyads the authors envisioned no need to establish such a system due to a lower cognitive load on the individual. The underlying assumptions of this dyadic context are: a) couples are assumed to be cognitively interdependent and to be aware of this interdependence, b) individuals in couples are considered to implicitly trust each other and to be willing to accept responsibility for different topics of expertise, c) the task of interest in the early research context was to manage knowledge entering the dyad as efficiently as possible, d) communication is proposed to directly lead to the development of TMSs, and e) the team-level expertise directories are uniformly shared and identical between both individuals in a couple. Wegner et al. (1985) were thus interested in how and why couples divide their cognitive labor in this context.

Regarding the definition of teams in this work as complex, adaptive, and social systems embedded within an organizational context (section 2.2), the assumptions of the dyadic research context have to be altered in order to account for the difference in context. First, the potential *contextual and organizational influences* on the development and functioning of a working TMS have to be considered. This refers to the integration of an organizational-level in the study of teams, as discussed in section 2.6.1. This change in assumed levels may be especially important in organizational contexts, because TMS theory focuses on actual information and knowledge sharing processes that may be susceptible to a change in organizational routines or informational technology regarding sharing behavior and possible content (e.g., Choi et al. 2010; Engelmann, Hesse 2011; Miller et al. 2012). Second, it cannot be assumed that individual team members are implicitly motivated to share their expertise and to be aware of their interdependence, as outlined in section 2.4. Here, the integration of such an awareness, potential trust between individual team members, and a differentiation in the task goal structures between individual-level and team-goals are needed in order to consider possible moderation effects (e.g., Brandon, Hollingshead 2004.; Edmondson, Lei 2014).

Relating to a) the role of communicative acts in the development of TMSs, b) the influence of TMSs on team performance, and c) the proposed form of the shared team-level cognitive structure, special attention will thus be paid to these propositions in the analysis of empirical TMS research in the next section. On this account, section 4 forms the foundation for the explicit adaptation of the original TMS construct that follows in section 5.

4 Analyzing Transactive Memory System research from a multi-level perspective

After transferring the original TMS concept by Wegner et al. (1985) into a multi-level model in section 3, it is necessary to analyze how this differentiated approach has been reflected in current empirical research that applies TMS theory as a lens for the analysis of teams.

To account for the operationalization of different sub-constructs (cognitive structures and interactive processes) of the multi-level TMS construct in current research settings, this section starts with a focus on how these different variables and levels have been operationalized in measurement methods (section 4.1). This discussion is followed by the explicit analysis and categorization of TMS findings in dyadic, group, and organizational settings (section 4.2). This section then closes with a summary and discussion of the findings regarding the propositions and underlying assumptions made in the original TMS concept (section 4.3). Special emphasis will be put on how research has reflected a) the shared and configural team-level properties and their interrelations, b) the interactive and communicative processes, c) the development (and therefore path dependence) of a TMS, d) contextual influences, and e) variables regarding the interdependence of individual team members. Before starting with the analysis, a brief insight into the strategy of literature retrieval is provided.

Strategy of literature retrieval

To evaluate the current state of empirical TMS research, the following review strategy has been applied in this work. The starting point for the review was determined by the bibliography and reference list of current reviews in the field of TMSs (e.g., Lewis, Herndon 2011; Peltokorpi 2008, 2012; Ren, Argote 2011). Furthermore, I scanned the Web of Science database with the search term "Transactive Memory" in the title, topic, abstract, or keywords of articles. This search yielded 585 articles (December 2015) that were further analyzed for fit to the evaluation of TMSs at the team-level. I included articles on TMSs in dyads, groups, and teams that are focused on the research on TMSs as an independent, dependent, or mediating variable (see Ren, Argote 2011, p. 193 for this focus). Research on organizational-level TMSs understood as mere knowledge repositories was not the primary concern of this search, given that it cannot be used to infer direct team-level relationships. In contrast to Ren & Argote (2011), I included research on TMSs as a moderating variable, since, as per the definition of the multi-level TMS model, emergent cognitive states are thought to moderate and therefore not to mediate the relationship between interaction and team performance (Marks et al. 2001).

Hence, research on the influence of cognitive structures on coordination effectiveness and efficiency represents an integral part of TMS research.

The final sample included 11 articles in a dyadic context (Appendix A) and 29 articles in a group context under experimental conditions (Appendix B). For organizational research, 42 quantitative articles have been included that matched the categories above. Furthermore, four case studies have been included in the sample, bringing it to a total of 46 included articles in organizational settings (Appendix C).

A brief review of the TMS literature supported the notion that measurement strategies within TMS research have to be discussed prior to the explicit analysis of TMS research regarding different sub-constructs of TMSs. This prior discussion is justified due to the prevalence of measuring TMSs as a latent construct in field settings and thus the lack of explicit measurement of cognitive structures and interactive processes. In fact, in 24 of the 42 studies in field settings, a questionnaire that provides a composite TMS score (Lewis 2003) has been used for the measurement of behavioral indicators that represent behavior that is thought to be relevant for a functioning TMS (see section 4.1.3 for a further discussion). Furthermore, in two of these studies, the dimensions in the composite score have been interpreted as direct reflections of a TMS. In four more field studies that did not use this questionnaire, neither processes nor cognitive structures have been measured and a functioning TMS has only been implied. In group settings, the measurement method developed by Lewis (2003) has been used in 10 of the 29 studies.

In sum, almost 54% of the group and field studies in TMS research do not directly measure cognitive structures or interactive processes. This in turn implies that more than half of these studies do not directly reflect the core of the TMS construct that is grounded in expertise and communication (Wegner et al. 1985). Therefore, it is important to discuss the different measurement strategies in existing TMS research.

4.1 Measurement strategies in TMS research

In this section, different TMS measurement strategies in organizational settings are discussed. Measurement strategies in organizational settings are emphasized here given that the focus of this work is set on analyzing the value of the TMS construct for organizational research. This discussion is guided by the measurement method framework developed by Kozlowski & Klein (2000) focusing on content treatment and the applicability for team-level analysis. The section begins with a discussion of the measurement of cognitive structures and interaction and continues with the measurement of TMSs as a latent construct, as it is applied in studies using Lewis' (2003) composite TMS scale.

4.1.1 Measurement of cognitive structures

In the original multi-level TMS model (as presented in section 3), emergent shared and configural cognitive constructs are hypothesized to be manifest at the team-level and to originate in the affect, cognition, and behavior of individuals at the individual-level (Kozlowski, Klein 2000, p. 27). This implies that these constructs should be measured and analyzed at their respective construct levels – the level of origin (individual-level) and the emergent level (team-level). Since shared and configural cognitive constructs are theorized to emerge through different types of emergence, namely compositional and compilational types, it is important to consider this difference in the development of measurement strategies for their specific analysis.

Shared cognitive structures

As explained in section 2.6.2, shared cognitive structures are constructs theorized as emerging from compositional types of emergence promoting isomorphism. Accordingly, compositional processes should lead to a similarity in content and function between individual-level and team-level properties. In terms of the TMS construct, these shared cognitive structures are represented by the shared expertise directories that are stored in the individual cognitive structures of team members in combination with an awareness of this sharedness. The latter implies that individual team members possess information about the expertise directories of other team members.

In developing a measurement strategy for this type of emergent cognitive construct, it is therefore necessary to explain and measure how within-unit consensus (agreement) and accuracy of the individual expertise directories emerge from individual-level characteristics and interactive (transactive) processes (Kozlowski, Klein 2000, p. 30). As Kozlowski & Klein (2000, p. 34) further propose, data on shared cognitive structures in form of content and agreement should consequently be assessed at the individual-level and the awareness of shared cognitive structures should be evaluated by aggregating individual-level data (e.g., high aggregated scores indicate similar and thus shared individual-level expertise directories). This approach is similar to the measurement of similarity and accuracy of Shared Mental Models or Team Mental Models, who are defined as a shared understanding of important facts and characteristics about the task and the team (Mohammed et al. 2010, p. 880). For the measurement of Team Mental Model data, individual-level mental models are assessed and aggregated for a composite score (ibid., p. 885).

In organizational settings, there is evidence of the measurement of shared cognitive structures in the measurement methods utilized by Austin (2003), Palazzolo (2005), Rau (2005; 2006), Child & Schumate (2007), Yuan et al. (2007; 2010b; 2010a), Ho & Wong (2009), Smith-Jentsch et al. (2009), Su & Contractor (2011), Su (2012), Mell et al. (2014a), and Treem & Leonardi (2015). This amounts to around 33% of the reviewed field studies.

The most common methods to study individual-level data in these settings are the application of questionnaires or interviews with individual team-members and experts. Within these methods, individual expertise (in expertise areas assessed relevant for the task), the awareness of other team members' expertise, the identification of personal knowledge sources (experts), or the importance of expertise are assessed. The data is then aggregated to represent team-level sharedness, consensus, and accuracy of the individual expertise directories. Subsequently, the aggregated data is for example matched for accuracy with the expert or management-level assessment of expertise distribution for the evaluation of accuracy.

Researchers using these methods in order to aggregate individual-level data to team-level data for the assessment of shared cognitive structures are thus seen to operationalize the hypothesized construct of shared team-level cognitive structures (expertise directories) in a valid form. Hence, data retrieved from studies following this research strategy is interpreted to be a representation of the shared cognitive team-level construct within the multi-level TMS model.

Configural cognitive structures

Configural cognitive structures are constructs theorized as emerging from compilational types of emergence promoting discontinuity (see 2.6.2). Accordingly, it is proposed that compilational processes lead to a difference in content but a similarity in function between individual-level and team-level properties. In terms of the TMS construct, these configural cognitive structures are represented by the actual expertise that is stored in the individual cognitive structures of team members that, in combination, represent the configuration or pattern of the team's expertise as a whole. Therefore, a different research and measurement approach is needed compared to the measurement of shared cognitive constructs.

Following Kozlowski & Klein (2000, p. 34), research that seeks to assess configural team-level properties is supposed to summarize and not aggregate individual-level data. This summary should reflect the pattern or configuration of the configural-team level property. As suggested for the team-level construct of expertise in the original multi-level model of TMSs, this pattern can also represent parts of integrated (shared) and differentiated (unique) expertise of individual team members. In TMS research, these configural team-level cognitive structures have been assessed and interpreted by Austin (2003), Lewis (2004), Palazzolo (2005), Rau (2005; 2006), Child & Schumate (2007), Yuan et al. (2007), Ho & Wong (2009), Su & Contractor (2011), Su (2012), Sung & Choi (2012), and Treem & Leonardi (2015). This amounts to around 29% of the reviewed field studies.

Similar to the evaluation of shared cognitive structures, individual-level data is mostly collected by conducting interviews or questionnaires with team members, team leaders, or experts. Team member individual-level data is for example measured by giving individual team members lists of task-relevant knowledge areas that can be answered by rating one's own expertise for each knowledge area. This individual-level data is then transformed into either knowledge lists for complete knowledge stock, cognitive maps, team maps, or expertise matrices. These lists or maps are then further evaluated by experts or team leaders for accuracy and task-relevance of individual knowledge areas. Based on these results, the pattern or configuration of expertise for the team as a whole can be assessed.

Researchers using these methods for summarizing individual-level data to represent team-level data for the assessment of expertise distribution are therefore seen to operationalize the hypothesized construct of configural team-level cognitive structures (actual expertise) in a valid form. Data retrieved from studies following this research strategy is accordingly interpreted to be a representation of the configural cognitive team-level construct within the multi-level TMS model.

4.1.2 Measurement of interaction

In the multi-level TMS model presented in section 3, two types of interactive processes are hypothesized to constitute integral parts of a working TMS within the IMOI framework. These types are represented in the transactive processes for information and knowledge sharing (and potential knowledge creation) as well as the application of information and knowledge within coordinative processes to execute the task. This differentiation between two types of processes is guided by the assumption and respective research that the interactive sharing on its own does not constitute the execution of the task but – together with the emergent cognitive structures – moderates the relationship between coordinative task processes of information and knowledge application and team performance (see section 3.4.2).

In contrast to the assessment of cognitive structures, expert ratings should not be used as a direct reflection of communicative acts (Kozlowski, Klein 2000, p. 37). This implies that communicative and interactive acts have to be observed or stored in the research process for subsequent evaluation of the content of interaction. But whereas direct observation via video tapes or observers can be frequently used in group settings, "live" measurement of these interaction acts is limited in organizational settings. Nonetheless, in TMS field research, measurement methods for the assessment of team interaction are used by Faraj & Sproull (2000), Lewis (2004), Peltokorpi (2004), Akgün et al. (2005), Palazzolo (2005), Rau (2006), Yuan et al. (2007; 2010a; 2010b), Peltokorpi & Manka (2008), Smith-Jentsch et al. (2009), Su & Contractor (2011), Su (2012), Sung & Choi (2012), and Treem & Leonardi (2015). This amounts to around 36% of the reviewed field studies.

In the above mentioned studies, the measurement of communicative and interactive acts is mostly carried out by applying questionnaires and self-reports about the frequency of communication, the frequency of knowledge application, the communicative network of individual team members, information gathering behavior, information exchange (for retrieval and allocation), requesting and accepting backup, and team members reporting knowledge utilization.

While the measurement via questionnaires and self-reports cannot be regarded as a direct reflection of the content and function of individual interactive acts, Lewis (2003) has shown that scales used for the assessment of knowledge-relevant behavior within groups are highly correlated with the actual behavior observed via videotapes (the scale developed by Lewis is discussed in the next subsection). Therefore, and due to the lack of a direct observation method used in organizational TMS research for interactive processes (possibly due to data privacy and data security reasons in actual organizations), studies utilizing the aforementioned measurement methods are used as a substitute for the reflection of communicative and interactive behavior in this work.

4.1.3 Measurement of TMSs as a latent construct

In this section, the measurement method to evaluate TMSs as a latent construct developed by Lewis (2003) is discussed in more detail. In this discussion, special attention will be paid to the construct validity regarding the multi-level TMS construct. The questionnaire developed by Lewis consists of 15 likert-scale items that are divided into three behavioral dimensions called specialization, coordination, and credibility that, according to the author, should be answered by every individual of the team and aggregated to form a composite TMS score (see Appendix D). Higher scores are interpreted as indicators for an efficiently working TMS whereas lower scores are interpreted by Lewis (2003, p. 600) as indicators for issues within the three behavioral dimensions in the team's TMS.

Study background

The above mentioned dimensions are inferred from the group studies conducted by Liang, Moreland, and colleagues (e.g., Liang et al. 1995; Moreland et al. 1996; Moreland et al. 1998; Moreland, Myaskovsky 2000), in which the effects of group training on behavioral indicators and the development of TMSs in form of shared and configural cognitive structures have been studied. In these studies, the researchers observed and filmed individuals in groups assembling the AM part of radio kits that were purchased in local electronics stores (e.g., Liang et al. 1995, p. 387). To assess different behavior, the authors coded individual communicative and interactive acts that were related to memory differentiation (encoding, retrieval, and allocation acts), task coordination (representing smooth operation within the task), and task credibility (the trust in each other's expertise about assembling the radio) within the group. After integrating the results of the memory recall and assembly performance into the model, a direct relationship between the development of a TMS in terms of cognitive structures and the three dimensions of behavioral indicators was found (ibid., pp. 388-390). From this, the authors deduced that these behavioral indicators could be interpreted as a manifestation of a working TMS within a group. Furthermore, it was concluded that the effectiveness of the group training resulted from these communicative acts, as was also tested in later group studies replicating these tests with communication conditions in the training sessions (Moreland et al. 1996; 1998).

Lewis (2003, p. 590) concluded that if the development of a TMS causes teams to show these behavioral indicators – specialization, coordination, and credibility –, such indicators could be used then to infer that a working TMS exists within a team. It is important to stress that Lewis does not understand these dimensions as direct reflections of for example shared or configural team-level properties, but more accurately as a reflection of a latent construct. Therefore, according to the author, only the existence of all of the three dimensions should be interpreted as an underlying working TMS. As Lewis & Herndon (2011, p. 1257) deduced later, these behavioral dimensions should not be interpreted independently or as components of a TMS.

In the following paragraphs, the validation process of Lewis' (2003) composite scale is discussed to evaluate if a) the scale accurately measures these behavioral indicators, and if b) these behavioral indicators accurately represent a functioning TMS as a latent construct in organizational contexts.

Validation process of Lewis' (2003) *composite TMS scale*

To validate the appropriateness of the scale, Lewis (2003) conducted three separate studies in which the scale was applied in combination with either direct or indirect measurement of cognitive structures and interactive processes. In the first study (124 groups, 372 students), the author replicated the radio assembly task and directly observed behavioral indicators by videotaping the conversations within groups. For convergent validity analysis, Lewis (2003, p. 594) analyzed the correlations between the dimensions in the developed scale and the behavioral indicators. All three dimensions showed significant medium levels of correlation (r=.34 for specialization; r=.41 for credibility; r=.51 for coordination) with ratings of the behavioral indicators, implying that the scale could possibly be used to assess interaction within teams.

Furthermore, Lewis (2003) tested criterion validity by correlating the composite scores of the developed scale with a measure for functional communication and the results of the assembly task. The functional communication measure in this case indicates the amount of task-relevant information that is communicated within the team, relating to the knowledge-application aspect within the multi-level TMS construct as opposed to pure knowledge-sharing. The results indicated that the composite TMS score was positively correlated to functional communication (r=.61) and negatively correlated to low assembly performance (r=-.76) (ibid., p. 595). In summary, these findings implicate that, individually, the scale dimensions showed medium positive correlations with actual behavioral indicators and high positive correlations with functional communication and group performance. These results can be interpreted insofar as that the scale developed by Lewis (2003) can be used to assess knowledge-relevant and functional communicative and interactive acts within teamwork that are positively correlated to group performance.

The second study (64 teams; 260 MBA consultants) and the third study (27 teams; 146 individuals) in management consulting and project settings were used to replicate the results of the relationship between Lewis' (2003) scale and functional communication ratings. In both settings, the correlations between the composite TMS score and functional communication were strongly positive (study 2: r=.89; study 3: r=.79) and positively related to ratings for team performance (study 2: r=.48; study three: r=.57 and r=.73), thus replicating the results of the first study and confirming the relationship between the composite scale and functional communication within teams. In addition to these indirect measures for behavioral dimensions and functional communication in these field settings, Lewis (2003) applied methods that are used in Shared Mental Model and Team Mental Model research (see section 4.1.1) to evaluate the agreement (or sharedness) about existing configural cognitive structures within teams (without actually evaluating the relationship between expertise and performance in this context). In another attempt to assess convergent validity, Lewis (2003, p. 597) measured these agreement scores in combination with the composite TMS score. In both studies (2 and 3), the composite TMS score was positively correlated with the expertise agreement scores (study 2: r=.55; study 3: r=.48), implying that the composite TMS score measures some part of the expertise agreement within the team. In this context, an analysis of the aggregation process in the composite TMS score offers the following possible explanation for this relationship.

Similar to the measurement of agreement in shared cognitive structures, in a first step, the 15 items in Lewis' (2003) scale are aggregated to the three dimensions of specialization, credibility, and coordination for each individual team member. Following this, these three dimensional scores are aggregated for each individual to form the composite individual-level score. In the last step, the scores for each individual within the team are aggregated to form a composite team TMS score. As Kozlowski & Ilgen (2006, p. 85) discuss, high scores require within-group perceptual consensus, implying that there has to be an agreement about the different dimensions within the team. This agreement (as has been discussed in section 3.2.2) is thought to emerge from compositional processes that promote isomorphism, thus not representing processes that promote the development of configural team-level cognitive structures (Kozlowski, Bell 2013, p. 37). Therefore, it is reasonable to assume that there should in fact be a relationship between the composite TMS score and measurement methods assessing within-group agreement of expertise structures.

In summary, the analysis of the validation process supports the interpretation that Lewis' (2003) composite TMS scale can be used to measure behavioral indicators for functional communication and coordination. Furthermore, due to the aggregation process, the scale captures parts of the agreement between individual team members regarding functional communication within the team, which are related to measures of within-group agreement of expertise structures. Although this result positively answers the first question related to the use of the composite scale to accurately measure these behavioral indicators, the question of construct validity with regard to the use of this scale to measure TMS as a latent construct is still not answered.

Using Lewis' (2003) composite TMS scale to measure Transactive Memory Systems

After clarifying the validation process and the background of the composite TMS scale developed by Lewis (2003), it is important to subsequently discuss the question of "what is actually being captured by the measure" (Kozlowski, Bell 2013, p. 37). In this context, Lewis & Herndon (2011, p. 1257) argue that high scores of this measure can be used to infer that a TMS is working as a latent variable in the background within a team.

However, this argument is only valid if a latent TMS is the only possibly explanation for functional communication and coordination within the team. Although Liang et al. (1995, p. 388) tested for social factors such as task motivation, group cohesion, or social identity, other factors such as existing compulsory routines for knowledge sharing, explicit expertise directories or team leadership that are proposed to influence the efficiency for functional communication or coordination have not been tested for (see the further findings in section 4.2). On these grounds, it should be inferred that TMSs may very well influence functional communication and coordination, but that they are not the only possible explanation for high scores in Lewis' (2003) composite TMS scale.

But what does a low score indicate? Since neither the shared – at least not in the sense of an actual mental model of expertise distribution – nor the configural team-level cognitive properties are measured, low scores could therefore only indicate that "something is not working right" within the interactive processes of a TMS. In terms of the multi-level TMS model, this implies that a low score represents problems within the communicative and interactive processes, given that, as per definition in this work, the latter are both the actual processes and the source for emergence within a working TMS. This proposition is supported by the validation process of Lewis' (2003) method, where it has been consistently shown that the composite score is highly correlated with actual behavior and indicators of functional communication. As such, it is only logical that the score would positively correlate with an actual agreement about expertise distribution. This is because, according to the theoretical multi-level framework of TMSs, the shared team-level cognitive structures are hypothesized to develop through functional communication and coordination within the team and therefore as the further basis for the latter processes.

As the discussion above shows, Lewis' (2003) composite TMS scale should consequently not be used to measure TMS as a latent construct without testing for other possible explanations. Without further validation, it cannot be confirmed that TMSs are the only possible cause for functional communication and coordination within a team. On this account, the composite TMS scale will only be interpreted and recoded as a representation of a coordinative system for functional communication in the analysis of empirical TMS research. Based on the preceding discussion of the different measurement strategies in TMS research, it is now possible to interpret the findings of empirical studies. This is the topic of the next section.

4.2 Findings in TMS research

In this section, research in dyadic, group, and field settings is analyzed each separately (see Appendices A, B, and C, accordingly). This separation is based on the differences in the application of direct and indirect measurement methods (or the imposition of explicit cognitive structures) on the one hand and the definition of teams and interdependence in this work on the other hand. Here, it is proposed that in organizational settings, interdependencies and differences in power bases (as discussed in section 2.4) may influence the interrelations within the proposed multi-level TMS construct.

