JULIJA NIA MELL

Connecting Minds

On the Role of Metaknowledge in Knowledge Coordination

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ON THE ROLE OF METAKNOWLEDGE IN KNOWLEDGE COORDINATION

De hoofden bij elkaar steken: De rol van metakennis in kenniscoördinatie

Thesis

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Preface

Many pages of this thesis talk about the importance of other people in the creation of any piece of complex work – and what else is writing a dissertation? Yet, in talking about interactions like sharing information, exchanging knowledge, and seeking advice, it only tells one part of the story. The other part are all those interactions and relationships whose value can hardly be pinned down to any specific idea, reference, or paragraph – those people that inspire, motivate, energize, help, listen to, support, distract, make laugh, ground, warm the heart, and, on the whole, carry one through the peaks as well as the inevitable slumps of academic pursuit. So, let me use these first pages for thanking those people who have made up this, in many ways more important, part of the story.

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The last lines are reserved for the most important people in my life. Bernardo, I am so grateful to all the weird coincidences in life that ended up bringing two people born on opposite sides of the earth together in Rotterdam. I am so grateful to have met you, to have got to know you, and to have had you by my side these past four years. We have found our own definition of home (okay, the IKEA song did help to put it in words) and thanks to

you Rotterdam has been – and is – a happy home to me. Thank you for being there, for listening, for caring, for putting up with the occasional hangriness, for introducing me to picanha and for so many more things. Thank you also to your family and friends who have made me feel welcome in Brazil.

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Julija N. Mell,
September 2015, Cergy

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Chapter 1 - Introduction

In an economy relying increasingly on intellectual capabilities rather than on physical inputs (Drucker, 1968; Powell & Snellman, 2004), knowledge residing in an organization's employees is one of its most important resources (Grant, 1996b). In other words, their knowledge, skills and abilities are among the major reasons why organizations hire people. Still, simply hiring the best individuals does not by implication yield effective solutions to complex problems, scientific breakthroughs, or innovative products. Increasingly, knowledge-intensive work requires a collaborative effort in which the knowledge of multiple individuals is brought to bear - as evidenced, for example, by the persistently rising dominance of teams over solo authors in knowledge production (Wuchty, Jones, & Uzzi, 2007). Accordingly, it is not just the knowledge of an organization's members as such, but rather its ability to bring together and integrate the knowledge of its individual members that constitutes a critical source of competitive advantage (Grant, 1996a).

Yet, this process of *knowledge coordination*, which comprises locating, transferring, and integrating the specialized knowledge of multiple individuals (Faraj & Sproull, 2000; Grant, 1996b), is everything but trivial. Even the smallest groups regularly fail to effectively utilize the specialized, unique knowledge held by their members (Brodbeck, Kerschreiter, Mojzisch, & Schulz-Hardt, 2007; Stasser & Titus, 1985). As we look beyond small groups to larger and more differentiated social units such as departments, business units, or entire organizations, the challenges associated with locating, transferring, using, and integrating the knowledge of different experts further increase (e. g., Hansen, 1999; Reagans & McEvily, 2003; Tortoriello, Reagans, & McEvily, 2011). Thus, with knowledge coordination being as challenging as it is important, an important motivation behind the research presented in this dissertation is to create a better understanding of how teams, units, and organizations can make fuller use of the knowledge enclosed in their members' minds.

In approaching the question of how social units – dyads, teams, larger collectives – collectively process information and integrate their knowledge and what factors help or hinder them in doing so, I take a socio-cognitive perspective and build on transactive memory system (TMS, Wegner, 1986) theory. TMS theory suggests that social units develop a division of cognitive labor with regard to learning, retrieving, and sharing knowledge (Hollingshead, 2001). This division of labor entails several aspects (Lewis & Herndon, 2011). First, it is based on a differentiation of knowledge among the members of a social unit (Wegner, Giuliano, & Hertel, 1985). In a team, for instance, team members may assume responsibility for learning and storing information about different aspects relevant to the task. In organizations, such a differentiation is often already inherent by design, teams being composed of members knowledgeable in different areas in order to increase the collective knowledge pool (Denison, Hart, & Kahn, 1996). Second, a core foundation of a TMS is transactive memory or, the term I will mainly use in this work, metaknowledge. Simply put, metaknowledge is the knowledge of who knows what – a form of "expertise directory" in individuals' minds (Wegner, 1995). Third, based on this understanding of who knows about what, social units can develop effective and efficient processes for searching, allocating, and sharing information among the members. Finally, such interactions update and shape the TMS in a dynamic process. Prior research has demonstrated the value of TMSs for knowledge coordination and integration across a range of settings (e.g., Akgün, Byrne, Keskin, Lynn, & Imamoglu, 2005; Austin, 2003; Gino, Argote, Miron-Spektor, & Todorova, 2010; Liang, Moreland, & Argote, 1995; Zhang, Hempel, Han, & Tjosvold, 2007).

The core concept on which I focus more closely in this dissertation is metaknowledge, which can be argued to constitute the back bone of TMSs. I depart from previous TMS research, however, in that I do not focus on metaknowledge that is necessarily shared among the members of a social unit. Rather, I view metaknowledge as individuals' cognitions about other individuals' expertise – a form of socio-cognitive ties, i.e. cognitive connections between individuals' minds (Borgatti & Cross, 2003) – and, in the aggregation of such cognitions, as an individual resource that can be shared but, more often than not, varies among people. It is the consequences of these differences in metaknowledge for knowledge coordination and integration in teams and between business units that are the main theme of the first two studies of this dissertation and, in a way, their antecedents that are examined in the third.

Dissertation Overview

The main body of this dissertation consists of three empirical chapters, based on extensive data collection undertaken in the lab as well as in the field. Although all of these chapters revolve around the role of metaknowledge in knowledge coordination, they have been developed as stand-alone research papers. Consequently, they can be read independently from each other, albeit at the expense of a certain amount of overlap between the chapters. As a case in point of knowledge production being the product of collaborative effort, the empirical chapters presented in this dissertation are based on research that I conducted in collaboration with my supervisors and other co-authors. In the following chapters, I will therefore use “we” rather than “I” in order to reflect their contribution.

In chapter 2 we first examine the consequences of differences in metaknowledge on knowledge integration and decision making in small groups. Much of the prior research on TMSs adopts a definition of a TMS that emphasizes the development of shared metaknowledge in groups – that is, of similar or overlapping perceptions of who knows what (Brandon & Hollingshead, 2004). Such a definitional emphasis, however, builds on the implicit assumption that metaknowledge is uniformly distributed in a group. In this study, we relax this assumption, acknowledging that even within the same group members can differ in metaknowledge, and we examine the consequences of such differences on team information processing and decision making. To do that, we introduce the concept of TMS centralization, which captures the disparity of metaknowledge levels within the team. Holding the average level of metaknowledge constant, in a centralized TMS structure one or a few central team members possess a high level of metaknowledge while the rest of the team members have a low level of metaknowledge, while in a decentralized TMS structure all members have a similar level of metaknowledge which corresponds to the team average. We argue that in a centralized TMS structure central members can play a role of process catalysts stimulating important team processes: First, they can encourage and model transactive retrieval, i.e. communication aimed at retrieving specific information from other team members (Wegner, 1995). Transactive retrieval, in turn, can enhance information elaboration, i.e. the exchange, discussion, and integration of task-relevant information (van Knippenberg, De Dreu, & Homan, 2004). Through this path, we argue that a centralized TMS structure can ultimately benefit team performance on tasks that demand information exchange and integration such as team decision making, complex problem-solving, or creative tasks. We furthermore suggest that this effect is stronger the more the knowledge distribution that characterizes the team's task requires coordination of expertise for the team to effectively integrate team members' knowledge. To test our hypotheses, we conducted a laboratory experiment (N = 112) in which three-person teams performed a group decision making task which required the integration of distributed information.

In chapter 3 we expand our perspective from small independent teams onto larger interdependent organizational groups and consider the role of metaknowledge in intergroup knowledge integration, that is group-level relations of acquiring, processing, and utilizing other groups' knowledge. An important vehicle for intergroup knowledge integration are informational boundary spanning ties, i.e. relations of knowledge exchange between members of different groups (Tortoriello et al., 2011). However, we argue that achieving knowledge integration between two groups is less straightforward than simply ensuring that such communication ties exist. Boundary spanning ties may differ in their effectiveness in the sense of the extent to which they contribute to intergroup knowledge integration. We suggest that one important factor that influences the effectiveness of boundary spanning ties is the level of metaknowledge of the boundary spanners enacting the ties and hypothesize that ties that involve individuals who have a good understanding of who knows what in their own group are particularly effective. To test these predictions, we collected field data in a Dutch engineering consultancy, analyzing knowledge integration relations among 22 interdependent business units and boundary spanning knowledge exchange ties among 457 engineering consultants nested in these units.

Chapter 4 approaches the topic of knowledge coordination from a broader perspective, focusing on the role of formal hierarchy in shaping intra-organizational advice networks, that is networks of "relations through which individuals share resources such as information, assistance, and guidance that are related to the completion of their work" (Sparrowe, Liden, Wayne, & Kraimer, 2001, p. 317). In this study, we make a distinction between two main informational resources sought in advice relations: task knowledge and metaknowledge. Prior work suggests that in choosing whom to ask for advice, individuals consider the potential value of the advice a source can provide, their ability to do so in a timely manner, and relational costs associated with the interaction (Borgatti & Cross, 2003). Building on this, we argue that individuals' positions in the formal hierarchy of an organization will have different effects on their popularity as a source of task knowledge and as a source of metaknowledge. We suggest that while higher-ranking individuals are more likely to be sought out in pursuit of metaknowledge – referrals to others who possess relevant expertise – they are less likely to be asked for task knowledge. We test these hypotheses in field data collected in the engineering consultancy introduced in chapter 3, analyzing the knowledge exchange and metaknowledge exchange networks among 457 members of this organization.

Finally, in chapter 5 I summarize the findings of the empirical chapters and discuss their implications for different streams of literature as well as for future research.

Chapter 2 - The Catalyst Effect: The Impact of Transactive Memory System Structure on Team Performance[1]

Introduction

The increasing complexity of tasks and decision issues faced by today's organizations has motivated the use of teams at all hierarchical levels. Engaging teams rather than individuals with complex tasks can be beneficial because it enlarges the pool of knowledge resources to draw from (Ilgen, Hollenbeck, Johnson, & Jundt, 2005). Yet, teams consistently fall short of making full use of this potential, failing to effectively share and integrate distributed knowledge. This realization has given rise to a burgeoning stream of research addressing collective information processing in teams (Hinsz, Tindale, & Vollrath, 1997; Mesmer-Magnus & DeChurch, 2009; van Knippenberg et al., 2004). One stream of research that has particularly shaped our understanding of the role of team cognition for knowledge utilization and integration is research on *transactive memory systems* (TMS, Wegner, 1986). TMS theory suggests that teams develop a division of cognitive labor with regard to learning, retrieving, and sharing knowledge (Hollingshead, 2001). In a TMS, team members are argued to develop specialized knowledge stocks and shared *metaknowledge* – knowledge of who knows what. This metaknowledge in combination with the distributed expertise forms the *TMS structure*. Alongside this structural aspect, members develop a set of communication processes to collectively use the distributed knowledge. Originally describing the implicit division of cognitive labor in intimate couples (Wegner et al., 1985), the notion of TMSs has since been elaborated and widely applied to understanding information processing in teams and organizations (Austin, 2003; Lewis, 2003; Liang et al., 1995; Peltokorpi, 2011). TMSs have been found to be positively related to a range of desirable team level outcomes such as performance, learning, and creativity (e.g., Akgün et al., 2005; Austin, 2003; Gino et al., 2010; Liang et al., 1995; Zhang et al., 2007).

This line of research has provided consistent evidence for the importance of TMSs for team processes and outcomes, but it is characterized by an important blind spot in that it ignores the role of the distribution of metaknowledge among team members. The

[1] A version of this chapter was published in 2014 in the Academy of Management Journal (Mell, van Knippenberg, & van Ginkel, 2014).

definitional emphasis on *sharedness* of metaknowledge, that is, the similarity of perceptions of the distribution of expertise among team members (Brandon & Hollingshead, 2004), seems to build on the implicit assumption that metaknowledge is uniformly distributed in a team – meaning that team members do not differ in the extent to which they have knowledge of who knows what. This implicit assumption has largely constrained TMS research to the investigation of the implications of different average levels of metaknowledge in the team. As a case in point, experimental research has mainly compared the extremes of no member having any metaknowledge and all members having complete metaknowledge (Stasser, Stewart, & Wittenbaum, 1995; Stewart & Stasser, 1995). Field research has allowed deviations from these extreme points, but has not deviated from a focus on team average metaknowledge only (e.g., Austin, 2003).

However, metaknowledge is an individual resource derived from partly idiosyncratic sources (e.g., Cross, Borgatti, & Parker, 2001) and a fully shared and complete understanding of the expertise distribution within the team seems to be an advanced state of a TMS (Brandon & Hollingshead, 2004). Thus, partially distributed metaknowledge may be the rule rather than the exception. It is thus somewhat striking that we do not know anything about how the distribution of metaknowledge in a team affects team process and performance – TMS research has turned a blind eye to what arguably is an important aspect of metaknowledge.

The primary aim and contribution of the present study is to address this neglected role of metaknowledge distribution. In doing so, we introduce the concept of *TMS centralization*, which captures the disparity of metaknowledge levels within the team. We contrast a *centralized TMS structure*, which is a situation in which one or a few central team members possess a high level of metaknowledge while the rest of the team members have a low level of metaknowledge, with a *decentralized TMS structure*, which is a situation in which all members have a similar level of metaknowledge. We argue that in a centralized TMS structure central members can play a role of process catalysts stimulating important team processes. In particular, they can encourage and model *transactive retrieval*, i.e. communication aimed at retrieving specific information from other team members (Wegner, 1995), which, in turn, can enhance *information elaboration*, i.e. the exchange, discussion, and integration of task-relevant information (van Knippenberg et al., 2004). Through this effect on team information processing, a centralized TMS structure ultimately can improve *team performance*, i.e. the extent to which a team accomplishes its goals or mission (Bell, 2007), on tasks that demand information exchange and integration such as team decision making, complex problem-solving, or creative tasks. We furthermore examine how the distribution of task knowledge among team members moderates this process. We suggest that the catalyst effect of TMS centralization is stronger the more the knowledge distribution requires coordination of expertise for the team to effectively integrate team members' knowledge.

In addition to contributing to a better understanding of TMSs in revealing how and under what conditions member differences in metaknowledge can impact team process and outcomes, our study makes at least two further contributions. First, we present a conceptualization of TMS structure that is a powerful source of new questions in TMS research. By acknowledging that metaknowledge can differ among team members and by putting the spotlight on the implications of these differences, our study opens up new avenues for research on different levels of analysis which can greatly advance our understanding of information processing and knowledge integration in teams. Second, our study has implications for team cognition research more broadly. Our conclusion that not only the degree but also the configuration of metaknowledge in a team is relevant may also hold for other aspects of team cognition such as task representations, attitudes, or preferences (Salas & Fiore, 2004).

Theoretical Background and Hypotheses

A transactive memory system is an emergent property of a team that is conceptualized in terms of two components. The structural component consists of individual knowledge, while the process component is a set of communication processes among individuals that coordinate learning, retrieval, and application of knowledge (Wegner, 1986; Wegner et al., 1985). *Transactive memory,* or metaknowledge, forms a basic constituent of TMSs. Metaknowledge describes a person's understanding of what knowledge other individuals possess; it is individual cognition reflecting awareness of the expertise of different team members (Ren & Argote, 2011).

The prevailing view on TMS structure strongly emphasizes sharedness of metaknowledge among team members. For instance, Lewis and Herndon (Lewis & Herndon, 2011, p. 1256) define TMS structure as “a knowledge representation of members’ unique and shared knowledge (including members’ shared understanding of who knows what)”. An implicit assumption entailed in this definitional emphasis on shared metaknowledge is that metaknowledge is uniformly distributed among team members. This emphasis on sharedness of metaknowledge is reflected in the field’s use of average team scores as for example established in Lewis’ (2003) and Austin’s (2003) measures of TMSs as well as in experimental designs comparing teams where no member has any metaknowledge with teams where each member has complete metaknowledge (Stasser et al., 1995; Stasser, Vaughan, & Stewart, 2000; van Ginkel & van Knippenberg, 2009).

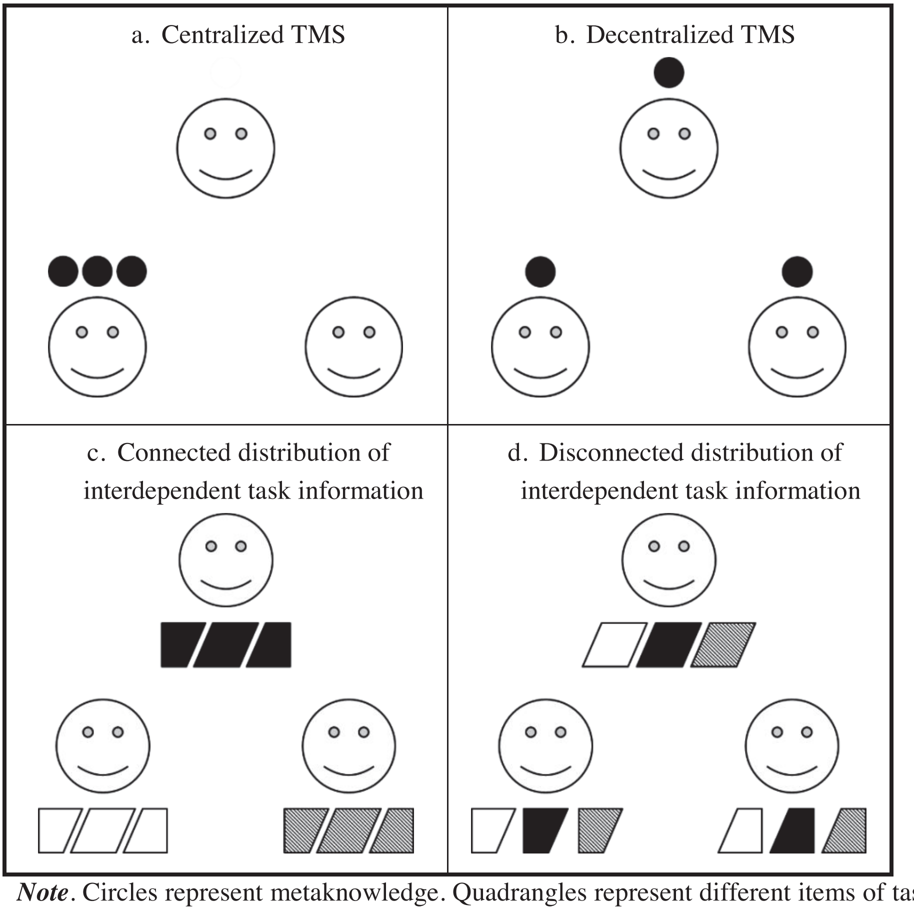
We do not argue with the important insights derived from this research on team level differences in metaknowledge. However, we do contend that the emphasis on team level metaknowledge has resulted in an important blind spot in TMS research. TMS theory is inherently a multilevel theory with team level cognition, i.e. a TMS, arising from the compilation of individual level cognition, i.e. metaknowledge (Lewis & Herndon, 2011; Yuan, Fulk, Monge, & Contractor, 2010). The fact that individual cognition – metaknowledge – lies at the core of TMS implies that there may be differences in metaknowledge between team members; metaknowledge can be shared, but it need not be. The fact that distributions of team cognition need not be uniform is recognized in other areas of team cognition research (e.g., cross-understanding, i.e. the understanding of others’ mental models, Huber & Lewis, 2010) but TMS research has generally ignored the possibility that metaknowledge can take different distributions in a team. We argue that TMS research can take important steps forward by analyzing the potential influence of member differences in metaknowledge.

Metaknowledge can vary among members of a team for several reasons. As a team forms, some members might already be familiar with each other, have shared experiences, or have knowledge about each other from other sources. These factors have been shown to affect the building of metaknowledge (Akgün et al., 2005; He, Butler, & King, 2007; Liang et al., 1995; Yuan et al., 2010), and may thus result in differences in metaknowledge within the team. Over time, asymmetries in metaknowledge can arise through subgroup interdependence and communication (Brandon & Hollingshead, 2004; Lewis, 2004), or through individual access to metaknowledge via other sources, such as external communication, gossip, or research (Cross et al., 2001). Finally, team members may differ in the metaknowledge they are able or motivated to extract in the course of team interaction.

Although the optimal state of a TMS is a complete and shared understanding of available knowledge resources in the team (Brandon & Hollingshead, 2004), this ideal state is likely to be the exception rather than the rule. First, in the process of TMS development, metaknowledge converges, i.e. becomes shared, at a rather late stage (Brandon & Hollingshead, 2004). Second, teams experience turnover which has a disruptive effect on TMSs (Lewis, Belliveau, Herndon, & Keller, 2007; Moreland, 1999). Third, transactive memory can decay with time or become obsolete as team members' knowledge changes (Ren & Argote, 2011). In short, average metaknowledge levels that differ from the extremes of none or full are not uncommon and at these intermediate average levels non-uniform metaknowledge distributions are likely. Ignoring the distribution characteristics of metaknowledge thus implies considerably limiting the scope of our understanding of transactive memory and its implications for team process and performance. Therefore, we conceptualize the structural component of a TMS as capturing members' individual expertise alongside their mental representations of expertise location in the team, and highlight that this conceptualization implies that such individual cognition need not be shared.

In a shorthand rendition of Brandon and Hollingshead's (2004) notion of task-person-expertise unit, we consider a *metaknowledge unit*, i.e. a cognition linking a person with an area of expertise (e.g., "Paul knows about marketing"), to be the elementary unit of TMS structure. A person's *level of metaknowledge* corresponds to the number of metaknowledge units this person holds. Members of a team can differ with respect to their levels of metaknowledge. An important dimension of TMS structure arising from these differences is its *centralization*. TMS centralization describes the disparity of the number of metaknowledge units held by each team member or, in other words, the relative concentration of metaknowledge within the team (Harrison & Klein, 2007). In a team with a highly centralized TMS structure one or few members hold many units of metaknowledge while most members hold few. In decentralized TMS structure, on the other hand, every member holds roughly the same amount of metaknowledge. Figure 1, panels a and b, illustrates this distinction.

Figure 1. Examples of Different Degrees of TMS Centralization and Different Distributions of Interdependent Task Information



Note. Circles represent metaknowledge. Quadrangles represent different items of task information. Task information of the same color is interdependent.