4.2.1 Dyadic research

TMS research in dyadic contexts is mostly focused on Wegner's (1987) proposition that a working TMS would increase the amount of information or the size of the configural team-level cognitive structure that a dyad could potentially store within their minds. As such, researchers conducting these kind of studies use memory recall (Wegner et al. 1991; Hollingshead 1998b, 2000; Johansson et al. 2000; Hollingshead 2001; Hollingshead, Fraidin 2003; Johansson et al. 2005; Baumann, Bonner 2011) or knowledge pooling tasks (Hollingshead 1998c; Littlepage et al. 2008) to assess the volume of specific information that a dyad has stored (see Appendix A). Only in one of the analyzed dyadic studies, an actual decision-making or problem solving task (Fraidin 2004) has been used to study TMSs. In this regard, the results of this sample should be interpreted carefully regarding an application in organizational contexts.

Configural and shared cognitive structures

In one of the first studies in the TMS context, the role of specific expertise assignments on memory recall performance has been tested by Wegner et al. (1991). The authors were interested in the relationship between existing cognitive structures in close couples and explicit expertise assignments in a memory recall task. The results of their study indicate that existing couples performed better in recall tasks if they could rely on their existing expertise differentiation. However, if expertise in this recall task was not assigned according to the existing cognitive structures, recall performance of close dyads was found to be worse than that of control (impromptu) dyads. These control dyads consisted of strangers that were assembled for the task and were thus not able to possess pre-developed team-level cognitive structures (Wegner et al. 1991, p. 925).

Related to this, Hollingshead (2000) found a relationship between the depth (and thus volume) of individual-level expertise and the shared team-level expertise directories, indicating that individuals in dyads concentrated on their own areas of expertise in a memory recall task when they could rely on their partner in different areas of expertise. Similarly, Fraidin (2004) found that distributing expertise within the dyad led to a reduction of cognitive load and an enhancement of individual learning.

Regarding the influence of incentives or interdependence on the configuration of expertise within a dyad, Hollingshead (2001) tested this hypothesis by imposing cognitive interdependence through different incentive conditions in her experiment. The author found that the expected configuration of expertise matched the incentive conditions in so far as that expertise was differentiated when the scores of the recall task were matched for total number of different recalled items and that expertise was integrated (and thus shared) when the recall of matched items (both individuals recalled the same item) was scored.

In sum, these results regarding configural cognitive structures indicate that a relationship between expertise assignments and memory recall performance (as indicator of the dyad's expertise) does exist. However, the results also indicate that expertise assignments can negatively influence a dyad's performance if the newly assigned expertise structure does not match existing cognitive structures in the form of expertise directories (related to the turnover proposition in section 3.2.3). Furthermore, the distribution of expertise and sharing behavior within a team can potentially be influenced by incentive conditions.

Studies on shared cognitive structures (in the form of expertise awareness or agreement) are not as present in dyadic contexts as studies on configural cognitive structures. For example, Wegner et al. (1991) and Hollingshead (1998c) found that the agreement about the partner's relative expertise is higher in existing dyads compared to control (impromptu) dyads. Additionally, Hollingshead (1998b) found that communication influenced the development of these shared cognitive structures. The results of Littlepage et al. (2008) indicate that the agreement and accuracy of the shared cognitive structures influence the performance of dyads in job knowledge quizzes, suggesting that these shared cognitive structures in existing dyads are more important than sole communication. Next to this result, they found that performance was positively influenced if expertise differed in abilities and if dyads explicitly assigned work to the specific expert. Fraidin (2004) identified similar relationships in the study of imposed expertise directories and actual expertise distribution and their influence on hidden profile decision-making tasks. The author found that presenting individuals explicit information about the distribution of expertise within the dyad influenced the salience of information within the dyad, which in turn led to an enhanced use of unshared (differentiated) expertise. Similar to the distribution of actual expertise, Fraidin (2004) found that shared cognitive structures can indeed positively influence learning and problem-solving within dyads.

Regarding the possibility of default entries in the shared cognitive structures, Hollingshead & Fraidin (2003) showed that similar gender stereotypes (representing culture-dependent Shared Mental Models) regarding expertise domains exist in male and female participants. In this regard, the results revealed that individuals rely on these stereotypic default entries if no other information regarding the actual expertise is present. Presenting individuals information about the actual expertise distribution reduced the effects of stereotypes on negotiated entries. Similar to this, Hollingshead (2000) found that role-based expertise perceptions can serve as negotiated entries (see section 3.3) in shared cognitive structures. This study showed that stereotypic default entries could be substituted by distributing information about job responsibilities (i.e., roles) to individuals.

These results indicate that the development of shared cognitive structures in the form of expertise directories is influenced by communication. In addition to this influence, the study of Baumann & Bonner (2011) showed that the development of cognitive structures is also influenced by the expected longevity of the dyad, indicating that individuals adjust their effort concerning this development to their expected time span of membership in the dyad. Furthermore, shared cognitive structures can potentially influence team performance and learning through the development of agreement and the promotion of differentiation within a team. These findings also indicate that, to eliminate the influence of stereotypes or other culture-specific SMMs on the development of shared cognitive structures, information about actual expertise should be distributed as early as possible in the team's development.

Communication and expertise utilization

Next to the study of cognitive structures, both the influence of these structures on communication and the influences of communication and knowledge utilization have been studied in dyadic settings. In this context, much research has been conducted by Hollingshead (1998b; 1998c). The author found that the negative influence of missing communication is reduced if dyads have an agreed upon expertise directory, suggesting that these dyads can rely upon existing cognitive structures for coordination. In contrast to this, in control (impromptu) couples, missing communication had negative effects on the recall or knowledge pooling performance. The performance of control couples was greatly enhanced if communication was allowed and this communication in turn influenced the learning strategy of dyads (Hollingshead 1998b). Furthermore, Hollingshead (1998c) found that the mode of communication (face-to-face or computer-mediated) can influence learning strategies and memory recall performance. While existing dyads benefited from face-to-face communication, no such difference between existing and control dyads was found in computer-mediated communication conditions. Accordingly, it can be assumed that existing dyads might use their information on the other's nonverbal cues for coordination, which in turn is not possible without this information through, for example, the experience of working together. Regarding the content of communication relating to the sharing and utilization of information and knowledge, Littlepage et al. (2008) found that the utilization rather than the sharing of expertise led to a higher performance, and that this utilization was affected more by shared cognitive structures than by communication.

Together, these results indicate that communication and expertise utilization can play an important role in the relationship between cognitive structures and performance. Moreover, emphasis should be put on the mode of communication and the effect of communication regarding expertise assignments in earlier stages of team development.

Costs of coordination

In dyadic settings, potential costs of teamwork have been studied in only two settings with elderly couples. Johansson et al. (2000; 2005) found that individuals that learned and recalled items individually showed a higher performance than either existing or control dyads. This can be interpreted as a difference in coordination costs within a dyad compared to individuals working independently on their tasks. However, existing dyads that agreed upon their division of responsibility and claimed to use their shared cognitive structures performed almost as good as the control individuals. Control dyads on the other hand did not show this kind of improvements. Johansson et al. (2000; 2005) interpreted these results as having implications for the benefits of a working TMS. In this context, the authors proposed that TMSs could potentially counterbalance the transaction costs of dyads or groups working together, showing the importance of shared cognitive structures in teamwork.

As noted above, the results of studies in dyadic contexts should be carefully interpreted regarding propositions for an organizational context. Only one of the reviewed studies explicitly integrates the concept of interdependence in the development of cognitive structures. Furthermore, an explicit decision-making task has been used in only one of the studies, which hinders the generalizability of the results and proposed relationships. Also, none of the reviewed studies explicitly studied or applied path dependence or longitudinal settings. Nonetheless, the discussed results form a basis for the interpretation of TMS constructs and further TMS studies in group and field settings.

4.2.2 Group research

In this section, the findings of group TMS research will be elaborated. Before explicitly discussing these findings, it is important to illustrate the use of Lewis' (2003) measurement scale in these group settings. In 10 of the 29 studies, this method has been used to analyze TMSs (see Appendix B). As discussed in section 4.1.3, this method will not be interpreted as a direct reflection of a TMS but as a reflection of functional communication and task coordination in the specific study if no other direct measurement of either cognitive structures or interaction was applied.

In contrast to the dyadic context, a variety of tasks has been studied in group settings. For example, in many of the earlier studies (Liang et al. 1995; Moreland et al. 1996; Moreland et al. 1998; Moreland, Myaskovsky 2000; Rulke, Rau 2000; Myaskovsky et al. 2005; Lewis et al. 2005; Lewis et al. 2007; Prichard, Ashleigh 2007), the assembly of an electronic device (combined with recall) has been utilized to study TMSs. Furthermore, decision-making and problem-solving (van Ginkel, van Knippenberg 2009; Schreiber, Engelmann 2010; Engelmann, Hesse 2011; Baumann, Bonner 2013; Bazarova, Yuan 2013; Gockel, Brauner 2013; Mell et al. 2014b), business simulation (Yoo, Kanawattanachai 2001; Cruz et al. 2007; Kanawattanachai, Yoo 2007), control-and-command simulation (Ellis 2006; Pearsall, Ellis 2006; Pearsall et al. 2009; Pearsall et al. 2010), product or software development (He et al. 2007; Gino et al. 2010), written deliveries (Jackson, Moreland 2009; Michinov, Michinov 2009; O'Leary, Mortensen 2010), and other intellective tasks (Gupta, Hollingshead 2010) have been employed, providing the sample with a variety of tasks reflecting actual teamwork in organizations. In addition, this sample includes studies (next to group training settings), in which more than one point in time has been observed, providing potential evidence for the development of a TMS (Yoo, Kanawattanachai 2001; Lewis et al. 2005; He et al. 2007; Kanawattanachai, Yoo 2007; Jackson, Moreland 2009; Michinov, Michinov 2009).

Group training and the development of TMSs

To convert the study of TMSs from the dyadic settings to group settings and tasks that are proposed to depend on the development of shared cognitive structures and group coordination, Liang et al. (1995) developed a group training setting that is related to the radio assembly tasks. In this setting, the interaction between different group members can be directly assessed by the study of video tapes that were taken in the group training and assembly sessions. In their study, the authors found that group members that had been trained together recalled the assembly task more accurately and showed a higher performance in the task than members that had been trained individually. Furthermore, the positive results of the group training were attributed to the development of interactive acts of memory differentiation, task coordination, and task credibility, interpreted by Liang et al. (1995) as the development of an efficient coordination system based on the shared and configural cognitive structures. This attribution was supported by the fact that the results were controlled for the development of group cohesion and social identity (ibid., p. 388). However, as discussed in section 4.1.3, the authors did not explicitly measure shared and configural cognitive structures, but focused only on these behavioral indicators.

To assess if group training sessions would indeed foster the development of the behavioral indicators, Moreland et al. (1996; 1998)[19] implemented an interaction condition into their studies, in which the individuals were not allowed to talk to each other. The respective results indicate that interactive group training indeed fostered the development of communicative acts of memory differentiation, task coordination, and task credibility within the groups. In a later study, Moreland et al. (1996; 1998) further assessed the development of shared cognitive structures in this context. Here, the shared expertise directories showed greater complexity, accuracy, and agreement in the group training condition, suggesting that group training positively influences the development of shared cognitive structures. Moreover, the indices for shared cognitive structures and behavioral indicators were highly correlated, implying that shared cognitive structures could develop through interactive acts, which is a proposition of compositional processes in the multi-level TMS construct. Moreland & Myaskovsky (2000) further refined this proposition: the results of their study indicate that the volume of communication on its own is not the basis for the development of shared cognitive structures, but communicative acts that are indicative of memory differentiation, task coordination, and task credibility. Besides, giving individuals access to the information about the configuration of cognitive structures enhanced the development of shared cognitive structures.

The influence of group training on the development of a functional communication and coordination was also analyzed in the study of Prichard & Ashleigh (2007). The authors studied the effects of team-skills based training on the development of functional

[19] The same experiments are reported in both 1996 and 1998 articles. Therefore, I decided to mention both since in TMS research, some researchers report either one or the other, which could indicate different studies.

communication and coordination (through the application of Lewis' (2003) composite TMS score) and performance in an assembly task with similar results. In this context, Rulke & Rau (2000) found that individuals in groups which had developed a coordination system consisting of communicative acts for the encoding of information would declare their individual expertise earlier in the process of group training, which in turn influenced the development of shared cognitive structures. Also, the frequency in which expertise is evaluated was higher in groups which had developed this functioning coordination and encoding system. In the only TMS group training study that – as opposed to the former studies – evaluated group training in mixed sex groups, the latter showed inconsistent results, implying that group training does not automatically foster the development of shared cognitive structures and a coordination system (Myaskovsky et al. 2005). In this connection, the authors state that group training sessions should be explicitly build around this development of TMSs to counteract the influence of, for example, stereotyping. This finding indicates the same relationship as suggested by Hollingshead & Fraidin (2003) in the dyadic context.

Next to the study of group training sessions, the development of a TMS has also been studied in other settings. For example, He et al. (2007) looked into the development of shared awareness about expertise distributions in a synthetic software development task. Here, face-to-face communication and communication via telephone positively influenced the development of shared cognitive structures. In contrast to Myaskovsky et al. (2005), He et al. (2007) found a positive relationship between gender diversity and the development of shared cognitive structures in a business simulation task, implying that this relationship should be further studied for clarification. Analyzing the importance of communication in the development of a TMS (while not directly measuring cognitive structures), Yoo & Kanawattanachai (2001) found that the importance of communication is higher in earlier stages of a business simulation game for the evaluation of expertise between members of the group.

The influence of communication on the development of shared cognitive structures has also been analyzed by Kanawattanachai & Yoo (2007) in a later study. Next to the importance of communication in the early stages of the development of expertise directories and cognition-based trust, they found that, in later stages of the task, task-knowledge coordination had a stronger influence on team performance compared to communication. This implies that – as proposed in the IMOI model – sharing and utilization of expertise should be regarded as separate processes. Furthermore, these results suggest that it is important to differentiate between the development of TMSs and their functioning as well as that the role of communication and coordinative mechanisms can change in the lifecycle of a TMS. Analyzing the influence of role identification behavior on the development of TMSs (measured with Lewis' (2003) composite TMS score) and Shared Mental Models, Pearsall et al. (2010) found that role identification was positively related to the development of shared cognitive structures and functional communication and coordination, implying that what Wegner called perspective taking (section 3) might play an important role for the development and accuracy of shared cognitive structure that influence coordinative behavior. In combination, both shared cognitive structures and functional communication and coordination influenced the performance of groups in a decision-making control-and-command task, indicating that the influence of shared cognitive structures on performance can indeed be exerted through coordinative behavior as proposed in the multi-level TMS model.

Drawing on the concept of a developing TMS, Lewis et al. (2005) transferred this idea to a TMS-Learning framework by integrating explicit learning cycles into the development of TMSs. Compatible with the discussion about the discursive validation of statements, they adopt Argote's (2011, p. 440) definition of organizational learning as the creating, retaining, and transferring of knowledge. TMS learning in this context is defined as the transfer of created knowledge about specific task and team characteristics that has been validated in a first task to a second task and further subsequent tasks. Thus, Lewis et al. (2005) introduced the concept of refinement of existing cognitive structures and processes into the study of TMSs. In a set of three functionally equivalent assembly tasks, they found that functional communication and coordination (through the application of Lewis' (2003) TMS composite score) were positively correlated to the development of an abstract understanding of underlying task characteristics, further refining the coordinative processes within the group. Next to this, the results imply that the functional communication and coordination in fact influence the group's learning within and between the tasks, suggesting that transactive processes and coordination can indeed influence the path dependence and development of cognitive structures, as proposed in the multi-level TMS construct.

In sum, these results indicate that cognitive structures and processes for the sharing and coordination of information and knowledge can indeed be developed by group training sessions and similar quasi organizational tasks. They also show that it is important to train individuals together with a particular focus on such development to counteract potential negative effects of stereotyping or clique building. Furthermore, the findings reveal that not the sole communication but purposeful communicative acts of coordination influence the development of TMSs, as is in line with the proposed multi-level TMS model and the transactive processes. These results thus imply that the benefits of a working TMS could be transferrable between different task contexts provided that information and knowledge about underlying task dependencies are stored within a team's TMS.

Shared and configural cognitive structures

In contrast to the dyadic context, researchers within group settings apply more realistic tasks and settings to study the relationship between cognitive structures and group performance as well as the interrelations between shared and configural cognitive structures. Here, research has gone beyond the simple proposition that a TMS enhances the volume of information and knowledge that a team can potentially store, asking how expertise directories and group knowledge stock actually influence performance.

For example, Cruz et al. (2007) found that cognitive structures can indeed be used to understand differences in performance in a decision-making business simulation. The size of the configural cognitive structure was found to only have an influence on performance when the pattern represented a differentiated structure. Interestingly – in contrast to the proposition about the importance of developing shared cognitive structures of the expertise distribution that are agreed upon – groups whose members did not show these shared cognitive structures but relied upon their group leader to coordinate expertise showed higher performance (ibid., p. 199). Interpreted together with the positive relationship between psychological safety and the group's performance, this indicates that not only might the proposition in TMS theory about shared cognitive structures be too simplistic (and therefore has to be altered), but also that it could be possible to substitute shared cognitive structures by installing team leaders whose decisions about the utilization of the team's expertise are trusted in. Furthermore, the influence of TMSs as coordination systems could be dependent on the specific task complexity and thus on the need for coordination within the task (Lewis, Herndon 2011, p. 1258), implying that the benefit of TMSs may not be universal in task settings.

Next to the study of developed cognitive structures, various researchers explicitly manipulated the shared and configural cognitive structures in groups by imposing these structures in their study conditions (van Ginkel, van Knippenberg 2009; Gupta, Hollingshead 2010; Schreiber, Engelmann 2010; Engelmann, Hesse 2011; Baumann, Bonner 2013; Gockel, Brauner 2013; Mell et al. 2014b). For example, van Ginkel & van Knippenberg (2009) studied the influence of the awareness of expertise distribution in hidden-profile decision-making groups. They found that this shared cognitive structure on its own did not influence the decision performance. Shared cognitive structures only had a positive influence on decision-making performance in combination with information elaboration and reflection on this information, thus providing evidence that cognitive structures as emergent states can indeed moderate the influence between behavior and performance. This aligns with what Marks et al. (2001) proposed regarding the application of emergent states as mediating variables.

Similar to this, Schreiber & Engelmann (2010) studied the influence of TMSs on decision-making performance while manipulating the shared cognitive structures within the group. In this study, the tool for fostering shared cognitive structures did indeed positively influence the development of these structures. The results showed that, while the decision performance was not directly influenced by the awareness of each other's expertise, groups with such an awareness needed less time to come to a decision and had a greater agreement on the reasons for this condition compared to groups without this awareness. However, in an organizational setting that might show contextual influences of time constraints, this result could be interpreted as higher team performance inasmuch as the team could, for example, start earlier with the next sub-task.

Similar to van Ginkel & van Knippenberg (2009), Gockel & Brauner (2013) found that perspective taking positively influenced the development of shared cognitive structures in terms of accuracy and agreement in problem-solving tasks, and that an integrative pattern of the configural cognitive structures positively influenced the problem-solving performance. In another study, this integrative pattern of the configural cognitive structures was also identified to enhance a group's performance in an intellective task (Gupta, Hollingshead 2010), thus confirming the influence of the pattern of configural cognitive structures on problem-solving performance. While differentiated structures led to the use of unshared information, integrated structures led to the use of mainly shared information in the task. Though these results stand in contrast to the performance implication of the pattern of configural cognitive structures by Cruz et al. (2007), they can be interpreted meaningfully in combination with each other. In this context, the role of a team leader could be crucial with regard to the influence of configural cognitive structures on task performance. Since groups with a team leader and high amounts of psychological safety trusted more in the differentiated expertise possessed by the other group members, it could be inferred that in groups without leading members, an integrated structure serves as a conveyor of trust in each other's expertise. Given that this status within a group may not have to be developed in groups with team leaders, the cognitive load of maintaining the TMS could be lowered to free further cognitive resources for task completion. It will be interesting to see how this issue is discussed in field settings.

Further investigating the role of shared cognitive structures in the discussion of unshared information, Engelmann & Hesse (2011) imposed different states of awareness of expertise in a computer-supported problem-solving task. They found that providing group members with expertise maps displaying the pattern of the configural cognitive structure decreased the time until the group started the "sharing of unshared" information (ibid., p. 2078) within the problem-solving process compared to a condition in which the group did not possess this information. Moreover, in the awareness condition, previously unshared (and thus differentiated) information was extensively applied to the problem-solving task and more thoroughly understood by individual group members. However, groups with these enhanced expertise maps did not outperform control groups, implying that shared cognitive structures alone do not directly influence the group's performance. This is in line with the proposition that shared cognitive structures do not directly mediate between inputs and outputs and that a coordinative process has to be affected by them. In this regard, the authors also state that the study of communication may be important to interpret these results.

Related to the results regarding the discussion of unshared information, Baumann & Bonner (2013) tested the TMS proposition that expertise directories should be shared by all group members in a hidden-profile decision-making task. The findings of their study indicate that a complete sharedness and awareness by all group members is not needed to foster a discussion of unshared information. In this setting, such discussion started if the majority of group members possessed these expertise directories (ibid., 548). This implication is further supported by a study by Mell et al. (2014b), in which the distribution of awareness of expertise within the team was analyzed in a decision-making task. In this study, groups in which the information about expertise distribution was centralized within one group member outperformed teams with a decentralized expertise directory structure. These results can however not be directly interpreted in line with the study of Cruz et al. (2007), because the decentralized condition did not imply that every group member had complete information about the pattern of expertise distribution. Rather, every group member had only some part of this information. Therefore, the results can only be interpreted to imply that a centralization of this information may entail lower transaction costs than an incomplete sharedness of expertise directories. Nevertheless, the findings by Mell et al. (2014b) further support the proposition that the shared and configural cognitive structures do not directly mediate between input and output factors but rather moderate the relationship between information coordination and decision-making performance.

Communication and expertise utilization

Group research on the influence of communication and expertise coordination in the TMS context has mostly been conducted in problem-solving and decision-making, as well as project presentation, and product-development tasks. In this context, the recoding of Lewis' (2003) composite TMS score into a measure for functional communication and coordination helps to explain direct mediation effects between supposed shared and configural cognitive structures and group performance in these settings. For example, Pearsall & Ellis (2006) found a direct mediation effect of TMSs between team member assertiveness and decision-making performance that cannot be explained without considering team behavioral processes of task coordination within this setting (for a discussion, see section 4.1.3). Similar to this, Jackson & Moreland (2009) found a positive relationship between functional communication and coordination (measured with Lewis' (2003) composite scale) and group performance in project presentation tasks.

The findings by Michinov & Michinov (2009) in a learning task setting are more complex to discuss, because the authors interpreted individual dimensions within Lewis' (2003) composite TMS score as direct reflections of TMS dimensions. The authors found a direct relationship between the coordination dimension and group learning performance, although this result should be treated with care due to the change in a validated measure. In a product-development setting, Gino et al. (2010) found that the development of functional communication and coordination (again, measured with Lewis' (2003) scale) may be improved when group members directly train on the future task as opposed to watching another team perform the future task. According to this study, the development of functional communication and coordination was further improved by group member stability, which is in line with the proposition in the multi-level TMS model.

Regarding the mode of communication, Bazarova & Yuan (2013) found that the perception of expertise between group members of different cultures (Western and East Asian culture) was influenced by face-to-face and computer-mediated-communication settings in so far as that the differences between the perception in face-to-face settings disappeared if group members had no information about the other members' culture. This result is supported by earlier TMS studies discussed above that indicated the use of stereotypes for the development of default entries in the expertise directories. In this context, it would have been interesting to see if the differences in the face-to-face condition would disappear if the group members had been trained together with a focus on the development of shared cognitive structures.

In sum, the results of the group TMS research on communication and coordination are not very much surprising and support the proposition in the multi-level TMS model that communication and coordination mediate the relationship between input and output factors. Furthermore the differentiation between expertise sharing and utilization is supported in this context.

Contextual factors

Contextual factors have only been implemented and studied in few group settings. For example, Lewis et al. (2007) found support for the path dependence in an electronic assembly task with turnover as a contextual factor. Measuring both shared and configural cognitive structures, the authors found a direct relationship and influence of the developed shared cognitive structures in the first week of the task on the pattern of the configural cognitive structure in the second week of the task. Even with partial turnover in the group, the existing members relied on the developed and no longer fitting expertise directories as a basis for their own development of expertise and specialization. This result indicates that the proposed path dependence between different cognitive structures and interactive processes in the original multi-level TMS model (see section 2.6.3) can also be found in group settings. The researchers concluded that turnover has a negative impact on the development of a TMS and found that reflection sessions within the newly formed groups can be applied to avoid negative effects of existing shared cognitive structures in turnover situations. This proposition is supported by the studies of Moreland et al. (1996; 1998) in which the relationship between the performance of groups assembling electronic kits and existing cognitive structures was negatively affected by turnover.

Another contextual factor in group TMS research has been studied by Ellis (2006) and Pearsall et al. (2009) in control-and-command simulations. Both studies found that stress negatively influences TMSs and performance. While Ellis (2006) showed this relationship between acute stress and shared cognitive structures as well as transactive communicative acts of directory updating, information allocation, and retrieval coordination, Pearsall et al. (2009) found a negative relationship between hindrance and challenge stressors and functional communication and coordination. Moreover, Ellis (2006) found that an interaction between functioning shared cognitive structures and transactive communication did mediate the effects of stress on performance, thus implicating that group members could rely on existing coordination systems in times of stress. Supporting this implication, the results by Pearsall et al. (2009) showed that functional communication and coordination (measured with Lewis'

(2003) composite TMS score) positively influenced psychological withdrawal in a group, implicating a positive influence on commitment.

Next to the direct effects of turnover and stress, the influence of geographic dispersion of groups has been studied in written delivery intellective tasks. In this context, O'Leary & Mortensen (2010) found that the social categorization in teams with geographically based subgroups negatively affected the identification with the group, as well as conflict, and functional communication and coordination (measured with Lewis' (2003) composite TMS score). Furthermore, an imbalance in group sizes between subgroups negatively influenced functional communication and coordination, implicating the potential costs of coordination in geographically dispersed groups. Even with this small sample of studied contextual influences in group settings, it can be shown that TMSs do not function independently of contextual factors, but that such factors should be integrated in terms of possible moderation effects into the study of real work settings.

To summarize, the analysis of group TMS studies clearly indicates that transferring the original TMS performance propositions to groups in more realistic task settings shows quite different interrelations between shared and configural cognitive structures and coordinative processes than proposed in the original multi-level TMS model. The proposition that coordination and efficient task-relevant communication mediates between training sessions and other inputs on the one hand, and group performance and decision-making as outputs and the development of cognitive structures on the other hand, can be clearly supported. However, the relationships regarding the influence *and* pattern of cognitive structures on efficient coordination and, to that effect, on group performance seem to be more complex than generally proposed in TMS research by the common statement that TMSs enhance team performance. Besides the explicit study of shared and configural cognitive structures in combination with communicative acts in electronic kit assembly and recall tasks, none of the group studies actually analyzed the proposed original multi-level TMS construct. In the next section, this situation is further questioned by analyzing TMS research in organizational settings. Since the differentiation of research into shared and configural cognitive structures and coordinative processes has been promising so far, it will be further applied for the analysis in these settings.

4.2.3 Organizational research

After analyzing TMS research in dyadic and group settings, this section's focus is on the particular context of interest in this work: actual teams working in organizational settings (see Appendix C for the sample). As in the case of group settings, the TMS composite score developed by Lewis (2003) is also applied in many organizational research settings. In fact, this measurement method has been applied in specific field settings in 23 of the 39 field studies that were published after Lewis' original article. Again, if cognitive structures were not explicitly measured in such settings, the score will be interpreted as a representation of functional communication and coordination (see section 4.1.3). Furthermore, in six of the studies that applied Lewis' (2003) composite score (Zheng 2012; Hammedi et al. 2013; Li, Huang 2013; Pullés et al. 2013; Zheng, Mai 2013; Heavey, Simsek 2015), the questionnaire has been answered by only one individual, thus questioning the validity of the results. Since Lewis' (2003) TMS composite score is based on the assumption of aggregating perceptions of behavior to form a representation of compositional forms of emergence (which is reflected in the positive relationship between this score and agreement about expertise, as discussed in section 4.1.3), single informants should not be used to measure this construct (Kozlowski, Klein 2000, p. 34). Following this, these studies will not be interpreted as a reflection of parts of the proposed multi-level TMS model and were thus taken out of this sample. This also applies to the study of Gockel & Brauner (2013) who assessed TMSs with a questionnaire that has also been answered by single individuals.

In contrast to group research, in which no explicit combined measurement of all of the proposed components (shared and configural cognitive structures and processes) of Wegner's original multi-level TMS construct within a single study could be found, evidence of this combined measurement setting can be found in field settings. This combined measurement strategy – as visible in the studies by Palazzolo (2005), Rau (2006), Su & Contractor (2011), and Treem & Leonardi (2015) – will thus be analyzed separately at the beginning of this section in terms of its fit to the proposed multi-level TMS model and its contributions. Furthermore, the results of the four case studies included in the sample (Oshri et al. 2009; Jarvenpaa, Keating 2011; Leonardi, Treem 2012; Whelan, Teigland 2013) will be discussed at the end of this section concerning their contribution to the understanding of underlying processes in a working TMS. These case studies will be discussed separately due to their qualitative nature compared to the quantitative approaches that are predominantly applied in field settings.

Measuring TMSs in the field – Results from a combined research strategy

The first field study that implemented a combined research strategy for the analysis of TMSs has been published by Palazzolo (2005). The author studied task-relevant information retrieval and the influence of shared and configural cognitive structures on such retrieval in a sample of existing organizational teams in different contexts (including academic, consulting, governmental, management, and manufacturing contexts). Proposing that both shared and configural cognitive structures would influence information retrieval, Palazzolo (2005) found only partial support for these assumptions. With regards to the configural cognitive structures, the author found no support for the proposition that a differentiated pattern of expertise would lead to more unidirectional communication (indicating information retrieval). In fact, most of the communication patterns in the network were symmetric in this regard. Concerning the shared cognitive structures, Palazollo (2005) found strong support for the proposition that awareness of expertise would influence the communicative patterns in the team's network, indicating that information was actually retrieved from the team member that was perceived to be an expert. Interestingly, this pattern was not found for the self-declared expertise pattern, pointing to the importance of expertise awareness and acceptance in contrast to merely stating one's expertise (ibid., p. 747).

A similar result relating to cognitive structures and their relationship with communication can be found in the study by Treem & Leonardi (2015). The authors were mainly interested in the potential role of communication in terms of the ability of team members to recognize expertise in financial service sector teams. Contrary to their propositions, the pattern of the configural cognitive structure in the form of unique or integrated expertise did not influence the recognition of this expertise within the team. Even possessing expertise that is crucial to the task did not affect the perception of this team member as a potential expert (ibid., p. 17). Furthermore, factors of proximity and centrality in the team's friendship network did not influence the perception of expertise in the team. The only variables that directly correlated to expertise recognition were the information seeking behavior of team members and the utilization of shared forms of communication (which are visible to all team members) such as visible digital knowledge repositories in the team (e.g., wikis or internal blogs).

These results indicate that, initially, differentiated team-level expertise on its own may not be sufficient for the development of shared cognitive structures (expertise directories) and that both of these structures may influence each other through communicative processes. But since individual-level cognitive structures in the form of explicit expertise are proposed to influence individual behavior, long-term influences of differentiated team-level expertise on the development of shared cognitive structures should not be ruled out in general. Besides, such development may be dependent on the visibility of the mode of communication within the team. This proposition is supported by TMS research in group settings, suggesting that team members need to be aware of the configural cognitive structure for unique expertise to be discussed and used within the team (e.g., Engelmann, Hesse 2011; Baumann, Bonner 2013). Treem & Leonardi (2015, p. 20) thus conclude that in organizational settings with teams of a greater size and task complexity, the use of communal (shared and visible) forms of communication may be more important to foster a shared cognitive structure than interpersonal (and therefore more dyadic or sub-group) forms of communication.

Related to the information retrieval patterns that were found by Palazzolo (2005), Rau (2006) studied the influence of shared and configural cognitive structures on information gathering behavior in top management teams in the banking sector. Despite assuming that the expertise composition and the expertise location dimension would increase information gathering between two analyzed points in time, the author found no significant relationship between cognitive structures and information gathering. Neither was there support for the proposed relationship between information gathering and perceptual accuracy of task-related information (environmental volatility). The only proposition that could be supported was the correlation between prior team stability and perceptual accuracy of task-related information. In this regard, Rau (2006) speculates that the cognitive structures do not increase the frequency of information gathering but instead could influence the efficiency of individual information gathering acts. This proposition is underpinned by the finding that information gathering only affected perceptual accuracy when the team identified other important relationships between variables in the task (ibid., p. 423).

The last study to be discussed here that explicitly integrated both shared and configural cognitive structures and interaction is the study of information seeking behavior in consulting projects by Su & Contractor (2011). The authors found a difference in variables that would indicate the use of human knowledge sources on the one hand and digital knowledge sources on the other hand. Regarding human knowledge sources, they found that seeking behavior is influenced by the perception of expertise and accessibility of the possible expert. Interestingly, with regards to this relationship with digital knowledge repositories, individuals sought more knowledge from digital knowledge repositories that other team members used more often, indicating that trust in a digital knowledge source was fostered by overall team use. The actual configural structure of expertise and the complexity of the stored knowledge affected seeking behavior in an interesting way (ibid., p. 1267). The more complex knowledge was perceived, the more individual team members sought for this information in human knowledge repositories, indicating that the codifiability of knowledge or – according to the definition of this work – the complexity of possible statements and their interrelation influence the use of digital knowledge repositories negatively. This result may indicate that individuals seek out other team members when they are unsure regarding the underlying structure of the task and knowledge that is required for its completion. In contrast to digital knowledge repositories, other team members could possibly be cued for further information about the underlying relationships within the task.

In sum, studies in which both shared and configural cognitive structures as well as transactive processes have been studied support the proposed relationships in the multi-level TMS model only insofar as that shared cognitive structures and coordinative processes influence each other directly. However, the actual configuration of the team-level cognitive structures seems to have either no direct influence on coordination and performance or a negative influence regarding the complexity of its content and the use of digital knowledge repositories. These results will be further interpreted in section 4.3, where the complete findings in TMS research are discussed.

Shared and configural cognitive structures

One of the most thorough analyses of the structure and content of cognitive structures in TMS research has been conducted by Austin (2003). The author studied the relationship between cognitive structures and team performance operationalized as goal attainment and internal and external evaluation in sales teams. For this, the author divided Transactive Memory into a) task knowledge stock or the size of the configural cognitive structure, b) task knowledge specialization or the pattern of the configural cognitive structure, c) task transactive memory consensus or the sharedness of the shared cognitive structure, and, d) task transactive memory accuracy or the accuracy of the shared cognitive structure in order to represent the configural cognitive structure.

The respective results indicate a complex relationship between cognitive structures and team performance on the condition that objective goal attainment and evaluation are analyzed separately (ibid., pp. 871-872). In combination, all of the dimensions of TM have a positive relationship with objective and subjective evaluations of performance, implying that a team that contains a high volume of specialized information and knowledge, is in agreement about this specialization, and has accurate shared representations of this expertise distribution performs best and gets the highest internal and external ratings. Analyzed separately, only the accuracy of the shared cognitive structures is in significant positive relation with both objective and subjective measurements of performance. The agreement or consensus about these structures on its own is not significantly related to either of the performance measures, implying that researchers should not only measure the sharedness of expertise directories but also the accuracy of their representation of actual configural cognitive structures. The results concerning the configural cognitive structures are even more ambiguous and relate to the findings within group research. In this setting, knowledge stock on its own is negatively related to internal evaluations and is not related to either goal attainment or external evaluation. The configural cognitive structures are only positively related to internal and external evaluation in combination with knowledge specialization. However, in neither case are the configural cognitive structures related to objective performance without considering shared cognitive structures, strengthening the proposed importance of shared cognitive structures. In support of these results, the findings of Sung & Choi (2012) also suggest that the relationship between team knowledge stock and creativity or financial performance in sales teams might not be a direct relationship. Here, team knowledge stock was not positively related to creativity without integrating knowledge utilization into the proposed model (ibid., p. 8). In combination with the identified interaction effect of leadership cognitive style, these results indicate that configural cognitive structures can indeed only moderate the relationship between knowledge utilization and performance. Without a shared awareness of task-relevant expertise within the team, either directly or indirectly through leadership – as has also been found in group settings –, the configural cognitive structures might not be much of a predictor for utilization, coordination, or further performance.

The relevance of shared cognitive structures has also been shown in the studies by Ho & Wong (2009) and Smith-Jentsch et al. (2009) in management and air traffic control settings. Ho & Wong (2009, p. 153) found that the influence of expertise recognition on work performance was mediated by job resourcefulness and thus the possibility of interaction with other members of the organization. This result indicates that shared cognitive structures may indeed be more helpful in situations where they can be acted on in terms of information retrieval as compared to more restricted work settings. Smith-Jentsch et al. (2009) tested the proposition that Shared Mental Models of expertise would influence the backup behavior of air traffic controllers in so far as that they increase the frequency of accepting and requesting backup when needed. The results support the proposition that shared cognitive structures of expertise are positively related to coordinative behavior (ibid., p.188), implying that – as proposed in the multi-level TMS models – they can indeed influence and be influenced by transactive processes and coordination. Moreover, since the relationship between the experience of working together and the backup behavior was mediated or – referring to the discussion in this work – moderated by the shared cognitive structures, it can be further implied that it is in effect the development of shared cognitive structures – and not only experience of working together – that influences coordinative behavior.

In an attempt to study individual-level and team-level awareness of expertise distribution on expertise retrieval behavior, Yuan et al. (2010a) used a multi-level shared cognitive structure approach to study behavior in a global sales team. Their results suggest that both individual-level and team-level awareness influence expertise individually, implicating that a multi-level approach to cognitive structures can actually explain more variance in behavior than studying teams at a single level of analysis. Furthermore, the results show that not only does the awareness of expertise distribution relate to expertise retrieval behavior, but that individuals with an accurate and shared awareness of this distribution retrieve expertise more successfully than without this awareness (ibid., p.707).

Next to this implication, and relating to the discussion of accessibility and interdependence in section 2.4, the findings also reveal that the relationship between shared cognitive structures and expertise retrieval is moderated by the reported social and technological accessibility of the perceived expert, indicating that the costs of sharing and accessing expertise are indeed relevant for individuals seeking expertise (ibid., p.708). This proposition of the relationship between individual-level expertise directories and information exchange between team members has already been tested in a previous project teams setting by Yuan et al. (2007). The proposed direct relationship could be found and further suggests that not only do shared cognitive structures influence exchange behavior in teams, but that this relationship also exists with individual-level expertise directories. This result corresponds with the results of Baumann & Bonner (2013) and Mell et al. (2014b) in group TMS research, which implies that there does not have to be a completely shared cognitive expertise directory for individuals to share expertise and coordinate efficiently. According to this, individual expertise directories should be studied in TMS research.

The use of digital knowledge repositories regarding the accuracy of cognitive structures has been studied by Su (2012). In this context, the author found that centrality within the team can indeed positively influence awareness and accuracy of expertise recognition. While this may be interpreted as standing in contrast to the results by Treem & Leonardi (2015), it needs to be stressed that Su (2012) explicitly focused on a communication rather than an experience or friendship network. Accordingly, the results showed that a centrality in the actual flow of communication has a positive effect on the other's awareness of one's expertise within a TMS. Furthermore, Su (2012) found the same relationship between the use of digital knowledge repositories and expertise recognition as Treem and Leonardi (2015), further strengthening the implication that other team members need to explicitly be aware of communication and coordination for a shared cognitive structure to develop. The use of digital knowledge repositories moderated the negative relationship between work remoteness and accuracy in expertise recognition insofar as that it lowered the negative influence of remoteness (Su 2012, p. 14). Su's study therefore indicates that in remote conditions, digital knowledge repositories and forms of communication should be used to lessen the negative effects of remoteness on the development of shared cognitive structure and, moreover, that centrality within communication networks should be integrated into the study of developing individual and shared cognitive structures.

The topic of centrality within a TMS has also been the focus of a study by Mell et al. (2014a) in a business consulting context. While Su (2012) referred to centrality within the communication network, Mell et al. (2014a) focused on the centrality within the distribution of expertise awareness in the team. In their study, the authors proposed and found that team members with a more accurate awareness of the expertise in another team would seek expertise more frequently within the other team than team members without this awareness (ibid., p. 11). This relationship was further strengthened by the degree to which other team members in the first group sought expertise in the second group, indicating that this could potentially build trust for further expertise exchange.

In sum, the results above indicate that, in field settings, the proposition of a uniformly shared cognitive structure of expertise awareness might not be necessary for teams to efficiently share and coordinate their expertise. In addition, the role of team leadership within TMS theory may have to be conceptually differentiated, given that the results confirm the findings in group TMS research on team leadership and its influence on the necessity of shared cognitive structures and coordination efficiency. The findings furthermore indicate that the configuration of expertise within the team might not be directly related to expertise exchange and coordination without the awareness of this configuration within the team. Although these results might not be surprising on their own, their difference to Wegner's originally proposed multi-level TMS model regarding the importance of configural cognitive structures and the sharedness of expertise directories is relevant to this work and will be discussed in section 4.3.

Communication and coordination

Prior to analyzing TMS research on communication and coordination, it is necessary to stress the conservative recoding of Lewis' (2003) composite TMS scale into a measure for functional communication and coordination within settings that did not explicitly integrate cognitive structures (see section 4.1.3). Therefore, although some of the findings in this part may not be particularly surprising (e.g., the correlation between this scale and other indicators for interaction), they are relevant to illustrate because the focus of the corresponding studies is set on the study of TMSs.

Relating to the discussion in section 3.4.1, Faraj & Sproull (2000) as well as Choi et al. (2010) differentiated communicative acts into expertise sharing – compatible with the transactive processes – and expertise application which is defined as the actual process that mediates between inputs and outputs in the IMOI framework. Faraj & Sproull (2000) studied this coordination within software development teams and found that – in combination with a shared awareness of expertise within the team – bringing expertise to bear (implicating expertise application) was positively correlated to team performance in this setting. Moreover, this form of coordination explicitly differed in the results from administrative coordination (implying sharing and communicating), thus implicating that expertise sharing and application should indeed be divided in the study of expertise management (ibid., p. 1563). These findings are supported by the study of Choi et al. (2010), who explicitly distinguished between expertise sharing and expertise application in their study of TMSs in two South Korean firms. In this study, the IT support for knowledge management was positively correlated with the development of functional communication and coordination (measured with Lewis' (2003) composite TMS score), which in turn was correlated with both expertise sharing and application. However, only expertise application was directly correlated with team performance, whereas the influence of expertise sharing on team performance was mediated by expertise application (Choi et al. 2010, p.865). Furthermore, this suggests that IT support can actually be used to foster a system of functional communication and coordination within a team. In combination, both studies support the differentiation within the IMOI TMS model between moderation and mediation of transactive processes (expertise sharing) and explicit task-relevant coordination (expertise application).

A third study by Chen et al. (2013) also supports this suggestion. Here, expertise sharing was studied in open source software project teams. The authors did not find the predicted relationship between knowledge sharing and technical achievement but rather a direct relationship between communication quality (defined as the extent of task relevant communication between developers) and technical achievement (ibid., p. 559). This further suggests that expertise sharing and task-relevant coordination of expertise should be regarded as two distinct processes in the construct of teamwork.

Next to the differentiation between modes of communication and coordination, the development of a system for functional communication and coordination has also been studied in field settings. For example, Lewis (2004) found that initially distributed expertise in conjunction with team member familiarity predicted the development of such a system (measured with Lewis' (2003) composite TMS score) in consulting teams. This finding indicates that configural cognitive structures only foster functional communication when team members are familiar with each other. Thus, the result is similar to the relationship that was found between shared and configural expertise structures in other studies. Furthermore, the frequency of face-to-face communication was positively correlated with the development of functional communication and coordination, which in turn was correlated to client and team ratings of performance.

Next to these results for familiarity, expertise distribution, and communication, Peltokorpi & Hasu (2011) found that task orientation fostered the development of functional communication and coordination (measured with Lewis' (2003) composite TMS score) in organizational research settings. In addition, the mediation of functional communication and coordination of the relationship between task orientation and team innovation was moderated by transformational leadership insofar as that transformational leadership in combination with functional communication and coordination positively influenced team innovation (Peltokorpi, Hasu 2011, p.5). Next to these antecedents, Liao et al. (2015) analyzed the relationship between perceived communication quality and the development of functional communication and coordination (measured with Lewis' (2003) composite TMS score) in healthcare teams. Their findings indicate that perceived communication quality influences the development of functional communication and coordination through team identification and professional identification (Liao et al. 2015, p. 971). This suggests that – as has been discussed in section 2.4 – an identification with the team and team goals may be crucial for the development of a coordinative system in an organizational context.

The other field studies that applied TMS theory regarding the influence of communication and coordination provide further support for the proposition that coordinating and communicating expertise within teams mediates between input and output variables. For example, Michinov et al. (2008) found that functional communication and coordination (measured with Lewis' (2003) composite TMS score) predicted the perception of team effectiveness and affective outcomes in healthcare settings and that coordination was a better predictor for team effectiveness than team membership length or the size of the team (Michinov et al. 2008, p.330). In a similar context (daycare), Peltokorpi & Manka (2008) analyzed the relationship between personal communication, functional communication and coordination (measured with Lewis' (2003) composite TMS score), and team performance. Their results showed that coordination fully mediated between interpersonal communication and team performance, whereas supportive supervision had no influence on this relationship (Peltokorpi, Manka 2008, p. 110). Marques-Quinteiro et al. (2013) found that functional communication and coordination (measured with Lewis' (2003) composite TMS score) were positively related to both team adaptive behavior and team performance in tactical police team settings. Furthermore, implicit and explicit coordination interacted and, in combination with each other, led to higher team adaptive behavior than team implicit coordination on its own.

Next to these results in healthcare and tactical settings, Tang et al. (2014) applied Lewis' (2003) composite TMS score to a new product development setting with similar results. Functional communication and coordination were positively correlated with new product development performance (in both subjective rating and market performance). The findings suggest that in explorative projects, informal communication was a better predictor than formal communication for the development of functional communication and coordination (Tang et al. 2014, p. 12). In explorative tasks, however, formal communication predicted this development. The authors thus suggest different modes of communication relating to the task context for the development of a coordinative system within a team.