TMS Centralization and Team Performance: The Catalyst Effect

As illustrated in Figure 2.1 (panels a and b), at the same team average metaknowledge level, a striking difference between a team with a decentralized TMS structure and a team with a centralized TMS structure is the maximum level of metaknowledge of an individual member. Whereas in a team with a decentralized TMS structure each member has approximately the same number of metaknowledge units that corresponds to the team average, a centralized TMS structure is defined by at least one member holding an above average number of metaknowledge units – a *central* member in terms of metaknowledge. In other words, comparing two teams with a similar average level of metaknowledge but a different degree of TMS centralization, the central member(s) of a team with a centralized TMS will have a higher level of metaknowledge than any member of a team with a decentralized TMS. In the following, we argue that such central members are likely to show behaviors that will stimulate the exchange and integration of task information in the team. In performance contexts where TMSs are deemed relevant – tasks with clear information exchange and integration demands such as decision making with distributed information – this should result in higher team performance.

Individuals with a high level of metaknowledge are more likely to engage in behaviors that stimulate team information processing because they are more likely to recognize the importance of information exchange to team performance (van Ginkel & van Knippenberg, 2009). The more metaknowledge a person has, the more complete that person's understanding of the knowledge accessible to the team and the distributed nature of this knowledge is. As van Ginkel and van Knippenberg argued and showed, realizing that different team members have unique expertise leads individuals to the understanding that the team can benefit from exchanging and discussing this information. As a result, they approach the team task from this perspective and more actively pursue information exchange. Relating these insights to the fact that, given a certain level of team average metaknowledge, a central member in a team with a centralized TMS structure has more metaknowledge than any member of a team with a decentralized TMS structure, we can expect central team members in teams with a centralized TMS structure to more actively pursue the exchange of information than any member of a team with a decentralized TMS structure.

Such behavior in pursuit of information is known as transactive retrieval. Transactive retrieval is one of the transactive processes – interactions that coordinate a team's encoding, storage and retrieval of information relevant to the team task (Wegner, 1986; Wegner et al., 1985). It refers to communication behaviors aimed at accessing specific information held by other team members, for instance by asking questions that invoke labels referring to a specified knowledge domain (Hollingshead, 1998; Wegner, 1995).

Team members observing transactive retrieval in a fellow member are likely to follow this example. Seeing a member taking the lead in transactive retrieval may signal that such behavior is appropriate and safe to members who may otherwise be hesitant to reveal own lack of knowledge and encourage them to ask for information, too (Edmondson, 1999; van Ginkel & van Knippenberg, 2009). In addition, observing a member successfully retrieving wanted information can inspire other members to show the same behavior in order to find information that is missing from their perspectives (Bandura, 1965). Moreover, transactive retrieval questions can help other members to develop their own metaknowledge by communicating the asker's metaknowledge. For example, the question "Peter, what is our financial situation with regard to this issue?" reveals that the asker thinks that Peter has financial information and deems such information important to the task. As a result, other team members observing this communication may also be more likely to ask Peter for financial information.

For teams with distributed information, transactive retrieval is important as it stimulates information elaboration, i.e., the exchange, discussion, and integration of task-relevant information (van Knippenberg et al., 2004). First, in contrast to more general questions about others' opinions and preferences seeking subjective judgments, transactive retrieval questions aim to elicit specific, relatively objective task information. Thus, they make information available for team discussion and collective judgment. Second, members engaging in transactive retrieval are consciously seeking information unknown to themselves, which makes it likely that they will indeed consider and process the obtained information and integrate it with what they already know. This process of information elaboration, in turn, has been consistently shown to be a key driver of the performance of teams with distributed information and diversity of perspectives (Hoever, van Knippenberg, van Ginkel, & Barkema, 2012; Homan et al., 2008; Kearney & Gebert, 2009; van Ginkel & van Knippenberg, 2008).

To sum up, we propose that teams with a more centralized TMS structure engage in more transactive retrieval, because the central members in such teams can fulfill a catalyst role in setting off transactive retrieval in the whole team by taking the lead in this behavior. We expect the higher levels of transactive retrieval in teams with a more centralized TMS structure to result in more information elaboration, which in turn results in better team performance.

The Moderating Role of the Distribution of Interdependent Task Information

TMS centralization can enhance transactive retrieval and thus information elaboration and team performance for teams with distributed information and perspectives. However, not all tasks are equally conducive to this catalyst effect. Rather, this catalyst effect should be contingent on the extent to which the task at hand poses demands for *expertise coordination*, i.e. team interactions to manage knowledge dependencies (Faraj & Sproull, 2000). Such demands rise, e.g., with task novelty, complexity, or the manner in which needed knowledge is distributed. In this study, we focus on the role of the distribution of task information. We argue that the distribution of task information can take different forms that put greater or lesser demands on expertise coordination. As a result, in some information distributions the catalyst effect of TMS centralization becomes more pronounced and more critical to team performance than in others. That is, we investigate the interacting effects of the distribution of two kinds of information on team performance: task information (i.e., knowledge that is directly relevant to the task at hand) and metaknowledge (i.e., knowledge about the distribution of task information).

One aspect of task information that has important consequences for the coordination demands of a task is its *interdependence*. Information items are interdependent whenever the meaning of one statement is dependent on other statements (Pennington & Hastie, 1993). For example, knowledge about an upcoming change in legislation such as a change in safety requirements for production facilities can be highly meaningful for a team involved in strategic planning. However, it only acquires its full meaning when related to knowledge about, e.g., design features of the currently available facilities. Together, these pieces of information allow judging whether and how the upcoming changes affect the current plan of action.

Interdependent information can be distributed in a team in different manners that vary in the extent to which interdependent information is known by one individual or rather distributed over individuals (Fraidin, 2004). Figure 2.1 captures two illustrative cases. In a *connected distribution* (panel c), each team member possesses a complete (and different) set of independent information. In other words, each member holds items of information whose meanings are dependent on other items of information that are known to that same member. An example of such a connected distribution is a team of different industry specialists or product champions, every one of them knowledgeable about all relevant aspects of his or her product area. On the other hand, in a *disconnected distribution* (panel d), a set of interdependent information is distributed over different team members. That is, each member holds items of information whose meanings are dependent on other items of information that are known to other members but not to that same member. An example of such a distribution is a team of functional specialists, each knowledgeable of a specific class of aspects regarding different products.

The distribution of interdependent information has important consequences. As suggested by the very definition of interdependence of information, members possessing a more complete set of interdependent information are in a better position to understand the meaning of these pieces of information and judge their relevance to the task. Thus, as demonstrated by Fraidin (2004), a connected distribution helps team members to recognize the implications and the importance of their knowledge for the task. As a result, they may be more likely to share and discuss relevant information with the team or even to integrate interdependent information on their own and present the team with an accurate conclusion without necessarily discussing the constituting information. In a disconnected distribution, on the other hand, individual members are less able to accurately judge the meaning and relevance of their knowledge for the team task. Thus, they may be less likely to share potentially relevant information unprompted – while at the same time, the disconnected distribution requires information to be explicitly shared with the team in order to be integrated with interdependent information held by others. Thus, in a disconnected distribution establishing the right connections among interdependent pieces of information becomes a team task that raises additional coordination demands and decision quality is critically dependent on how well the team achieves this coordination.

As a consequence of this increased coordination demand, a disconnected distribution of interdependent information is more conducive to the catalyst effect of TMS structure centralization on team performance. When team members are less likely to share relevant information unprompted, the role central members in a centralized TMS structure can have in driving transactive retrieval and, consequently, information elaboration will be highly important. In a task with a connected distribution of interdependent information, on the other hand, TMS centralization is less likely to play a role as members can easily recognize, share or individually combine relevant information unprompted and therefore rely less on transactive retrieval.

To sum up our conceptual analysis, we argue that TMS structure impacts the quality of team decision making such that, in a task with a disconnected distribution of interdependent task information, teams with a centralized TMS structure outperform teams with a decentralized TMS structure. We do not expect this effect in a task with a connected distribution of interdependent task information. We furthermore argue that this interaction is mediated by a rise in transactive retrieval and, as a consequence, information elaboration. We tested the following hypotheses:

> ***Hypothesis 1:*** *Teams with a centralized TMS structure perform better than teams with a decentralized TMS structure when there is a disconnected distribution of interdependent task information, but not when there is a connected distribution of interdependent task information.*

> ***Hypothesis 2:*** *The interaction effect of TMS structure and the distribution of interdependent task information on team performance is sequentially mediated by (a) transactive retrieval and (b) information elaboration.*

To test these hypotheses we conducted a laboratory experiment in which teams performed a decision making task that required the exchange and integration of distributed information – a prototypical setting for the effects of metaknowledge to unfold (Stasser et al., 1995; van Ginkel & van Knippenberg, 2009). We manipulated the connected versus disconnected distribution of interdependent task information and the centralized versus decentralized nature of the TMS structure. We opted for this experimental method because it allowed us to draw conclusions about causality and enabled us to use audio-video recordings of the team discussions rather than self-reports for an unobtrusive and reliable measure of the team processes (Weingart, 1997).

Methods

Experimental Design

The experiment had a 2 (TMS structure: centralized/ decentralized) by 2 (distribution of interdependent task information: connected/ disconnected) design. Three-person groups engaged in a "hidden profile" task, i.e. a decision making task in which the information required to find the optimal solution is distributed among individuals (Stasser & Titus, 1985). Because no experimental task in prior literature met all our requirements to simultaneously manipulate TMS structure and distribution of interdependent information, we developed a new task for this study, modeling it on tasks used in earlier studies. In the task, participants acted as business consultant teams evaluating the profitability of product innovations. During a pilot phase we ensured that the optimal solution could be found with the complete information set and fine-tuned the task difficulty to produce sufficient variation in performance among the teams within our sample population of students of business and economics.

Participants

Three-hundred seventy two students at a Dutch university (190 males, 182 females, mean age 20.6, SD = 2.5) volunteered to participate in the study for extra course credit (36%) or a monetary compensation of 10 euro (64%). The majority of the volunteers (93%) were students in the business and economics departments. Because we could not completely control the sampling procedure, a small part of the participants were following non-business related majors and therefore were outside of the population the task was designed for and piloted on. We tolerated groups that included one such participant (21 groups), but excluded groups in which participants with a non-business related major constituted the majority[2]. Furthermore, we dropped three groups in which participants explicitly indicated that their level of English was too low to understand the instructions and two further groups due to procedural errors. The final sample consisted of 112 groups, with between 26 and 29 groups per condition.

[2] Additional analyses showed that our conclusions were not affected by including either the choice of reward or the presence of one non-business related major.

Experimental Task

In order to be able to meaningfully manipulate information distribution and metaknowledge distribution, we developed a new task based on several requirements. First, information items that were critical to the task solution were designed to be interdependent, i.e. to acquire the specific meaning and relevance for the task solution only once combined. Second, the critical items of information were designed to lend themselves to a labeling that allowed a cross-classification into two sets of information categories that make intuitive sense to the participants – products and functions. Third, the task was made up for teams of at least three persons.

The task requires the participants to assess the profitability of food product innovations. Participants are asked to take the role of a team of consultants and to make recommendations to two independent clients. These recommendations consist of a ranking of five product ideas in terms of profits for a given time period for each of the clients. Twenty-five critical items of information describe each of the two choice sets, each item providing information from one of five functional categories with regard to one of the products (see Table 1).

Functional information within every product alternative was created to be interdependent in a similar way as in Fraidin's (2004) study. For example, information from the research and development department reveals parts of the formula of a product while the legal department informs about a law change which limits the use of a certain substance. On their own both pieces of information are insufficient and seemingly irrelevant for the task solution, but combined they reveal that the particular product will shortly be banned. To accurately assess the profitability of any of the five products, information from all five functional categories needs to be integrated.

Each of the team members received the same background information about the clients, a short description of the product alternatives (see Appendix A2.1 for a sample) and five pieces of additional information about the product alternatives which were irrelevant for the task solution. Each product was described as being designed for a particular target group, the target groups being the same across both choice sets. Furthermore, each member received one or two sets of the critical information items which were uniquely assigned to them. Text length was kept similar among the different members. As is customary practice in research in distributed information (e.g., Gruenfeld, Mannix, Williams, & Neale, 1996), all of the team members were told that the information the members received could differ.

Table 1. Overview over the Structure of Information Items in the Experimental Task

Functional category	Product targeted at…				
	Young adults (P1)	Fashion-conscious adults (P2)	Quality-driven adults (P3)	Health-conscious adults (P4)	Kids and their parents (P5)
Research & development (RD)	P1, RD	P2, RD	P3, RD	P4, RD	P5, RD
Financial forecasts (FF)	P1, FF	P2, FF	P3, FF	P4, FF	P5, FF
Legal information (LI)	P1, LI	P2, LI	P3, LI	P4, LI	P5, LI
Production processes (PP)	P1, PP	P2, PP	P3, PP	P4, PP	P5, PP
Market research (MR)	P1, MR	P2, MR	P3, MR	P4, MR	P5, MR

Note. Each cell represents one item of critical information, stemming from one functional department and referring to one product. Items referring to the same product are interdependent among each other.

Experimental Manipulations

Distribution of interdependent task information. To manipulate the distribution of interdependent task information we split up the critical information items among team members in different manners. In the *connected distribution* condition information was split up according to the products (target groups) the items described (see Appendix A2.2), i.e. by columns of Table 1. Thus, each of the three team members received all the information required to accurately judge the profitability of one or two of the five products - interdependent information was located “in one head” (Fraidin, 2004). In the *disconnected distribution* condition information was split up according to the functional categories (see Appendix A2.3), i.e. by rows of Table 1. Thus, every group member received a part of the critical information for every product. Here, interdependent information was located “in different heads”.

TMS structure. TMS structure was manipulated by means of written instructions (van Ginkel & van Knippenberg, 2009). Metaknowledge, i.e. information about which member of the team held extra information about which functional category or product group (e.g., "market research" in the disconnected distribution or "products designed for young adults" in the connected distribution, see Table 1 for all labels), was presented in writing and on a sketch showing a map of the table the participants were seated at. In total, all teams received an equal number of metaknowledge units, namely five relations between information category and person with extra information on it. However, teams differed with regard to the distribution of the metaknowledge units. In the *centralized TMS structure* one person received all five units of metaknowledge while the other two members did not receive any metaknowledge. In the *decentralized TMS structure* every team member received one or two units of metaknowledge. In both conditions all five existing units of metaknowledge were disclosed to the team.

Procedure

On arrival, each team was orally introduced to the task. Teams were given information on the full procedure, including the time frames for reading and discussing. Furthermore, they were told that the teams with the best solutions had a chance to win a prize of 150 euro to be split evenly among team members. The participants then had up to 25 minutes to individually read the task materials which consisted of a general introduction, information on the clients and products, and the metaknowledge presentation for those participants who received any based on the design.

Next, the teams continued with the discussion phase. They were allowed to keep and review the information booklets during the discussion but not to show them to each other. They had fifteen minutes to make decisions on both choice sets. Teams that had not finished by the time the fifteen minutes elapsed were asked to finish as quickly as possible. Discussion time in the final sample varied between 11.2 and 18 minutes with an average of 15.2 minutes.

After finishing the task, participants filled in individual questionnaires, were debriefed, received their credits or payment and were dismissed.

Measures

Performance. Team performance scores reflected the quality of the team's decisions and were based on the similarity of their solutions to the objectively correct solution. For each choice set, one objectively correct ranking order of the five product alternatives existed. To assess team performance, we calculated the deviation of the rank a team gave to each product alternative within the choice sets from their optimal rank positions. We summed these ten deviation scores into an overall score that ranged from 0 to 24. For ease of interpretation, we subtracted this value from 24 which yielded a performance score with higher values indicating better performance.

We used audio-video recordings of the team discussions to assess the team process. One rater, blind to the experimental conditions, coded transactive retrieval and information elaboration for all 112 teams. A second independent rater provided overlapping ratings for 24 of the 112 teams in order to determine the inter-rater reliability of the coding scheme (see Homan, van Knippenberg, van Kleef, & De Dreu, 2007; Velden, Beersma, & De Dreu, 2010 for a similar procedure). We used intraclass correlations (ICC) to assess inter-rater reliability, ICC1 referring to the reliability of a single rater and ICC2 referring to the reliability of the averaged rating (Bliese, 2000; LeBreton & Senter, 2008; Shrout & Fleiss, 1979).

Transactive retrieval. Transactive retrieval (ICC1 = .74, ICC2 = .85) was operationalized in line with its original descriptions (Hollingshead, 1998; Wegner, 1995) as communication acts aimed at searching for information pertaining to a specified knowledge domain within the other team members. Information search was recognized as transactive retrieval when questions invoked labels of the product category or the functional category (e.g., "*Do you know anything about the iced tea*?" or "*Are there any legal issues with this?"*) or when askers tried to elicit specific information complementary to their own (e.g., "*Market research says that we will sell out this product if the price is not higher than three euro. Do you know the price?").* In contrast, questions asking for a contribution to the discussion without referring to a specified knowledge domain as well as questions aiming to elicit statements of preferences were not coded as transactive retrieval. Team scores were based on the frequency of transactive retrieval acts.

Information elaboration. Information elaboration (ICC1 = .93, ICC2 = .97) was operationalized on the basis of a rating scheme successfully employed in previous research (Homan et al., 2007; Kooij-de Bode, van Knippenberg, & van Ginkel, 2008; van Ginkel & van Knippenberg, 2008, 2009). Each item of information but for the distractor items received an elaboration score from 0 to 5. To receive a score higher than 0 an item must be mentioned during the discussion. Thus, if a member silently drew a conclusion based on his or her information and only shared the conclusion without recounting the constituting information items, these items received a score of 0. A score of 1 was given when a member mentioned an item. A score of 2 was given when a mentioned item was acknowledged by at least one of the other team members (e.g., by nodding or saying "*OK*"), or when the item was mentioned in response to a question but was not further discussed after that. A score of 3 was given when a mentioned item was clearly responded to by asking a clarifying question about it (e.g., "*Is that the sales prediction for one or for two years?").* A score of 4 was given when a conclusion was drawn from the item without explicitly integrating it with other information (e.g., "*This definitely brings the product down!").* A score of 5 was given when an item was combined with another piece of information (e.g., *"So far we had a profit of 250 000 but with these extra costs we're down to 200 000."*). Items that were integrated by different people ("*You say x but I know y, hence z.*") as well as items that were integrated by one and the same person ("*I know x, but I also know y, hence z.*") received the same high elaboration score of 5.[3] Each item received the highest elaboration score observed during the discussion phase. The item scores were summed over the fifty items to give a total information elaboration score that theoretically could range between 0 and 250.

Results

The Effect of TMS Structure and Distribution of Interdependent Task Information on Team Performance

Table 2 presents the descriptive statistics for the observed variables and partial correlations among them after controlling for the influence of the experimental

[3] We also coded elaboration according to an alternative conceptualization, deeming an item strongly elaborated only if a different person executed the integration. The measures were highly correlated (r = .93) and analyses conducted with either measure resulted in identical conclusions.

manipulations. Hypothesis 1 predicted an interaction effect between the two experimentally manipulated factors of TMS structure and the distribution of interdependent task information on team performance.

Table 2. Descriptive Statistics and Correlations among the Observed Variables

	Descriptive statistics: *M* (*SD*)					Correlations[a]	
	Full sample	Connected distribution		Disconnected distribution		1	2
		Centralized TMS	Decentralized TMS	Centralized TMS	Decentralized TMS		
Transactive retrieval	6.17 (3.89)	5.86 (2.17)	5.69 (3.22)	8.11 (4.86)	5.03 (4.23)		
Information elaboration	101.83 (39.52)	64.24 (18.94)	73.00 (22.61)	117.64 (42.54)	108.55 (46.69)	.46**	
Performance	11.27 (5.34)	12.00 (5.21)	13.69 (5.05)	11.00 (4.94)	8.62 (5.13)	.25**	.38**

a. The reported correlations are partial correlations, controlling for the effect of the experimental conditions and their interaction.

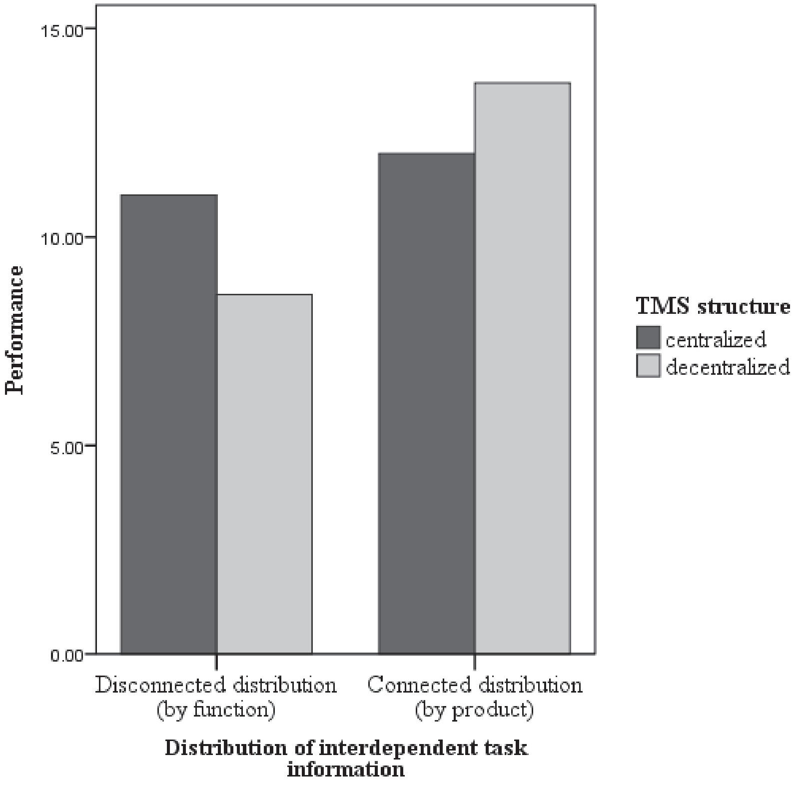
** $p < .01$

We tested this hypothesis in a 2 x 2 analysis of variance. In line with Fraidin's (2004) results, we found a significant main effect of the distribution of interdependent information on team performance, $F(1,108) = 9.95$, $p < .01$, $\eta^2 = .08$. On average, teams in the connected distribution condition performed significantly better ($M = 12.85$) than teams in the disconnected distribution condition ($M = 9.81$)[4]. Furthermore, consistent with our hypothesis, while we found no main effect of TMS structure, $F(1,108) = .13$, *ns*, we found a significant interaction between the distribution of interdependent task information and TMS structure, $F(1,108) = 4.48$, $p < .05$, $\eta^2 = .04$. We used planned contrasts to test whether within the more demanding disconnected information distribution condition teams with a centralized metaknowledge structure indeed outperformed teams with a decentralized metaknowledge structure as we predicted. The contrast analysis confirmed a performance difference in the expected direction, $t(108) = 1.76$, $p < 0.05$, one-tailed, $\eta^2 = .03$. In contrast, teams working on a task with a connected distribution of interdependent

[4] As anticipated, participants in the connected distribution condition more often presented a conclusion about a product after individually integrating their interdependent information, which resulted in lower team information elaboration scores in the connected distribution condition, $F(1,108) = 44.98$, $p < .01$, $\eta^2 = .29$; with more integrated conclusions shared by individual members, there was less need for the team to accomplish such integration in team discussion.

information did not differ in their performance as a function of their initial metaknowledge structure, $t(108) = 1.23$, *ns*. Figure 2 illustrates the interaction.