The influence of psychological safety and conflict on TMSs

In contrast to the focus on cognitive structures and coordinative behavioral processes, affective factors have only played a small role in organizational TMS research so far. In fact, only six studies focus on the influence of trust and conflict and their influence on the development or functioning of a TMS (Peltokorpi 2004; Akgün et al. 2005; Rau 2005; Nevo et al. 2012; Bachrach et al. 2014; Hood et al. 2015).

Peltokorpi (2004) was among the first researchers to integrate the concept of psychological safety into the construct of TMSs. Psychological safety has been mainly used in the concept of team learning to incorporate the influence of perceptions of the interpersonal context into the willingness to show potentially risky learning behavior in a team (Edmondson 1999, p. 352). Accordingly, it is defined as the individual's perception of the consequences of taking interpersonal risks in a particular context (Edmondson, Lei 2014, p. 1). As briefly discussed in section 2.4, such interpersonal risks can be defined as giving each other access to one's expertise in an organizational context. As such, psychological safety has been proposed by Peltokorpi (2004, p. 451) as one of the antecedents of interpersonal communication and expertise sharing. In the analysis of the development of expertise directories within sales teams, the author did not find the direct proposed relationship between psychological safety and the development of expertise directories, but found an indirect positive relationship between value congruence, psychological safety, and directory development that is mediated by interpersonal communication (Peltokorpi 2004, p. 459).

This result is in line with the proposition in the multi-level TMS model that communicative and coordinative processes directly influence shared team-level cognitive structures and that these processes mediate between inputs – e.g., in the form of psychological safety – and cognitive structures. The findings of the study of TMSs in software implementation teams by Hood et al. (2015) further support this proposition. Next to the effect of psychological safety on functional communication and coordination (measured with Lewis' (2003) composite TMS score), the authors were interested in the influence of team affectivity as a potential antecedent to psychological safety in this context. Hood et al. (2015) found that psychological safety was indeed positively related to functional communication and coordination – and thus supporting Peltokorpi's (2004) proposition – but that affectivity was directly related to psychological safety (Hood et al. 2015, p. 12). Negative affectivity, or the tendency toward negative perceptions of the team and avoidance of interpersonal communication, was negatively related to psychological safety, while positive affectivity, or the tendency toward positive perceptions and team goals, was positively related to psychological safety. These findings indicate that not only do affective team-states such as perceived psychological safety or a safety climate affect the development of a TMS through their influence on expertise sharing behavior, but also that these perceived team-states are influenced by individual-level affective states such as positive or negative affectivity.

Related to the concept of psychological safety and positive affectivity, Nevo et al. (2012) integrated a measure for willingness to help into the study of TMSs. The respective results showed that, next to the awareness of other's expertise, willingness to help was the most important indicator for allocation and retrieval in a team (ibid., p. 85). This further supports the proposition that individual-level affective states should be integrated into TMS research.

Similar to the concept of psychological safety, Akgün et al. (2005) integrated the concepts of cognitive- and affect-based trust into the study of TMSs. In this context, cognitive-based trust is defined as the trust in the reliability and dependability of team members, whereas affect-based trust is defined as based on reciprocal interpersonal care and concern (McAllister 1995, p. 25). In a project-development setting, Akgün et al. (2005, p. 1112) found that both forms of interpersonal trust were positively related to functional communication and coordination (measured with Lewis' (2003) composite TMS score) and other measures of team learning.

Next to the role of psychological safety and trust, direct interpersonal conflict may potentially influence the development and functioning of a working TMS. In a top management team study in the banking sector, Rau (2005) tested the assumption that the positive influence of expertise awareness on team performance would be influenced by different levels of relationship conflict. As proposed, interpersonal conflict negatively moderated the relationship between expertise awareness and team performance, indicating that interpersonal conflict can indeed negatively influence a functioning TMS (ibid., p.762). The results of the study by Bachrach et al. (2014) also support this proposition. Here, relationship conflict negatively influenced the relationship between functional communication and coordination (measured with Lewis' (2003) composite TMS score) and team performance in a project task setting.

In summary, although there are only few studies in which the concepts of psychological safety, individual affectivity, and conflict have been implemented, their results provide support for the proposition that TMSs as a function of a social system are exposed to the same negative influences of interpersonal dysfunctions as teamwork in general. Furthermore, it has been shown that it is important to differentiate between individual-level affective states and perceived team-states such as psychological safety in TMS research.

Perceived interdependence and other factors

Perceived interdependence and contextual influences – while proposed to have influences on the development of a working TMS – have not been extensively studied in organizational TMS research. Only six studies could be determined that focused on these topics (Akgün et al. 2006; Child, Shumate 2007; Zhang et al. 2007; Jarvenpaa, Majchrzak 2008; Yuan et al. 2010b; Lee et al. 2014).

In their study of expertise directory development, shared task interdependence, and strength of communication network ties as predictors for expertise exchange in project teams, Yuan et al. (2010b) proposed that both individual-level and team-level shared task interdependence would be related to expertise exchange within the teams. Next to the finding that both individual-level and team-level expertise directory development were positively related to expertise exchange and thus replicating the results by Yuan et al. (2010a), this study showed that individual-level and team-level task interdependence were positively and distinctly related to expertise exchange (Yuan et al. 2010b, p. 34).

This finding supports the proposition that individuals have to be aware of their task interdependence to engage in the potentially risky behavior of expertise exchange (see psychological safety and section 2.4) and that there exists a difference in explanatory value between individual-level and team-level task interdependence – such as that team-level task interdependence can be regarded as part of the shared team-level cognitive structures that are proposed to develop within the original multi-level TMS construct. The results by Yuan et al. (2010b) are further supported by the study of Zhang et al. (2007). Here, the authors proposed that task interdependence (in the form of reciprocal interdependence in the task) and cooperative goal interdependence (the linkage between individual-level goals) are both antecedents to the development of functional communication and coordination (measured with Lewis' (2003) composite TMS score). Both forms of perceived interdependence were positively correlated with the TMS score (Zhang et al. 2007, p. 1726), indicating that they can indeed be seen as important factors in the development and functioning of a coordinative system in a team. Further support for this result can be found in the study by Child & Schumate (2007), where perceived task interdependence was positively related to the use of organizational repositories, suggesting that perceived interdependence can in effect foster expertise exchange within a team (ibid., p.41).

With regard to contextual factors, Akgün et al. (2006) studied the influence of market turbulence on the relationship between shared cognitive structures and speed-to-market in a new product development setting. As proposed, the authors found that market turbulence did moderate this relationship insofar as that when market turbulence is high, this relationship is negatively influenced (ibid., p. 105). Furthermore, Jarvenpaa & Majchrzak (2008) found that the development of a coordinative system (measured with Lewis' (2003) composite TMS score) within banking teams is negatively related to the network size of the team, indicating, as proposed, that costs of coordination may be related to team size and communication efficiency.

With regard to the network's size, Lee et al. (2014) analyzed the effects of network closure on the development of functional communication and coordination within project teams. Network closure is defined as the extent to which a network is represented by strong (and thus frequent) and reciprocal ties as opposed to a loose network in which structural holes, or a lack of these strong ties, exist (Burt 1992, p. 18). Lee et al. (2014, p. 962) found that, while the overall density of the network negatively influenced the relationship between functional communication and coordination (measured with Lewis' (2003) composite TMS score) and group performance, the development of transitive triads – or subgroups within the network that are constituted by efficient triadic expertise exchange – compensated this negative influence. The authors accordingly conclude that overall network size and closure should be differentially studied in the context of TMSs, given that subgroups of efficient exchange and coordination can be components of these dense networks.

In summary, the empirical study of perceived interdependence and especially the implementation of contextual factors is in its infancy in TMS research. The research on perceived interdependence, however, is promising since the propositions in the original multi-level TMS model in organizational settings are supported and even differentiated into individual-level and team-level effects.

Case studies – Understanding the underlying processes of expertise sharing

Next to quantitative methods of empirical research, qualitative approaches can give further insight into the specific social phenomenon of interest. Case study approaches are often used to study the underlying processes of the respective social phenomenon in a specific case in an organizational setting (Eisenhardt 1989, p. 534). In situations where a specific field of research such as TMS research may show a lack of conceptual clarity or agreed upon methods of measuring the phenomenon of interest, the case study approach can be used to retain the characteristics of the social phenomenon without omitting variables and interrelations that may be important to fully capture the phenomenon (Yin 2009, p. 4). Four case studies in TMS research have been identified and will be analyzed for the purpose of potentially revealing processes and issues that have not been studied in quantitative TMS research.

The case studies by Oshri et al. (2009) and Jarvenpaa & Keating (2011) are two examples of how approaching organizational phenomena through a TMS lens may contribute to our understanding of issues and solutions to information and knowledge exchange in globally distributed organizations. Jarvenpaa & Keating (2011) studied the role of cultural values, practices, and institutions in TMSs in an offshored engineering project that is defined by high coordination needs. The project setting was defined by teams in an U.S. and a Romanian subsidiary that had no prior expertise of working together and possessed no information about their cultural differences (ibid., p.786). In their analysis of the interview data, the authors identified a lack of a shared team-level cognitive structure containing an awareness of the expertise distribution between both subsidiaries. The reason for this deficient shared awareness was identified as originating from issues in the communication between the subsidiaries that led to problems in specialization and directory updating. Individuals reported problems in communication conditioned by differences in educational systems in the two countries that increased the time and costs of coordinating both teams due to a lack of commonly encoded task-relevant information (Jarvenpaa, Keating 2011, p. 790). Furthermore, gatekeepers locked individuals in different countries out of the expertise exchange loop. Since the frequency of communication between the teams was low, individuals mostly used cross-cultural stereotypes that were based on the difference in academic education between the U.S. and Romania regarding the training of engineers for default entries of expertise in case of a member of another subsidiary (ibid., p. 790). On this account, the lack of explicit organizational routines for expertise exchange and encoding or the development of a shared team-level cognitive structure was identified as the main source of issues within the subsidiaries' teamwork.

In a similar setting, Oshri et al. (2009) studied expertise transfer between two globally distributed software platform development teams. In contrast to Jarvenpaa & Keating's (2011) setting where teams did not possess organizational routines for the encoding, storage, and retrieval of information, such a system was available and compulsive in these software development teams. Oshri et al. (2009, p. 338) identified two organizationally accepted routines that were responsible for the efficiency and coordination of the teams working together. First, the teams used a digital repository with a shared template for encoding task-relevant information that was produced or encountered in each subsidiary. Furthermore, the teams resorted to the development of a shared task-language and the development of personal directories that linked expertise seekers and expertise holders. The retrieval of expertise and information in this case was supported by the codification of information regarding the owner of this expertise and its possible application that was frequently (and compulsory) updated by each team member (ibid., p. 341).

What the above cases support is the proposition in the original multi-level TMS model that a shared team-level cognitive structure of expertise distribution (e.g., a codified expertise directory) supports efficient teamwork in environments characterized by high coordination costs due to global distribution. In addition, the results facilitate the notion that explicit processes of information encoding, storage, and retrieval influence these shared cognitive structures and are further influenced by them. Next to these propositions, the findings of these case studies also provide support for the notion that a configural team-level cognitive structure is not sufficient to foster the sharing and application of unique expertise in teams, but that – as suggested in the original multi-level TMS model and also found in group and organizational TMS research – the communication and consequential development of shared cognitive structures are important for unique expertise to be used.

This proposition is further emphasized by the case study of Leonardi & Treem (2012). The authors studied the influence of implementing a technological system for expertise awareness on the actual awareness and expertise exchange in a recently reorganized IT department of a research center. Leonardi & Treem (2012, p. 46) found that even after five months of working in the new organization, the awareness of expertise between newly assigned teams was deficient. Technicians in different teams did not frequently exchange information and – just as has been found in group TMS settings (Lewis et al. 2007) – relied on existing expertise directories for the coordination of their work after the disruption of the existing organization. In this connection, the implementation of a support ticket system that was visible to all technicians immediately influenced the awareness of expertise between different teams and therefore possibly substituted a shared team-level cognitive structure. Due to the visibility of expertise linked to support tickets, a contextual influence – in the form of the implementation of a technological system that had to be used as an organizational routine – directly changed lower-level social structures and awareness as also proposed in section 3.2.3.

Next to problems of expertise exchange, Whelan & Teigland (2013) focused on the notion that expertise directories do not necessarily have to be shared by all team members for the team to be effective. Similar to the group study of Cruz et al. (2007), the authors questioned the idea that a uniformly shared expertise directory would be most beneficial. In a research and development setting in two high-technological multinational corporations – characterized by high information volume and overload – Whelan & Teigland (2013, p.186) found that other network structures of expertise awareness might emerge. The pattern of communication showed that information reaching the team via outside connections was filtered by so called technological scouts who possessed specialized expertise in a narrow field that was signaled by their education and self-reported interests. However, the encoding, retrieval, and allocation of this information was managed by so called central connectors, who linked technological scouts and recipients on a case-to-case basis. This finding is similar to the results in the study of Cruz et al. (2007) and shows that trust in the central connectors or boundary spanners can act as a substitute for uniformly shared expertise directories and entailing coordination costs.

In summary, the case studies in organizational TMS research support different results with regard to the influence of shared and configural cognitive structures within a TMS in the quantitative studies. Moreover, they emphasize the role of communication and shared expertise awareness in team settings, although the proposition of uniformly shared team-level cognitive structures has been challenged. In order to propose an adapted model of team TMSs in section 5, the results of organizational TMS research need to be summarized and interpreted with regard to the propositions in the original multi-level TMS model. For this purpose, they are interpreted in combination with the results of dyadic and group TMS research in the next section. Though this summary might introduce some redundancy (due to interpretations within the analysis of individual research settings), this combined summary and interpretation of dyadic, group, and organizational TMS research consolidates our understanding of TMSs in current empirical research.

4.3 Summary and discussion of empirical TMS research

How do the results of dyadic, group, and organizational TMS research relate to the propositions made in the original TMS model proposed by Wegner et al. (1985)? This is the focus of the present section, where Wegner's (1985; 1987; 1995) proposed components, interrelations, and performance propositions of a functioning TMS are evaluated with regard to the empirical results that have been presented in the previous section. A first general result is the implication that the differentiation into a multi-level TMS framework – and accordingly the differentiation into different components and levels of analysis – has contributed to the understanding of the diverse field of TMS research beyond the notion that, as others have stated, TMSs "contribute positively to team performance" (Ren, Argote 2011, p. 223). As will be discussed in this section, such a general notion of an unspecified construct has to be challenged and differentiated in order to evaluate the underlying processes within a TMS and expertise-dependent teamwork. For consistency reasons, this section is structured similar to the former findings section. Accordingly, the results regarding a) cognitive structures, b) interactive processes, c) the development of a TMS, d) perceived interdependence and affective factors, and e) contextual and organizational influences will each be discussed separately in the following.

Cognitive structures

As explained in section 3.2, the cognitive structures in TMS research have been originally defined in terms of "an organized store of knowledge that is contained entirely in the individual memory systems of the group members" (Wegner et al. 1985, p. 256). In terms of this work's understanding, these structures that are proposed to be "stored" within individual minds have been transferred into a multi-level model that contains individual-level and team-level cognitive structures. The proposed cognitive structures have been divided into two parts. The first part is a configural component that is defined as the pattern of actual expertise that is stored in a team and emerges from compilational forms of emergence. The differentiation or specialization of expertise is proposed to enhance the amount and efficiency of expertise that can actually be stored within a team (Wegner et al. 1985, p. 265). This proposition has then been further used to define behavioral indicators for memory differentiation, task credibility, and task coordination (Liang et al. 1995; Moreland et al. 1996; Moreland et al. 1998), thereby promoting the importance of the configural cognitive structure for efficient teamwork.

Besides the configural part, these cognitive structures are proposed to contain a shared part that is defined as the shared team-level cognitive structure or Shared Mental Model of expertise distribution (Cannon-Bowers et al. 1993; Mohammed et al. 2010) that emerges from compositional forms of emergence. This shared team-level cognitive structure has originally been proposed to enhance the coordination and exchange of expertise within the team (Wegner et al. 1985, p. 257). In later works, this proposition of a shared cognitive structure has been sustained by the notion of expertise directories (Wegner 1995, p. 324), shared higher-order information (Lewis et al. 2005, p. 582), knowledge about who knows what (Ren, Argote 2011, p. 193), or directly as Shared Mental Model of task, expertise, and persons in the team (Brandon, Hollingshead 2004, p. 634). What all these notions have in common is the proposition that the shared cognitive structures should be uniformly shared between team members and be contained only in the minds of the team members. This suggestion is further promoted by the measurement of accuracy and agreement in measures of expertise directory sharedness or measurement scale validation (e.g., Austin 2003; Palazzolo 2005; Lewis 2003).

In fact, most researchers in the field of TMS research do not challenge these assumptions and implement them into their study of TMSs (see Peltokorpi 2008; Lewis, Herndon 2011; Ren, Argote 2011). The question of interest here is thus formulated as follows: are these propositions regarding the configural and shared team-level cognitive structures actually supported by empirical TMS research?

After analyzing empirical TMS research in terms of a multi-level TMS model, one of the most interesting (and to the author unexpected) results is that configural cognitive structures on their own do not seem to be as influential as one would think by using a theoretical lens that is focused on differentiation and specialization of expertise. Besides the result that – both in dyadic research and group research using recall and assembly tasks – the notion of an increased amount of expertise that can be stored *and* applied in a differentiated expertise structure could be validated, empirical TMS research is not directly supporting the proposed influence of these differentiated structures. In the studies that actually measured cognitive structures in field settings, either no direct influence of configural team-level cognitive structures was found (e.g., Palazzolo 2005; Treem, Leonardi 2015) or the structures were only related to perceptions of performance and not to objective measurements of team performance

(Austin 2003). Relationships with coordination and team performance could merely be found in combination with an awareness of the pattern of actual expertise. These results are further verified by group TMS research that tested the importance of shared cognitive structures on the exchange and discussion of actual expertise (e.g., van Ginkel, van Knippenberg 2009; Baumann, Bonner 2013). The only studies that found an influence of the actual structure of expertise distribution within group settings showed that both differentiation (Cruz et al. 2007) and integration (Gupta, Hollingshead 2010; Gockel, Brauner 2013) can positively influence performance in decision-making or intellective tasks. As others have stated, the underlying task structure has to be controlled for in order to get meaningful results from the study of cognitive structures in organizational settings (Lewis, Herndon 2011, p. 1258).

Based on these findings, I argue that TMS research on actual configural cognitive team-level structures and the latter's influence on performance is thus in its infancy (due to the low number of studies actually measuring them). In addition, and more importantly, the existing studies do not support the proposition that these structures are an active part of the TMS, but rather imply that they are acted on and are influenced by interaction and shared cognitive structures. From this follows, that such "group knowledge stock" (Austin 2003, p. 867) can potentially be regarded as a resource that can be applied and changed within a working TMS. However, the proposition of differentiated configural cognitive structures as the constitutive component of a TMS (as proposed in the original model) is challenged by empirical results. On this account, they could rather be regarded as a component or input factor, whose influence is mediated by active interaction and shared cognitive structures. This does not imply that actual expertise is not crucial for successful teamwork, but that, for coordinative reasons, shared cognitive structures should instead be regarded as a more important component of the coordinative TMS that Wegner envisioned.

Evaluating the analysis of empirical research with regard to the second part of the cognitive structures in a TMS, the importance of expertise awareness – differentiated into individual-level awareness and team-level awareness – has been repeatedly shown in dyadic, group, and organizational research. Furthermore, it has been shown that the influence of expertise awareness is directly mediated by expertise exchange and application, thus providing support for the proposition that expertise awareness moderates the relationship between expertise application and team performance. Expertise awareness links actual expertise to interactive behavior and should thus be regarded as a crucial part in cognitive teamwork. The influence of expertise awareness has proven to be helpful in explaining differences in behavior and performance, even in those findings that have been controlled for the experience of working together and group cohesion (e.g., Austin 2003).

However, the analysis of TMS research has shown that it might not be necessary (or even beneficial) for shared team-level cognitive structures of expertise distribution to be uniformly shared between team members. One main evidence for this changed proposition was found in the studies by Johansson et al. (2000; 2005). In these studies, control dyads that did not actually interact with each other performed similar to dyads that had a shared awareness and division of expertise, indicating that shared cognitive structures might not always be the best option for coordination. The results further showed that the shared cognitive structures were the second best option, because dyads using these structures only outperformed the results of dyads interacting with each other without this awareness but not the results of individuals that did not interact.

Next to dyadic settings, group TMS research provides further evidence: for example, Baumann & Bonner (2013) showed that a convergence of individual Mental Models – such as proposed by Brandon & Hollingshead (2004) – is not necessary for groups in order to share unique and differentiated expertise. Furthermore, the study by Cruz et al. (2007) revealed that other mechanisms besides Shared Mental Models of expertise distribution can provide support for an efficient expertise coordination system. Hence, groups which relied on the individual-level expertise awareness of a group leader outperformed groups with a shared awareness of expertise distribution, further providing evidence that complete sharedness might be inefficient due to synchronization costs of individual-level Mental Models.

In this regard, Mell et al. (2014b) provided evidence that a centralization of expertise awareness in some cases might be more efficient than an incomplete sharedness of expertise awareness. In organizational settings, these results are supported by the case study of Whelan & Teigland (2013). As the authors showed, individual members of the team acted as so called *connectors*, linking expertise seekers to boundary spanners that retrieved new information from the outside world. In this globally distributed situation, there was no need for complete sharedness of expertise directories. If anything, this case study thus provides evidence that expertise directories can be specialized – implying that for an efficient coordination within a team it might be possible for certain assigned individuals to develop expertise directories for certain subtasks and connections to other subgroups that might be used by other team members. In this case, only the assigned specialists would have an accurate *map* of the team's expertise and thus are proposed to provide the team with a team-level awareness of expertise distribution. This finding indicates that only the team as a whole (in terms of a social system) has to know how expertise is configured, which might not be necessary for every individual team member. This proposition is further supported by the multi-level approach of Yuan et al. (2010b), who specifically distinguished between individual-level and team-level expertise directories and found distinct relationships between both levels and team performance, where, in combination, more variance in the team's performance could be explained.

Next to the structure and sharedness of the expertise directories, the results regarding the content of these cognitive structures have to be discussed. As explained in section 3, initially, only higher-order and location information were supposed to be stored within TM (Wegner et al. 1985). This assumption has been further differentiated into the notion that information about the task, expertise, and person should be stored within these shared cognitive structures (Wegner 1987; Brandon, Hollingshead 2004). This content is also called metaknowledge that provides information about "who knows what" in the team (Ren, Argote 2011, p. 192). In this context, the results from organizational TMS research provide further insight into the actual content of individual-level and team-level awareness of expertise distribution. For example, Su & Contractor (2011) provided evidence that individuals consider information about the accessibility and perceived task-relevance of expertise when choosing other team members for the retrieval of information, which is also supported by the results of Rau (2006). The latter's study showed that this information about accessibility does not only contain the time-, or technology-dependent accessibility of an individual, but also the costs of the expertise seeker that arise from retrieving expertise from the sender. These costs might potentially entail dimensions that have also been mentioned in section 2.4 with regard to the differences in power bases or potential costs of reciprocity. This implication is also supported by the study of Yuan et al. (2010b). The authors found that individuals include accessibility and costs into the retrieval decision within a team's expertise network. Furthermore, several other studies showed that individuals consider the centrality of a potential expert in the communication network in their decision to seek expertise from this individual (Su 2012; Mell et al. 2014a), which provides evidence that the network structure of the team might be a part of the individual-level Mental models of expertise distribution.

Another contribution of organizational TMS research is the integration of codifiable expertise directories into the study of TMSs. In this context, the studies of Su (2012) and Su & Contractor (2011) provided support for the proposition that external repositories can be used to develop a team-level awareness of expertise distribution. But, although the retrieval from human repositories was related to accessibility and cost, the use of digital repositories might depend on different factors. Su & Contractor (2011) found that the use of digital repositories depended on the perceived complexity of the sought expertise and the overall use of the repositories within the team. Both implications are supported by the case studies of Oshri et al. (2009) and Leonardi & Treem (2012). The authors showed that not only were digital repositories used to develop a team-level awareness of expertise distribution, but that these technological systems could be used for the development of a shared language for expertise exchange and retrieval within the teams.

Interactive processes

Originally, Wegner et al. (1985) proposed that a TMS would be based on communicative acts for the encoding, storage, and retrieval of expertise called transactive processes within a team. In section 3.2, this proposition has been transferred into the multi-level proposition by arguing that these transactive processes emerge from individual-level cognitive structures as emergent processes and influence the team-level cognitive structures bottom-up, thus linking the individual- and team-level. At the same time, it has been argued that the transactive processes are influenced top-down by the team-level cognitive structures themselves. This proposition has been further differentiated in section 3.4, and by dividing interaction into expertise exchange and expertise application, which are thought to have different influences on team performance and decision-making (Alavi, Leidner 2001, p. 114; Alavi, Tiwana 2002, p. 1030; Choi et al. 2010, p. 855).

In all of the analyzed TMS research settings, interaction and communication have been shown to mediate between inputs or expertise structures and outputs in the form of recall, assembly, decision-making, problem-solving, or task performance of a team (e.g., Michinov et al. 2008; Peltokorpi, Manka 2008; Marques-Quinteiro et al. 2013, for field settings). In this context, the conservative recoding of Lewis' (2003) composite TMS score into a measure for functional communication and coordination provided insight into the mediation and moderation processes within the IMOI model. Furthermore, the advanced differentiation between expertise exchange and expertise application contributed to the explanation of differences and interrelations in the proposed IMOI model of TMSs (e.g., Faraj, Sproull 2000; Kanawattanachai, Yoo 2007; Littlepage et al. 2008; Choi et al. 2010; Chen et al. 2013). It has been shown that interactive processes emerge through individual-level cognitive structures, influence team-level cognitive structures, and are influenced by team-level cognitive structures.

The results in TMS research differ in their contribution to our understanding of a) communicative acts and their influence on coordination and team cognition, b) the integration of communicative patterns or networks and modes of communication regarding their influence on expertise sharing and application, and c) their influence on cognitive structures. For example, Palazzolo (2005) directly studied the interrelations between cognitive structures and communicative network patterns in field settings and found different effects of cognitive structures on the communicative network. This proposition can be further strengthened by the results of Su & Contractor (2011), who pointed to two types of repositories (digital or human) that affect interactive seeking patterns differently. Moreover, Bazarova & Yuan (2013) showed that in group settings, modes of communication influence stereotyping and the perception of expertise.

To summarize, empirical TMS research has demonstrated that communicative patterns and networks in combination with the IT support for expertise sharing (regarding the modes of communication) constitute an important part of the social phenomenon that is called TMSs in organizational settings.

The development of Transactive Memory Systems

In section 3.3, Wegner's (1987) original proposition that a TMS is a consequence of everyday Social Cognition – in the form of meaning-making of other individuals – and social life has been discussed with regard to the path dependence in multi-level emergent systems (as explained in section 2.6.3). In this context, it has been argued that individuals develop default entries for individual Mental Models of expertise distribution based on social categorization, information about the education or work experience of each other, roles within the team, or prior experience of working together in other tasks that lead to the inference of expertise embedded within the team (Wegner et al. 1985, p. 263; Wegner 1987, p. 191; Wegner et al. 1991, p. 924). As also proposed, these default entries are thought to change into shared negotiated entries for expertise distribution through interaction and communication within the team. Regarding the path dependence in the development of a multi-level TMS, it has further been suggested that transactive processes and individual-level and team-level cognitive structures in point A in time influence individual-level and team-level cognitive structures as well as the form of transactive processes in point B in time.

Next to the results for cognitive structures and interaction discussed above, these propositions have been explicitly studied in TMS research and group training settings. In such settings, it has been shown that individuals rely on, for example, stereotypes for gender (Hollingshead, Fraidin 2003; Myaskovsky et al. 2005) or nationality (Bazarova, Yuan 2013), team familiarity (Lewis 2004), and role based expertise (Hollingshead 2000) for the development of default entries of expertise distribution. The results of these studies further indicated that these default entries are changed into negotiated entries based on the frequency and type of communicative acts (e.g., expertise declaring, seeking and retrieving information, encoding of information) as well as via presenting individuals explicit information about the expertise distribution in, for example, training sessions. In field settings, it has also been shown that supporting team members through information technology can positively influence the development of both negotiated cognitive structures and a communication and coordination system within the team (e.g., Choi et al. 2010; Schreiber, Engelmann 2010; Su, Contractor 2011).

Regarding the proposition of path dependence in the development and functioning of a TMS, the proposition that individuals rely on existing structures and that these structures would influence their behavior and cognitive structures in a further task was consistently supported by research in dyadic (Wegner et al. 1991), group (Lewis et al. 2005; Lewis et al. 2007), and organizational settings (Jarvenpaa, Keating 2011; Leonardi, Treem 2012). The most descriptive case of path dependence has been presented by Leonardi & Treem (2012). The authors demonstrated that even after five months of working in a newly structured organization, individuals still relied on existing cognitive structures for the perception of expertise distribution. Only the implementation of an external disruption – in the form of a compulsory system for workflow and visibility of expertise exchange and communication – finally changed the individual-level and team-level awareness of new responsibilities and expertise, which is supported in theory by the proposition that top-down contextual influences are able to change existing routines and lower-level constructs rather fast (section 3.2.3).

In sum, the propositions for the development of a TMS regarding default and negotiated entries and existing path dependence are supported by empirical TMS research, although these propositions should be further studied in organizational settings.

Perceived interdependence and affective factors

In the original definition of TMSs in dyadic contexts, Wegner et al. (1985) assumed that intimate dyads were interdependent in sharing one goal and aware of this kind of interdependence (see section 3.1). In contrast to this context and following McGrath et al. (2000, p. 98), teams as social systems have been defined as embedding different types of goals (see section 2.2). The first type of goals is supposed to consist of team-level goals relating to the specific team-task or sub-tasks that have to be executed. The second type of goals, however, is defined as individual-level member goals (e.g., career advancement, social goals), that do not necessarily have to be aligned with the team-level goals. In an effort to understand why team members would share their expertise with each other to reach the team-level goal, section 2.4 provided propositions regarding the perceived interdependence between team members and the perceived safety of sharing one's expertise. Based on this, it was concluded (see section 3.4.2) that the multi-level construct of TMSs has to be adapted to accommodate this different organizational context that is applied in this work.

The question of main interest in section 4.2 has thus been stated as follows: how does empirical TMS research reflect such integration of perceived interdependence and safety within the individual studies? A first evidence of this approach was found in dyadic settings. Hollingshead (2001) showed that different incentives can indeed influence the development and sharing of cognitive structures. This result was further supported by TMS research in field settings, where perceived interdependence at individual- and team-levels has been shown to influence expertise exchange behavior (Yuan et al. 2010b). Furthermore, other field studies also revealed a direct relationship between perceived interdependence and expertise exchange and the use of digital repositories (Zhang et al. 2007; Child, Shumate 2007). While TMS research seems to be in an early state regarding the issue of perceived interdependence, these studies already provide evidence that such perceived interdependence can indeed influence the core of the multi-level TMS construct that is defined in the transactive processes of expertise sharing.

With regard to affective factors such as psychological safety and relationship conflict, group and organizational TMS research – although not extensively – provide support for the proposition that these interpersonal factors influence the development and functioning of a TMS. In group settings, the results of Cruz et al. (2007) provided evidence that psychological safety is positively related to expertise exchange and group performance. In organizational settings, Peltokorpi (2004) showed that psychological safety moderates the relationship between communication and expertise awareness regarding the content of communication. In situations characterized by psychological safety, communication was specifically used to share and provide expertise for the development of expertise awareness and task-related coordination within a team. The results by Hood et al. (2015), Nevo et al. (2012), and Akgün et al. (2005) provided further evidence for this proposition.

The role of interpersonal conflict has been largely neglected in TMS research, although some evidence for this proposed negative influence is available. For example, O'Leary & Mortensen (2010) showed that in group settings, social categorization (in terms of default entries) affected team identification and conflict, which were both negatively related to functional communication and coordination. The field studies by Rau (2005) and Bachrach et al. (2014) further supported this proposition.

In summary, both affective factors and interpersonal conflict have an effect on the interrelations between components of a TMS insofar as that psychological safety fosters expertise exchange. Furthermore, interpersonal conflict potentially hinders expertise exchange and the development of individual-level and team-level awareness of expertise distribution.

Contextual and organizational influences

Section 2.6.1 focused on the levels of analysis that have to be integrated into the study of teams in organizational settings for a meaningful representation of actual contexts. Here, it has been proposed that next to the individual- and team-levels, the contextual- or organizational-level have to be integrated, since it is assumed that they can influence the relationships between and the development of constructs at lower levels (e.g., Bell, Kozlowski 2012, p. 45).

The analysis of empirical research showed only few studies in TMS research in which actual contextual influences are considered. Next to external disruptions such as turnover (Moreland et al. 1996; Moreland et al. 1998; Lewis et al. 2007), acute stress and time constraints (Ellis 2006; Pearsall et al. 2009) have been studied in group settings and found to have a negative influence on the development and functioning of a TMS. In field settings, market turbulence was found to negatively influence the relationship between shared cognitive structures and speed-to-market in a product development setting (Akgün et al. 2006).

Next to contextual influences, organizational influences such as the implementation of new technological systems or compulsory organizational routines for expertise sharing have been found to have direct top-down influences in organizational TMS research. For example, Oshri et al. (2009) found that a compulsory organizational routine for the use of a technological system directly affected expertise exchange and individual- and team-level awareness of expertise distribution. In this setting, an existing organizational influence constrained and formed the processes and structures of a TMS top-down. Next to this established organizational influence, Leonardi & Treem (2012) found that an organizational disruption (i.e., implementing a technological system for expertise exchange) had a direct effect on the lower level structures and processes of a TMS, providing further evidence for the proposition of higher-level organizational influences. Although the need for additional empirical backing has to be addressed in future TMS studies, the existing studies provide support for the integration of contextual- and organizational influences into the multi-level TMS model.

To summarize, the discussion in this section has shown that the analyzed findings in TMS research provide evidence for the need to adapt the TMS construct for utilization in organizational contexts. While many of the interrelations that have been proposed in the original multi-level TMS model can be supported by empirical results, some important changes regarding the cognitive structures and transactive processes still have to be made in order to address these findings. This task is the focus of the following section, in which an adapted model of TMSs for organizational contexts is presented. Furthermore, the possible contributions of this adapted model for team research will be discussed in detail.

5 Proposing an adapted multi-level Transactive Memory System model for organizational contexts

Based on the conceptual framework developed in section 2 and 3 and the analysis of empirical findings in section 4, I argue that it is necessary to propose an adapted multi-level team TMS model. The model to be presented in this section integrates the organizational context composed of individual-, team-, and contextual-/organizational-levels for the analysis of the social phenomenon that is defined as the cognitive division of labor in a team. As discussed in section 4.3, the original multi-level model has to be adapted since the originally proposed components and interrelations in a TMS are not directly and completely supported by empirical TMS research. Taking this into consideration, the adapted model reflects the suggested difference between shared and configural cognitive structures and their respective influence on team performance. It also allows for the differentiation between individual-level and team-level awareness of task characteristics and expertise distribution. The adapted model further incorporates affective factors and other input variables that have been found to influence the development of cognitive structures. Furthermore, it considers the contextual and organizational influences that are proposed to constrain and shape the cognitive division of labor in teamwork.

Next to the presentation of an adapted TMS model, it is also necessary to infer detailed propositions that can be tested as hypotheses in empirical research. These propositions are crucial in order to advance our understanding of TMSs beyond the general notion that TMSs positively influence team performance (e.g., Ren, Argote 2011, p. 223). Such propositions are thus formulated here to make predictions in organizational contexts regarding TMSs and the proposed sub-constructs possible – thus going beyond the sole description of the studied social phenomenon of cognitive division of labor (Godfrey-Smith 2003, p. 6). In the next section (5.1), the adapted model of team TMSs for organizational contexts is presented and discussed. Following this presentation, its contributions to Team Cognition and team research are discussed in more detail (section 5.2).

5.1 Components of the adapted model

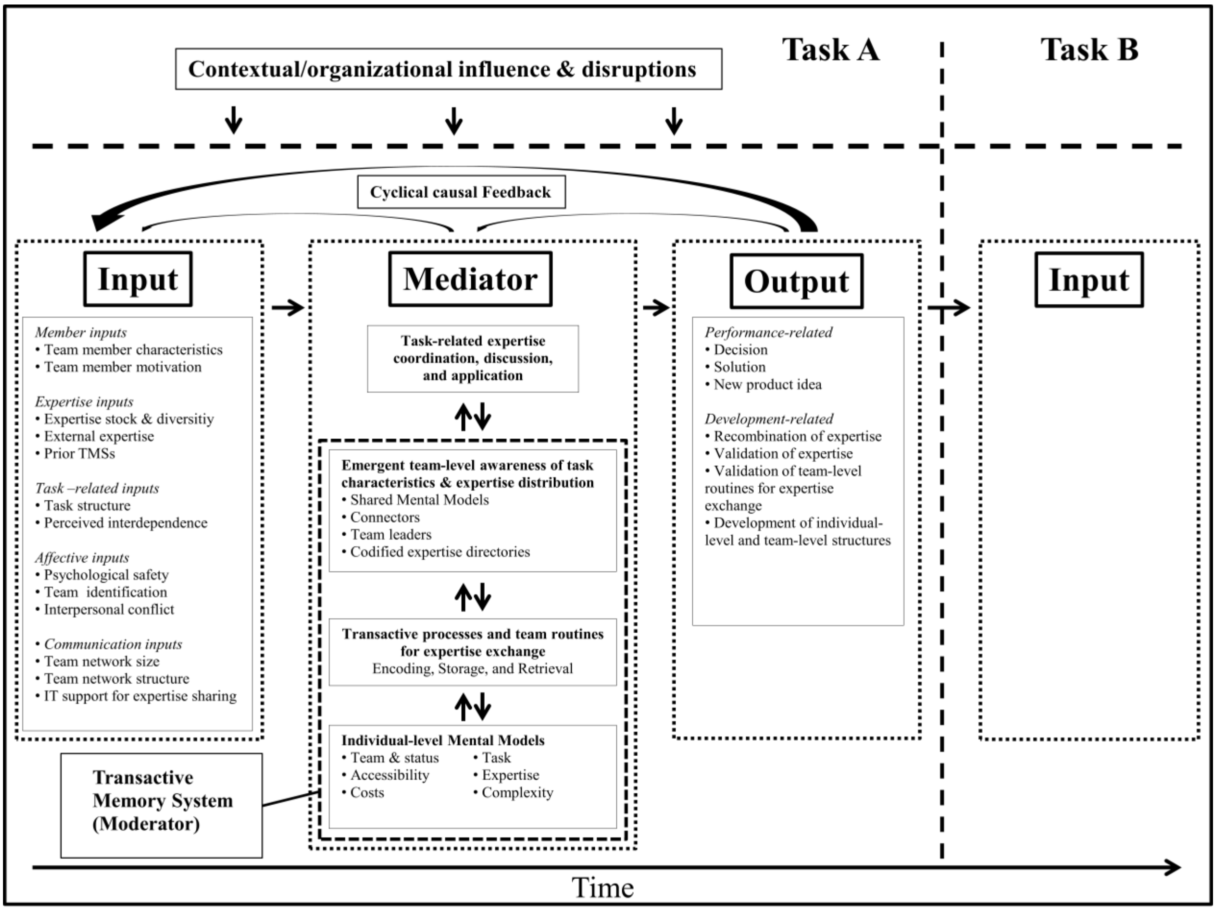
In this section, the adapted multi-level TMS model (see figure 13, next page) will be discussed in detail with regards to a) the adapted core of the TMS construct, b) input variables and their proposed influence, c) output variables, and d) contextual factors and time. Propositions relating to individual variables and interrelations are summarized at the end of each sub-section.

5.1.1 The core of the adapted model – Transactive Memory Systems

Wegner's original concept of TMSs is grounded in the explicit integration and specialization of expertise in combination with the development of a team-level cognitive structure that is used to coordinate this expertise within a team. In this regard, it has been originally proposed that differentiated expertise influences the exchange and discussion of this expertise. Furthermore, it has been proposed that the configuration of the team's expertise would directly influence team performance. As analyzed and discussed in section 4.3, these propositions are not (yet) supported by empirical TMS research. Instead, the analyzed results have shown that explicit expertise is acted upon and brought to bear when it is combined with individual-level and team-level awareness of this expertise distribution. To bring these results into the perspective of Wegner's (1995) computer network metaphor of a working TMS, it is proposed here that rather than the amount of storage, the distributed processing capacity – that is enabled through the directories, connections and communication between different processing units – should be considered as the constitutive component of a TMS. According to the analysis of empirical TMS research, there are a number of possible factors – which will be discussed below – that can enable the connectivity between these processing units in the form of team members.

Corresponding to these considerations, and in line with the multi-level IMOI model presented in section 3.4.1, the core of the adapted TMS concept is proposed to consist of a) the individual-level Mental Models of expertise distribution and task characteristics embedded within the team members, b) the transactive processes of shared encoding, storage, and retrieval of expertise, and c) an emergent team-level awareness of task characteristics and expertise distribution within the team.

Figure 13: Adapted multi-level model of team Transactive Memory Systems



Author's illustration.

Individual-level Mental Models

Similar to the explanation in section 3.2.1 and the original TMS construct, the individual-level Mental Models are supposed to contain details about the team's expertise distribution and task characteristics. But, as the analysis of empirical research has shown, individuals do not only consider the amount and distribution of expertise within the team in their decision to share, seek, and retrieve expertise from other team members. Rather – based on both the analysis of empirical results and the theoretical discussion in section 2.4 – individuals as agents with at least some amount of rationality are proposed to use information regarding the team's role distribution, their own and other member's status, the accessibility of other team members and digital repositories, and the costs (transactional and micro-political) of seeking and retrieving expertise from other team members into their decision of whom to retrieve expertise from (Hollingshead et al. 2002, pp. 342–343). This proposition is further supported by social network research regarding expertise retrieval behavior in teams (Borgatti, Cross 2003). Next to these interpersonal and task-related factors, the Mental Models are supposed to account for the complexity of expertise that is sought, since the empirical results analyzed in this work have shown that this complexity also influences the decision of seeking expertise from human or digital expertise repositories (Su, Contractor 2011). This proposition related to the content of Mental Models is further supported by SMM and TMM theory (Cannon-Bowers et al. 1993; Klimoski, Mohammed 1994). In the adapted model, it is proposed that these individual-level Mental Models directly influence the amount and shape of dyadic expertise exchange that in turn is supposed to be reflected in the transactive processes of encoding, storage (and directory updating), and retrieval of expertise.

Transactive processes

Based on the conceptual discussion in section 3.2.2 and the empirical results analyzed in section 4, the transactive processes of encoding, storage, and retrieval of expertise are proposed to bridge the individual-level and team-level cognitive structures within a team. In this regard, it is proposed that expertise is exchanged, shaped, and updated in discussions, conversations, and the explicit use of codified expertise repositories. In these transactions, the individual-level Mental Models and expertise directories are proposed to be shaped, updated and evaluated for accuracy and agreement (Palazzolo 2011, p. 117). In this context – as well as relating to the discussion regarding the development of a TMS in section 3.3 – transactive processes are furthermore proposed to change the default entries within cognitive structures that may be based on stereotypes or superficial appearances to negotiated entries that more accurately represent the team's expertise distribution. This influence on the individual-level Mental Models is proposed to manifest itself in the changed behavior and coordination capability of individual team members (Argote, Ingram 2000, p. 151).

The transactive processes are thus further proposed to be influenced and shaped by the individual-level Mental Models and to influence the emergent team-level awareness of task characteristics and expertise distribution within the team. This proposition is compatible to the proposition in organizational learning research that interactive organizational learning processes shape and change knowledge within individuals and organizations (Argote, Miron-Spektor 2011, p. 1128). The expertise exchange is however not supposed to directly influence team performance, but rather – as the analysis of the empirical TMS research based on the conceptual discussion in section 3.4 has shown – to influence explicit task-related expertise coordination and application in combination with individual-level Mental Models and emergent team-level awareness (Alavi, Leidner 2001, p. 114; Alavi, Tiwana 2002, p. 1030; Choi et al. 2010, p. 855). Thus, the TMS as a whole is supposed to moderate the relationship between expertise coordination and application, and team performance and outputs.

Team-level awareness of task-characteristics and expertise distribution

Another important modification of the original multi-level TMS model is the change from the shared team-level cognitive structure or Shared Mental Model of expertise distribution to a construct of team-level awareness of task characteristics and expertise distribution. Even though both concepts sound similar, they are distinct in their approach to the concept of sharedness at the team-level of analysis (Cannon-Bowers, Salas 2001, p. 198). While the shared team-level cognitive structures in Wegner's original concept of TMSs are supposed to emerge from compositional processes of emergence that lead to identical individual-level cognitive structures that are shared between all team members (see section 2.6.2), empirical TMS research is not in full support of this proposition. This result is compatible to the discussion about transaction costs regarding the exchange of information and knowledge in section 2.4. Rather than only referring to similar Mental Models, the adapted team-level awareness is supposed to also take the form of overlapping or compatible forms of sharedness (Hecker 2012, pp. 426–427). This implies that not every team member has to possess an accurate map of expertise distribution, but that the team as a whole has to be able to efficiently coordinate its expertise (Huber, Lewis 2010, p. 7).

Therefore, in the adapted model, the team-level awareness is proposed to take different forms that distinguish themselves in their coordination costs and underlying concepts of emergence. The analysis of empirical TMS research has shown that this awareness can be reflected by a) Shared Mental Models as in the original concept, b) a number of connectors or individuals within a team that specialize in developing accurate expertise directories and further the development of social competencies for connecting individuals with different expertise backgrounds, c) team leaders that take the role of connectors within a smaller team, and d) codified expertise directories that are used and updated by the individual team members. These codified directories can consist of artifacts or representations of expertise within the team that need usable and efficient methods for individuals to access these expertise maps (Dooley et al. 2002, p. 219) and can be represented by wikis, address books, and an organizational intranet, to name a few forms (Allan et al. 2009).