Figure 2. Interaction of TMS Structure and Distribution of Interdependent Task Information on Team Performance



The Mediating Roles of Transactive Retrieval and Information Elaboration

Hypothesis 2 posed that the interaction effect between TMS structure and the distribution of interdependent information is sequentially mediated by transactive retrieval and information elaboration. To test this prediction we relied upon recent models for mediated moderation and serial mediation (Edwards & Lambert, 2007; Muller, Judd, & Yzerbyt, 2005; Preacher, Rucker, & Hayes, 2007). In our analysis, we followed the procedure for serial multiple mediation suggested by Hayes (2013). As we were interested in the indirect effect of the interaction between TMS structure and the distribution of interdependent task information, we employed the interaction term as independent variable, and entered the contrast-coded variables denoting the experimental conditions as covariates into each regression (Preacher & Hayes, 2008).

In the first step of the analysis, we derived path coefficients for our model through a series of regressions (see Figure 3 and Table 3). Regressing team performance on the experimental conditions and their interaction (model 1) reproduces the total effect model discussed earlier. Regressing transactive retrieval on the experimental conditions and their interaction (model 2) yielded the path coefficients for the first stage of the mediation model. In line with our reasoning, we found a significant effect of TMS structure and the interaction term. Within the disconnected distribution conditions, teams with a centralized TMS structure showed more transactive retrieval acts than teams with a decentralized TMS structure ($F(1, 55) = 6.49$, $p < .05$, $\eta^2 = .11$). In contrast, transactive retrieval was virtually the same over both TMS structure conditions within the connected distribution conditions ($F(1, 53) = .05$, *ns*). Regressing information elaboration on the conditions, their interaction, and transactive retrieval (model 3) yielded the path coefficients for the second stage of the mediation model. We found that transactive retrieval significantly predicted information elaboration. Finally, regressing team performance on the full series of predictors (model 4) yielded the path coefficients for the last stage of the mediation model. In this model, information elaboration significantly predicted team performance while neither the interaction term nor transactive retrieval showed any residual effects.

In the second step of the analysis, we tested the indirect effect of the interaction term via transactive retrieval and information elaboration. The indirect effect consists of the product of the paths from the interaction term to transactive retrieval, from transactive retrieval to information elaboration, and from information elaboration to performance. We used a bootstrapping procedure to test the magnitude of the indirect effect in order to avoid shortcomings of the classical causal step approach and the parametrical Sobel test (Baron & Kenny, 1986; Edwards & Lambert, 2007; Hayes, 2009). In this procedure, 5000 random samples are drawn with replacement from the original sample and the indirect effect of interest is calculated from each bootstrap sample, thus yielding a sampling distribution which can be used to construct a confidence interval (Preacher et al., 2007). In support of

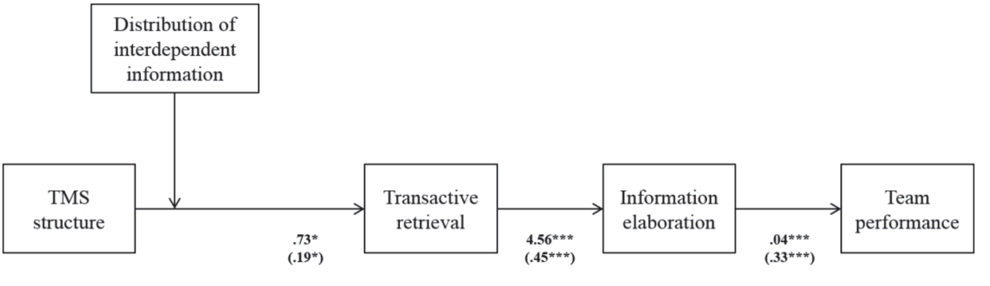
Hypothesis 2, the estimate of the indirect effect was positive and significant, the bias-corrected confidence interval not including zero ($b = 0.15$, 95% CI [.03; .37]).

Table 3. Regression Results for Serial Mediated Moderation Model

Predictor	b	SE	β	t	R2
Model 1: Performance (total effect model)					.12**
TMS structure (1=centralized)	.17	.48	.03	.36	
Information distribution (1=disconnected)	-1.52	.48	-.29	-3.16**	
TMS structure x Information distribution	1.02	.48	.19	2.12*	
Model 2: Transactive retrieval					.09*
TMS structure (1=centralized)	.81	.36	.21	2.28*	
Information distribution (1=disconnected)	.40	.36	.10	1.11	
TMS structure x Information distribution	.73	.36	.19	2.04*	
Model 3: Information elaboration					.29***
TMS structure (1=centralized)	-4.33	3.27	-.11	-1.32	
Information distribution (1=disconnected)	10.18	3.22	.26	3.17**	
TMS structure x Information distribution	1.60	3.26	.04	.49	
Transactive retrieval	4.56	.86	.45	5.28***	
Model 4: Performance					.25***
TMS structure (1=centralized)	.09	.46	.02	.19	
Information distribution (1=disconnected)	-2.11	.47	-.40	-4.47***	
TMS structure x Information distribution	.70	.46	.13	1.53	
Transactive retrieval	.14	.14	.10	1.02	
Information elaboration	.04	.01	.33	3.29***	

Note. Information distribution refers to the distribution of interdependent information. TMS structure and information distribution are contrast coded variables: 1 = centralized TMS structure; disconnected information distribution.
* p < .05. ** p < .01. *** p < .001

Figure 3. Results of the Mediated Moderation Model



Note. Path estimates are unstandardized regression coefficients, standardized regression coefficients are in parentheses.
* p < .05, ** p < .01, *** p < .001

Discussion

We investigated an important issue that TMS research has hitherto overlooked – the effects of member differences in metaknowledge (i.e., knowledge of who knows what) on information elaboration and team performance. Our findings show that a more centralized TMS structure (i.e., greater disparity of metaknowledge within the team) can result in more information elaboration and higher performance than a more decentralized TMS structure. As our results show, the condition for this catalyst effect to occur is that interdependent task information is distributed in a disconnected manner – a condition that is often present in teams of functional specialists. Such a disconnected distribution of information makes sharing of interdependent information more critical to performance - yet it renders the relevance of individual items of information less obvious to members holding them. In this situation, members that are central in the TMS structure can play a catalyst role by spurring transactive retrieval and information elaboration in the team - which benefits team performance.

Theoretical Implications and Contributions

Our study makes several contributions to TMS theory and research, the most important of which is to step away from the traditional focus on team average levels of metaknowledge only and to put the spotlight on the distribution of metaknowledge within the team. Integrating the notion of metaknowledge distribution into analyses of TMSs is valuable for several reasons. First and most straightforward, as we empirically showed, metaknowledge distribution is a performance-relevant characteristic of a team's TMS structure. Teams that do not differ in the average metaknowledge of their members can differ in information elaboration and performance as a function of the distribution of metaknowledge within the team. In short, complementing the dominant focus on average metaknowledge with a focus on metaknowledge distribution is necessary for a full understanding of TMSs.

Second, paying attention to metaknowledge distribution can be highly informative in the study of TMS development. Brandon and Hollingshead (2004) describe *convergence*, "where all members have similar representations of the transactive memory system that accurately reflect relative knowledge in the group and have been validated by members" as the theoretical ideal state of a TMS. TMS centralization could be an important predictor of the success and speed at which a TMS will develop toward this ideal state. As we showed, the initial distribution of metaknowledge can affect the extent to which a team engages in transactive retrieval and information elaboration. Such interactions, in turn, can allow metaknowledge to diffuse within the team as members learn metaknowledge in addition task information to in the course of such communication (Brandon & Hollingshead, 2004; van Knippenberg, van Ginkel, & Homan, 2013; Wegner et al., 1985). We therefore expect that to the extent that TMS centralization stimulates transactive retrieval and information elaboration, teams with a centralized TMS structure will experience a faster rise in average metaknowledge and metaknowledge sharedness. We note, however, that a likely boundary condition for this is the extent to which communication is "accessible" to all team members even when they do not directly take part in the specific exchange, e.g. takes place in face-to-face meetings of the complete team like in our experimental setup or in electronic spaces accessible to all members. This boundary condition may also apply to the catalyst effect more generally and is a subject for future research.

Third, recognizing that metaknowledge need not be shared within a team allows treating TMSs as a true multilevel phenomenon. This may also invite a methodological shift from the predominantly used team average scores to a network perspective (Lewis & Herndon, 2011; Peltokorpi, 2008). Using this view, the TMS structure can be represented as a network in which people and their expertise are nodes and awareness of each other's expertise are ties (Borgatti & Cross, 2003). Such a conceptualization of TMS structure allows considering its antecedents and outcomes at individual, dyadic, and team levels. For instance, while we showed that a centralized TMS structure can benefit team performance, other questions about the consequences of such a structure for the individual team members depending on their own position in this network or about the consequences of such a structure for dyadic relationships open up.

Beyond contributing to the study of TMSs, our study invites scholars to consider the application of a distribution perspective on the broader field of team cognition. The main focus of this field is – as exemplified by TMS theory – on *shared* cognition (Cannon-Bowers & Salas, 2001; Hinsz et al., 1997; Tindale & Kameda, 2000). As argued by this stream of literature, the *degree* of sharedness of cognitive elements such as attitudes and preferences, task knowledge, and knowledge about each other is a key aspect to understand team information processing. Our study suggests that, in addition to that, more carefully examining the configurations formed by these cognitive elements can be valuable. Examples of such an approach to team cognition are still few (e.g., Huber & Lewis, 2010; Kameda, Ohtsubo, & Takezawa, 1997), but we believe that a focus on the distribution of team cognition can open the view on many interesting questions. For instance, it allows investigating the repercussions of specific patterns of *un*shared cognition as, for example, caused by turnover.

Practical Implications

Knowledge has become a crucial resource in an organization's portfolio (Grant, 1996b). The increasing demand for the integration of diverse, highly specialized knowledge makes teamwork indispensable. TMSs play a key role in helping teams to capitalize on their knowledge resources as they allow members to specialize and gain extensive knowledge in their areas of expertise while granting them access to their coworkers' complementary knowledge (Wegner, 1986).

The present study suggests that metaknowledge may in itself be an area of expertise worth specializing in. In a context where the range of expertise domains is large, the number of actors is high, team membership is fluctuating, and knowledge is dynamic, developing accurate metaknowledge and keeping it up to date is costly. An attempt to foster complete and shared metaknowledge in a team operating in such a context requires a very high effort. A half-hearted attempt, on the other hand, might result in a waste, creating incomplete representations of the team's knowledge pool in the individuals' minds. Instead, our findings imply that it might be fruitful to focus the resources dedicated to raise metaknowledge upon a selected group of individuals who will function as information hubs and process catalysts. Indeed, some organizations seem to have such an intuition and assign central actors to manage expertise recognition (Garner, 2006, p. 334). Our study contributes to a theoretical and empirical grounding for such measures and furthermore suggests that they may be particularly important for teams whose members are specialists in different functional or disciplinary domains such as cross-functional teams in business organizations or inter-disciplinary research teams in academia.

Limitations and Future Research

We aimed to provide causal empirical evidence for our theoretical claim that the centralization of the TMS structure represents a performance-relevant dimension. We chose the experimental method in order to maximize internal validity and to closely observe the process mediating between cause and outcome. The random assignment of groups to conditions and of members to roles averts concerns about endogeneity and self-selection, as we can ascertain that the initial TMS structure is not caused by individual preferences or abilities or by team history. Such an experimental set-up may raise concerns with external validity, however. In this respect, previous research generally shows that findings in laboratory and field studies tend to converge (Anderson, Lindsay, & Bushman, 1999; Dipboye, 1990). For instance, both lab and field studies consistently found positive relationships between TMS and team performance (e.g., Austin, 2003; Moreland, 1999; Stasser et al., 2000) and between information elaboration and team performance (Homan et al., 2007; Kearney & Gebert, 2009; van Ginkel & van Knippenberg, 2008). Two recent meta-analyses further support convergence between effects found in field and experimental research on teamwork processes (LePine, Piccolo, Jackson, Mathieu, & Saul, 2008) and team cognition (DeChurch & Mesmer-Magnus, 2010). These findings provide reasonable grounds to expect that our results would generalize to field settings. Even so, future research extending the investigation of the effect of different TMS structures to field settings would be highly valuable.

In designing such field research, questions of measurement and aggregation may need to be addressed from a new perspective. As suggested above, we believe that taking a network approach (Borgatti & Cross, 2003) is a promising way to capture metaknowledge structures within teams more fully. With regard to aggregation of metaknowledge to the team level, our findings imply that a disjunctive aggregation capturing the metaknowledge level of the "best" member (LePine, Hollenbeck, Ilgen, & Hedlund, 1997) may be more appropriate than an additive aggregation generally used in TMS research. Again, the extent to which communication is accessible to all team members may be an important factor to consider when making decisions about the appropriate form of aggregation.

Our manipulation of metaknowledge followed previous research in using written instructions (Stasser et al., 1995; van Ginkel & van Knippenberg, 2009). However, the specific requirement of our study to create different metaknowledge distributions might have led to a potential side effect: While in both TMS structure conditions the total amount of metaknowledge assigned to the teams was identical, in the centralized condition only one rather than three group members received metaknowledge. Thus, in the decentralized groups all three members were made aware that information would differ among group members twice – in the general instructions and in the manipulation. In the centralized groups, on the other hand, only one member was told this twice. If anything, this might have made it more likely that in the decentralized groups the issue of information distribution would be breached and elaborated on during discussion (Stasser & Titus, 1985), which presumably would render information elaboration more likely (van Ginkel & van Knippenberg, 2008, 2009). To the extent that such an influence would obtain, it would make it harder rather than easier to find the hypothesized catalyst effect, making the present study a rather conservative test of our claim.

Our study focuses on TMS centralization as one important dimension of TMS structure. Yet, this is not to mean that this is the only dimension of interest. For instance, metaknowledge *sharedness*, i.e. the proportion of metaknowledge that members hold in common, assumed as a given in prior conceptualizations of TMSs, is another dimension on which teams can vary. In our study, we held sharedness constant in order to isolate the effects of metaknowledge centralization unconfounded with other factors. However, sharedness of cognitions could be an important moderator of the effects of team cognition (van Knippenberg et al., 2013).

We also held the average level of metaknowledge constant in order to compare the pure effects of metaknowledge distribution. While this is an important first step in the investigation of non-uniform metaknowledge distributions, future research might examine the average level as a possible boundary condition for the effect of TMS centralization. As we argue above, the advantage of centralization is driven by the central member having an above-average level of metaknowledge and, hence, a higher level of metaknowledge than any member of a decentralized team with a comparable average metaknowledge. Consequently, our expectation is that metaknowledge centralization will be most impactful at intermediate team average levels of metaknowledge. At very low levels the total amount of available metaknowledge might be so low that even complete centralization would not result in a sizeable behavioral impact on the central member. At very high levels, on the other hand, the central member's advantage above the already high team average would only be marginal.

We limited this study to the investigation of TMS structure effects on the team level under cooperative conditions. But, clearly, non-uniform metaknowledge distributions open the stage for future exploration on many interesting questions with regard to cross-level interactions. A central position in a team with a centralized TMS makes individuals occupying it critical for team performance as the potential for exploiting the benefits of possessing transactive memory resides almost exclusively with them (see Huber & Lewis, 2010 for a similar argument on cognitive centrality with regard to cross-understanding). Thus, individual factors that influence the central members' communication and information processing, e.g. personality characteristics such as extraversion, their cognitive ability or their individual social or epistemic motivation (De Dreu, Nijstad, & van Knippenberg, 2008) may become predictive for the performance of the whole team. Furthermore, it is important to investigate the role of goals and incentives. Team tasks may hold competitive elements (Wittenbaum, Hollingshead, & Botero, 2004), and this may incentivize strategic or even manipulative use of information (Steinel, Utz, & Koning, 2010; Toma & Butera, 2009). A metaknowledge advantage relative to the team provides opportunity to do so and members may try to hoard metaknowledge in order to keep this advantage.

The overlap of the position in the TMS structure with other roles in the team presents a further interesting avenue for future research. For instance, it is likely that a central position in the TMS structure and a formal leadership role often co-occur. However, there are scenarios in which this may not be the case – for example when a leadership role is absent, when a leader lacks skill or the intention to develop metaknowledge or when other team members are more tenured in the team than a freshly appointed leader. In a recent paper, Soda and Zaheer (2012) showed that the extent to which an individual's formal authority relationships overlap with his or her informal advice relationships impacts his or her productivity. It may well be that extent to which the formal leadership role overlaps with de facto centrality in the TMS structure affects team processes and outcomes in a similar way.

Finally, our study investigated the effect of the TMS structure in very small teams. This was sufficient to show a catalyst effect, but there is ample reason to expect that this effect will be more accentuated in larger teams. As the number of members grows, the distribution of the task information becomes more complex and its integration requires more coordination – while at the same time the team size holds back communication processes needed to acquire metaknowledge about the team (Palazzolo, Serb, She, Su, & Contractor, 2006). Hence, having at least one member who has a clear overview over the available information and can direct communication in the right direction becomes even more valuable. Future work could further explore this relationship as well as other boundary conditions to generalize or qualify our findings.

Conclusion

TMSs allow teams to capitalize on the diversity of the knowledge held by their members by supporting coordination and integration of knowledge. This study extends the understanding of TMSs by shedding light on the structural component of the construct and relating it with characteristics of the task. Whereas the present analysis provides several specific insights and contributions to theory and practice, its main argument is simple: TMS structure matters. After being neglected in TMS theory for a long time, a closer look at TMS structure from a metaknowledge distribution perspective may prove rewarding and open up a multitude of new questions on multiple levels of analysis which will advance our understanding of team cognition and team work.

Appendix

A2.1. General Description of the Product Alternatives for Client "Teasies" (Softdrink Manufacturer)

"Electric Grape", a grape-flavored energy drink. Its target market is young adults. Teasies' formula is less sweet than competitors' energy drinks but gives the same energy kick.

"Acqua di Roma", an exclusive flavored mineral water with a simple formula and a big name. It is targeted at rather well-off, fashion-conscious adults.

"BioBerry", a berry-flavored lemonade made from all-organic ingredients. Its target market is quality-driven adults. "BioBerry" is a drink to enjoy and to make a "green" statement.

"Vitfit", a sports drink low on calories and with an extra portion of vitamins. It is targeted at the group of health-conscious adults.

"Teasies' Lemon Iced Tea", THE original iced tea in the characteristic small bottles. Its target market is kids and their parents wishing to give their children the same memories they love.

A2.2. Sample Information Set for "Acqua di Roma" as Occurring in Connected Distributions of Interdependent Task Information

The R&D department developed a very simple and cheap formula for Acqua di Roma: mineral water with a hint of fruit syrup. For 10 million bottles it only needs to process 25 000 liters of syrup.

The financial department expects to sell 50 million of bottles of Acqua di Roma over 2 years and to make 1.5 Euro profit per bottle.

There is a legal conflict about the formula for Acqua di Roma because it is very similar to another product. To start production, Teasies has to settle this conflict. This would cause additional legal costs of 5 million Euro on top of the forecast.

Because the contracts with the syrup suppliers are limited, Teasies' will only be able to source 100 000 liters of syrup for the production of Acqua di Roma in 2 years.

Market research shows that the target group likes Acqua di Roma more than Teasies' management thought. Sales could be even 25% higher than initially expected.

A2.3. Sample Information Set for "Production Processes" as Occurring in Disconnected Distributions of Interdependent Task Information

The production of Electric Grape is very easy and Teasies can use their existing plants for this.

The organic ingredients needed for the production of BioBerry are very expensive and raise the selling price. At 3 Euro per bottle, it will be the most expensive lemonade on the market.

A safety inspection in Teasies' old brewing plant has revealed some problems. If Teasies absolutely wants to stick to the traditional brewing method for Teasies' Lemon

Iced Tea, it has to reconstruct it which would cost additional 15 million Euro on top of the forecast.

Because the contracts with the syrup suppliers are limited, Teasies' will only be able to source 100 000 liter of syrup for the production of Acqua di Roma in 2 years.

Some production space that is suitable for Vitfit has unexpectedly freed up. This would save Teasies 10 million Euro of rent costs they had calculated for Vitfit's production.

Chapter 3 – Integrating Knowledge Across Group Boundaries: The Role of Boundary Spanners' Transactive Memory[5]

Introduction

Knowledge is the primary resource of many modern organizations (Grant, 1996b; Kogut & Zander, 1996). However, it is a resource that resides in and is distributed across the individuals who form an organization. Thus, as Grant (1996a, p. 380) notes, it is an organization's ability to integrate knowledge rather than the knowledge itself that constitutes the critical source of competitive advantage. A particular challenge to knowledge integration is the knowledge-based differentiation inherent in organizational structures, which are often designed such as to cluster people possessing related specialized knowledge into groups such as teams, departments, or organizational units. At the same time, when groups are faced with increasingly complex and interdependent tasks and act in dynamic and uncertain environments, they become increasingly dependent on knowledge residing in other groups (Choi, 2002; Haas, 2010; Joshi, Pandey, & Han, 2009; Tushman, 1977). In other words, *intergroup knowledge integration* is of critical importance for organizations operating in such conditions (Singh, 2008). We understand intergroup knowledge integration as a dyadic relation between two groups in which one group acquires, processes, and utilizes knowledge stemming from another group in their own work. Importantly, intergroup knowledge integration goes beyond mere transfer of information from one group to another, but also involves its dissemination, translation, and application to the receiving group's own problems (Bechky, 2003; Carlile, 2004; Tushman & Scanlan, 1981). Intergroup knowledge integration thus represents a form of effective resource exchange and utilization and is a core aspect of intergroup effectiveness (Richter, Scully, & West, 2005).

Among the most important vehicles for knowledge integration are social relationships and communication among individuals (Gardner, Gino, & Staats, 2012). For intergroup knowledge integration, it is communication that aids the transfer of knowledge across

[5] A version of this chapter is currently under review at the Academy of Management Journal (revise and resubmit, 1st round) and is co-authored with Daan van Knippenberg, Wendy P. van Ginkel, and Pursey P. M. A. R. Heugens.

group boundaries, or *informational boundary spanning*[6] (Ancona & Caldwell, 1992a; Tushman, 1977), that is of particular relevance. Prior research points to the value of informational boundary spanning for the individual boundary spanners and for groups (Balkundi & Harrison, 2006; Cross & Cummings, 2004; Hansen, 1999; Tortoriello & Krackhardt, 2010; Tsai, 2001). The main argument for its value is access to non-redundant knowledge – knowledge not yet available within the group (Allen & Cohen, 1969; Tushman & Scanlan, 1981). However, acquisition of such non-redundant knowledge by individual group members triggers a notable paradox long recognized in the group information processing literature: Although non-redundant information can be particularly valuable to a group, it is precisely sharing, integrating, and utilizing this form of information that groups typically struggle with (Mesmer-Magnus & DeChurch, 2009; Stasser & Titus, 1985). In other words, achieving intergroup knowledge integration is less straightforward than simply ensuring communication between groups. Rather, it requires a deeper understanding of what makes individual members' informational boundary spanning *effective* (in the sense that it contributes to intergroup knowledge integration) than the state of the science currently provides. Understanding this, in turn, allows addressing a central question in boundary spanning literature: *Who* is effective as boundary spanner and hence should be carrying out this important function (Marrone, 2010)?

In this paper, we address this question by integrating theories of group information processing and group cognition with boundary spanning research. In particular, we investigate the role of boundary spanners' positions in their groups' *transactive memory systems* (TMS, Wegner, 1986) on intergroup knowledge integration. A transactive memory system is a group's division of cognitive labor with regard to learning, retrieving, and processing information (Hollingshead, 2001). Generally, TMSs represent a critical source of an organization's capability for knowledge integration (Argote & Ren, 2012), but knowledge integration in groups also depends on the level of *metaknowledge* - knowledge of who knows what - of *individual* group members (Mell, van Knippenberg, & van Ginkel, 2014). Leveraging these insights on the role of individual members' cognition for

[6] While boundary spanning activities can also encompass the representation of the group to outsiders and coordinating task interdependencies and expectations with external parties (Ancona & Caldwell, 1992a), informational boundary spanning is of particular importance for knowledge integration and thus the focus of the present study. For the sake of readability, however, in the remainder of the paper we use "boundary spanning" to denote "informational boundary spanning".

knowledge utilization in groups, we consider the boundary spanners' level of metaknowledge about their group as an important feature of boundary spanning ties. We suggest that boundary spanning ties enacted by individuals with a high level of metaknowledge are particularly important for intergroup knowledge integration. We test our predictions in a network study of 457 engineering consultants nested in 22 interdependent business units of an organization.

Our study contributes to boundary spanning research by demonstrating and explaining systematic differences in the effectiveness of individual boundary spanning ties for intergroup knowledge integration. In doing so, we provide a complementary perspective to prior research on the relation between individual boundary spanning activities and group level outcomes, which has predominantly focused on the quantity of boundary spanning activity, thus treating boundary spanning ties as largely interchangeable (e.g., Ancona & Caldwell, 1992b; Choi, 2002; Faraj & Yan, 2009; Marrone, Tesluk, & Carson, 2007). By integrating the literatures on group information processing and boundary spanning, we furthermore provide insight into the interplay between interpersonal relations, group processes, and intergroup relations, thus bridging micro and meso perspectives in an effort to build a better understanding of how groups can collaborate more effectively.

Theoretical Background and Hypotheses

Broadly, knowledge integration can be understood as the combination of individuals' knowledge resources in ways that create value (Grant, 1996a, 1996b; Kogut & Zander, 1992). Intergroup knowledge integration, then, refers to the combination of knowledge resources held in different groups. More precisely, we understand it as a group's acquisition, processing, and utilization of knowledge stemming from another group. Thus, we build on the conceptualization of an organization as a network of interdependent groups, e.g. business units (Brass, Galaskiewicz, Greve, & Tsai, 2004; Ghoshal & Bartlett, 1990; Tsai, 2001, 2002), and we consider intergroup knowledge integration as a relation at the group level, that is a relation that does not "belong" to any single individual, but rather arises from group-level activities and processes (Hansen, 1999).

It is important to delineate intergroup knowledge integration from other intergroup relations often studied in this context such as knowledge sharing or transfer (Hansen, 1999, 2002; Tsai, 2001, 2002). While these refer to the acquisition of knowledge from other groups and thus to a necessary component of intergroup knowledge integration, the latter furthermore involves group-level elaboration or in-depth processing (van Knippenberg et al., 2004) of the acquired knowledge. That is, it involves its dissemination and discussion within the receiving group, its translation and recombination with knowledge held in the receiving group, and its application to the receiving group's work (Bechky, 2003; Carlile, 2004; Tushman & Scanlan, 1981).

Research on knowledge integration highlights the role of communication and collaboration processes between individuals (Gardner et al., 2012; Grant, 1996b). Intergroup knowledge integration in particular relies on social and collaboration ties between the groups (Frost & Zhou, 2005; Singh, 2008), and, more specifically, on informational boundary spanning ties. In accordance with prior research, we define *informational boundary spanning ties* as a subset of the knowledge exchange network of an organization, namely knowledge exchange relationships between individuals who are members of different groups (Tortoriello et al., 2011). Knowledge exchange is an important facet of advice networks (Cross et al., 2001; Cross & Sproull, 2004) and an individual's access to knowledge from other parts of the organization via such ties has been shown to benefit their performance, creativity, and innovativeness (e.g., Burt, 2004; Cross & Cummings, 2004; Tortoriello & Krackhardt, 2010).

Prior research thus points to an important role of boundary spanning ties in the process of combining knowledge and information from distinct parts of an organization and underscores the role of interpersonal ties in the emergence of intergroup ties (Brass et al., 2004; Breiger, 1974). However, an *individual* member's access to knowledge resources external to his or her group does not necessarily mean that the *group* to which this individual belongs will be able to effectively utilize this knowledge. Individual members who acquire knowledge from other groups through boundary spanning ties acquire knowledge that is to a high extent non-redundant or unique with respect to their own group. Non-redundant knowledge can be highly valuable to a group – yet, research on group information processing consistently shows that it is precisely such non-redundant knowledge that has the lesser chance to be utilized by the group: All else being equal, shared rather than unique information is typically mentioned, discussed, and valued more (Brodbeck et al., 2007; Larson, Foster-Fishman, & Keys, 1994; Mesmer-Magnus & DeChurch, 2009; Stasser & Titus, 1985).

How can groups alleviate this effect? One possible strategy could be to increase the number of boundary spanning ties between two groups, this way reducing the uniqueness of knowledge acquired from a particular group in the knowledge-seeking group. Such an additive strategy would be consistent with recommendations to strive for a high number of boundary spanners in groups put forward in earlier research (Marrone et al., 2007; Tushman, 1977), but it entails a problematic trade-off: Creating and maintaining boundary-spanning ties is costly, taking up time and resources that could have otherwise been dedicated to a person’s primary task (Hansen, Podolny, & Pfeffer, 2001; McFadyen & Cannella, 2004), to maintaining relationships within the own group (Oh, Labianca, & Myung-Ho, 2006) and, more generally, to overseeing internal activities (Choi, 2002). Especially as the number of interdependent groups and, consequently, of potential boundary-spanning ties increases, such trade-offs can become sizeable.

An alternative strategy that takes such trade-offs into account can be to seek to establish a moderate rather than high number of boundary spanning ties. Such a strategy would be consistent with research arguing for the benefits of seeking a balance between internal and external activity (Choi, 2002; Gibson & Dibble, 2013; Oh et al., 2006), yet it shares a common implicit assumption with the former: Any strategy uniquely focusing on the optimal number of boundary spanning ties between groups – whether the optimum is conceived as high or as moderate – treats individual boundary spanning ties as largely interchangeable. In other words, it implies that as long as the *number* of boundary spanners is right, it does not matter much *who* the boundary spanners are that are connecting two groups. Yet, this is not consistent with the recognition that information utilization in groups at least in part depends on personal characteristics, motivations, or the position in intra-group networks of the individual members holding that information (Bonner, Sillito, & Baumann, 2007; De Dreu et al., 2008; Kameda et al., 1997; Mell et al., 2014). Thus, stepping aside from this approach, we focus on the question of *who* the individual members are whose boundary spanning ties are effective in the sense of contributing to intergroup knowledge integration.

As pointed out by Bresman (2013, p. 54), the ability of a seeking group to recognize the value of a source group's knowledge does not only depend on the seeking group's characteristics, but also on the source group's ability to assess and recognize the value of its knowledge for the seeking group. Consequently, in developing our hypotheses, we consider both sides of the knowledge integration relationship: the group seeking to integrate knowledge from another group (seeking group) and the group providing knowledge to another group (source group). Building on the group information processing perspective (Hinsz et al., 1997), we suggest that the effectiveness of a boundary spanning tie depends on the positions of the seeking and the source boundary spanners in the transactive memory systems of their respective groups.

Utilizing Distributed Knowledge: The Role of Transactive Memory

The challenging nature of knowledge integration in groups has motivated a rich literature on collective information processing in groups (Hinsz et al., 1997; Mesmer-Magnus & DeChurch, 2009; van Knippenberg et al., 2004). Group cognition, and in particular the notion of transactive memory systems (Wegner, 1986; Wegner et al., 1985), has been highlighted as an important antecedent of effective knowledge utilization and integration in groups (Ren & Argote, 2011; Stasser et al., 2000; Stewart & Stasser, 1995; van Ginkel & van Knippenberg, 2009).

According to TMS theory, groups develop a division of cognitive labor in their efforts to learn, retrieve, and share knowledge (Hollingshead, 2001). In a TMS, group members develop unique individual knowledge stocks alongside *transactive memory*, which is "memory influenced by the knowledge about the memory system of another person" (Lewis, 2004, p. 588). Simply put, it is knowledge about other members' knowledge - *metaknowledge*. Such metaknowledge forms the *TMS structure*. This structural component is complemented by a process component that consists of communication processes to coordinate and collectively utilize the knowledge held by the group members. In other words, metaknowledge provides the potential to access other members' knowledge (Nebus, 2006) and thus allows individual members to focus their cognitive resources on maintaining and extending their own individual expertise (Lewis, 2003). Groups with a strong TMS have been consistently shown to achieve desirable outcomes such as group performance, learning, and creativity (Austin, 2003; Gino et al., 2010; Liang et al., 1995; Zhang et al., 2007).

More recent work has furthermore shed light on the implications of *differences in the level of metaknowledge* among group members on knowledge integration processes in a group (Mell et al., 2014). Consistent with this focus is the recently suggested network perspective on TMSs (Lewis & Herndon, 2011; Peltokorpi, 2008). Using this view, the TMS structure can be considered as a socio-cognitive network in which individuals and their expertise are the units or nodes and metaknowledge about other individuals' expertise are ties that connect them (Borgatti & Cross, 2003). A group member's *centrality* in the metaknowledge network of his or her group is an important aspect of his or her position in the TMS structure of the group. In the context of TMS structure, centrality refers to a member's individual level of metaknowledge (Mell et al., 2014), that is their out-degree centrality in the metaknowledge network: Members who are metaknowledge-central have a good understanding about the expertise of many fellow group members. Earlier research has shown that such metaknowledge-central individuals can play a critical role for knowledge integration within their own group because they have the potential to spur knowledge coordination processes (Mell et al., 2014). We suggest that metaknowledge-central members can furthermore play an important role in enabling knowledge integration across group boundaries. To develop our hypotheses we consider the metaknowledge-centrality of the boundary spanners in the seeking group (knowledge seekers) and the metaknowledge-centrality of the boundary spanners in the source group (knowledge sources) as two characteristics of an informational boundary spanning tie that influence its effect on intergroup knowledge integration.

Boundary spanning ties in which metaknowledge-central individuals seek knowledge from another group are likely to be particularly valuable to the seeking group for several reasons. First, individuals with a high level of metaknowledge have been shown to develop the perception that discussion and integration of information are an essential aspect of their task (van Ginkel & van Knippenberg, 2009). Hence, members who are metaknowledge-central may be more likely to actively attempt to communicate and disseminate the information they obtain in the course of boundary spanning interactions within the group.

In addition, research relating metaknowledge and advice seeking (Borgatti & Cross, 2003; Cross & Cummings, 2004) suggests that individuals who are metaknowledge-central in their group are also likely to be central in their group's advice networks. In the course of such communication, they are in a better position to disseminate information received through boundary spanning connections (Tushman & Scanlan, 1981). It is important to note here, however, that while metaknowledge-centrality may be associated with centrality in the advice network, metaknowledge constitutes a potential for knowledge integration that goes beyond such realized communication. Whether or not a group member is central in the realized advice network, a high level of metaknowledge about his or her own group enables this member to view external knowledge not only in the context of their own expertise but also to recognize relations with areas of expertise of other members. This can make it more likely that metaknowledge-central individuals recognize gaps in their group's collective knowledge and thus are able to target their external information search accordingly, seeking information that is also relevant to other group members. Furthermore, it can make it easier to selectively direct incoming information the specific group members who need it most and are most likely to utilize it (Aral & van Alstyne, 2011), either by directly sharing the information or by referring a fellow group member to a member of a different group who may have useful knowledge.

In sum, we argue that informational boundary spanning ties positively contribute to knowledge integration between two groups when such ties originate from metaknowledge-central knowledge seekers, i.e. knowledge seekers with a high level of metaknowledge. Hence, as the number of such ties between two groups increases, we expect a higher likelihood of intergroup knowledge integration between these groups. Conversely, when *metaknowledge-peripheral* members, i.e. members with a lower level of metaknowledge, engage in boundary spanning knowledge seeking, we do not expect a further increase in intergroup knowledge integration beyond what is provided by the former. Consequently,

> ***Hypothesis 1:*** *A seeking group will be more likely to integrate knowledge from a source group the more informational boundary-spanning ties originating from metaknowledge-central knowledge seekers reach from the seeking group to the source group.*

Boundary spanners' metaknowledge-centrality is not only relevant when considering the seeking group, but also when considering the source group. Within a group, members typically have some knowledge that is shared among most members and, in addition, specialized knowledge that is unique to them. For instance, while in a group of construction engineers all members may have broad knowledge on physical laws and the structural performance of different materials and geometries, specialized knowledge about earthquake engineering might only be held by one expert member. A purely additive strategy as discussed above would suggest that, in order to increase the chance to obtain such unique information from another group, the seeking group may have to maintain ties to many different members of the providing group. TMS theory, on the other hand, holds that any member may be in the position to provide access to such unique information as long as this member has a high level of metaknowledge.

Sources who have a high level of metaknowledge – a good understanding of how expertise is distributed in their own group – are better able to assess whether the knowledge needs of a seeker are best served by their own or other group members' expertise. Where their own expertise makes them the best-suited source for a seeker, prior research suggests that the heightened sense of the uniqueness of their own expertise in the group enables them to present their unique expertise in a more confident manner. This, in turn, can lead to a higher acceptance and retention of the information they communicate (Stasser et al., 2000). Additionally, where metaknowledge makes them aware of overlapping knowledge with other members of their group, it makes it possible for them to corroborate the information they provide to seekers with referrals to other group members who can confirm it. Thus, they can indirectly invoke social validation of the communicated information, making it more persuasive. Together, these mechanisms are likely to increase the perceived validity of the knowledge provided by a metaknowledge-central source and, consequently, its retention, dissemination, and utilization by the seeker.

On the other hand, where other group members are better suited to provide a seeker with relevant knowledge, a metaknowledge-central individual is more likely to recognize it and better able to redirect the seeker's search towards those members than an individual with a low level of metaknowledge. A person seeking knowledge from another group will thus be more likely to find and acquire relevant knowledge and to do so in a more efficient manner when he or she approaches a person who is central rather than peripheral in that group's TMS structure. Picking the "right" knowledge source, in turn, frees the seeker's time for task work, for internal dissemination of the acquired knowledge, and for the integration of the acquired knowledge in his or her work that can result in outcomes that other group members can see, learn from, or utilize.

We thus argue that informational boundary spanning ties positively contribute to knowledge integration between two groups when such ties lead to metaknowledge-central knowledge sources. A higher number of such ties between two groups should result in the acquisition and integration of more relevant knowledge from the source group in the seeking group's work. On the other hand, increasing the number of ties that lead to metaknowledge-peripheral sources will likely not benefit intergroup knowledge integration beyond what is provided by the former. Hence:

> ***Hypothesis 2:*** *A seeking group will be more likely to integrate knowledge from a source group the more informational boundary-spanning ties leading to metaknowledge-central knowledge sources reach from the seeking group to the source group.*

In sum, we have put forward two hypotheses that link individual informational boundary spanning ties and intergroup knowledge integration. We characterize boundary spanning ties between any two groups according to the knowledge seeker's and knowledge source's position in the TMS structures of their respective groups and suggest that metaknowledge-centrality of the boundary spanners critically affects the effectiveness with which their boundary spanning ties contribute to the intergroup knowledge integration.

Methods

Setting

The setting for our study was a multi-unit engineering company in the Netherlands providing consultancy and designs for engineering projects across various disciplines such as water, construction, and environmental engineering. Engineering projects are highly knowledge-intensive activities and typically require an interdisciplinary approach, calling for the integration of knowledge from diverse fields of expertise. For example, a large-scale project like the modernization of a train station may require expertise in construction engineering, civil engineering, traffic management, knowledge on risk management and safety, expertise in project and process management as well as legal expertise to name just a few of the knowledge fields involved. Furthermore, projects such as these typically have a high degree of idiosyncrasy, requiring unique compilations of knowledge for most new projects. However, complementary knowledge is often dispersed across teams and units specialized in particular areas of expertise. Thus, knowledge exchange and integration across intra-organizational boundaries are critical for the effectiveness and success of such companies (Hansen, 1999; Tsai, 2001)

The company selected for our study consists of ca. 1000 employees and is organized into 26 business units, each of which focuses on a particular area of expertise and client base. These units are relatively autonomous, responsible for their own project acquisition, staffing, and execution. While each unit is furthermore subdivided into a number of smaller work groups that specialize on particular sets of activities, it is the business units that are considered as the primary groups comprising the organization by the members of the organization themselves. We therefore defined the business units as our units of analysis at the group level.

Due to the multidisciplinary nature of the majority of the projects, each unit depends on close collaboration with other units. Such collaboration occurs both formally through staffing project teams with experts from various units and informally through exchanging knowledge and advice across unit boundaries. These informal boundary spanning knowledge exchange relationships are of particular importance for the organization, often forming the base for as well as complementing formalized collaboration.

Data Collection and Sample

After negotiating access to the organization, we conducted a set of initial interviews of about an hour with 12 members of the organization (one director, five unit leaders, four employees in leading functions and two junior employees). The aim of these interviews was to gain a better understanding of the organization, to identify the relevant group and network boundaries, and to adapt our survey instruments to the specific setting.

The interviews confirmed that the business units were the most appropriate units of analysis on the group level. We limited our sample to the relations among the 22 business units primarily located in the Netherlands and constituting the core business, excluding four units located in other parts of the world. On the group-dyadic level, this resulted in a sample of $N_d = 22*(22-1) = 462$ directed dyads.

On the individual level, we defined the boundary of the network to be studied as all employees in primary functions, i.e. who are engaged in project work, project management, and work group management, excluding administrative and support functions. In total, our sample thus comprised 645 employees nested in 22 interdependent business units. Each unit contained between 20 and 50 individuals.

We then collected data capturing the knowledge exchange network among the individual employees, the metaknowledge network within the business units, and the inter-unit knowledge integration network using an online survey. We sent invitations and reminders to participate in the survey via e-mail. Furthermore, the survey was announced on the organization's intranet news page and was mentioned in group meetings by the unit leaders. In total, 457 respondents completed the survey, resulting in an overall response rate of ca. 71 percent. As social network analysis techniques are sensitive to bias arising from missing data, an adequate response rate is critical. In a simulation study, Kossinets (2006) found that non-response rates of up to 30 percent yield tolerably accurate measures. Smith and Moody (2013) found similar results across simulation studies based on several networks and noted that larger networks (containing several hundred nodes as does ours) appear to be more robust to the effects of missing data than smaller networks. In view of these findings, we consider our response rate adequate. The respondents comprised all 22 unit leaders, 80 out of 92 work group leaders, and 355 out of 531 consultants.

On average, respondents were 36.44 years old (SD = 9.44) and had been in the company for 10.27 years (SD = 7.88). 85.12 percent of the respondents were male and the vast majority of the respondents held a college or university degree (96 percent). Archival information on the non-respondents was available about their gender and tenure and we found no differences between respondents and non-respondents.

Measures

In our analyses, we modeled inter-unit knowledge integration as a function of informational boundary spanning ties among individual unit members, characterizing these ties based on the metaknowledge-centrality of the boundary spanners involved in each tie. Furthermore, in our models, we controlled for a number of unit- and dyad-specific variables.

Inter-unit knowledge integration. In line with our definition of intergroup knowledge integration, the dependent variable in our study is the acquisition, processing, and utilization of knowledge stemming from one group in another group. We relied on the unit leaders as key informants to provide information on the extent to which their unit as a whole utilized knowledge from each other unit. Such a key informant approach is consistent with prior research on inter-unit knowledge exchange relationships (Hansen, 1999; Hansen & Løvås, 2004; Sosa, Gargiulo, & Rowles, in press) as well as with the role and responsibility of unit leaders to have this high-level overview which was emphasized by our interviewees. In creating the wording of the question, we built on our definition of inter-unit knowledge integration as presented earlier. Unit leaders were presented with a roster listing all business units of the organization and the following question: "Please indicate to what extent the following statement describes the working relationship of your unit as a whole with each of the other units: *In our unit, we often use knowledge provided by this unit. This means that we exchange knowledge with this unit, discuss the knowledge gained from this unit in our groups, and integrate it in our work, for example as a solution for a problem or as a new approach to some aspect of our work*." Responses were provided on a Likert scale ranging from 1 ("very inaccurate") to 6 ("very accurate"). As a unit can receive and integrate another unit's knowledge without the latter necessarily receiving and integrating knowledge from the former, we treated this as a directed network.

Individual informational boundary spanning. To capture individual boundary spanning ties, we first collected data on the complete knowledge exchange network within our studied population. For this, we used a name generator asking participants to name up to 12 colleagues they "have turned to for specialist knowledge or information in the past 3 months". Respondents were told that they could name individuals within their own unit as well as in other units. Given the large size of our network, a full roster approach which would facilitate recall was not practicable. However, we presented participants with an interactive scheme of the complete organization on the same page. This scheme allowed them to review the list of employees in any unit as they wished, thus assisting the free recall of ties.

We considered a knowledge seeking tie from individual *i* to individual *j* to be boundary spanning whenever *i* and *j* were members of different business units. Of the 3097 reported knowledge seeking ties, 1960 were boundary spanning ties. As our analyses required information on metaknowledge from both sender and receiver, we excluded ties where one of the parties was a non-respondent. Furthermore, we excluded ties involving unit leaders – i.e. our key informants on the dependent variable - thus minimizing same-source bias[7]. We thus retained 1482 informational boundary spanning ties for our analyses.

Metaknowledge centrality. The metaknowledge network within the business units was assessed via a sociometric approach based on Borgatti and Cross's procedure (2003), introducing the concept as "expertise awareness" to the respondents and asking a single question in combination with a roster containing all unit members. Our initial interviews revealed that the organizational scheme itself already provided basic information about a person's expertise, e.g., allowing to identify a person as belonging to the risk management group in the unit dealing with underground construction. A good understanding of a colleague's expertise, however, was considered to go beyond that and include a person's more specific knowledge and tasks performed in projects. Based on these insights, we adapted the question used by Borgatti and Cross to the context of the organization in the following way: "Expertise awareness in an organization means that you understand what specialist knowledge another person has, potentially over and above what is revealed by his or her position in the organizational scheme. For example, you might know what kinds of projects a person typically works on and what kind of knowledge he or she uses to contribute to these projects. This does not necessarily mean that you have the same knowledge or that you interact regularly, but just that you understand what the other person is knowledgeable or expert about. Please, mark those people about whom the following

7 As a robustness check, we repeated our analyses including boundary spanning ties involving unit leaders, arriving at identical conclusions.

statement is true for you: *I have a good understanding of this person's knowledge that goes beyond what is reflected in his or her position in the organizational scheme*."