On this account, it is proposed that multiple sub-TMSs can exist within a large team based on the structure and type of the team-level awareness of expertise distribution and task characteristics, which may cross formal organizational boundaries (Anand et al. 1998, pp. 798–800). This proposition in turn entails the possibility of individual team members to be members of multiple sub-TMSs. In terms of the measurement of the team-level awareness of task characteristics and expertise distribution, this modification further implies that the sole measurement of aggregated scores for agreement and accuracy of expertise directories might not actually reflect the team-level awareness in a TMS. To give an example, this argument implies that low agreement and accuracy scores of all team members in the measurement of a Shared Mental Model do not necessarily indicate an issue in the team-level awareness of the team on their own. Without assessing the structure and efficiency of expertise exchange and coordination, this interpretation could falsely neglect the integration of expertise directory specialists that might in some cases be more efficient in coordinating the team than a Shared Mental Model. Therefore, it is proposed that team network size and communication structure have to be integrated into the analysis of a working and developing TMS (which will be further discussed in section 5.1.2).

Accordingly, this modification further implies that maintaining a team-level awareness is not without connection and synchronization costs that have to be integrated into the model (MacMillan et al. 2004). Keeping track of the explicit expertise of every individual in a large team consisting of more than 20 individuals – if this is even possible for team members in the case of expertise differentiation in, for example, a software development or research project – might entail a cognitive and communicative load for individual team members that cuts into the resources and time that are needed to actually work on the task. Such an example would therefore stand in contrast to the original proposition in TMS research that TMSs are supposed to reduce the cognitive load for individuals in a team. On this account, it is necessary to assess the structure of the team-level awareness construct before evaluating the influence of a TMS on the team's expertise coordination.

Based on the conceptual discussion in sections 3.2.2 and 3.2.3 and the analysis of empirical results, it is further proposed that the team-level awareness is shaped and formed by individual-level Mental Models and transactive processes bottom-up and at the same time shapes and constrains these lower-level cognitive structures and processes top-down. Where the individual-level Mental models are supposed to shape dyadic expertise exchange, the team-level awareness is proposed to influence the task-related pattern of expertise exchange and builds the foundation for task-related expertise coordination (Argote, Ingram 2000, p. 152). The team-level awareness of task characteristics in combination with the awareness of the team's cognitive interdependence is furthermore proposed to positively influence the team's psychological safety (see section 5.1.2 below). This proposition is in line with research which analyzes the positive effects of a shared task understanding on the team's expectations and trust (e.g., Borgatti, Cross 2003; Ilgen et al. 2005; Mathieu et al. 2008; van Ginkel, van Knippenberg 2008).

Expertise coordination – How expertise is brought to bear in the task

Supported by the discussion in section 3.4 and the empirical results that have been analyzed in this work, the processes of expertise sharing and task-related expertise coordination are separated, whereby expertise coordination is regarded as the mediator that directly links the input variables to the team's performance-related output. This separation is grounded in the discussion and results in this work, arguing that it is the process of expertise coordination and not expertise sharing that directly influences the team's performance. However, expertise sharing and the individual-level and team-level cognitive structures are proposed to influence the efficiency of expertise coordination and thus, in combination, are regarded as a TMS that moderates the relationship between coordination and performance. This influence is not only mediated by communication and exchange, but also by the individual-level Mental Models and the team-level awareness on their own. In this regard, these cognitive structures are proposed to act as tacit coordinators (Wittenbaum et al. 1998) that influence behavior without the need for explicit communication. Next to the empirical TMS results, this proposition is based on team coordination research (Rico et al. 2008, p. 166). Referring to this research, it is proposed that team members do not solely rely on communication for the synchronization of group member actions but further rely on the individual-level Mental Models and team-level awareness of task characteristics and expertise distribution for this purpose (Wittenbaum, Stasser 1996, p. 23), thus reducing transaction costs of coordination. Hence, expertise coordination is proposed to not only rely on explicit communication but also on tacit coordination through cognitive structures.

In summary, the following propositions regarding the core of the adapted model – TMSs – are formulated:

P1a: Task-related expertise coordination, discussion, and application – and not TMSs – mediate between the input factors and the performance-related output factors.

P1b: TMSs consisting of a) individual-level Mental Models, b) team-level awareness of task characteristics & expertise distribution, and c) transactive processes and team routines for expertise exchange moderate the relationship between expertise coordination, discussion, and application and performance- and development-related output-factors.

P2a: Individual-level Mental Models influence the shape of dyadic expertise exchange within the team.

P2b: Expertise exchange mediates the relationship between individual-level Mental Models and the team-level awareness of task characteristics & expertise distribution.

P2c: The content and frequency of expertise exchange influence the shape and content of the team-level awareness of task characteristics & expertise distribution.

P2d: Team-level awareness of task characteristics & expertise distribution positively influences team-level expertise exchange regarding the efficiency of expertise retrieval.

P2e: Team-level awareness of task characteristics & expertise distribution influences the content of individual-level Mental Models top-down via the channeling of expertise exchange.

5.1.2 Input variables

The analysis of empirical TMS research and related research on teams has shown that, next to the team's expertise, other interpersonal, affective, communicative, and task-dependent factors influence the development and functioning of the cognitive division of labor. In this connection, this section reflects such a more differentiated understanding of influences on teamwork. In contrast to static TMS frameworks such as Ren & Argote's (2011, p. 196) integrative framework of TMSs, these variables are not understood as antecedents of a working TMS, but as dynamic and alterable inputs in a cyclic model. The adapted model (see figure 13) reflects the proposition that inputs influence the development and functioning of a TMS, but at the same time are influenced by expertise sharing and coordination and outputs between sub-tasks and further tasks. Therefore, they are not understood as static inputs, but as dynamic factors in the lifecycle of a team – in short, input reflects what the team and the task bring to the table at a specific point of time to work in a TMS. In case of the adapted model, five input categories have been identified in the analysis of empirical TMS research that are proposed to influence the development and functioning of a TMS. These categories are member inputs, expertise inputs, task inputs, affective inputs, and communicative inputs, and will be further explained below.

Member inputs

Team members and their Human Capital stocks are the building blocks of a functioning team and the cognitive division of labor (Hansen, Alewell 2013, p. 2134). From this follows, that their individual-level inputs have to be integrated in order to fully understand the influences of team member characteristics such as motivation, cognitive abilities, and skills on the functioning of a TMS. However, the empirical TMS results and a recent meta-analysis of

Team Cognition research (DeChurch, Mesmer-Magnus 2010, p. 33) have shown that in many cases, these team member characteristics are commonly seen as being influenced by a functioning TMS or Team Cognition, and not as inputs to a functioning TMS. Accordingly, cognition is regarded as influencing motivational, affective, and behavioral variables, which stands in contrast to the emergence framework as presented in section 2.6, where individual-level and team-level cognition have been defined as emerging from the cognition, affect, and behavior of individuals. On this account, these inputs have to be further discussed in order to integrate them into the adapted model.

One of the most basic requirements for team members – as originally proposed by Wegner – is the cognitive ability to engage in the cognitive division of labor. This implies that individuals first have to be able to efficiently develop accurate and complex individual-level Mental Models of the team and the task in order to be able to engage in the combined encoding, storage, and retrieval of expertise, and to develop the skills to efficiently coordinate their expertise and behavior.

However, as Hinds and Pfeffer (2003, p. 10) argue, cognitive abilities cannot completely explain the influence team member characteristics may exert on expertise exchange behavior. This proposition has been extensively studied in team research regarding the influence of extrinsic and intrinsic motivational factors on knowledge exchange within organizations (e.g., Osterloh, Frey 2000; Bartol, Srivastava 2002; Lin 2007; Hung et al. 2011). Therefore, next to these cognitive requirements, motivational and affective states are proposed to influence individual commitment to expertise exchange and task coordination. As Huang (2009, p. 326) argues, individuals bring their motivational and affective history to the task when they have to perform as a TMS. In this context, long-term motivational attributes such as positive and negative affectivity – which have been shown to influence the development and functioning of a TMS according to the analysis – are integrated into the adapted model.

Next to these variables, member characteristics in the form of personality traits are integrated, since they have been consistently shown to influence teamwork and motivation in teams (Mount et al. 1998). In combination with the perceived interdependence and psychological safety of individual team members, these member inputs are further proposed to influence the individual contribution or withholding of expertise to an interpersonal or codified expertise directory, as has been also proposed by Hollingshead et al. (2002, p. 340) relating to TMSs as a form of public good. From this follows that issues of social loafing and free riding have to be considered in the study of TMSs (Fulk et al. 1996, p. 63). The potential influence of HRM systems regarding the structuring of team-level goals and the implementation of incentives (via individual-level and team-level goals) on the motivation of individual team members will be discussed in section 5.1.4.

Expertise inputs

To account for the expertise that is exchanged and coordinated in the mediator dimension of the adapted model, different input types of expertise have to be integrated. The latter's proposed influence on exchange and coordination is consequently discussed below. The first type of expertise is the expertise stock and diversity that is embedded within the minds of the individual team members as originally proposed in the TMS construct.

While expertise in the original TMS construct has been proposed merely in the sense that it takes either integrated (meaning shared) or differentiated (meaning unique) forms, its allocation within the team members and thus the diversity of expertise is proposed to have influences on its own in the adapted model. Diversity, in principle, refers to various dimensions such as nationality, religious background, functional background, or task skills that are studied in team research (van Knippenberg et al. 2004, p. 1008). In the particular context of this work, expertise diversity refers to the differences in knowledge bases and perspectives that are embedded in the team's members and is referred to as the basic component of knowledge-worker teams (Griffith, Neale 2001, p. 390). While this expertise diversity is assumed to have beneficial effects in teams due to the increase in the expertise stock and different perspectives, the discussion in section 2.4 and the analysis of empirical TMS research have shown that knowledge diversity in an organizational setting can lead to a team discussing previously shared information in favor to new or more relevant information, thereby preventing unshared and perhaps more relevant information to be discussed (Stasser et al. 1989; Stasser et al. 1995; Stasser, Stewart 1992). This favoring of shared information can thus negatively influence expertise sharing and the perceived differences in roles and status between individual team members.

In this regard, section 2.4 and the discussion by Wittenbaum & Stasser (1996, p. 7) offer an insight into the issues that different expertise bases might cause in the perception of power and status differences between team members as well as their negative influence on expertise sharing and psychological safety within the team (as will be discussed below). Accordingly, these issues have to be accounted for in the study of TMSs. Next to such power- and safety-related issues, other effects of expertise diversity have to be considered. For example, – similar to the discussion above about transaction costs of synchronizing individual-level Mental Models – the costs of encoding and meaning-making of diverse expertise stocks have to be regarded in order to account for the influence of member expertise on the development and functioning of a TMS.

The second type of expertise is regarded as new information and knowledge reaching the team through external sources – as originally discussed in Wegner's theory. In this context, external expertise is proposed to increase the adaptability of the team to new and unknown task contexts at the same time as it increases the encoding and validation costs of discussing this new expertise. This proposition indicates that teams have to account for such influences on efficiency and coordination costs when deciding to integrate novel or unique expertise sources into their existing expertise base.

The third type of expertise relates to the prior TMSs and accordingly the experience of team members working together in the same task or related and unrelated former tasks (Skilton, Dooley 2010, p. 122). Similar to the original proposition by Wegner, the analysis of empirical TMS research has shown that team members are able to use prior individual-level Mental Models, established routines for expertise sharing, and the team-level awareness of task characteristics and expertise distribution to transfer prior experience to similar or new task settings. Although prior TMSs are thus proposed to positively influence interpersonal factors and current TMSs, their effects on the current task may be negative if individuals in newly established or changed teams (e.g., through turnover) rely on existing cognitive structures, as the analysis of TMS research has also shown.

Task-related inputs

The analysis of empirical TMS research has shown that TMSs are studied in a variety of tasks such as assembly or recall, decision-making, product- or software development, consulting, top-management, and other tasks. On this account, Lewis and Herndon (2011, p. 1258) criticize the lack of consideration of the underlying task structures in the study of TMSs. While the empirical results imply that TMSs can be helpful for a team in many task contexts, they do not help us in the understanding of those contexts where a functioning TMS or the form of team-level awareness matters most. The purpose of this section is thus not to develop an optimal task structure but to reflect on the task characteristics that influence the relevance, development, and functioning of a TMS – although it is proposed that functioning TMSs might show their biggest influence in situations with high interdependent work load that depends on tacit coordination and is restrained in the amount of communication that is able to occur due to geographical distribution or time constraints (Busch, Oelsnitz 2010, p. 108). In this regard, it is necessary to detail the underlying task structure in the study of TMSs to make the transfer of results and interpretations possible.

Concerning the influence of the task's structure, one of the most important factors is the possibility of interdependence and simultaneous task execution that are both proposed to influence the development and functioning of a TMS. Without the necessity exerted through the team-level goal and the existence of sub-tasks for team members to actually share their cognitive labor and bring different expertise to the task, the conditions for the development of individual-level Mental Models and a team-level awareness of task-characteristics and expertise distribution are likely not set. Hackman (1968, p. 164) therefore differentiates between the task types of a) producing ideas, b) discussing values and issues requiring team consensus, and c) problem-solving tasks, that vary in their difficulty as perceived by the team members. While Lewis and Herndon (2011, p. 1258) argue for a differentiation between these task types in TMS research, the approach advanced in this work is rather focused on the complexity (matching the team size and thus the capability of the possible TMS) and interdependence through sub-tasks in the analysis of different tasks in the study of TMSs. Based on the size of these sub-tasks, it is proposed that the task structure also influences the development of sub-TMSs, as already discussed in section 5.1.1.

A proposition following from this discussion is that team-level task and goal structure influence the development of a working TMS, but – and perhaps more so – that the perceived interdependence by the team's members fosters this development. As Hackman (1987, p. 324) also argues, such perception is likely to motivate individuals to exchange their expertise and is therefore proposed to be influenced by not only the perceived task structure but also the perceived organizational reward system that "provides challenging performance objectives and reinforces their achievement." As discussed in the member and expertise subsections above, this perceived interdependence is thus proposed to foster commitment and to minimize social loafing through the alignment of individual-level goals (see section 2.2). The analysis of empirical results has provided further evidence for this proposition in field, group, and organizational settings.

Affective inputs

With regard to these objective and subjective task-related influences, the analysis of empirical TMS research has shown that affective inputs such as psychological safety and interpersonal conflict influence the development and functioning of a TMS. While psychological safety in combination with the perceived interdependence is supposed to foster the development of a coordinative system through expertise exchange, psychological safety is also proposed to moderate the possible negative effects of expertise diversity relating to the power and status differences that might follow such diversity (see section 2.4). As supported by the empirical TMS results, a lack of shared psychological safety may lead to the exchange of previously shared information in favor of unique and perhaps more task-relevant information in the team's discussions. According to Ashleigh & Prichard (2012, p. 9), psychological safety and trust have to be understood as antecedents for the declaration of embedded and unique expertise. Therefore, if psychological safety in a team is missing, expertise diversity is supposed to potentially lead to issues in sharing this expertise because team members would not trust each other’s intentions (e.g., Edmondson 1999, p. 354).

As Edmondson (1999) further argues, psychological safety should not be regarded as identical to team cohesion or identification. Besides the argument made in the discussion in section 4.3 that psychological safety is understood as the perceived risk (or rather perceived minimal risk) of sharing unshared information within a team that fosters the retrieval and sharing of unique expertise, it is also proposed to foster risk taking or engaging in discussions with one's own perspective of how to potentially approach the task or problem. Team identification, on the other hand – although argued to be a foundation for the relationship between communication and the development of cognitive structures in TMS research (Liao et al. 2012, p. 207) – can, according to Edmondson (1999), lead to a team climate that hinders risk taking and willingness to disagree through the development of a common perspective. As Wegner et al. (1985, p. 254) originally discussed with regard to the group mind concept and within-group similarity, team identification and team cohesion might be a two-edged sword given that they can foster and hinder the development of a TMS at the same time. On this account, both concepts of psychological safety and team identification are integrated into the adapted TMS model.

Based on this discussion as well as research regarding the role of conflict in organizational knowledge sharing (Cummings 2004; Panteli, Sockalingam 2005), the role of interpersonal and functional conflict is integrated into the adapted TMS model. Although the analysis of empirical TMS research has shown that such conflicts can hinder the development and functioning of a coordinative system, van Knippenberg et al. (2004, p. 1011) argue that these conflicts do not necessarily hinder team performance and efficient coordination. According to the authors, conflict in the value of different expertise holds the potential to promote the processing and recombination of existing expertise and perspectives. Therefore, in the adapted model it is proposed that conflict only hinders expertise exchange and performance if psychological safety and a system or routine for the constructive management of these conflicts is missing.

Communicative inputs

The analysis of empirical research in section 4 has shown, that – next to task-related inputs of complexity and size – the influence of communicative inputs such as the team's network size and structure in combination with IT support for expertise sharing influence the development and functioning of a TMS.

The team's communication network size is proposed to increase coordination costs within the team through a phenomenon called communication overhead (MacMillan et al. 2004), or, in terms of the TMS, the costs of aligning individual-level Mental Models with the team-level Shared Mental Model, as previously discussed in section 5.1.1. Based on the results in empirical TMS research and supported by social network theory (Slaughter et al. 2009, p. 435), it is proposed that – next to the influence on coordination costs – team network size influences the shape of the team-level awareness of expertise distribution. This proposition is based on the assumption that, in large networks, Shared Mental Models will be further substituted by codified expertise directories and so called connectors – human agents that are responsible for embedding expertise maps that individual team members can access and use for the retrieval of expertise in the team. According to this assumption, the team's network size further increases the cognitive load on the individual if the team members – through for example organizational routines or team training sessions – are obligated to develop individual expertise maps for the complete team.

Related to the team's network size, the analysis of empirical TMS research provides further support for the proposition that the team's existing communication network structure – in terms of tie strength and reciprocity – influences the development and functioning of a TMS. Following this, it is proposed that strong and reciprocal ties promote the development and functioning of a TMS (Ling et al. 2011, p. 259) and that tie strength and reciprocity are further related to psychological safety and the perceived interdependence of team members. This proposition is supported by social network theory, which states that the social network structure regarding relational ties of individual team members channels the flow of both material and nonmaterial resources and, furthermore, shapes and constrains individual action (Wasserman, Faust 1994, p. 4).

In this regard, it is further proposed that communicative patterns – in form of unidirectional (retrieval of expertise) or symmetric (exchange of expertise) communication (Palazzolo 2005)

– in combination with task-related factors, the team network size, and IT support for expertise exchange predict the form of the developing team-level awareness within a TMS.

Such IT support has not only been shown to influence the development and functioning of TMSs (Choi et al. 2010; Nevo, Ophir 2012), but is supposed to often play a crucial role in knowledge management within organizations (Griffith et al. 2003, p. 266). In case of the coordination and communication within a TMS, these technological support systems are proposed to influence the coordinative costs especially in large teams and teams within different geographical and time zones (e.g., Oshri et al. 2009) due to the storage facilities and possible asynchronicity of communicative modes (e-mail, newsletter) within these systems (Echterhoff 2013, p. 298). While this influence is proposed to be primarily positive, possible increases in cognitive load that are conditioned by the implementation of IT support systems or ambiguous routines for the use of these systems should also be regarded in the study of TMSs.

In summary, the following propositions regarding the input factors are formulated:

P3a: Team members' cognitive abilities positively influence the development and functioning of a TMS.

P3b: Motivation and commitment to share expertise positively influence the development and functioning of a TMS.

P4a: Expertise diversity negatively influences the development of a TMS; this influence is moderated by psychological safety, perceived interdependence, and prior TMSs.

P4b: Prior TMSs influence the development and functioning of a TMS.

P5a: Complexity of task structure and perceived interdependence positively influence the development and functioning of a TMS.

P5b: Complexity of task structure regarding the need for coordination moderates the relationship between mediation- and output-dimensions in the proposed IMOI TMS model.

P6a: Psychological safety positively influences the development and functioning of a TMS.

P6b: Interpersonal conflict negatively influences the development and functioning of a TMS.

P7a: Team network size and structure influence the shape of the team-level awareness of task characteristics & expertise distribution.

P7b: Team network size negatively influences the development of a uniformly Shared Mental Model of task characteristics & expertise distribution.

P7c: IT support for expertise sharing positively influences the development and functioning of a TMS.

5.1.3 Output variables – Recombination of expertise and performance

In the adapted model, output variables are divided into two categories. Next to the influence of TMSs on performance-related variables – such as decision- and solution-quality and the generation of new product ideas – development-related variables are proposed to manifest as output in the IMOI cycle within the adapted TMS model (see figure 13).

This proposition of development, recombination, and validation of expertise serves two purposes. First, relating to the discussion in section 2.5.3, this integration of development-related variables enables the study of the proposed model as a dynamic model that can be used to explain the development and change of the team's TMS and input variables through cyclical causal feedback as well as the influence of outputs in task A on the future inputs in task B of the team. Second, and more importantly, this integration further proposes that knowledge can be created and validated within and between TMSs and task cycles in the model (see sections 2.2.3 and 2.2.4). On this account, it is argued that through cycles and manifestations of team-level routines for expertise exchange, individual-level and team-level structures can be developed and validated by the interpretation of structures and their relationship to performance-related outputs within the team's internal discourse (e.g., Schreyögg, Geiger 2003; Schreyögg, Geiger 2007a; Schreyögg, Geiger 2007b). As the analysis of empirical TMS research has shown, those structures and routines can indeed develop within a team and, moreover, have been shown to influence the effectiveness and efficiency of the team's task-related expertise coordination between different tasks (e.g., Lewis et al. 2005). Although conceptual discussions of SMM and TMM literature provide further support for this proposition, empirical research regarding the development of such team-level Mental Models is not widely published in SMM and TMM research (see Mohammed et al. 2010, p. 901).

Following this discussion, it is proposed that knowledge creation and learning can occur within a team when existing TMS routines and structures are validated or changed for retention (Fulk et al. 2005, p. 173) or when the team generates knowledge that is novel to the team as a whole through recombination or integration of new expertise inputs in, for example, new product ideas or novel solutions to existing problems (Argote, Miron-Spektor 2011,

p. 1128). This proposition further implies that teams can enhance their capabilities for expertise exchange and coordination through learning and adjustment of structures (Arrow, Cook 2008, p. 47). Therefore, and following Argote & Ren's (2012) interpretation of TMSs, TMSs are regarded as a foundation for dynamic capabilities within organizations that enable teams to adapt to newly structured contexts and validate their expertise structures through the interpretation of performance outcomes.

In summary, the following proposition is formulated regarding the output variables:

P8: Output in (sub-)tasks influences the development and functioning of TMSs in further (sub-)tasks.

5.1.4 Contextual and organizational factors and temporal dynamics

Although the study of contextual and organizational influences has been shown to be in an underdeveloped state in empirical TMS research, the respective results have also shown that contextual influences – such as stress and time constraints, market turbulence, or turnover – can influence the development and functioning of expertise exchange routines as well as individual-level and team-level structures. On this account, potential influences of the context are integrated into the adapted TMS model in order to account for such moderating contextual influences.