We consider individuals to be central in their unit's TMS structure when they have metaknowledge about many other members. As maintained earlier, metaknowledge can be viewed as potential to directly access needed information or directly provide information known to be needed by others (Borgatti & Cross, 2003; Nebus, 2006). Therefore, we used out-degree centrality (Freeman, 1978) as the appropriate measure to capture this direct effect of the position in the metaknowledge network (Borgatti, 2005). For each respondent, we thus calculated metaknowledge out-degree centrality as the number of his or her outgoing ties within the corresponding unit's metaknowledge network, standardizing these individual indicators across units by dividing them by N-1 as suggested by Freeman (1978), N standing for the unit size. Consequently, this indicator is interpretable as the proportion of a person's fellow unit members about whose expertise this person has a good understanding. Across all respondents, metaknowledge-centrality was distributed around a mean of 0.46 with a standard deviation of 0.27 and a median of 0.46.

Metaknowledge density. Metaknowledge constitutes a relational resource for a group's general capability for knowledge integration (Gardner et al., 2012). Groups with a high average level of metaknowledge typically consider discussion and integration of knowledge to be an integral part of their task (van Ginkel & van Knippenberg, 2008) and engage in more information exchange and integration (Austin, 2003; Stasser et al., 2000). To control for such effects both on the seeking group's side and the source group's side, we include two covariate effects in our model denoting the metaknowledge density of the tie sender, i.e. seeking unit, and the tie receiver, i.e. source unit. Descriptive statistics for this and the remaining control variables can be found in Table 1.

Unit size. Larger units may have more resources, potentially more diverse knowledge and a higher visibility within the organization than smaller units. At the same time, group size increases the difficulty of knowledge coordination within the group (Palazzolo et al., 2006). To control for potential effects of unit size, we include two covariate effects in our model denoting the size of the seeking unit and the size of the source unit.

Inter-unit deliveries. While informal communication ties are a critical vehicle for intergroup knowledge integration, prior research also points to the role of formal collaboration or “co-practice” (Frost & Zhou, 2005) for knowledge integration between units. Such co-practice between two units refers to formally bounded activities in which members from both units are involved. In the present organization, formal collaboration can be operationalized as the co-staffing of projects. While each project is formally nested in one business unit, it is possible and common that a part of the project members are hired from other units and are then internally paid for their work hours or “deliveries”. The flow of such deliveries between the units constitutes a fairly accurate representation of formal collaboration between units and likely affects intergroup knowledge integration in two ways. On the one hand, when members from the source unit work in the seeking unit’s projects (i.e. seeking unit receives deliveries from source unit), this creates a direct vehicle for the seeking unit to integrate knowledge from the source unit. On the other hand, when members from the seeking unit work in the source unit’s projects (i.e. seeking unit sends deliveries to source unit) this also provides an opportunity for the seeking unit to learn from the source unit. Thus inter-unit deliveries in both directions likely contribute to the rate at which one unit integrates knowledge from another unit. The organization provided information on the sum of such deliveries, expressed in euro, between each pair of units in the calendar year preceding the data collection. Using this data, we controlled for formal collaboration between pairs of units operationalized as the amount of sent and of received deliveries in 100000s euro.

Shared sector assignment. Finally, prior research on relative absorptive capacity, i.e. the ability of a firm to “value, assimilate, and apply new knowledge from a learning alliance partner” (Lane & Lubatkin, 1998, p. 462) suggests that inter-organizational learning is facilitated by similarity of the knowledge bases, organizational structures, and typical problems and projects between the knowledge seeking and knowledge providing organizations. While units within an organization arguably are more similar to each other than different organizations are among each other, also within organizations the extent to which units focus on similar kinds of strategic assets such as technological expertise, market knowledge, or customer bases has been shown to affect inter-unit linkages (Tsai, 2000, 2002). In the organization studied in this paper, such similarity was indicated by a shared assignment to one of six business sectors. In our model, we therefore control for such relatedness by including a dyadic covariate denoting whether each pair of units was assigned to the same sector.

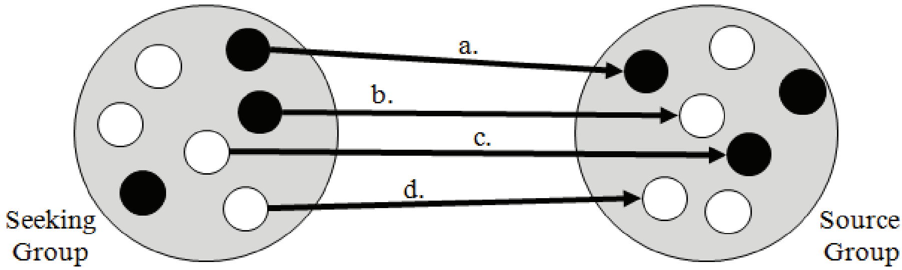
Analytical Approach

Tie decomposition. Our hypotheses hold that knowledge integration between two units depends on the number of ties between individual members of these units to the extent that the individuals forming these ties are metaknowledge-central in their own units. In order to test these hypotheses, we used a decomposition approach as applied by Tortoriello and Krackhardt (2010). That is, we partitioned the 1482 boundary spanning ties into mutually exclusive and exhaustive categories based on the knowledge seekers' and knowledge sources' centrality in the TMS structure of their own units. In this procedure, we considered individuals who had a metaknowledge centrality score higher than the median (0.46) across all respondents as metaknowledge-central. Individuals with a metaknowledge centrality score equal to or below the median were considered as metaknowledge-peripheral. Figure 4 clarifies the decomposition.

We then modeled intergroup knowledge integration between any two units as a function of the number of ties of each category between these units, controlling for the variables described above and endogenous network effects described below. Using this approach we could determine the effects of each additional boundary spanning tie involving a metaknowledge-central boundary spanner as a knowledge seeker or as a knowledge source on intergroup knowledge integration, thus testing the hypotheses we posed. In order to test the first hypothesis, we estimated the effect of the number of boundary spanning ties sent by metaknowledge-central seekers (ties a and b in Figure 1), controlling for ties sent by metaknowledge-peripheral seekers (ties c and d in Figure 1). To test the second hypothesis, we estimated the effect of the number of boundary spanning ties sent to metaknowledge-central sources (ties a and c in Figure 1), controlling for ties sent to metaknowledge-peripheral sources (ties b and d in Figure 1).[8]

[8] To check the robustness of our analyses to the choice of the cut-off, we ran two additional versions of the model, using the tertiles as alternative cut-off values. In one version, we defined individuals with a score of higher than 0.32 (first tertile) as metaknowledge-central and the remaining as metaknowledge-peripheral. In the second version we defined individuals with a score of higher than 0.58 (second tertile) as metaknowledge-central and the remaining as metaknowledge-peripheral. Both alternative models yielded the same conclusions as the model using the median split.

Figure 4. Decomposition of Boundary Spanning Knowledge Exchange Ties Based on Metaknowledge Centrality of the Boundary Spanners



Note. Nodes (circles) represent group members. Metaknowledge-central members are indicated with a black dot, metaknowledge-peripheral members with a white dot. A solid arrow from one node to another node indicates that the former node seeks knowledge from the latter.

Exponential Random Graph Models. Intergroup knowledge integration in our conceptualization represents a dyadic relation in the inter-unit network of an organization. Relations in a social network are inherently interdependent. For instance, units may prefer to establish links to units that other units have also chosen to integrate knowledge from (popularity). Or a focal unit may be more likely to establish a relationship of knowledge integration with another unit if it shares other knowledge integration partners with this unit (closure). As social network data thus violates the assumption of observational independence, appropriate statistical methods need to take interdependence into account (Snijders, 2011). Exponential random graph models (Lusher, Koskinen, & Robins, 2013; Robins, Snijders, Wang, Handcock, & Pattison, 2007) constitute a class of models that account for interdependence by explicitly modeling endogenous network effects and have been increasingly applied to the study of organizational social networks (Caimo & Lomi, in press; Ellwardt, Labianca, & Wittek, 2012; Lomi, Lusher, Pattison, & Robins, 2014; Lomi & Pallotti, 2012; Pauksztat, Steglich, & Wittek, 2011; Sosa et al., in press).

ERGMs model the probability that a tie between two actors occurs as a function of local network configurations which represent different claims about how network ties form. Such configurations can be purely structural, e.g. the presence of a tie from node A to node B may affect the probability of a tie from node C to node B (popularity). They can involve actor attributes, e.g., a particular characteristic of a node may affect the probability of ties being sent to this node. They can also involve dyadic covariates, e.g. the similarity of node A and node B on a characteristic may affect the probability of a tie between these nodes. An ERGM simultaneously tests the effects of all configurations included in its specification. ERMGs thus provide certain advantages over other common approaches to address non-independence of dyads. While introducing fixed or random effects for the actors (Reagans & McEvily, 2003; Tortoriello et al., 2011) can address the clustering of standard errors associated with the multiple observation of the same nodes, it ignores the larger structure in which dyads are embedded. Permutation-based techniques such as multiple regression quadratic assignment procedures (Dekker, Krackhardt, & Snijders, 2007; Krackhardt, 1988) control for network structure, yet they treat structure as “nuisance rather than substance” (Snijders, 2011, p. 134) and refrain from modeling endogenous network processes. However, modeling the effects of actor or tie covariates while ignoring endogenous network processes may result in theoretically inappropriate models (N. S. Contractor, Wasserman, & Faust, 2006) and biased conclusions (Lomi et al., 2014). By explicitly modeling endogenous processes, a correctly specified ERGM thus allows a robust test of the main hypotheses while at the same time accurately characterizing the network structure in which the dyads are embedded.

In the process of estimating an ERGM, we estimated a parameter for each specified configuration. A positive parameter indicates that, conditional on all other effects in the model, the configuration in question is observed more often than expected by chance; a negative parameter indicates the reverse. Parameters are estimated using Markov chain Monte Carlo maximum likelihood estimation (Robins, Snijders, et al., 2007). For our analysis we used the *ergm* package implemented in the *statnet* suite for R (Hunter, Handcock, Butts, Goodreau, & Morris, 2008).

As noted earlier, our dependent variable consists of the relations in the inter-unit knowledge integration network. As ERGMs require a binary matrix, we had to dichotomize this variable, initially measured on a six-point Likert scale. We chose the midpoint of the scale as our cut-off value, defining a tie from unit A to unit B as present if the unit leader of unit A indicated a value higher than three in response to this question and absent otherwise[9].

Parameters Modeling Endogenous Network Effects. Based on the recommendations by Lusher and associates (2013) as well as on typical structures found in networks of collaboration among groups (P. Wang, Robins, Pattison, & Lazega, 2013), in our analysis we included parameters that model tendencies for reciprocation of ties, heterogeneity among units with regard to sending and receiving ties, and tendencies towards closure. We briefly describe each of the included parameters.

The *arc* parameter is comparable to an intercept in standard regression. It denotes the baseline propensity of units to form ties to other units after accounting for all other effects in the model. *Reciprocity* captures the tendency of units to integrate knowledge from units that integrate knowledge from them.

Units are likely to not be homogeneous with regard to the number of units they integrate knowledge from (*activity*) and the number of units that choose to integrate knowledge from them (*popularity*). These differences may arise from network processes such as a preference of actors to send ties to actors that have also been chosen by others. We therefore include parameters that model heterogeneity in activity (*activity spread*) and popularity (*popularity spread*) among the units – after accounting for the effects of all other covariates in the model. These effects are captured by geometrically weighted in- and out-degree statistics in our model, whereby positive values indicate homogeneity and negative values indicate heterogeneity in degrees (Hunter, 2007).

Finally, we include three parameters that model tendencies for closure in social networks. Specifically, we include a parameter for *transitive closure*, that is, a tendency of a seeking unit A to integrate knowledge from a source unit B when other units that serve as sources to unit A also integrate knowledge from unit B. Such an effect can be, for instance, the effect of referral processes. As a counterpart to transitive closure, we furthermore include a parameter for *multiple connectivity*, representing the presence of open paths or

[9] The midpoint of the scale is a theoretically appropriate cut-off point given that values between one and three correspond to responses ranging from "very inaccurate" to "somewhat inaccurate" to the question regarding knowledge integration. 68% of the responses fell into these categories and were defined as "no intergroup knowledge integration". Values between four and six, on the other hand, correspond to responses ranging from "somewhat accurate" to "very accurate". 32% of the responses fell into these categories and were defined as "present intergroup knowledge integration".

structural holes between units. This second parameter represents an important control and sharpens the interpretation of the transitive closure parameter. In a network governed by a tendency for transitive closure, the first parameter is typically positive and the second negative (Robins, Pattison, & Wang, 2009). Third, we include a parameter for *cyclic closure*, which is a situation in which unit A serves as a knowledge source for unit B, who serves as a source for unit C, who in turn serves a source for unit A. The presence of such cyclic triads is often interpreted as an indication of a network governed by a logic of generalized exchange (Bearman, 1997; Lazega & Pattison, 1999), that is a logic of indirect reciprocity wherein the giver of a benefit “eventually receives some benefit in return, but from a different actor” (Molm, Collett, & Schaefer, 2007, p. 208). In other words, a tendency for cyclic triads would be consistent with the presence of “diffuse cooperation” among the units (Lomi & Pallotti, 2013). A tendency against such cyclic triads, on the other hand, could be interpreted as an indication of a local status hierarchy, in which a unit would be unlikely to choose the “advisees” of its “advisees” as its own “advisors” or sources (Agneessens & Wittek, 2012; Lusher et al., 2013).

Results

Table 4 shows descriptive statistics for the network of individual knowledge exchange and for the inter-unit knowledge integration. Table 5 summarizes the results of our analyses. All presented models have successfully converged and exhibit acceptable goodness of fit (see Appendix for goodness of fit analyses). The coefficients in the model can be interpreted as the change in the log-odds of a tie due to the variable in question, conditional on all other effects in the model.

The control variables show fairly consistent effects across the models. The negative arc parameter indicates that inter-unit knowledge integration is unlikely to appear randomly outside of the specified, more complex configurations. Knowledge integration relationships among units tend to be reciprocated and, furthermore, exhibit transitive closure as denoted by the positive transitivity and the negative multiple connectivity parameters. Finally, as expected, being assigned to the same sector and being engaged in formal collaboration in the shape of sending and receiving work deliveries contributes to intergroup knowledge integration. Given these background effects, we now turn to our main hypotheses tests.

In model 1, we decomposed the informational boundary spanning ties into two categories based on the metaknowledge-centrality of the knowledge *seeker*. Consistent with our predictions, ties sent by metaknowledge-central knowledge seekers had a positive effect on inter-unit knowledge integration: Each additional individual knowledge-seeking tie sent by a metaknowledge-central member of one unit to any member of another unit increased the odds of a knowledge integration relation between these two units by 16.18 percent (exp(0.15) = 1.1618). Ties sent by metaknowledge-peripheral seekers, on the other hand, did not have a significant effect on inter-unit knowledge integration. In model 2, we decomposed the informational boundary spanning ties based on the metaknowledge-centrality of the knowledge *source*. As predicted, ties sent to metaknowledge-central knowledge sources had a positive effect on inter-unit knowledge integration while ties sent to metaknowledge-peripheral sources did not. More specifically, each additional individual knowledge-seeking tie sent by any member of one unit to a metaknowledge-central member of another unit increased the odds of a knowledge integration relation between these two units by 19.72 percent (exp(0.18) = 1.1972). These results support our hypotheses 1 and 2.[10]

[10] As a further control, we ran additional versions of the models including the boundary spanners' average degree centrality in their units' advice networks as a control variable. Inclusion of these controls did not affect the results and conclusions concerning our main variables and hypotheses tests. However, as noted in footnote 3, variables denoting average characteristics of boundary spanners are ambiguous whenever there are no ties and hence no boundary spanners between two units. We therefore report the models without these variables as our main results.

Table 4. Descriptive Statistics and Correlations for the Inter-Unit Knowledge Integration Network

Network Statistics	Statistic								
Density	0.32								
Average degree	13.36								
Degree variance (indegree)	6.70								
Degree variance (outdegree)	14.70								
Reciprocity	0.69								
Average geodesic distance	1.98								
Dyadic variables	*M*	*SD*	D1	D2	D3	D4	D5	D6	D7
D1. Intergroup knowledge integration (raw)	2.60	1.70							
D2. Number MK-central to MK-central ties	1.09	2.06	0.35**						
D3. Number MK-central to MK-peripheral ties	0.68	1.26	0.28**	0.46**					
D4. Number MK-peripheral to MK-central ties	0.75	1.56	0.34**	0.44**	0.25**				
D5. Number MK-peripheral to MK-peripheral ties	0.54	1.07	0.29**	0.23**	0.39**	0.40**			
D6. Inter-unit deliveries (sent)	1.53	4.49	0.31**	0.21**	0.31**	0.32**	0.27**		
D7. Inter-unit deliveries (received)	1.53	4.49	0.37**	0.22**	0.27**	0.41**	0.48**	0.44**	
D8. Same sector assignment (1 = same sector)	0.18	-	0.36**	0.24**	0.21**	0.29**	0.26**	0.33**	0.33**
Unit attributes	*M*	*SD*	U1						
U1. Size	29.31	7.66							
U2. Metaknowledge density	0.47	0.10	-.49*						

Notes. MK: Metaknowledge. Correlations among the dyadic variables are permutation-based QAP correlations.
* $p < 0.05$; ** $p < 0.01$

Table 5. Maximum Likelihood Estimates of ERGMs for Inter-Unit Knowledge Integration Ties

	Model 1	Model 2	Model 3
Network effects [statnet terms]			
Arc [edge]	-4.99 (1.63)**	-4.88 (1.66)**	-4.58 (1.66)**
Reciprocity [mutual]	0.84 (0.41)*	0.82 (0.4)*	0.80 (0.42) $^{+}$
Popularity spread [gwidegree, α=.25]	7.58 (9.88)	9.18 (10.33)	8.70 (10.24)
Activity spread [gwodegree, α=.25]	0.26 (1.62)	0.04 (1.55)	0.08 (1.59)
Transitive closure [gwesp, α=.25]	0.98 (0.34)**	0.98 (0.33)**	0.96 (0.33)**
Multiple Connectivity [gwdsp, α=.25]	-0.32 (0.06)***	-0.33 (0.06)***	-0.32 (0.06)***
Cyclic Closure [ctriple]	-0.19 (0.11)	-0.18 (0.11)	-0.18 (0.12)
Control variables			
MK density of knowledge providing unit	2.35 (1.34) $^{+}$	1.70 (1.43)	1.66 (1.42)
MK density of knowledge seeking unit	0.59 (1.29)	1.01 (1.18)	0.50 (1.22)
Size of knowledge providing unit	0.03 (0.02)	0.03 (0.02)	0.03 (0.02)
Size of knowledge seeking unit	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)
Shared sector assignment	0.65 (0.29)*	0.60 (0.30)*	0.67 (0.3)*
Received inter-unit deliveries	0.24 (0.12)*	0.28 (0.13)*	0.28 (0.12)*
Sent inter-unit deliveries	0.23 (0.13) $^{+}$	0.23 (0.12) $^{+}$	0.23 (0.12) $^{+}$
Decomposed boundary spanning ties			
Ties from MK-central members (a & b)	0.15 (0.05)**		
Ties from MK-peripheral members (c & d)	0.05 (0.07)		
Ties to MK-central members (a & c)		0.18 (0.05)***	
Ties to MK-peripheral members (b & d)		0.00 (0.07)	
Ties from MK-central to MK-central members (a)			0.22 (0.08)**
Ties from MK-central to MK-peripheral members (b)			0.03 (0.11)
Ties from MK-peripheral to MK-central members (c)			0.11 (0.1)
Ties from MK-peripheral to MK-peripheral members (d)			-0.06 (0.13)

Notes. N_d = 462. MK: Metaknowledge. Standard errors are in parentheses. The *statnet* terms used to operationalize the network effects are in square brackets.
$^{+}p < 0.10$; * $p < 0.05$; ** $p < 0.01$

To further explore our results, we decomposed the boundary spanning ties based on the metaknowledge-centrality of the seeker and the source simultaneously. This decomposition resulted in the four categories as depicted in Figure 1: ties from metaknowledge-central to metaknowledge-central members, ties from metaknowledge-central to metaknowledge-peripheral members, ties from metaknowledge-peripheral to metaknowledge-central members, and ties from metaknowledge-peripheral to metaknowledge-peripheral members. First, we then ran four separate models, each including the controls and one of the categories of boundary spanning ties, ignoring the other three categories. Considered separately, central-to-central ties ($\theta = 0.26$, $SE = 0.07$, $p < .001$), central-to-peripheral ties ($\theta = 0.19$, $SE = 0.09$, $p < .05$), and peripheral-to-central ties ($\theta = 0.22$, $SE = 0.09$, $p < .5$) contributed to intergroup knowledge integration, while peripheral-to-peripheral ties did not have a significant effect ($\theta = 0.05$, $SE = 0.11$, $p = .64$). Finally, we included all four tie categories simultaneously (model 3 in Table 1). In this model, only informational boundary spanning ties connecting two metaknowledge-central individuals had a positive effect on intergroup knowledge integration: Each additional central-to-central tie between two units increased the odds of a intergroup knowledge integration relation between these units by 24.61 percent (exp(0.22) = 1.2461). Ties involving metaknowledge-peripheral individuals, on the other hand, did not significantly contribute to intergroup knowledge integration over and above central-to-central ties. These results further sharpen and refine the conclusions suggested by models 1 and 2: In order for a boundary spanning tie have consequences for intergroup knowledge integration, it appears necessary that at least one of the boundary spanners enacting this tie is metaknowledge-central in their group. Ties connecting metaknowledge-central individuals on *both* sides furthermore emerge as key for intergroup knowledge integration. Once their effect is accounted for, boundary spanning ties involving metaknowledge-peripheral boundary spanners seem to provide little additional benefit.

Metaknowledge vs. Formal Role

A possible alternative explanation for the effects we found is that rather than differences in metaknowledge centrality it may be differences in the formal role and accompanying status that account for the differences in the effect of individual ties on intergroup ties. Previous research has emphasized the particular role of vertical bridging relationships to leaders of other groups for group effectiveness (Mehra, Dixon, Brass, & Robertson, 2006; Oh et al., 2006) as well as the potentially particular role of the leader in managing their group's external relations (Marrone, 2010; Richter, West, van Dick, & Dawson, 2006). Furthermore, it is conceivable that individuals who occupy a formal leadership role are more central in the metaknowledge networks of their group by virtue of this role (Peterson & Kim, 2012) and that the role of metaknowledge is thus confounded with the role of formal status in our analyses. In order to explore this possibility, we conducted additional analyses.

An analysis of variance showed that the formal role (non-leader, work group leader, unit leader) indeed significantly affected respondents' metaknowledge-centrality ($F(2,454) = 16.36$, $p < 0.001$). A post-hoc test of all pairwise comparisons between groups using the Bonferroni correction furthermore showed that non-leaders ($M = 0.43$) were significantly lower in metaknowledge-centrality than work group leaders ($M = 0.56$, $p < 0.001$) or unit leaders ($M = 0.69$, $p < 0.001$). The difference between work group leaders and unit leaders was not significant ($p = 0.11$). Given these differences, we repeated our analyses only including boundary spanning ties between non-leaders in the calculation of our independent variables. If formal role rather than metaknowledge-centrality accounted for the differential effectiveness of boundary spanning ties, we should not find differences between the different types of ties after thus excluding all leaders. The pattern of results in this alternative analysis, however, closely corresponded to the pattern of results found in our main analysis: ties from metaknowledge-central to metaknowledge-central non-leaders contributed to intergroup knowledge integration ($\theta = 0.35$, $SE = 0.13$, $p < .01$), while ties involving metaknowledge-peripheral non-leaders did not have an effect beyond that of the central-to-central ties (central-to-peripheral: $\theta = 0.09$, $SE = 0.16$, *ns,* peripheral-to-central: $\theta = 0.12$, $SE = 0.14$, *ns,* and peripheral-to-peripheral: $\theta = -0.07$, $SE = 0.16$, *ns*).

Discussion

We found that metaknowledge-central individuals are of critical importance for achieving intergroup knowledge integration. The more informational boundary spanning ties between two groups existed that involved metaknowledge-central members on both sides, the more likely was intergroup knowledge integration between these groups.

Boundary spanning ties involving metaknowledge-peripheral members, on the other hand, did not carry additional benefits for intergroup knowledge integration when central-to-central ties were present. We furthermore showed that this effect of metaknowledge-centrality of the boundary spanners persisted after excluding ties among formal leaders, which lends further support to our conclusion that metaknowledge-centrality rather than formal role drives the observed relationships between informational boundary spanning ties and intergroup knowledge integration.

Theoretical Implications

Our findings have several implications for boundary spanning research and beyond. First, our findings question the assumption that boundary spanning ties are largely interchangeable with respect to their contribution to intergroup relations that is implicitly present in much of the earlier research. Rather, by demonstrating systematic differences in the effectiveness of informational boundary spanning ties, this study suggests that – at least where intergroup knowledge integration is an effectiveness criterion – certain boundary spanning ties deserve a stronger focus than others. While our study did not find any negative effects of ties involving metaknowledge-peripheral members on intergroup knowledge integration, the inherent trade-offs between boundary work, task work, and internal relational activities (Choi, 2002; Hansen et al., 2001; McFadyen & Cannella, 2004; Oh et al., 2006) suggest that investing in suboptimal boundary spanning may negatively affect other aspects of individual and group performance. The exact nature of these trade-offs, however, remains a subject for future research.

Our approach is distinct from the focus of much of prior research connecting boundary spanning activity and group outcomes on the optimal number of boundary spanning ties between groups or, more broadly, on the quantity of boundary spanning behavior of a group (Ancona & Caldwell, 1992b; Choi, 2002; Faraj & Yan, 2009; Marrone et al., 2007). By directing the attention towards differences in tie effectiveness driven by differences of the boundary spanners involved, our study contributes to developing a better understanding of how the characteristics of boundary spanners shape intergroup relations, thus addressing the question of *who* should be carrying out this important role (Marrone, 2010). Our results furthermore suggest that the answer to this question is broader and more complex than a choice between leaders or (also) members as implied by Marrone (2010).

While leaders may be more likely to occupy a central position in their groups' TMSs, even among non-leaders we observe the same pattern of boundary spanning effectiveness being dependent on individuals' metaknowledge-centrality. On the other hand, focusing on leader boundary spanners only, Richter and colleagues (2006) found that differences in leader boundary spanners' group and organizational identification predicted differences in intergroup effectiveness and conflict. Likely, future research will identify further characteristics of group members and leaders that may make them more or less effective in establishing and maintaining intergroup relations, e.g. individual differences in proactivity, self-monitoring, extraversion, or motivation. A possibly even more intriguing question for future research is whether those characteristics that make individuals more *likely* to adopt boundary spanning roles such as tenure, breadth of experience, and organizational identification (Ancona & Caldwell, 1990; de Vries, Walter, van der Vegt, & Essens, 2014; Lomi et al., 2014) also make them more *effective* in that role.

Second, our study emphasizes a group's dual role within a broader system of interdependent groups: While each group pursues its own goals and in the process of doing so engages in external activity to acquire necessary knowledge resources, at the same time each group is a potential source of knowledge resources to other groups. Although this notion is seemingly straightforward, research on groups' external activities tends to focus on the acquiring side only, investigating how groups accrue benefits from their external environment in order to increase their own performance (Ghoshal & Bartlett, 1990; Hansen, 1999; Reagans, Zuckerman, & McEvily, 2004; Tsai, 2001), with Bresman's (2013) discussion of source units' transmission capability being a notable exception. The present study shows that a group's internal characteristics such as its transactive memory system are not only relevant for their own knowledge processing but can furthermore benefit *other* groups who depend on its knowledge by facilitating access and integration. Understanding and emphasizing groups' dual roles as knowledge seekers and sources is particularly important in contexts in which interdependence among groups is high, for instance in multi-team systems, i.e., sets of teams who act interdependently in pursuit of a common goal (Mathieu, Marks, & Zaccaro, 2001).

Finally, our study also contributes to literature on TMSs by providing further evidence for the usefulness of taking the specific pattern rather than only the average level of metaknowledge into account when considering a group's TMS. While Mell and colleagues (2014) showed that the presence of a metaknowledge-central member can have positive implications for intra-group knowledge integration and performance, the present work shows that metaknowledge-central members can furthermore have implications for intergroup knowledge exchange and integration. Our findings are also relevant for nascent work on organizational-level transactive memory systems (Peltokorpi, 2008; Ren & Argote, 2011), which conceptualizes organizational-level TMSs as systems of networked groups who use each other as external cognitive aids (Peltokorpi, 2011), and can provide a first empirical basis for developing an understanding of what factors make an organizational TMS effective.

Managerial Implications

Knowledge integration across group boundaries is a critical activity for groups in knowledge-intensive organizations as well as for such organizations as a whole (Grant, 1996a; Hansen, 1999). Our study shows that in order to achieve a higher level of knowledge integration, it is important to consider group-internal knowledge coordination in the form of a group's transactive memory system and group-external knowledge coordination in the form of informational boundary spanning simultaneously. Metaknowledge critically affects the effectiveness of individuals serving as knowledge coordinators in organizational networks (Garner, 2006). Accordingly, our results suggest that where metaknowledge-centrality and boundary spanning communication coincide groups are in a better position to benefit from each other's knowledge.

Such an alignment can be achieved via two routes. The first route involves groups' identifying their internal knowledge coordinators and encouraging these particular members to engage in informational boundary spanning as knowledge seekers and knowledge sources. In order to encourage acting as boundary spanning knowledge seeker, they may, for instance, formulate boundary spanning as an explicit role of these members as suggested by Marrone et al.'s (2007) results. To encourage serving as a boundary spanning knowledge source, they may want to ensure that these members are known and visible to other groups who are dependent on their knowledge. This way, members of other groups will be able to direct their questions to those who can best provide access to the right knowledge or redirect them to the right sources. The second route involves identifying which members currently are engaged in boundary spanning communication and developing these members' metaknowledge in order to increase their effectiveness as intergroup liaisons. In other words, alignment between group-internal and group-external knowledge coordination can be achieved both by selection of internal coordinators into boundary spanning positions and by managing and developing existing boundary spanners' capacity for group-internal knowledge coordination. In addition, our results call upon organizations to invest in activities targeted at developing expertise recognition more broadly. Such activities are useful not only because they can improve internal group processes and the performance of the target group but also because increasing transactive memory and knowledge coordination within a group may have positive externalities for other groups interacting with it.

Limitations and Future Research

Despite its contributions, our study has several limitations that call for future research. First, the cross-sectional nature of our data collection does not allow establishing the causal direction of the found relationships. It is plausible that individual boundary spanning activity and group-level knowledge integration influence each other in a dynamic interplay over time: while individual boundary spanning contributes to intergroup knowledge integration, such intergroup ties can encourage further interpersonal boundary spanning communication in the future. Future research employing longitudinal designs will be useful in extending our understanding of these dynamic processes. However, even cross-sectional network research is taxing for respondents. Thus, researchers planning a longitudinal investigation may want to consider alternative methods of data collection in order to alleviate the burden on respondents. A promising way is the analysis of electronic communication such as the analysis of organizational e-mail networks (Aral & van Alstyne, 2011; Kleinbaum, Stuart, & Tushman, 2013), albeit e-mail networks can have somewhat different properties from reported advice networks (Quintane & Kleinbaum, 2011). Ultimately, the goal of establishing causal relationships requires experimental research. Here, paradigms developed in the experimental investigation of multi-team systems can be a useful stepping stone towards developing appropriate experimental designs (DeChurch & Marks, 2006; Marks, DeChurch, Mathieu, Panzer, & Alonso, 2005).

Second, while our study setting allowed for collecting unique data on a complete network of interdependent groups on multiple levels of analysis that is well suited to study our research question, it remains a case study within a single organization. Such a study design, albeit typical in research on intra-organizational networks, presents questions of generalizability and strongly relies upon replication and extension in future research.

Lastly, in the present study we focused on the consequences of the alignment of metaknowledge-centrality and boundary spanning activity for intergroup relations. However, we recognize that the suggestion that internal and external knowledge coordination may be most effective when carried out by the same persons may imply trade-offs for other group-internal processes or for the individuals finding themselves in these positions. Groups relying on the catalyzing role of metaknowledge-central members (Mell et al., 2014) might suffer when these members increasingly direct their time and attention to boundary spanning activities. The individuals in question might feel overloaded by the simultaneous demands from within and outside of the group (Marrone et al., 2007). In sum, more research is needed to further understand not only what characteristics make individuals effective as boundary spanners but also what factors at the individual, group, and network levels support or oppose them in carrying out this important role.

Conclusion

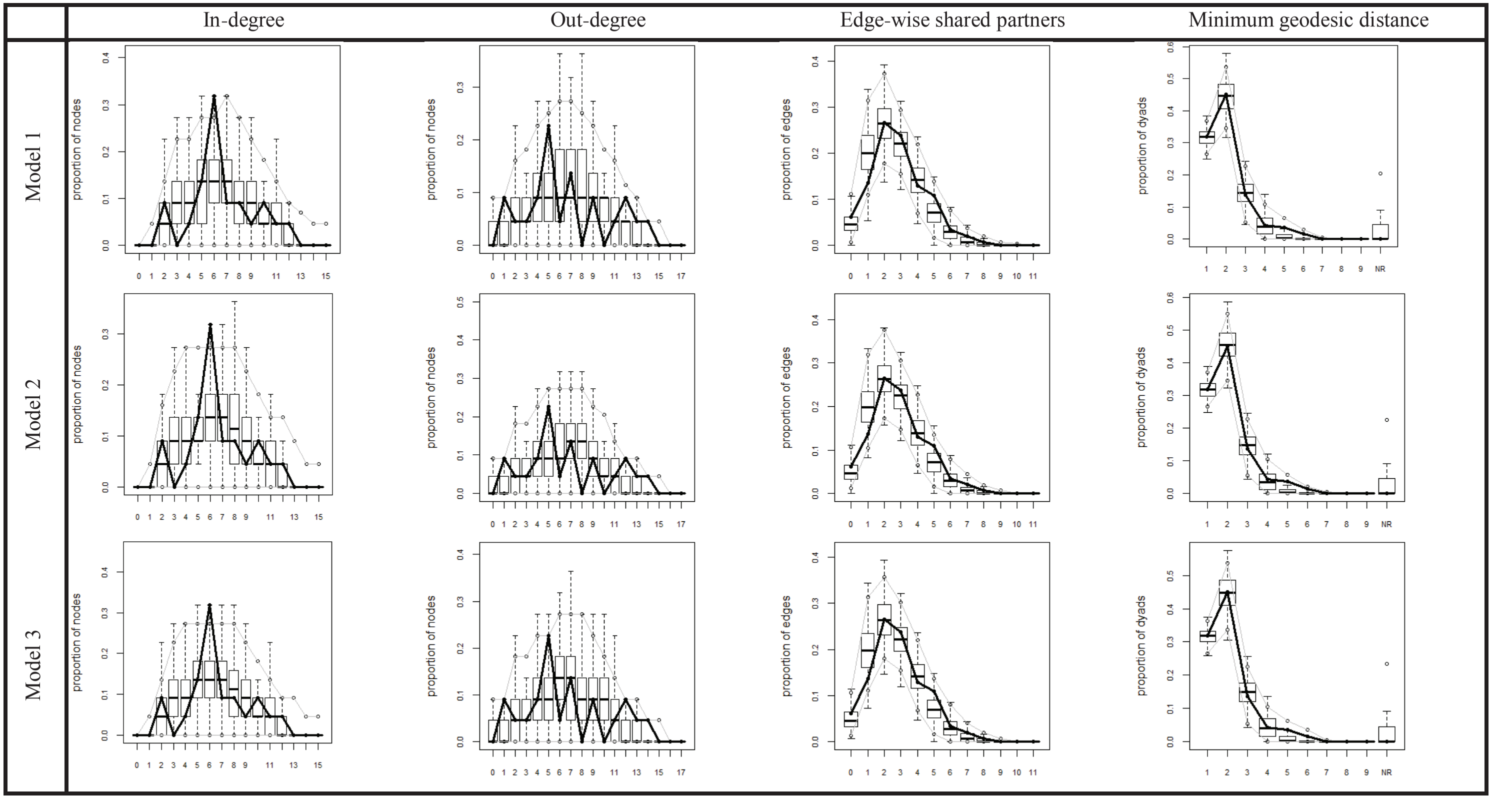
With this study, we advance our collective understanding of the antecedents of intergroup knowledge integration by integrating research on informational boundary spanning with theories of group information processing and group cognition. We find that metaknowledge-centrality of the boundary spanners is a critical variable affecting the extent to which an informational boundary spanning tie contributes to intergroup knowledge integration. The conclusion that some boundary spanning ties matter more for intergroup relations than others furthermore implies a call for future research adopting a multilevel perspective on organizational knowledge networks (Phelps, Heidl, & Wadhwa, 2012). The better we are able to understand the interplay between interpersonal ties, group processes, and intergroup relations, the closer we will get to developing an understanding of the multilevel nature of knowledge coordination in organizations.

Appendix

Goodness of Fit Analyses

To test goodness of fit for the three models presented in our results section, we followed the graphical procedure as laid out by Hunter, Goodreau and Handcock (2008). That is, for each of the models, we simulated a large number of networks (500) according to the fitted ERGM and compared these with the observed original network based on a number of network statistics. We followed Hunter et al.'s suggestions in the choice of the network statistics and considered the in- and out-degree distribution, the edgewise shared partner distribution, and the geodesic distance distribution. As laid out by the authors, this set of statistics captures the main features of a network with respect to degree distribution, centrality, and clustering and provides a good assessment of a model's fit. Figure 5 presents the results of the goodness of fit analyses. As can be seen in the results, all three models result in simulated networks that are very similar to the observed network, with the only outlier being a high proportion of nodes with in-degree of 6 in the observed network that the models slightly underestimate. Overall, these results suggest a good fit of the models.

Figure 5. Graphical Goodness of Fit Tests



Note. Simulation results for models 1-3. The observed statistics are indicated by the solid lines, the boxplots include the median and interquartile range. The light-gray lines indicate the range in which 95% of simulated observations fall.

Chapter 4 – Seeking Knowledge and Metaknowledge: The Role of Formal Hierarchy in Intraorganizational Advice Networks[11]

Introduction

In a powerful metaphor, Krackhardt and Hanson (1993, p. 104) described the formal organizational structure as the "skeleton of a company" and the informal social ties connecting its actors as its "central nervous system driving the collective thought processes, actions, and reactions of its business units". Despite the inherent interdependence of formal and informal aspects of organizational functioning, however, for the most part, scholarly investigation has treated them separately. As McEvily, Soda, and Tortoriello (2014) review, while the 1960s and early 1970s were characterized by a predominant focus on the formal organizational structures and mechanisms, neglecting informal and emergent processes, recent decades have seen an explosion of attention to "the company behind the chart" (Krackhardt & Hanson, 1993). This increased interest in informal social structures has yielded rich insights into their role in organizational processes and outcomes (Borgatti & Foster, 2003; Brass et al., 2004), albeit typically at the expense of treating formal organizational elements as not more than a source of "unobserved heterogeneity" to be controlled for (McEvily et al., 2014, p. 303).

However, considering the "nervous system" of an organization without taking into account its "skeleton" necessarily yields an incomplete understanding of organizational behavior. Informal relations in organizations do not exist in a vacuum. Rather, they are formed within a context that is shaped by the tasks, roles, relations, social foci, and geographical structures that are defined by formal structures and create constraints and opportunities for interaction. Developing a better understanding of how formal structures shape informal social structures among organizational members is critical to a better understanding of the joint role of formal and informal processes for organizational functioning (McEvily et al., 2014). Recent work has begun to examine the role of formal structure in the emergence of informal structure by considering the effects of formally mandated relations. For instance, formally defined intra-organizational units such as

[11] The computational tests of this research were performed on the Dutch National LISA cluster, and supported by the Dutch National Science Foundation (NWO).

project teams, business units, job roles, or assigned locations have been found to constrain informal communication across unit boundaries (Brennecke & Rank, in press; Caimo & Lomi, in press; Kleinbaum et al., 2013; Lomi et al., 2014). On the other hand, formally prescribed relationships such as vertical reporting and horizontal cooperation relations have been shown to encourage the formation of informal ties along these paths (Agneessens & Wittek, 2012; Caimo & Lomi, in press; Rank, Robins, & Pattison, 2009).

We contribute to this emerging literature by examining the role of formal hierarchy in the emergence of advice ties among employees. Hierarchical differentiation is a pervasive feature of organizations. Higher formal rank is typically associated with greater control over resources as well as with respect and deference from others (Magee & Galinsky, 2008). At the same time, hierarchical differentiation is a powerful coordination mechanism, inducing relatively uniform expectations about the skills, abilities, motivation, and appropriate behaviors of the individuals occupying different positions (Halevy, Chou, & Galinsky, 2011). Thus, although formal hierarchy does not directly mandate specific interactions, it is nevertheless a highly relevant feature in organizational networks, often influencing the instrumental value of social ties. For instance, vertical ties, that is ties to high-ranking actors, have been shown to be of particular importance for the ability of individuals as well as groups to mobilize needed resources (Cross & Cummings, 2004; Galunic, Ertug, & Gargiulo, 2012; Kilduff & Krackhardt, 1994; Mehra et al., 2006; Oh, Chung, & Labianca, 2004; Oh et al., 2006). There are two reasons for why we focus on the role of formal hierarchy in *advice networks*, that is networks of "relations through which individuals share resources such as information, assistance, and guidance that are related to the completion of their work" (Sparrowe et al., 2001, p. 317). First, advice networks form a central foundation for the creation, diffusion, and use of knowledge – one of the most important resources in modern organizations (Drucker, 1968; Grant, 1996b; Kogut & Zander, 1992; Phelps et al., 2012). Second, given the instrumental nature of advice ties, we expect considerations regarding the instrumental value of ties to high-ranking actors to play an important role in their formation.

In developing our hypotheses, we uncover a tension between two intuitive yet contradictory arguments raised in prior work. On the one hand, the individual qualities and access to resources of high-ranking individuals can make them particularly attractive as sources of advice (Galunic et al., 2012). On the other hand, concerns about time constraints, accessibility, and interpersonal costs associated with seeking assistance from high-ranking individuals can make them less attractive as advisors than mid- or lower-level colleagues (Borgatti & Cross, 2003). Correspondingly, the available empirical evidence on the influence of rank on advice ties presents a highly inconsistent picture (Agneessens & Wittek, 2012; Borgatti & Cross, 2003; Fragale, Sumanth, Tiedens, & Northcraft, 2012; Johnson, Kovács, & Vicsek, 2012; Lazega, Mounier, Snijders, & Tubaro, 2012). To resolve this contradiction, we zoom in on the content of advice ties. Although most prior research treats "advice" ties as unidimensional, organizational members have been shown to distinguish between different kinds of informational resources their advice contacts provide and to choose different advisors in pursuing them (Cross et al., 2001; Cross & Sproull, 2004). Focusing on *task knowledge,* i.e. answers, solutions, task information, and *metaknowledge,* i.e. referrals to third parties with relevant expertise, as two principal resources sought in advice relationships (Cross et al., 2001; McGrath, Vance, & Gray, 2003), we argue that the formal rank of an actor plays a different role for knowledge seeking than it does for metaknowledge seeking. While high-ranking actors are more likely to be sought out as sources of metaknowledge, they are less likely to be approached in the search for task knowledge.

This paper makes two key contributions to the literature. First, this study answers recent calls for research on the interplay between the formal organization and informal social structures (McEvily et al., 2014). In doing so, it goes beyond prior research in that it examines how informal networks are influenced by formal elements that do not directly specify certain interactions such as project co-membership (Brennecke & Rank, in press) or supervisory relations (Caimo & Lomi, in press) but rather induce expectations about the individuals holding different formal positions. Second, in showing that the effect of antecedents to advice ties depends on the dimension of advice under study we provide a possible explanation for inconsistent findings in prior research treating advice seeking as a unidimensional construct. Thus, this study underlines the multidimensional nature of advice networks (Cross et al., 2001) and highlights the importance of specifying the content of ties beyond the most common distinction between affective and instrumental relations (Brass, 2012).

Theoretical Background and Hypotheses

Advice networks play a critical role in knowledge-intensive work, providing the channels for the transfer of complex knowledge (Reagans & McEvily, 2003; Tortoriello et al., 2011), means for obtaining resources that facilitate task performance (Cross & Cummings, 2004; Sparrowe et al., 2001), and exposure to diverse information and perspectives that spark creative ideas and contribute to the generation of innovations (Burt, 2004; Hansen, 1999; Rodan & Galunic, 2004; Tortoriello & Krackhardt, 2010). Advice relations are a multidimensional construct, serving to access different kinds of informational resources such as task knowledge, metaknowledge, problem reformulation, validation, and legitimation (Cross et al., 2001; Cross & Sproull, 2004). In the present work, we focus on task knowledge and metaknowledge as the resources most commonly sought in advice relationships (Cross et al., 2001; McGrath et al., 2003).