Regarding organizational influences, there is even fewer evidence in empirical TMS research for their influence on structures and processes. While the analysis of dyadic and group research has shown that imposing a configuration or sharedness of expertise directly influences the development and functioning of a TMS, organizational influences have only been studied in case study contexts and are therefore somewhat missing in organizational TMS research. Regarding the discussion in section 2.6.2, this is somewhat unexpected, given that organizational-level variables are proposed to shape and constrain lower-level units top-down either directly or indirectly. Next to the proposed direct influence of organizational factors on the functioning of TMSs through, for example, the implementation of compulsory organizational routines for expertise sharing or technological systems (Oshri et al. 2009; Leonardi, Treem 2012), indirect effects have to be discussed as well by virtue of their influence on input variables. In this connection, organizational Human Resource Management systems (HRM systems) are proposed to exert influences on all of the five input categories through selection and staffing, training and development, performance appraisal, or reward and compensation systems (Bedwell et al. 2012, p. 139). Therefore, HRM systems and

instruments for the structuring of tasks (regarding individual-level and team-level goals) are proposed to bridge the organizational- and team-levels through their indirect influence on the development and functioning of TMSs by shaping and constraining input factors and through their direct influence on TMSs via compulsory organizational routines and technological systems that shape and constrain expertise exchange and individual-level and team-level structures (Alewell, Hansen 2011, p. 95). In this context, the implementation of training sessions is further proposed to influence the development of negotiated entries from default entries and should therefore be integrated into the study of TMSs. In a broader context, the consistency of HRM systems and organizational routines have been defined as being representations of organizational culture and socialization processes (Levine, Moreland 1991). On this account, Chao (2000, p. 311) proposes that the multi-level construct of culture influences the input variables and TMSs indirectly top-down and, accordingly, has to be accounted for in the study of TMSs. This is because individual-level perceptions of the organizational interaction culture may influence individual decisions to seek and retrieve expertise from other team members (Connelly, Kelloway 2003, p. 295).
The analysis of empirical TMS research has also yielded some contributions regarding the influence of and differences in temporal dynamics in the development and functioning of TMSs. Supporting the discussion in section 2.6.3, the findings have shown that it takes time for cognitive structures to develop and that top-down organizational-level disruptions may influence the individual-level behavior and cognition rather fast. On this account, it is proposed that temporal dynamics exist between different levels of analysis in the IMOI TMS framework regarding the development, functioning, and disruption of TMSs. Next to the temporal differences, path dependence in cognitive structures and exchange routines within and between tasks has to be considered. The analysis has also provided empirical support for this original proposition of developing cognitive structures and processes in TMS research (see sections 2.6.3 and 3.3). Therefore, it is necessary to account for existing structures and routines at all proposed levels of analysis when studying the development of TMSs in organizational contexts.

In summary, the following propositions regarding the organizational and contextual influences are formulated:

P9a: Contextual and organizational influences shape and constrain the development of a functioning TMS.

P9b: Contextual and organizational influences shape and constrain the moderation effect of TMSs on the relationship between task-related expertise coordination, discussion, and application and performance- and development-related output factors.

5.2 Contributions of the adapted model

After presenting the adapted multi-level model of team TMSs, it needs to be clarified how it solves the issues discussed in the introduction and section 2.1 of this work and how this model can contribute to our understanding of the cognitive division of labor and team learning within organizations.

The first category of issues directly relates to the conceptual and empirical approach in research concerning the evaluation of the TMS concept. The following elements have to be considered here: a) discrepancies and simplification in defining TMSs, b) the simplistic assumption that team-level shared cognitive structures develop through isomorphic emergent processes, c) the assumption that team members are implicitly willing to contribute to the development of a TMS through expertise exchange and revealing of own expertise, d) neglecting the task context and its influence on the development and functioning of a TMS, e) the extrapolation of TMS research and conceptual design to teams without explicitly integrating the organizational-level of analysis, and f) the conceptualization of predictors and moderators (including interrelations) for the development and functioning of a TMS. Each of these elements will be further discussed in the following.

First, regarding the simplification and discrepancies in defining TMSs, the proposed model integrates the original proposition and conceptualization by Wegner et al. (1985) into a multi-level framework that is compatible with the analyzed TMS studies and conceptualizations. Furthermore, where other TMS conceptualizations remain vague about possible negative effects of expertise differentiation regarding psychological safety and the tendency to share one's expertise, the model advanced in this work provides specific propositions that can be used to study such factors.

Second, – next to the contribution to conceptual clarity – this model also integrates empirical research on the development and differentiation between individual-level and team-level cognitive structures. On this account, the model differentiates the simplistic assumption and offers a more specific approach. The latter includes propositions regarding the development of team-level awareness of expertise distribution and task characteristics based on team network size and structure or compulsory hierarchical expertise and collaboration modes (i.e., through team leaders or connectors) as well as the resulting differences in communicative synchronization costs between the members of a team. In this regard, the integration of IT support and communicative modes further transfers the original TMS model into current organizational contexts and therefore renders the study of TMSs in these contexts possible.

Regarding the third issue of the willingness to share and reveal one's expertise unconditionally, based on the discussion in section 2.4 and the analysis in section 4, this model offers a sensible approach to the member-specific differences and influences. Accordingly, it considers the integration of individual-level and team-level goals that have to be aligned in order to motivate individuals to contribute to the development and functioning of a TMS. In this context, the integration of psychological safety and interpersonal conflicts furthermore contributes to the explanation and study of the seemingly risky behavior of granting access to one's expertise-based power.

Directly related to the willingness to share is the explicit integration of task-related inputs into the adapted model, which concerns the fourth issue. Next to the integration of objective structural task criteria that require cognitive interdependence for the successful completion of the task, the advanced model therefore integrates the perceived interdependence of individual team members in order to further account for the factors that influence expertise sharing behavior.

As discussed in section 2.5 and further revealed through the analysis of empirical TMS research, most TMS studies following the I-P-O approach do not include any other levels than the individual-level and team-level of analysis. Although this focus on single-level analysis offers a reasonable approach that provides insight into relationships through abstraction, the analysis in this work has shown that this single-level approach is not sufficient in the study of TMSs. On this account, the study of TMSs in organizational settings has been criticized to extrapolate the propositions and assumptions of the original dyadic and group TMS research context to organizational team settings without accounting for the distinct differences of these settings.

In this context, and thus related to the fifth issue, the proposed model offers a differentiated approach by explicitly integrating contextual-level and organizational-level influences that render the study of organizational routines or HRM practices and their influence on the development and functioning of TMSs possible. While other researchers have integrated these levels as antecedents to a functioning TMS (e.g., Ren, Argote 2011, p. 196), in the adapted model advanced in this work it is proposed that contextual-level and organizational-level influences shape and constrain the relationships and interactions of lower-level (individual- and team-level) units top-down at every stage of the IMOI model within and between tasks.

Therefore, the model offers an integration of the organizational context for the study of TMSs.

Another issue that has been discussed in TMS research is the conceptualization of predictors for the development of a TMS and interrelations within a working TMS. In this regard, the model offers five distinct input categories (section 5.1.2) that have been shown to influence and predict the development and working of a TMS in the analyzed empirical settings. Moreover, possible interrelations between components and inputs have been integrated – as proposed and discussed in section 5.1 – that offer a further insight into the TMS lifecycle within an existing team. The model further contributes to the understanding of the relationship between configural expertise and individual-level and team-level awareness of expertise distribution and task characteristics. Where the original TMS model and further conceptualizations have proposed that explicit expertise is an active part of the coordinative system, the proposed adapted model is based on the empirical evidence that explicit expertise is acted on through the awareness of this expertise distribution within a team. Accordingly, the model offers compatibility to the integration of team selection, staffing, and development through team training within organizations that influence both expertise stock and diversity on the one hand and the awareness of this expertise distribution through a focus on expertise maps and interrelations between team members and tasks on the other hand. In summary, the evaluation of the conceptual and empirical issues has shown that the proposed multi-level model of team TMSs can indeed contribute to the solution of such issues.

The second category of issues relates to the current discussion in Team Cognition research about a static and dynamic perspective of Team Cognition and the call for an integration of both perspectives (see section 2.1). As others have proposed (Hollingshead et al. 2012, p. 421), the concept of TMSs is supposed to possibly offer an explanation for different types of Team Cognition: the structure and organization of Team Cognition, the underlying processes of Team Cognition, and the content of cognitive structures and interactions within Team Cognition.

Due to the issues in TMS research discussed above, such possible contributions have been hindered primarily by the lack of conceptual clarity and transfer of the original context to an organizational context. The adapted model of TMSs offers contributions to both static and dynamic perspectives by combining both perspectives and can be further adapted to integrate other cognitive concepts into the study of teams. In this context, the adapted model offers a direct insight into the development and differences in the concept of Mental Models between individual-level and team-level constructs. Furthermore, the model contributes to our understanding that Shared Mental Models do not necessarily have to emerge from isomorphic processes at the individual-level. Therefore, the model proposes that it is necessary to account for the differences in structure and content between different levels of Mental Model analysis. Regarding the concept of Distributed Cognition, the adapted model furthermore offers an insight into the possible negative effects of expertise diversity and, on this account, the organizational preparations that are required to render the Distributed Cognition possible. The adapted model integrates both of these static perspectives with the process approach of Team Cognition by offering a thorough explanation of the development of these cognitive structures at the individual-level and team-level and their interaction through expertise exchange and task-related coordination. Based on these considerations, it can indeed be argued that the proposed model contributes to the call for an integration of both perspectives.

Besides confronting and resolving existing issues in TMS and Team Cognition research, this adapted model can potentially contribute to our understanding of learning within organizations (see section 5.1.3). As discussed in organizational research, organizational learning is proposed to occur when organizations acquire experience through changes in the capabilities or changes in organizational routines (e.g., Argote 2011, p. 441; Argote, Miron-Spektor 2011, p. 1124). Following Kozlowski & Klein (2000, p. 7), these changes in capabilities are primarily thought to occur within teams and individual team members. In this regard, the development of adaptive teams that can work and develop within ever changing contexts (Kozlowski et al. 1999) is seen as an important contribution to organizational learning research. The adapted model offers propositions for the change in capabilities through the integration of the development of cognitive structures at different levels of analysis and their influence on performance-related coordinative mechanisms within the cognitive division of labor. Due to the cyclic nature of the model, effects of experience (e.g., through prior TMSs and their influence on the other input categories) and learning can be studied and operationalized within an actual organizational context. In this respect, the adapted model offers an important contribution to our understanding of organizational-level and team-level learning.

6 Discussion and Outlook

In this concluding section, the main contributions of this work concerning the objectives formulated in the introduction are discussed. Furthermore, by considering possible limitations of the approach advanced here, an outlook is given.

Based on the discussion in the introduction and the corresponding findings that TMS literature is fragmented and currently lacks conceptual clarity, the first objective of this work has been to conceptualize the unit of interest in TMS research – the team and its cognitive division of labor – from a multi-level perspective. For this purpose – and related to the second objective – a multi-level framework that integrates the individual-, team-, and organizational-/contextual-levels of analysis has been developed. Based on this theoretical framework, it has then been possible to transfer the original TMS concept by Wegner et al. (1985) into a dynamic model that enables the analysis of empirical TMS research – thus meeting the third objective – from a multi-level perspective. This analysis offered two distinct contributions. First, by discussing the current measurement strategies in TMS research it has provided further evidence for the diverse conceptualizations of TMSs and their foundation in the understanding of TMSs as either cognitive structures, interactive processes, or as a latent and thus unobservable construct that can only be inferred but not directly measured in organizational settings. Second, this discussion has served as a framework for the analysis of empirical research and has been combined with the multi-level approach to infer a differentiated understanding of these diverse research approaches and conceptualizations of TMSs.

The subsequent differentiated analysis of the findings in TMS research did not provide complete support for the original TMS model and the proposed role and form of shared and configural cognitive structures. This has been unexpected because other authors conclude that the concept of TMSs is an established concept at the team-level and that, accordingly, further research is merely needed regarding specific antecedents and outcomes (Ren, Argote 2011, p. 223). However, the analysis of the findings in TMS research has pointed to the existence of more complex multi-level relationships between individual-level and team-level cognitive structures as well as their connection to the shape and direction of interactive processes in the cognitive division of labor in a team. Although the analysis of empirical TMS research in this work has thus not validated all of the propositions concerning cognitive structures in the original TMS concept, it has provided evidence for the proposed distinction between expertise exchange and application concerning their influence on team performance in organizational settings. Furthermore, the findings have provided support for the differentiated examination of the input factors that contribute to or hinder the development and functioning of a team TMS in organizational contexts.

The third objective of this work has been to integrate the results of empirical TMS research into an adapted multi-level model of team TMSs – including research propositions that are suitable for the study of this construct in organizational settings. On this account, the adapted core of the concept – individual-level Mental Models and the team-level awareness of task characteristics and expertise distribution in combination with transactive processes for the exchange of expertise and the development of these structures – has been formulated and thus explicit expertise has been transferred to a dynamic input factor to account for the findings in empirical TMS research. This adapted core advances our understanding of the cognitive division of labor in three ways.

First, it integrates the finding that individuals consider more factors than merely expertise- and task-related factors within their individual-level decision to seek and retrieve expertise from other team members. This enables the application of the proposed model in organizational contexts that are characterized by differences in power and psychological safety between team members.

Second, the change from the originally proposed uniformly Shared Mental Models to a construct of team-level awareness accounts for the findings that uniformly shared expertise directories entail certain synchronization and coordination costs that have to be integrated into the study of team-level cognitive structures. Furthermore, it reflects the proposition that different forms of team-level awareness (e.g., connectors, team leaders, or codified expertise directories) have been found to substitute team-level Shared Mental Models in specialized or larger teams.

The third advancement to our understanding originates from the differentiation between the influence of individual-level and team-level structures on expertise exchange and coordination. In this context, it has been revealed that individual-level structures shape and form dyadic-level expertise exchange and that team-level structures shape and form the expertise exchange and coordination at the team-level regarding the related task-structure.

Next to the adapted core of TMSs, the adapted model broadens our understanding of the dynamic interrelations between inputs, mediators, and outputs in combination with meso-level (bottom-up and top-down) influences of contextual- and organizational-level factors. In combination with the integration of individual-level and team-level goals, the proposition of these interrelations links the adapted model to research that is concerned with the influence of organizational level routines and disruptions such as HRM practices and instruments (e.g., staffing and development, performance appraisal, feedback, or socialization and culture). This combination is a factor that has been largely neglected in TMS research to date.

This brings the discussion to the final objective of this work, namely the question of how this adapted multi-level TMS model can contribute to the analysis of Team Cognition and TMS research in organizational settings? At the beginning of this work, the potential role of the TMS concept in the study of Team Cognition has been discussed with regard to the call for an integration of both static and dynamic perspectives in Team Cognition research. In this context, it has been concluded that the discrepancies in conceptual definition and empirical measurement in TMS research hinder the evaluation of this concept for such purpose. By transferring the TMS concept to a multi-level perspective and analyzing research from this perspective, as well as integrating empirical findings into a multi-level TMS model, it can now be argued that the call for an integration of both static and dynamic perspectives of Team Cognition can be answered by TMS research.

Furthermore, the adapted model contributes to the understanding of a differentiated approach that is needed in Shared Mental Model and Team Mental Model research concerning the form of isomorphic emergence from the individual-level to the group- or team-level that is applied in both concepts. Through the analysis of empirical TMS research, it can be inferred that it is necessary to account for the configuration of cognitive structures at the team-level prior to an aggregated approach of measuring these constructs in the field (see above). In addition, the adapted TMS model contributes to our understanding of the coordination costs and influencing factors that may hinder or foster the functioning of Distributed Cognition. Moreover, the adapted model presents an approach that links the levels of analysis by integrating explicit interactive and communicative processes to the study of Team Cognition.

Finally, the adapted TMS model provides propositions that are based on the theoretical multi-level framework, the analysis of empirical TMS research, and the integration of related research fields. These propositions render the empirical analysis of the TMS construct and the integration of interdisciplinary research possible. However, the approach applied in this work is not without limitations, as will be discussed next.

Limitations and future perspectives

Limitations of the research approach advanced in this work can be formulated with regards to three main points: the method for the analysis of empirical TMS research, the strategy for the development of the adapted model, and the explicit focus on only integrating studies that explicitly applied a TMS lens on their research question.

Concerning the method for the analysis of empirical research, different research strategies regarding the measurement of TMSs have been discussed. Although the categorization of studies in which cognitive structures and interaction are measured followed existing research guidelines, the recoding of Lewis' (2003) composite TMS scale into a measure of functional communication and coordination needs to be addressed here. As elaborated in section 4.1.3, the author's scale is directly related to measures of functional communication and measures for the analysis of team-level agreement on expertise credibility and differentiation. Therefore, it can be argued that Lewis' (2003) scale can indeed be used to evaluate shared team-level structures in combination with functional communication and coordination. In this work, however, the conservative recoding of the scale proofed to be compatible with the proposed differentiation between individual-level and team-level awareness in the adapted multi-level TMS model. Since the measures applied by Lewis (2003) for the analysis of team-level agreement on expertise credibility and differentiation are based on an isomorphic understanding of emergence, merely applying this scale without assessing the structure and form of team-level awareness of expertise distribution and task characteristics hinders the explanatory value of the results. For example, in a team consisting of six team members including one that is a connector who specializes in the development of expertise maps for specific tasks, low scores in the composite TMS scale do not reflect issues in the team-level awareness of expertise distribution. Therefore – and although the results should be interpreted with care – the decision to recode this scale in order to not reflect a latent construct has proven to be legitimate.

Furthermore, this work's approach to the adaptation of the original TMS model based on empirical research – compared to an approach that is based on theoretical research – has to be discussed. Although one could argue that the approach used in this work is thus grounded in empiricism and could therefore question how the analyzed "observational evidence can justify a scientific theory" (Godfrey-Smith 2003, p. 5), I would like to clarify that the analysis and interpretation of empirical TMS research is based on the conceptual development of a multi-level framework in this work that is grounded in theoretical research. On these grounds, I understand the interpretation of the empirical results and their integration into an adapted model as theoretically guided. In this work, the results and discussion within the studies have accordingly not just been restated and summarized, but have rather been analyzed and interpreted regarding their actual method of analysis and contribution to our understanding of the construct of TMSs. If I had just restated the results, it would not have been necessary to propose a model, because, generally, TMSs are proposed to positively influence team performance as an acknowledged construct (see Peltokorpi 2008; Lewis, Herndon 2011; Ren, Argote 2011). Furthermore, the propositions that have been formulated regarding the adapted model are supported by research in related fields. However, it has to be recognized that many of the fields related to TMS research and the TMS model adapted in this work – such as motivation theories, network theory, research on personality factors, and computer-supported-collaborative-learning – have only been briefly discussed and thus have not been thoroughly integrated into the concept. In this regard, I argue that, nonetheless, the focus on TMS literature has been a necessary first step to approach this intriguing research field.

Another limitation resulting from the explicit focus on studies in which a TMS lens has been applied concerns the generalization and explanatory power of the findings and the adapted TMS model. A brief review of overview articles in the related fields of Social Cognition (Lambert, Scherer 2013), Team Cognition measurement (Wildman et al. 2014), Cognitive Diversity (Mello, Rentsch 2015), Team Mental Models (Mohammed et al. 2010), Team Knowledge (Wildman et al. 2012), and organizational Social Network Analysis (Borgatti, Foster 2003) reveals that comparable problems of conceptualization, measurement, and interpretation of the division of cognitive labor also exist in these fields. Although the chosen focus therefore constitutes a limitation, integrating all of the aforementioned fields with regard to their depth and research history would have clearly gone beyond the scope of this work. This limitation has to be faced in future research settings.

While it is important to integrate these different approaches to the concept of cognitive division of labor, it is at the same time important to structure and analyze the findings in individual fields such as the field of TMSs in the first place. Without this conceptual clarity in individual fields, the comparison of findings between fields is severely hindered. Thus, the adapted multi-level TMS model proposed in this work brings together what we currently know (or thought to know) in TMS research. While it has not been empirically tested in its entirety, this model is based on the findings of the existing empirical TMS research and offers testable propositions for the study of the interrelations between interactive processes and cognitive structures in teamwork – and may thus prevent other researchers from having to answer the same questions as the ones that have been stated in the beginning of this work.