Following Cross and colleagues' work, we define *knowledge seeking relations* as advice relations in which the accessed resource is specialized knowledge or information directly related to the accomplishment of specific tasks. This can consist of declarative (*know-what*) as well as procedural (*know-how*) knowledge. Such relations are instrumental to generating effective solutions to problems in a timely manner (Cross et al., 2001, p. 217) and result in direct benefits for employees' performance (e. g., Cross & Cummings, 2004; Rodan & Galunic, 2004). *Metaknowledge seeking relations,* on the other hand, are advice relations in which the accessed resource is not task information as such but rather pointers to other sources of task information. While such sources can be documents or databases, the overwhelming majority of metaknowledge seeking interactions yields *referrals* to other people holding relevant expertise (Cross & Sproull, 2004), and these are the interactions we will focus on in this study. *Metaknowledge*, that is knowledge about who knows what (Ren & Argote, 2011), is a critical ingredient in teams' and organizations' knowledge coordination mechanisms. It forms the back bone of transactive memory systems (Wegner, 1986) - social systems for the division of the cognitive labor of encoding, retrieving, and sharing knowledge in groups – and enables employees to effectively and efficiently access needed expertise held by others. While the role of metaknowledge has been mostly studied on the group level of analysis, recent work suggests that individuals' efforts to proactively build knowledge about others' expertise can result in faster career progression (Galunic, Sengupta, & Petriglieri, 2014).

Commensurate with the recognition of the importance of advice networks, increasing attention has been devoted to understanding their formation and internal logics. This research has shed light onto the role of endogenous processes such as reciprocity, closure, and informal status dynamics (Agneessens & Wittek, 2012; Caimo & Lomi, in press; Lazega et al., 2012) as well as onto the role of exogenous factors. Among the latter are tendencies for homophily in demographic characteristics and values (Ibarra, 1992; Klein, Lim, & Saltz, 2004; Lazega et al., 2012), affective relations between potential exchange partners (Casciaro & Lobo, 2008, 2014), and effects of formal structures such as intra-organizational boundaries (Johnson et al., 2012; Lomi et al., 2014), formally defined relations (Agneessens & Wittek, 2012; Caimo & Lomi, in press), and formal status (Lazega et al., 2012). While the structuring roles of formal boundaries and of prescribed direct relations of hierarchical subordination or cooperation emerge with consistency across different contexts and studies (Agneessens & Wittek, 2012; Caimo & Lomi, in press; Johnson et al., 2012; Lazega et al., 2012; Lomi et al., 2014), the role of actors' position in the organizational hierarchy is less clear. For example, while some studies found that high-ranking individuals were more likely to be sought out for advice (Borgatti & Cross, 2003, sample 1; Lazega et al., 2012), others found no effect (Agneessens & Wittek, 2012; Borgatti & Cross, 2003, sample 2), and yet others found that high-ranking actors were less likely to be chosen as sources of advice or assistance (Fragale et al., 2012; Johnson et al., 2012).

As noted earlier, unlike formal group boundaries and prescribed relations, formal hierarchical differentiation does not necessarily directly mandate relations between specific individuals beyond direct supervisor-supervisee relationships. Rather, its influence on informal structures should obtain through its influence on perceptions and expectations about the characteristics and behaviors of individuals occupying different positions (Halevy et al., 2011). In order to better understand the role of formal hierarchy in advice networks, in the following, we therefore consider how the formal rank of an individual influences others' perceptions and expectations relevant to the choice of advice sources. To structure this theoretical analysis, we draw upon Borgatti and Cross's (2003) model for the relational antecedents of information seeking, considering task knowledge and metaknowledge as two distinct types of informational resources as laid out above.

In their influential framework, Borgatti and Cross argued that as actors search for information, the choice of a specific individual to turn to among the set of potential sources is informed by four characteristics of the relationships between the seeker and the potential sources. They suggested that seekers are more likely to choose sources whose expertise they are aware of and perceive as valuable to their own tasks. In addition, when choosing a source of advice, seekers consider the accessibility of sources and the interpersonal costs they would incur by approaching the source. Borgatti and Cross (2003) provided empirical support for the roles of metaknowledge, perceived value, and accessibility for information seeking, further confirmed by related research in the fields of transactive memory systems and help seeking (e.g., Hofmann, Lei, & Grant, 2009; Mell et al., 2014; van Ginkel & van Knippenberg, 2009; Yuan et al., 2010). While in Borgatti and Cross's original study considerations of interpersonal costs did not emerge as a consequential factor for advice seeking, their role has been well established in affecting help seeking, a closely related behavior (Hofmann et al., 2009; Lee, 1997, 2002). Finally, these elements have been shown to partially explain the effects of more distal factors on the formation of advice ties such as co-location, the source's experience and the source's job role (Borgatti & Cross, 2003; Hofmann et al., 2009). Building on this work, in the following, we consider how the formal rank of a potential source affects seekers' perceptions of each of these factors depending on whether the type of information looked for is task knowledge or metaknowledge.

Formal Rank and Knowledge Seeking

Higher-ranking individuals are typically more visible within an organization than lower-ranking actors (Lazear, 2012). For instance, high-ranking actors' names recur in the roles of project leaders or directors on project proposals and reports, are referenced in internal news or possibly even mentioned in external media. This exposure makes it possible for other members of the organization to learn what fields of expertise they engage in even in the absence of direct interaction with them. Furthermore, as higher rank in organizations is more often obtained through internal promotion than through external hire (Chan, 1996), high-ranking individuals are typically longer-tenured, which enhances their visibility as their exposure accumulates over time. Thus, as an actor's rank increases, it becomes more likely that others will have formed an understanding of that actor's task-related knowledge.

Next to affecting others' awareness of his or her task knowledge, an actor's rank likely influences the instrumental value attributed to it. As individuals achieve promotions at least partially based on the skills and abilities they demonstrate and the work experience they accumulate (Ng, Eby, Sorensen, & Feldman, 2005), formal rank and associated job titles are relevant signals of expertise (Bunderson, 2003; Bunderson & Barton, 2011). Thus, on the one hand, high-ranking individuals could be expected to possess more valuable task knowledge. On the other hand though, the content of their knowledge may be different from the content of the knowledge of lower-ranking individuals. Actors in higher-ranking positions typically come to engage in a different type of tasks: Rather than performing specialist functions, they provide oversight and coordination, often acting in a supervisory role on a multitude of tasks and projects at the same time. In other words, high-ranking individuals are more likely to be or to become generalists rather than specialists (Lazear, 2012; Wang & Murnighan, 2013). Depending on the specificity of a seeker's problem, this can make a high-ranking individual more or less suitable as a knowledge source than a lower-ranking specialist. For example, a software engineer looking for help on the implementation of a particular function in a project will likely see more value in seeking knowledge from the specialist worker who wrote the code for a similar function in a different project than in seeking knowledge from the supervisor who managed that project. Conversely, actors seeking to obtain a birds-eye view on the project or to improve their knowledge on how to best coordinate such a project will likely want to connect with the supervisor rather than with a team member who was only engaged in a circumscribed aspect of it.

Finally, an actor's formal rank likely has pronounced consequences on others' perceptions of his or her accessibility and, related to it, interpersonal costs associated with seeking knowledge from him or her. Accessibility refers to the expectation that a contact can and will provide timely access to a sought resource, while costs arise from, e. g., incurring a social debt through requesting an alter's help (Borgatti & Cross, 2003; Nebus, 2006). As actors move up in the organizational hierarchy, the scope of their responsibilities becomes wider and, as a consequence, the time they can bestow on individual knowledge requests becomes scarcer. This can constrain their ability to react to knowledge requests in a timely manner or to devote adequate time to engaging with the seeker's questions. Furthermore, their time becomes – quite literally – increasingly more valuable as compensation increases in a convex fashion throughout increasing ranks (Connelly, Tihanyi, Crook, & Gangloff, 2014; Lazear & Rosen, 1981). As the social debt incurred by seeking assistance increases with the value of the advisor's time, obtaining task knowledge from higher-ranking individuals is likely to be perceived as more costly than obtaining task knowledge from lower-ranking colleagues. Accordingly, potential ties to higher-ranking individuals have been shown to be perceived as less accessible and more costly than ties to lower-ranking individuals (Borgatti & Cross, 2003).

In sum, an actor's formal rank exerts somewhat contradictory forces on the attractiveness of that actor as a source of task knowledge. On the one hand, as an actor's rank increases, visibility and implied expert status increase the likelihood that this person will be considered as a potentially attractive source by seekers. On the other hand, as actors rise in the formal hierarchy, accessibility and costs become an increasing concern for those considering to approach them. The convex nature of the cost component furthermore suggests a non-linear effect of rank on being sought out as a source of task knowledge: While mid-level actors may experience more approaches for task knowledge as seekers accept the disadvantages in timeliness and costs in order to access high-quality information, these concerns may overshadow the potential instrumental value of the interaction with high-ranking sources. Thus, we expect that:

Hypothesis 1a: *Knowledge seeking ties are more likely to be directed to mid-level actors than to low-ranking actors.*

Hypothesis 1b: *Knowledge seeking ties are less likely to be directed to high ranking actors than to low- ranking or mid-level actors.*

Formal Rank and Metaknowledge Seeking

Just as the heightened visibility of higher-ranking actors increases the chance that other employees will have formed an understanding of their task-related knowledge, we can expect that it will also impact others' conjectures about their metaknowledge. Higher hierarchical positions are typically associated with leadership roles which comprise, among other functions, knowledge coordination (Peterson & Kim, 2012). Thus, in encountering a high-ranking individual's name as a supervisor of a specific project, an observer will likely not only form the expectation that this individual possesses expertise in the associated field but also that he or she will have built metaknowledge about the other colleagues involved in it in the course of fulfilling the coordinating role.

Unlike learning relevant task information from a source, learning metaknowledge does not directly impact a seeker's productivity. Rather, the value of metaknowledge lies in that it constitutes a *potential* to establish knowledge seeking ties to third parties who possess relevant and valuable expertise (Borgatti & Cross, 2003; Nebus, 2006). To realize this potential, the seeker furthermore needs to gain the cooperation of these third parties. Yet, providing help and sharing knowledge is costly to the third party source as it entails the investment of time and energy on their side (Barnes et al., 2008). Moreover, competing goals and political considerations can reduce the third party's motivation to share their knowledge with an unknown seeker (Evans, Hendron, & Oldroyd, 2014; Wittenbaum et al., 2004). Thus, the value of an actor as a source of metaknowledge depends not only on the accuracy and quality of the directions provided but also on the extent to which their referral and mediation helps in persuading the third parties to cooperate. For this, the source's formal rank likely plays a decisive role for several reasons. First, metaknowledge sources frequently not only provide information on others' expertise but also personally effect an introduction to the third party source (Cross & Sproull, 2004), thus effectively requesting cooperation from the third party on the seeker's behalf. As higher-ranking individuals can more easily obtain cooperation in knowledge exchange relations, their rank serving as a substitute for social pressures as inducement for cooperation (Gargiulo, Ertug, & Galunic, 2009), such an introduction is the more valuable the higher ranked the metaknowledge source is. Particularly where the organizational context is characterized by a high degree of competitiveness constraining the motivation for knowledge sharing, obtaining the backing of upper management can help actors acquire needed information from others (Bresman, 2012). Second, even where no direct introduction takes place, simply citing a higher-ranking individual as the source of metaknowledge can make the seeker's request for information from the third party more persuasive. As Kilduff and Krackhardt (1994) found, being *perceived* as being connected to a high-status individual can already be enough for an individual to reap reputational benefits. In sum, as an actor's rank increases, the value attributed to him or her as a source of referrals rises.

Finally, while, as elaborated above, increasing rank of an actor is associated with increasing concerns about accessibility and costliness of a tie to him or her, these concerns should play a considerably smaller role when the resource in question is metaknowledge rather than task knowledge. First, although providing metaknowledge might require a source to expend more time and effort on understanding a seeker's problem than a request for specific task information, once the request is clear, providing a referral to a relevant expert poses considerably less demands on the source's time than transferring potentially complex knowledge. Second, while higher-ranking individuals experience more time constraint due to an increase in their responsibilities, coordinating knowledge is precisely one of the responsibilities distinguishing leadership roles (Peterson & Kim, 2012). In other words, higher-ranking individuals may be less available to answer to requests about specific task information precisely because they are expected to spend more time on providing referrals and establishing connections between third parties. Moreover, the provision of metaknowledge being part of the job responsibilities of higher-ranking actors, this behavior is less likely to constitute a "favor" requiring reciprocity. This should buffer concerns about interpersonal costs associated with seeking metaknowledge.

In sum, when the sought resource is metaknowledge an actor's rank exerts positive influence on his or her attractiveness as a source as high-ranking actors are more visible and their referrals, arguably, more valuable. At the same time, their roles as leaders and coordinators serve to mitigate accessibility and cost concerns. Thus, we expect that:

Hypothesis 2a: *Metaknowledge seeking ties are more likely to be directed to mid-level actors than to low-ranking actors.*

Hypothesis 2b: *Metaknowledge seeking ties are more likely to be directed to high ranking actors than to low-ranking or mid-level actors.*

Methods

Setting and Sample

The setting for our study was the engineering consultancy in the Netherlands introduced in the preceding chapter. As engineering constitutes highly knowledge-intensive work, often requiring the combination of multidisciplinary expertise, engineering companies rely on extensive communication and collaboration among their employees (Alvesson, 2004). The company in question is organized in 26 business units focusing on different areas of expertise, for example coastal engineering, waste water management, or infrastructure. Units revolving around similar expertise and targeting similar customer bases were considered as belonging to the same business sector. Each business unit is further subdivided into multiple specialized work groups. Based on preliminary interviews, we defined the boundary of the network to be studied as all employees in "primary functions" in the 22 units located in the Netherlands and at the time constituting the core business. Primary functions include project work, project management, and work group management, excluding administrative and support functions. This resulted in a target population of 645 individuals.

We collected data from multiple sources. We obtained data on individuals' positions in the formal structure of the organization (hierarchical position, unit and group affiliation, office location) and their company tenure from company archives. Based on a set of initial interviews with twelve members of the organization (ten senior managers, two junior employees), we developed a web-based survey in which we collected data on knowledge seeking and metaknowledge seeking as well as a set of control variables. Out of 645 possible respondents 457 (ca. 71 percent) completed the network survey. All 22 unit leaders responded to the network survey, as did 80 out of 92 work group leaders, and 355 out of 531 consultants. Respondents were, on average, 36.44 years old (SD = 9.44) and had been in the company for 10.27 years (SD = 7.88). 85.12 percent of the respondents were male and the vast majority of the respondents held a college or university degree (94 percent). This demographic composition of the sample was representative of the demographic composition of the organization as a whole as provided by company archives.

Focal measures

Advice networks. In order to ease the recall we first prompted participants to consider the tasks and projects they had been working on in the preceding three months and the specialist knowledge or information they needed to find to complete those tasks. We then measured knowledge seeking by asking participants to name up to twelve colleagues they had “turned to for specialist knowledge or information in the past three months”. In order to facilitate recall, an interactive scheme of the complete organization chart was presented on the same page. Thus, albeit the size of our network made a full roster approach impracticable, respondents had easy access to the complete roster of all units while responding to the name generator questions. Participants could name individuals pertaining to their own as well as to other units. Subsequently, we measured metaknowledge seeking ties by asking participants to name up to twelve colleagues they had “turned to for advice on whom to ask for knowledge in the past three months”. Thus, we obtained two networks, organized in two 457x457 matrices. In each matrix, “1” represented the presence of a knowledge – or metaknowledge - seeking tie from actor i to actor j, while “0” represented its absence. Table 6 provides descriptive statistics on both networks.

Formal position. Based on the organizational chart we coded each individual’s position in the formal hierarchy as consultant (1), group leader (2), and unit leader (3). Each consultant reported to a group leader and each group leader reported to a unit leader. Thus, group leaders in this organization can be considered as holding a mid-level rank, while unit leaders can be considered as high-ranking actors. Ten individuals constituted particular cases in that they constituted a “group” on their own, reporting to the unit leader but not having direct reports of their own. We coded their hierarchical position as equivalent to a consultant, reflecting the absence of a leadership function.

Control variables

Direct reporting relationships. Using the organizational chart, we furthermore derived two dyadic variables that reflect direct reporting relationships in the organization: “*reports to*” and “*supervisor of*”. The “reports to” relation is coded as 1, when actor i is a direct supervisee of actor j, and 0 otherwise. The “supervisor of” matrix is the transpose of the “reports to” matrix.

Table 6. Descriptive Statistics of the Knowledge Seeking Network and the Metaknowledge Seeking Network

Network Statistic	Knowledge Seeking Network	Metaknowledge Seeking Network
Number of nodes (N)	457	457
Number of dyads (N * (N-1))	208392	208392
Number of directed ties	2408	1393
Density	0.012	0.007
Reciprocity	0.10	0.07
Average degree	10.54	6.09
Degree variance (indegree)	25.43	15.53
Degree variance (outdegree)	9.09	6.99
Average geodesic distance	4.11	5.60

Notes. Only ties among respondents were considered in the analyses. Reciprocity refers to the number of reciprocated pairs relative to the number of connected pairs.

Shared affiliations. We coded each individuals' affiliation with a business sector, business unit, a work group (creating a unique category for each individual not pertaining to a work group), and office location from the organization chart. As advice ties tend to be organized around social foci (Lomi et al., 2014), shared affiliations represent important control variables in models testing antecedents of advice ties.

Inter-unit formal collaboration. As complex engineering assignments require the combination of multi-disciplinary expertise, project teams are often assembled across group and unit boundaries. Such formally defined collaboration relations are an important influence on the formation of informal advice ties (Brennecke & Rank, in press). Although we did not have data on individuals' co-memberships in projects, we were able to control for the likelihood of any two individuals being assigned to shared projects by using information on the aggregate co-staffing of projects between business units. In the studied organization, while each project was formally nested in one business unit, members of other units could be hired to work on it. When this happened, the host unit would internally pay the home unit for the work delivered by the hired member. Using aggregate accounting information on such inter-unit deliveries in the calendar year preceding the data collection, we created a dyadic covariate matrix in which each relation between actor i and actor j was set equal to the average of the deliveries from i's unit to j's unit and the deliveries from j's unit to i's unit. Where i and j belonged to the same unit, the value was set to 0. Thus, this variable served as a proxy for the likelihood of a pair of individuals from different units to be co-workers on shared projects.

Expertise similarity. Common knowledge is a critical factor in knowledge exchange among individuals (e. g., Kameda et al., 1997; Reagans & McEvily, 2003; Stasser & Titus, 1985) and likely has a sizeable influence on actors' understanding and perceived value of each other's expertise. In order to create a measure of actors' expertise similarity, we asked respondents to provide a set of keywords describing their area of expertise. Respondents provided at least six keywords, but were free to add more. We used this data as input for a latent semantic analysis (LSA) procedure. LSA (Deerwester, Dumais, Furnas, Landauer, & Harshman, 1990; Landauer, Foltz, & Laham, 1998) has been developed as a method to extract latent dimensions of meaning underlying words by analyzing their co-occurrence in passages of text, assuming that words that are similar in meaning will occur in the same passages more frequently. In brief, in a LSA a term-by-source matrix created from a corpus of text is decomposed into a reduced set of latent dimensions using singular value decomposition – a two-mode factor analysis that maps terms and sources as vectors in a single, high-dimensional semantic space. In our case, terms are the expertise keywords while sources are the individuals. After pre-processing the data in order to homogenize spelling, we identified all unique keywords and arranged the data in a two-mode keyword-by-individual matrix, each cell (i, j) indicating the presence or absence of keyword i in individual j's report. This matrix served as input for a LSA in which we used a share of 50% of the cumulated singular values as a cut-off to reduce dimensionality (Wild, Stahl, Stermsek, Neumann, & Penya, 2005). As a result, we obtained a high-dimensional semantic space in which the dimensions represent latent skill or knowledge domains, akin to factors in exploratory factor analysis. Furthermore, for each keyword as well as for each individual we obtained a vector which contained their loadings on each dimension. We then derived expertise similarity scores for each pair of individuals by taking the cosine between their vectors (Deerwester et al., 1990). To assess the content validity of our resulting indicators we also derived keyword-to-keyword similarity scores from the same semantic space and mapped this keyword similarity network onto a two-dimensional space. We discussed the emerging keyword clusters with senior managers, finding that the procedure generated keyword similarity structures that the managers perceived as recognizable and valid.

Metaknowledge-centrality. Individuals can differ in the amount of metaknowledge they possess about their colleagues. These differences can affect knowledge sharing in groups (Mell et al., 2014) and individuals' positions in advice networks (Borgatti & Cross, 2003). In particular, individuals with a high amount of metaknowledge may find it easier to establish knowledge and metaknowledge seeking ties and they may also be more attractive as a source of metaknowledge to others. We therefore controlled for the effect of *metaknowledge-centrality* of individuals within their own business unit on their propensity to send or receive advice ties. To measure metaknowledge-centrality, we collected data on the metaknowledge network within each unit using a sociometric approach similar to Borgatti and Cross's (2003) procedure. We presented participants with a full roster of their unit together with the following instruction: "Expertise awareness in an organization means that you understand what specialist knowledge another person has, potentially over and above what is revealed by his or her position in the organizational scheme. For example, you might know what kinds of projects a person typically works on and what kind of knowledge he or she uses to contribute to these projects. This does not necessarily mean that you have the same knowledge or that you interact regularly, but just that you understand what the other person is knowledgeable or expert about. Please, mark those people about whom the following statement is true for you: *I have a good understanding of this person's knowledge that goes beyond what is reflected in his or her position in the organizational scheme*." We adapted Borgatti and Cross's wording to the organizational context in this manner based on extensive discussions with our interviewees and we pilot tested this question with other organizational members. To capture the extent to which individuals had metaknowledge about their fellow unit members we calculated their out-degree centrality as the number of their outgoing metaknowledge ties, standardizing the values across units by dividing them by N-1, N being the unit size (Freeman, 1978).

Use of knowledge management system. Next to other people as sources of metaknowledge, actors can gain metaknowledge by using knowledge management tools provided by the organization. An important tool are company "yellow pages" that list employees and their areas expertise. Individuals vary in the extent to which they proactively use such systems (Galunic et al., 2014) and these variations are likely to affect both knowledge and metaknowledge seeking ties that they send and receive. To capture these effects, we asked respondents to indicate how often they had used the company yellow pages to find an expert in the preceding three months. Responses were provided on a five point Likert scale, reaching from 1 (never) to 5 (several times per week). Seven participants omitted answering this question and we imputed the sample mean for their responses.

Demographic attributes. We furthermore controlled for a number of demographic variables that might affect actors' propensities to send or receive advice ties. We collected information on *gender* (dummy variable, male denoted by 1) and *tenure* (in years) from company information systems. Participants provided information on their *age* and *highest level of education*. Nine participants omitted age information and we imputed the missing values, replacing them with the average age of members of the respective business units. Participants indicated their highest level of education as – in descending order - "research university degree", "applied university degree", "vocational training", or "lower". As most of the respondents fell into either the first (ca. 59 percent) or the second (ca. 35 percent) category, not belonging to one category almost certainly indicated belonging to the other (r = 0.87). We therefore simplified the coding to a single dummy variable indicating "research degree" vs. "non-research degree".