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Appendices

Appendix A – Dyadic TMS research

Author(s)	Year	Sample	Context/task	Interaction/transactive processes	Shared cognitive structure	Configural cognitive structure	Main finding
Wegner, Erber, & Raymond	1991	59 couples; 118 students	Memory recall task	not measured	measured	measured	Natural couples performed better than impromptu couples when expertise was not assigned; if expertise was assigned, impromptu couples performed better; difference between expertise conditions greater in natural than in impromptu couples; natural couples were in substantial agreement about partner's relative expertise
Hollingshead	1998	88 couples; 176 students	Memory recall task	measured	measured	measured	Natural couples recalled more words than strangers when not able to communicate during learning; if communication was allowed, impromptu pairs recalled more words; communication influenced assessment of relative expertise; communication influenced learning strategy
Hollingshead	1998	49 couples, 98 students	Knowledge pooling task; first individually; second, together with partner; then again individually	measured	measured	measured	Natural couples in the face-to-face condition performed better on the memory recall task; natural couples in the communication condition performed better than in the no communication condition; natural couples were in substantial agreement about partner's relative expertise; no difference between natural and impromptu couples in the cmc condition; channels of communication and communication at all is important for the retrieval, communication, and coordination of knowledge in TMS, especially in a differentiated TM structure
same as above		34 couples; 68 students	Knowledge pooling task; first individually; second, together with partner	measured	measured	measured	Natural couples scored higher with access to either mode of communication compared to no communication at all
Hollingshead	2000	22 dyads; 44 clerical office workers; mostly women	Memory recall task; first individually; second, together with partner	not measured	measured	measured	People learn and recall more information in their own areas of expertise when their partner has different work-related expertise; effect reverses for recall of information outside work-related expertise; role-based expertise can serve as negotiated entry
Johansson, Andersson, & Rönnberg	2000	77 elderly couples; 114 individuals;	Memory recall task in time-schedule based setting	not measured	not measured	measured	Control dyads performed best followed by married couples which performed better than the arranged pairs; couples who claimed to use a TMS performed as well as control dyads; TMS may lessen performance loss due to coordination
Hollingshead	2001	58 dyads; 116 students	Memory recall task	not measured	measured	measured	TM structures were most differentiated when individuals had different expertise and incentives for differentiation; TM structures were most integrated when individuals had similar expertise and incentives for integration

Author(s)	Year	Sample	Context/task	Interaction/transactive processes	Shared cognitive structure	Configural cognitive structure	Main finding
Hollingshead & Fraidin	2003	26 dyads; 52 students	Memory recall task	not measured	not measured	measured	Both male and female participants share similar gender stereotypes for knowledge domains; default and negotiated entries are dependent on gender stereotypes, if no other information is available
Fraidin	2004	184 dyads; 368 students	Hidden-profile decision-making tasks; individual decisions followed by a group decision	measured	Imposed by study design	Imposed by study design	Information distribution affects the salience of information in the dyad; awareness of different expertise positively influences the use of unshared information; dividing task information helped groups manage cognitive load; differentiated distribution of information can enhance learning of information
Johansson, Andersson, & Rönnberg	2005	62 elderly couples; 124 individuals	Memory recall task	Not measured	measured	not measured	Groups outperform individuals; groups perform worse than two individuals; division of responsibility positively influences performance; couples in agreement of this division did not explicitly perform better
Littlepage, Hollingshead, Drake, & Littlepage	2008	18 dyads; 36 clerical staff members	Job knowledge quiz	measured	measured	measured	TM facilitated group performance; specificity led to more effective utilization of member knowledge; communication had no influence; performance was higher when members differed in ability and allocated work to expert

Appendix B – Group TMS research

Author(s)	Year	Sample	Context/task	Lewis (2003) scale	Interaction/Transactive processes	Shared cognitive structure	Configural cognitive structure	Main finding
Liang, Moreland, & Argote	1995	30 same sex groups; 90 students	Radio assembly; recall of assembly procedure	-	measured	not measured	measured	Groups whose members were trained together recalled more about the assembly procedure and produced better-quality radios; results indicate that group training improved group performance primarily by fostering the development of TMS among group members; results controlled for group cohesion and social identity; groups with a well developed TMS show behavior in memory differentiation, task coordination, and task credibility
Moreland, Argote, & Krishnan	1996/1998	small same sex groups; 186 students	Radio assembly; recall of assembly procedure	-	measured	not measured	measured	Replication of Liang, Moreland, and Argote 1995; training sessions modified; group development and TMS indices were higher in group training condition; TMS negatively influenced by turnover
Moreland, Argote, & Krishnan	1996/1998	small same sex groups; 78 students	Radio assembly; radio was assembled individually; recall of assembly procedure	-	measured	measured	measured	Replication of Liang, Moreland, and Argote 1995; greater complexity, accuracy, and agreement in group training condition; indirect (behavior) and direct (questionnaire) measures of shared and configural cognitive structures are strongly correlated;
Moreland & Myaskovsky	2000	63 same sex groups; 189 students	Radio assembly; group recall of assembly procedure	-	measured	measured	measured	Improved communication does not influence performance as much as the development of TMS; information about each other's expertise is important in training contexts and may substitute group training
Rulke, Rau	2000	30 same sex groups; 90 students	Radio assembly	-	measured	not measured	not measured	Group members with a developed TMS declare domains of expertise in earlier stages of group interaction; frequency of members' expertise evaluation increases over time
Yoo, Kanawattanachai	2001	38 virtual groups; 146 MBA students	Web-based business simulation game	-	measured	not measured	not measured	Early communication is important to evaluate expertise in group; importance of communication decreases over time; influence of TM on performance changes over time
Myaskovsky, Unikel, Dew	2005	97 mixed sex groups; 288 students	Radio assembly; recall of assembly procedure	no	measured	not measured	not measured	In same sex groups, group training increased recall, decreased assembly errors, and increased assembly time; in mixed sex groups, results were not consistent; authors state that group training decreases performance, supported by the fact that TMS scores were not higher in these conditions; therefore, TMS have to develop for group training to be effective

Author(s)	Year	Sample	Context/task	Lewis (2003) scale	Interaction/Transactive processes	Shared cognitive structure	Configural cognitive structure	Main finding
Lewis, Lange, & Gillis	2005	100 groups; 300 students	Three functionally similar but differing assembly tasks	yes	not measured	not measured	measured	Introduced development and learning cycles into the study of TMS; Development of TMS* inferred from questionnaire; TMS* influences the degree to which groups develop an abstract understanding of the task; TMS* has broader benefits beyond single task; TMS* influence group learning and learning transfer
Ellis	2006	97 groups; 388 students	Decision-making, control-and-command simulation	no	measured	measured	not measured	Acute stress negatively affects mental models and transactive memory, which explains poor team performance; in combination team interaction mental models and TMS mediate the effects of accute stress on team performance
Pearsall & Ellis	2006	64 groups; 268 students	Decision-making, control-and-command simulation	yes	not measured	not measured	not measured	TMS* mediated the relationship between team member dispositional assertiveness and team performance/satisfaction
Cruz, Perez, Ramos	2007	44 groups; 167 students	Decision-making business game	no	not measured	measured	measured	Transactive memory can help to understand differences in team results; group knowledge stock had no influence on team results; specialization had positive influence on team results; consensus was negatively related with team results; accuracy had no influence on team results; psychological safety positively related to team results
He, Butler, & King	2007	51 groups; 156 students	Synthetic software development	no	measured	measured	not measured	Some forms of communication and team diversity affect the formation of awareness and shared task understanding; communication frequency by face-to-face and telephone was positively related to development of team cognition; gender diversity had a positive effect on the development of team cognition;
Lewis, Belliveau, Herndon, & Keller	2007	90 groups; 270 students	Telephone assembly; individual recall	no	measured	measured	measured	Groups with partial turnover rely on existing TMS structures, this decreases group performance; reflection on the change of expertise distribution can be used to avoid negative effects of turnover; elaborated shared cognitive structures allow members to better adapt to the dynamic characteristics of tasks
Kanawattanachai, Yoo	2007	38 groups; 146 participants	Business simulation game	no	measured	measured	not measured	Frequency of communication in early stages positively influenced development of expertise directories and cognition-based trust; in later stages, task-knowledge coordination had major influence on team performance

Author(s)	Year	Sample	Context/task	Lewis (2003) scale	Interaction/Transactive processes	Shared cognitive structure	Configural cognitive structure	Main finding
Prichard, Ashley	2007	16 groups; 48 students	Radio assembly; recall of assembly procedure	yes	measured	not measured	not measured	Teams which had training and developed team skills had more developed TMS* and team performance
Jackson & Moreland	2009	63 groups; 209 students	Long-term project; presentation, paper, & worksheet; first individually, then in group	yes	measured	not measured	not measured	Stronger TMS* were associated with better group performance; TMS was best predicted by communication among group members
Michinov & Michinov	2009	45 groups; 113 students	Learning tasks; reports for learning tasks	yes, adapted; 13 of 15 items	not measured	not measured	not measured	Well-established positive relationship between TMS* and performance based on coordination; specialization and performance linearly related
Pearsall, Ellis, & Stein	2009	83 groups; 332 students	Command-and-control simulation	yes	not measured	not measured	not measured	Introduction of hindrance stressor negatively affected team performance; TMS* positively affected psychological withdrawal; hindrance and challenge stressor combined led to lowest performance and TMS*
van Ginkel & van Knippenberg	2009	125 groups; 375 students	Hidden profile Decision-making	no	measured	imposed by condition	imposed by study design	Knowledge of distributed information interacted with reflection to affect decision quality; mediating role of task representations and information elaboration was confirmed
Gino, Argote, Miron-Spektor, & Todorova	2010	89 groups; 239 students	Product-development task	yes	not measured	not measured	not measured	TMS* was higher in direct experience conditions; TMS* was higher with member stability; TMS* fully mediated between experience, member stability and creativity
		34 groups; 102 students	Product-development task	yes	not measured	not measured	not measured	TMS* was higher in direct experience conditions; TMS* fully mediated between prior experience and team creativity
Gupta & Hollingshead	2010	20 groups; 60 students	Recall and intellective task	no	measured	not measured	imposed by study design	No performance difference in recall task between types of TM; Integrative TM lead to higher performance with higher accuracy in intellective task; more constructive interaction in groups with integrative TM; integrative TM led to the use of shared information, differentiated TM led to the use of unshared information
O'Leary & Mortensen	2010	62 groups; 248 individuals	Written delivery	yes	not measured	not measured	not measured	Social categorization in teams with geographically based subgroups triggers weaker identification with the team, less effective TMS*, more conflict, and more coordination problems; imbalance in group size has negative effect on TMS*; isolated teams had better scores than teams with subgroups

Author(s)	**Year**	**Sample**	**Context/task**	**Lewis (2003) scale**	**Interaction/Transactive processes**	**Shared cognitive structure**	**Configural cognitive structure**	**Main finding**
Pearsall, Ellis, & Bell	2010	60 groups; 240 students	Decision-making, control-and-command simulation	yes	measured	measured	imposed by study design	In combination, team mental models and TMS* convey the effects of team compilation behavior; role identification behavior is positively related to the development of team interaction mental models and TMS*
Schreiber & Engelmann	2010	30 groups; 90 students	Hidden profile Decision-making	no	measured	imposed by study design	imposed by study design	Shared agreement of the knowledge of the other group members' knowledge influenced group performance positively; mediating effect of TMS processes (in the form of acquired information) did not significantly mediate
Engelmann & Hesse	2011	40 groups; 120 students	Computer-supported problem-solving	no	measured	imposed by study design	imposed by study design	Expertise maps influenced the discussion of unshared information, the application of unshared information, and the processing of unshared information; expertise maps are not sufficient to influence group performance
Baumann & Bonner	2013	95 groups; 446 students	Hidden profile Decision-making	no	measured	imposed by study design	imposed by study design	Only a majority (not all) group members need to be aware of differences in expertise for unique expertise to be discussed
Bazarova & Yuan	2013	134 students	Group decision simulation	no	measured	measured	measured	In face-to-face groups, east asian experts had a lower participation rate, were perceived as less competent, less confident, and less influential than experts from western culture; if CMC was used, no such differences were found;
Gockel & Brauner	2014	51 groups; 153 students	Problem-solving	no	not measured	measured	imposed by study design	Perspective taking led groups to form more accurate TM and agree more on each other's knowledge assessments
Mell, van Knippenberg, & van Ginkel	2014	112 individuals	Decision-making	no	measured	imposed by study design	imposed by study design	Interaction effect between TMS structure and the distribution of task information. Mediating role of transactive retrieval and team information elaboration found

TMS*: variable recoded into functional communication and coordination due to the use of Lewis' (2003) composite TMS scale

Appendix C – Organizational TMS research

Author(s)	Year	Sample	Context/task	Lewis (2003) scale	Interaction/Transactive processes	Shared cognitive structure	Configural cognitive structure	Main finding
Faraj & Sproull	2000	69 teams; 333 individuals	software development	no	measured	not measured	not measured	Scale development for expertise coordination in knowledge teams; expertise coordination plays a significant role in explaining team performance
Austin	2003	27 teams; 263 individuals	responsibility for merchandize product line	no	not measured	measured	measured	TM is positively related to group performance, external group evaluations, and internal group evaluations; TM accuracy is shown to be the most significant predictor of group performance; awareness of external relationships is positively related to group performance
Lewis	2003	124 groups; 372 students	telephone assembly	yes	measured	not measured	not measured	TMS scale development; TMS scale correlates highly with behavioral indicators and functional communication scores
same as above		64 teams; 260 MBA students	management consulting projects	yes	not measured	measured	not measured	TMS scale development
same as above		27 teams; 146 individuals	project & cross-functional tasks	yes	not measured	measured	not measured	TMS scale development
Lewis	2004	64 MBA consulting teams; 261 members	consulting projects in single client organizations	yes, twice at planning and project completion phase	measured	not measured	measured	TMS emerge during project-planning phase; later develop as a function to the nature and frequency of communication; positive relationship between TMS and team performance; teams with initially distributed expertise are more likely to develop a TMS; face to face communication had a positive influence on TMS development
Peltokorpi	2004	10 sales subsidiaries; 111 individuals	various sales tasks	no	measured	not measured	not measured	Interpersonal communication mediates the impact of value congruence and psychological safety to directories; Expertise directories have a positive relationship with service capital
Akgün, Byrne, Keskin, Lynn, & Imamoglu	2005	69 product development projects	new product development projects	yes, adapted	measured	not measured	not measured	Team stability, team member familiarity, and interpersonal trust had a positive impact on the transactive memory system; TMS's* benefit to performance was higher in more complex tasks
Palazzolo	2005	12 teams; 154 individuals	various including academic, consulting, governmental, management, and manufacturing	no	measured	measured	measured	Emergent communication patterns only partially match the theoretical predictions and are highly related to members' perceptions of others' expertise; self-reported expertise levels were not good indicators of the communication patterns

Author(s)	Year	Sample	Context/task	Lewis (2003) scale	Interaction/Transactive processes	Shared cognitive structure	Configural cognitive structure	Main finding
Rau	2005	111 top management teams	banking	no	not measured	measured	measured	Location dimension of transactive memory positively influences performance for teams with low levels of relationship conflict; no significant effect of location dimension in teams with high levels of relationship conflict
Akgün, Byrne, Keskin, & Lynn	2006	18 firms; 79 projects	new product development projects	no	not measured	not measured	not measured	TMS has a positive impact on team learning and speed-to-market; collective mind and speed-to-market mediates between TMS and new product success
Rau	2006	55 top management teams	banking	no	measured	measured	measured	TMS at point one of time does not influence the information gathering between point one and two; different influences of TM structure and information gathering are discussed
Child & Schumate	2007	13 teams; 160 individuals	various tasks and industries	no	not measured	measured	measured	Repository use was not positively related to perceived team effectiveness; perception of accuracy of cognitive map was positively related to team effectiveness
Yuan, Fulk, & Monge	2007	15 teams; 179 individuals	varying project tasks	no	measured	measured	measured	Usage of information repositories was significantly related to individual access to information; development of individual expertise directories significantly influenced individual direct information exchange with team members; perceived usage of organizational repositories influenced actual usage of repositories; technology-specific competence influenced actual usage of intranets as organizational repositories
Zhang, Hempel, Han, & Tjosvold	2007	104 teams; 566 individuals	various settings	yes	not measured	not measured	not measured	Results suggest that task interdependence, cooperative goal interdependence, and support for innovation are positively related to TMS*; TMS* is positively related to performance
Jarvenpaa & Majchrzak	2008	104 respondents	various security tasks in banking sector	yes, adapted	not measured	not measured	not measured	Network size negatively related to TMS*; communication, and clarity of knowledge ownership positively related to TMS*; TMS* positively related to Combinative capabilities; TMS* indicates what should and what needs to be shared
Michinov, Olivier-Chiron, Rusch, & Chiron	2008	8 hospitals; 193 nurse and physician anaesthetists	not applicable	yes	not measured	not measured	not measured	TMS* predicted perception of team effectiveness and affective outcomes such as job satisfaction and team identification

Author(s)	Year	Sample	Context/task	Lewis (2003) scale	Interaction/Transactive processes	Shared cognitive structure	Configural cognitive structure	Main finding
Peltokorpi & Manka	2008	33 daycare work groups; 157 individuals	daycare	yes, adapted	measured	not measured	not measured	TMS* mediated the interpersonal communication and group performance linkage; TMS* partially mediated the group potency and group performance linkage
Ho & Wong	2009	25 employees	top-management; mid-level executives; administrative and support officers	no	not measured	measured	measured	Positive impact of expertise recognition on work performance was mediated by job resourcefulness
Smith-Jentsch, Kraiger, Cannon-Bowers, & Salas	2009	51 teams; 184 air traffic controllers	air traffic control	no	measured	measured	not measured	TM theory extends to high-stress environments; SMM of expertise increase likelihood that they will request and accept backup
Choi, Lee, & Yoo	2010	139 teams; 743 individuals	various knowledge-worker tasks	yes	measured	not measured	not measured	IT support has positive impact on development of TMS*; TMS* and IT support have positive impact on knowledge sharing and application; knowledge sharing has impact on knowledge application; knowledge application has direct impact on team performance; knowledge sharing has no direct impact on team performance, is mediated by knowledge application
Yuan, Carboni, & Ehrlich	2010	1 global sales team; 43 individuals from different divisions	sales support tasks	no	measured	measured	not measured	Perceived social accessibility, technological accessibility, awareness of expertise distribution had positive impact on expertise retrieval on dyadic and individual level; Study confirms conceptual and theoretical value of approaching TM from a multilevel network perspective
Yuan, Fulk, Monge, & Contractor	2010	18 organizational teams; 218 individuals	aerospace, hospitality, legal, military, and consulting	no	measured	measured	not measured	At the individual level, the relationship between directory development and expertise exchange was mediated by communication tie strength and moderated by shared task interdependence; individual expertise exchange happened more frequently in teams with team-level expertise directories and team communication tie strength and shared task interdependence
Peltokorpi & Hasu	2011	124 research teams; 531 individuals	research	yes	not measured	not measured	not measured	Task orientation was a predictor of TMS*; TMS* was a predictor of team innovation; TMS* mediated between task orientation and team innovation; combined TMS* and transformational leadership had a positive impact on team innovation

Author(s)	Year	Sample	Context/task	Lewis (2003) scale	Interaction/Transactive processes	Shared cognitive structure	Configural cognitive structure	Main finding
Su & Contractor	2011	9 project teams; 110 individuals	consulting projects	no	measured	measured	measured	Information seeking behavior from human knowledge sources was mostly influenced by expertise and accessibility levels of their team members; information seeking behavior from digital knowledge sources influenced by information amount in digital knowledge source and how much other team members used digital knowledge source; information complexity had negative influence on information seeking from digital knowledge sources
Nevo, Benbasat, & Wand	2012	114 individuals	not relevant in study context	yes, adapted	not measured	not measured	not measured	Traditional TMS* measure was related to awareness but not to perceptions of processes; in augmented TMS*, all dimensions of Lewis scale were related to transactive encoding; providing information on the subject and location of knowledge is important in developing and conveying specialization within the team
		180 individuals	not relevant in study context	yes, adapted	not measured	not measured	not measured	Willingness to help, communication skills, network ties, self-identified expertise, knowledge of others' expertise were related with allocation and retrieval processes
Su	2012	17 teams; 208 individuals	not relevant in study context	no	measured	measured	measured	Accuracy in expertise recognition was positively influenced by degree centrality in the communication network and negatively influenced to remote work conditions; use of digital knowledge repositories had a positive interaction effect on the relationship between remote work conditions and expertise recognition
Sung & Choi	2012	65 sales teams; 307 individuals	sales tasks	no	measured	not measured	measured	Team knowledge utilization, but not team knowledge stock, was positively related to team creativity, which in turn was related to team performance; leader's cognitive style influenced effects of knowledge utilization; leader's systematic cognitive style moderated relationship between knowledge stock and team creativity
Zheng	2012	98 start-ups	various tasks	yes	not measured	not measured	not measured	TMS* mediated the relationship between prior shared experience and new venture growth; no significant moderation of the TMS* mediated by task similarity or intra-team trust

Author(s)	Year	Sample	Context/task	Lewis (2003) scale	Interaction/Transactive processes	Shared cognitive structure	Configural cognitive structure	Main finding
Chen, Li, Clark, & Dietrich	2013	95 open software projects	software development	yes, adapted	not measured	not measured	not measured	Knowledge credibility had a positive influence on knowledge sharing; knowledge location, usage of mailing list, and credibility had positive influence on communication quality; communication quality had a positive influence on knowledge sharing and technical achievement
Hammedi, van Riel, & Sasovova	2013	136 screening committees	screening	yes	not measured	not measured	not measured	TMS* is positively related to decision-making effectiveness as well as efficiency in a screening context; transformational leadership and open organizational climate were identified as antecedents of TMS* emergence
Li & Huang	2013	218 taiwanese firms	various	yes	not measured	not measured	not measured	Specialization* is positively related to exploitative learning; credibility* is positively related to exploitative and explorative learning; coordination* is positively related to exploratory learning; Explorative and exploitative learning are positively associated with project performance
Marques-Quinteiro, Curral, Passos, & Lewis	2013	42 police tactical teams; 200 individuals	various	yes, adapted	not measured	not measured	not measured	Implicit coordination is positively related to performance; relationship between team implicit coordination and adaptive behaviors is strengthened by TMS*
Pullés, Gutiérrez, & Lloréns-Montes	2013	257 university R&D groups	research and development	yes, adapted	not measured	not measured	not measured	Relationship between knowledge transfer and TMS* is moderated by quality management practices
Robertson, Gockel, & Brauner	2013	383 and 40 employees	various	no, own adaptation	not measured	not measured	not measured	Trust in teammates predicted TM; TM predicted perceived team performance and job satisfaction
Zheng & Mai	2013	137 start ups	various	yes	not measured	not measured	not measured	Founding teams with strong TMSs* are less inclined to acquire external knowledge but are more prone to improvise in response to surprises
Bachrach, Hood, Lewis, & Bendoly	2014	107 project teams; 590 individuals	project tasks	yes	not measured	not measured	not measured	Mediating role of intrateam task and relationship conflict in the relationship between TMS* and team performance; TMS* reduce dysfunctional intrateam conflict involvement

Author(s)	**Year**	**Sample**	**Context/task**	**Lewis (2003) scale**	**Interaction/Transactive processes**	**Shared cognitive structure**	**Configural cognitive structure**	**Main finding**
Lee, Bachrach, & Lewis	2014	132 teams; 528 individuals	project tasks	yes	not measured	not measured	not measured	Negative direct effect of closure over time on TMS* development; Mediating effect of the number of transitive triads on the relationship between closure and TMS* was predictive of subsequent group performance
Mell, van Knippenberg, van Ginkel, & Heugens	2014	22 business units; 457 individuals	consulting projects	no	not measured	measured	not measured	Individual boundary spanning ties contribute to inter-group knowledge integration when knowledge-seeker chooses a central person in the group's TMS as source for information; peripheral persons in a group's TMS are not as useful for inter-group knowledge integration
Tang, Mu, & Thomas	2014	272 teams	new product development projects	yes	measured	not measured	not measured	In explorative tasks, informal communication and face-to-face communication are positively associated with TMS*; in exploitative tasks, formal communication and computer-mediated communication are positively related to TMS*; TMS* are positively related to NPD performance
Heavey, Simsek	2015	99 firms; mostly CEO and one member of top management team answered	top management	yes	not measured	not measured	not measured	Effect of TMS* on subjective performance and sales is stronger when TMT maintain strong ties with external actors; in dynamic environments, effects of TMS* are more pronounced
Hood, Bachrach, Zivnuska, & Bendoly	2015	107 teams; 590 individuals	software implementation	yes	not measured	not measured	not measured	Generalized tendencies toward positive and negative experiences influence the evaluation of an environment as safe; this evaluation influences the development of TMS*; psychological safety is positively related to TMS* and mediates between negative affectivity and TMS*
Liao, O'Brien, Jimmieson, & Restubog	2015	126 teams; 882 individuals	healthcare	yes, adapted (13 items)	not measured	not measured	not measured	Perceived communication quality predicted TMS* through team identification; high levels of professional identification compensated for low levels of team identification in predicting TMS*
Treem, Leonardi	2015	99 employees	financial services	no	measured	measured	measured	Communication practices, and not structural influences, that primarily relate to group members having their expertise recognized by coworkers

TMS*: variable recoded into functional communication and coordination due to the use of Lewis' (2003) composite TMS scale

Appendix D – Lewis' (2003) composite TMS scale items

Transactive Memory System Scale Items

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

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

Coordination

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

Note. All items use a 5-point disagree–agree response format, in which 1 = *strongly disagree,* 2 = *disagree,* 3 = *neutral,* 4 = *agree,* and 5 = *strongly agree.*

Eidesstattliche Versicherung

Hiermit erkläre ich, Volker Wagner, an Eides statt, dass ich die Dissertation mit dem Titel

"An analysis of the Transactive Memory System construct and corresponding empirical research from a multi-level perspective"

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