Analytical Approach

To test our hypotheses, we fitted exponential random graph models (ERGMs) to our knowledge seeking and metaknowledge seeking networks. ERGMs constitute a class of statistical models for social networks permitting to test hypotheses about why and how network ties arise (Lusher et al., 2013; Robins, Pattison, Kalish, & Lusher, 2007). A core assumption of ERGMs is that ties in a network are interdependent – the presence of one tie can affect the formation of others. Tie formation is viewed as a function of local processes that result in specific local configurations. For instance, the presence of a tie from Anne to Peter and of a tie from Peter to Bill can increase the chance that a tie forms from Anne to Bill through a process of transitive closure. The presence of many transitive triples in the observed network, then, constitutes evidence for the operation of such a process. Multiple processes are assumed to be operating simultaneously (Contractor et al., 2006), including endogenous network processes as well as processes arising from exogenous factors such as actor or dyadic attributes. Thus, in an ERGM, each network tie between an actor i and an actor j is considered as a random variable that can take the value 1 (present) or 0 (absent) and the probability of its occurrence is modeled as a function of a set of local configurations that represent different claims about how ties form.

ERMGs are particularly well suited for testing our hypotheses for two reasons. First, they account for the non-independence of observations inherent in network data by explicitly modeling local interdependencies. Second, they provide an inferential framework to test our hypotheses about how the formal rank of actors affects knowledge and metaknowledge seeking while at the same time offering an accurate characterization of the structural features of the networks in which the actors are embedded. The latter is an important advantage given that modeling effects of actor or tie covariates while ignoring endogenous network processes may not only result in theoretically inappropriate models (Contractor et al., 2006), but also in biased conclusions (Lomi et al., 2014).

We used the *statnet* suite in R (Goodreau, Handcock, Hunter, Butts, & Morris, 2008) to estimate parameters for each graph configuration included in the models. Parameters are estimated using Markov chain Monte Carlo maximum likelihood estimation (Robins, Snijders, et al., 2007). A significantly positive parameter for a configuration indicates that, conditional on all other effects in the model, this configuration is observed more often than expected by chance while a negative parameter indicates the reverse. As individuals could not name more than twelve sources for either type of advice, we constrained the maximum out-degree to twelve. After obtaining converged models, we assessed their goodness of fit by examining to what extent networks simulated from the fitted models were similar to the networks we observed (Hunter, Goodreau, et al., 2008).

ERGM Parameters. In order to be able to compare the parameters obtained in the two networks, we specified identical models for the knowledge seeking and the metaknowledge seeking networks. For simplicity, we will refer to knowledge seeking ties in our explanation of the parameters. Building on Lusher and colleagues' (2013) recommendations, prior work modeling advice networks (Agneessens & Wittek, 2012; Caimo & Lomi, in press; Lazega et al., 2012; Lomi et al., 2014), and our hypotheses we included the following configurations in our model specification.

The *arc* parameter captures the baseline propensity of individuals to form ties and is comparable to an intercept in standard regression. *Reciprocity* captures the tendency of individuals to seek knowledge from those actors who also seek knowledge from them. *Activity spread* refers to the variation among actors with respect to how many knowledge seeking ties they send, while *popularity spread* models the variation among actors with respect to how many others seek knowledge from them. In our model, these effects are captured by geometrically weighted in- and out-degree statistics, positive values indicating homogeneity and negative values indicate heterogeneity in degrees (Hunter, 2007).

We included three parameters that together model processes leading to network closure. *Transitive closure* models the tendency of an actor to seek knowledge from his or her advisor's advisor. *Multiconnectivity*, representing the presence of open paths or structural holes between actors, is a counterpart to the transitive closure parameter and sharpens its interpretation. In a network governed by a tendency for transitive closure, the first parameter is typically positive and the second negative (Robins et al., 2009). *Cyclic closure* captures the tendency of individuals to seek knowledge from others who have sought knowledge from their own advisees. The presence of such cyclic triads is often interpreted as an indication of a network governed by a logic of generalized exchange (Bearman, 1997; Lazega & Pattison, 1999), that is a logic of indirect reciprocity wherein the giver of a benefit "eventually receives some benefit in return, but from a different actor" (Molm et al., 2007, p. 208). However, Agneessens and Wittek (2012) found that advice networks rather tend to exhibit structures consistent with the emergence of local hierarchies, where advisors of advisors are more readily sought out than advisees of advisees.

In addition to these controls representing endogenous network processes in the two networks, we included a set of parameters involving exogenous attributes. First, we included effects that model common tendencies for advice relations to emerge between actors who are in physical proximity, i.e. in the same location, between actors who share social foci such as work groups or business units (Lomi et al., 2014), and between actors in units that belong to the same business sectors, i.e. that share similar kinds of strategic assets such as technological expertise, market knowledge, or customer bases (Tsai, 2000, 2002). In addition, recent work by Caimo and Lomi (in press) suggests that advice ties across social foci are more likely to be embedded in reciprocal relationships than ties within social foci, a tendency we also observe in our data and control for by including within-group reciprocity effects for work group, business units, and location. Second, we included sender and receiver effects for gender, tenure[12], education, use of knowledge management systems, and metaknowledge centrality. While sender effects control for tendencies of individuals with specific attributes to seek more knowledge or metaknowledge, receiver effects control for tendencies of individuals with these attributes to receive more requests. Furthermore, we controlled for the tendency of actors to develop relations with similar others (McPherson & Smith-Lovin, 2001) by including parameters modeling gender matching and education matching, and a parameter modeling the effect of differences in tenure as predictors of knowledge and metaknowledge seeking ties. Third, we included four dyadic covariate matrices defined earlier: "*supervisor of*", "*reports to*", "*formal inter-unit collaboration*", and "*expertise similarity*". The presence of a tie in the other network constituted a fifth important dyadic covariate. Finally, we included sender, receiver, and matching effects of formal rank. While the sender and the matching effects act as controls, the receiver effects represent the tests of our hypotheses.

Results

Descriptive statistics of the knowledge seeking and the metaknowledge seeking networks can be found in Table 6. Descriptive statistics and intercorrelations of the individual covariates can be found in Table 7.

Table 8 presents the results of the fitted ERGMs. Both models have successfully converged and exhibit acceptable goodness of fit (see Appendix for goodness of fit analyses). Before we turn to the parameters constituting our hypotheses tests, we will briefly examine the effects of the control variables to characterize the networks in more detail.

Both the knowledge seeking and the metaknowledge seeking network exhibit a tendency for reciprocity, tendencies for centralization in the in-degree (negative gwidegree parameter) and in the out-degree (negative gwodegree parameter), a tendency for local

[12] Given the high correlation between age and tenure (r = 0.83), we only included tenure in our models. Our results were not substantively changed when we included age instead of tenure.

hierarchies rather than indirect reciprocity (negative cyclic closure parameter) as well as a tendency for transitive closure. Not surprisingly, there is considerable entrainment between both types of ties: If actor i seeks metaknowledge from actor j, the odds of i seeking knowledge from j increase by a factor of exp (2.77) = 15.96 compared with the case that no metaknowledge seeking tie exits. The other way around, a knowledge seeking tie increases the odds of a metaknowledge seeking tie by a factor of exp (2.89) = 17.99. Furthermore, we observed significant tendencies for homophily based on expertise similarity, education, and tenure in both networks and gender homophily in the metaknowledge network. In the knowledge seeking network, metaknowledge-centrality and usage of knowledge management systems were significant predictors of seeking activity, while tenure and, marginally, research degree and metaknowledge-centrality predicted being chosen as a source. In the metaknowledge seeking network, tenure and non-research degree predicted activity as seeker and tenure, female gender, and, marginally, metaknowledge-centrality predicted popularity as a source.

Next, we consider the effects induced by formally defined collaboration structures. We find that the organizational groupings strongly influence tie formation: Knowledge seeking as well as metaknowledge seeking ties were more likely to be observed between members of the same work group, same unit, same business sector, and operating from the same locations. Similar to Caimo and Lomo (in press), we observed that while there was a strong tendency for reciprocity overall, reciprocity was more relevant in governing inter-group relations than within-group relations: In the knowledge seeking network, the effect of reciprocity was significantly reduced for dyads who were members of the same sector, unit, location, or, marginally, work group. In the metaknowledge seeking network, reciprocity was reduced by shared unit membership and, marginally, shared sector. Formal collaboration between business units increased the odds of informal knowledge and metaknowledge seeking ties between their members. Direct reporting relationships also influenced both knowledge and metaknowledge seeking, albeit in opposite ways: While seekers were less likely ask their direct supervisors than other actors for task knowledge, they were more likely to ask them for metaknowledge.

Having thus accounted for a number of relevant endogenous network processes, structural variables, and actor attribute effects, we turn to the role of formal hierarchy in both networks. To test our hypotheses, we examine the receiver effects of formal rank, controlling for sender and rank matching effects. In the models reported in table 3, we compare the receiver effects of mid-level rank (group leader) and high rank (unit leader) with the receiver effect of low rank (consultants) which is the omitted base category. In the knowledge seeking network, we found no difference in the likelihood of being chosen as a source of task knowledge between consultants and group leaders. Unit leaders, however, were significantly less likely to be approached for task knowledge than consultants (odds ratio: exp(-0.49) = 0.61) or group leaders (odds ratio: exp(-0.51) = 0.60)[13]. These results support our contentions in hypothesis 1b, but not 1a. In the metaknowledge seeking network, formal rank had consistently positive effects on the likelihood of receiving ties: Group leaders (odds ratio: exp(0.72) = 2.05) and unit leaders (odds ratio: exp(1.45) = 4.26) were significantly more likely to be approached as a source of metaknowledge than consultants. Unit leaders were also significantly more likely to be approached as a source of metaknowledge than group leaders (odds ratio: exp(0.73) = 2.08). These results are in line with our hypotheses 2a and 2b. As a final note, we observe a significant rank matching effect in the metaknowledge seeking network. To interpret it, we need to consider it jointly with the sender and receiver effects: As consultant-to-consultant ties are captured by the lowest rank being defined as our base category for both sender and receiver effects, the rank matching effect effectively denotes the presence of rank homophily in the mid-level and high ranks.

[13] To directly compare the effects of high rank with the effects of mid-level rank, we ran a second set of models, this time treating the mid-level rank as base category. As the remainder of the model is identical, we do not report the full models here, but only include the relevant parameters.

Table 7. Descriptive Statistics and Intercorrelations of the Individual Variables

	M	SD	1	2	3	4	5	6	7	8	9	10	11
1. KS outdegree	5.27	3.02											
2. KS indegree	5.27	5.04	0.24**										
3. MKS outdegree	3.05	2.64	0.39**	0.16**									
4. MKS indegree	3.05	3.94	0.25**	0.58**	0.27**								
5. Group leader	0.18	0.38	0.10*	0.23**	0.11*	0.31**							
6. Unit leader	0.05	0.21	0.10*	0.09	0.20**	0.60**	-0.10*						
7. Male gender	0.85	0.35	-0.04	0.14**	0.04	0.13**	0.11*	0.09*					
8. Age	36.44	9.44	0.03	0.20**	0.11*	0.30**	0.22**	0.25**	0.21**				
9. Tenure	10.27	7.88	0.02	0.22**	0.13**	0.34**	0.20**	0.27**	0.23**	0.81**			
10. Research degree	0.59	0.49	0.12*	0.16**	0.07	0.17**	0.06	0.10*	-0.08	-0.06	-0.14**		
11. MK centrality	0.47	0.27	0.29**	0.27**	0.17**	0.33**	0.16**	0.19**	0	0.17**	0.19**	0.06	
12. KMS use	3.11	1.5	0.19**	-0.01	0.13**	-0.05	0.01	-0.09	0.01	-0.19**	-0.17**	0.02	0.05

Notes. KS: Knowledge Seeking, MKS: Metaknowledge seeking, MK: Metaknowledge, KMS: Knowledge management system.
*$p < 0.05$, **$p < 0.01$

Table 8. ERGM results for Knowledge Seeking and Metaknowledge Seeking Ties

	KS network	MKS network
Network effects		
Arc [edges]	-5.210 (0.239)***	-5.996 (0.34)***
Reciprocity [mutual]	3.576 (0.138)***	2.399 (0.316)***
Activity spread [gwodegree, α=ln(2)]	-0.827 (0.157)***	-1.392 (0.137)***
Popularity spread [gwidegree, α=ln(4)]	-1.545 (0.095)***	-1.054 (0.147)***
Transitive closure [gwesp, α=ln(2)]	0.820 (0.036)***	0.603 (0.053)***
Multiple connectivity [gwdsp, α=ln(2)]	-0.047 (0.005)***	-0.042 (0.01)***
Cyclic closure [ctriple]	-0.491 (0.075)***	-0.521 (0.132)***
Entrainment with MKS	2.771 (0.072)***	
Entrainment with KS		2.893 (0.072)***
Effects of actor attributes		
Male sender	-0.137 (0.086)	-0.153 (0.113)
Male receiver	0.059 (0.073)	-0.355 (0.114)**
Same gender	0.050 (0.087)	0.257 (0.124)*
Tenure of sender	0.007 (0.003)*	0.022 (0.004)***
Tenure of receiver	0.015 (0.002)***	0.025 (0.004)***
Tenure difference	-0.021 (0.003)***	-0.043 (0.005)***
Research degree of sender	-0.003 (0.043)	-0.116 (0.058)*
Research degree of receiver	0.065 (0.034) $^{+}$	0.019 (0.061)
Same degree	0.198 (0.043)***	0.323 (0.065)***
Expertise similarity	1.275 (0.12)***	1.270 (0.167)***
MK centrality sender	0.35 (0.08)***	-0.007 (0.099)
MK centrality receiver	0.111 (0.059) $^{+}$	0.195 (0.103) $^{+}$
KMS use sender	0.057 (0.014)***	0.078 (0.018)***
KMS use receiver	0.010 (0.010)	0.029 (0.018)
Effects of formal collaboration structure		
Same sector	0.402 (0.061)***	0.444 (0.093)***
Same unit	0.772 (0.077)***	1.271 (0.111)***
Same work group	0.758 (0.105)***	0.65 (0.123)***
Same location	0.604 (0.05)***	0.643 (0.069)***
Reciprocity within sector	-0.93 (0.232)***	-0.752 (0.414) $^{+}$
Reciprocity within unit	-1.433 (0.264)***	-1.042 (0.396)**
Reciprocity within work group	-0.549 (0.281) $^{+}$	-0.052 (0.364)
Reciprocity within location	-1.015 (0.187)***	-0.464 (0.29)
Inter-unit formal collaboration	0.050 (0.010)***	0.071 (0.016)***
Reports to	-0.353 (0.16)*	1.814 (0.167)***
Supervisor of	-0.03 (0.181)	-0.265 (0.254)
Effects of formal hierarchy		
Sender is group leader	0.149 (0.058)**	0.301 (0.072)***
Sender is unit leader	0.189 (0.101) $^{+}$	0.479 (0.14)***
Receiver is group leader	0.015 (0.047)	0.717 (0.084)***
Receiver is unit leader	-0.498 (0.082)***	1.445 (0.113)***
Same rank	0.084 (0.055)	0.441 (0.077)***

Notes. KS: Knowledge Seeking, MKS: Metaknowledge seeking, MK: Metaknowledge, KMS: Knowledge management system

$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.01$

Discussion

For an organization relying on its ability to use, combine, and create knowledge, its advice networks constitute a crucial foundation, shaping the conduits by which employees identify, access, and share relevant expertise. Rather than emerging in void space, however, such informal social structures are to a considerable extent shaped by formally defined group boundaries, relations, and – the focus of the present study – hierarchies. In a detailed analysis of two distinct kinds of advice relations in a knowledge-intensive firm, we have found that while the likelihood of being asked for metaknowledge monotonously increased with a person's rank, the likelihood of being asked for task knowledge decreased for high-ranking actors compared with low and mid-level ranks.

Theoretical Implications

Our study extends the emerging literature on the interplay between formal and informal structures in several important ways. First, prior work explicitly addressing the influence of formal organization on social structure has primarily considered how formally mandated specific interactions created by, e.g., group membership (Lomi et al., 2014), reporting and supervisory relations (Caimo & Lomi, in press), and formal collaboration (Brennecke & Rank, in press) manifest in informal interactions. But, as we showed, formal structure carries weight beyond the rather straightforward imprinting of specific formally mandated exchanges. While the formal rank or job title of an individual does not, in itself, specify interactions with particular alters, it provides cues about the individual's qualities that can be highly relevant in others' choice of interaction partners. Such qualities include expertise (Bunderson, 2003), access to resources (Magee & Galinsky, 2008), reputation (Kilduff & Krackhardt, 1994), and accessibility (Borgatti & Cross, 2003). In other words, without negating the fundamental understanding that formal positions are interconnected by a network of relations which are designed to be independent from the individuals occupying specific positions (McEvily et al., 2014, p. 306), we hold that formal positions create expectations about the characteristics and behaviors of the individuals occupying them (Halevy et al., 2011). Such expectations can be based on the selection procedures, experiences, roles, and tasks accompanying formal positions and can, in turn, guide the formation of informal ties even in the absence of direct formally mandated ties.

Second, we have argued that the same formal position can provide different cues about the position holder's value and accessibility as an advisor depending on the dimension of advice – the type of informational resource – that is being considered. Our empirical results are consistent with the contention that the same hierarchical position has very different implications for an actor's popularity as a source of task knowledge than his or her popularity as a source of metaknowledge. More broadly, we hold that if the goal is to build a better understanding of how formal organizational elements shape informal social networks, the specific content of the informal ties in question matters. Prior research has noted the different impact of formal relations on informal affective and instrumental ties (Rank et al., 2009). Our results go beyond that, suggesting that formal structure also influences different kinds of instrumental ties in different ways. While in the present study we have focused on two primary dimensions of advice ties – knowledge seeking and metaknowledge seeking – we expect that future research will further disentangle the interplay between formal structure, affective relations, and instrumental ties.

Third, our arguments and findings hold implications for research that considers the joint effects of formal and informal structure on organizational outcomes. Prior research notes that individuals experience performance benefits of an alignment of informal advice seeking with formal authority structures (Soda & Zaheer, 2012) as well as of connecting to brokers occupying a high formal rank (Brass, 2009; Galunic et al., 2012). Yet, our findings did not indicate that individuals necessarily preferred forging upward connections when seeking advice. On the contrary, where advice referred to search for specific task information, individuals avoided rather than sought out high-ranking individuals or even their direct supervisors. In order to fully understand the implications of this finding, a missing piece in the puzzle is a better understanding of the potentially different performance implications of alignment and misalignment of distinct advice dimensions with formal structures. Here, it will be important to more clearly characterize the different bases from which the value of an advice tie to a specific source derives and on which formal position has different effects. For instance, in seeking knowledge, the critical source characteristic is relevant task expertise, for which the formal rank may be a valid though diffuse cue. In in seeking referrals, the important quality is the source's social capital and the ability to employ it on the seeker's behalf, i.e. to help in obtaining the cooperation of relevant third parties, for which formal rank can carry an advantage. In seeking legitimation - another important dimension of advice outside of the scope of the present work (Cross et al., 2001) - it may specifically be the formal authority exclusively residing in formal rank that is of crucial importance. In sum, just as an organization's formal structure has a different influence on the emergence of different dimensions of informal structure, we expect that the effect of its interaction with informal networks on organizational outcomes will depend on the content of the networks under study.

Practical Implications

Our study yielded two main insights into the influence of formal rank on advice seeking behavior in organizations. While higher rank attracts metaknowledge seeking, it deters others from approaching a high-ranking individual in search for task knowledge. These findings carry several implications for practice in knowledge-intensive firms that are best conveyed in discussing an intuition expressed by one of the managers of the studied company during the preliminary interviews: *"If you get promoted to the head of the geotechnical engineering department it is clear that you are a very important geotechnical engineer."* We could add to this that a possibly even more important information attached to this position is that the person occupying it knows who the *other* important geotechnical engineers are, can direct a seeker to the ones with the most relevant expertise for the problem at hand, and, in doing so, persuade them to share their specialist knowledge with the seeker. While other considerations may deter seekers from requesting geotechnical expertise directly from the head of the geotechnical engineering department, their knowledge coordinator function makes them a key source in the search for a related expert. An important implication of this finding is that the level and accuracy of metaknowledge of high-ranking actors is a key lever in ensuring effective knowledge coordination across the organization. Metaknowledge can be acquired not only through direct shared experiences and interdependent collaboration, but also through proactive efforts to learn about others' expertise from both social and technological sources (Ren & Argote, 2011). While the individual career benefits of engaging in proactive building of metaknowledge through, e.g., the use of knowledge management systems, may decline with rising rank (C. Galunic et al., 2014), our results suggest that the importance of maintaining a wide and accurate understanding of who knows what may become the more important in order to provide much sought after direction to others.

Limitations and Future Research Directions

Notwithstanding the contributions of our paper, it counts several limitations that call for future research. First, a big part of our theoretical reasoning rests on the premise that an individual's formal rank acts as a signal that influences others' perceptions and expectations about that individual's qualities as a source of advice. Although we build on prior work establishing connections between formal roles and perceptions of expertise, accessibility, and relational costs (Borgatti & Cross, 2003; Bunderson, 2003; Hofmann et al., 2009), the absence of a direct measurement of such perceptions in the present study is an important limitation.

A second important limitation of our study is its cross-sectional nature, which can raise concerns about reverse causality. For instance, it is conceivable that individuals who at earlier stages of their careers are recognized as valuable sources of metaknowledge – who, in other words, assume an informal knowledge coordinator role – are more likely to be promoted into leadership roles and higher ranks. Such selection effects might partially explain the effects we find in the metaknowledge seeking network, yet they would be a highly implausible explanation for the opposite effect we find in the knowledge seeking network. It appears unlikely that *not* being sought after as a source of task expertise would increase the chance of promotion in a knowledge-intensive industry. Rather, the pattern of results in the knowledge seeking network is more consistent with the contention that promotion into a higher-ranking formal position constitutes an important transition in roles and tasks that shapes others' perceptions and expectations of these individuals' behavior in the informal network. Future longitudinal research simultaneously tracing changes in formal status and informal networks would provide valuable insights into these dynamics.

A third limitation of the present study is its reliance on a single organization in – possibly even more critical – a single culture. Examinations of how individual behavior is shaped by formal structures and hierarchies are arguably contingent on the national culture in which the studied organizations are embedded. A particularly important dimension in this context is power distance, that is, the extent to which individuals accept unequal distribution of power and authority (Hofstede, 2001). In organizations, high power distance translates into centralization of decision authority. Organizations in low power distance cultures such as the Netherlands, on the other hand, are better characterized by decentralization of authority and a facilitating rather than directive role of management (Hofstede, 1983). The pattern of advice seeking ties in the studied organization is quite consistent with the latter depiction, with higher-ranking actors serving as hubs that coordinate and facilitate information search, but not necessarily provide top-down problem solutions. These networks can, however, look very different in high power distance cultures.

Conclusion

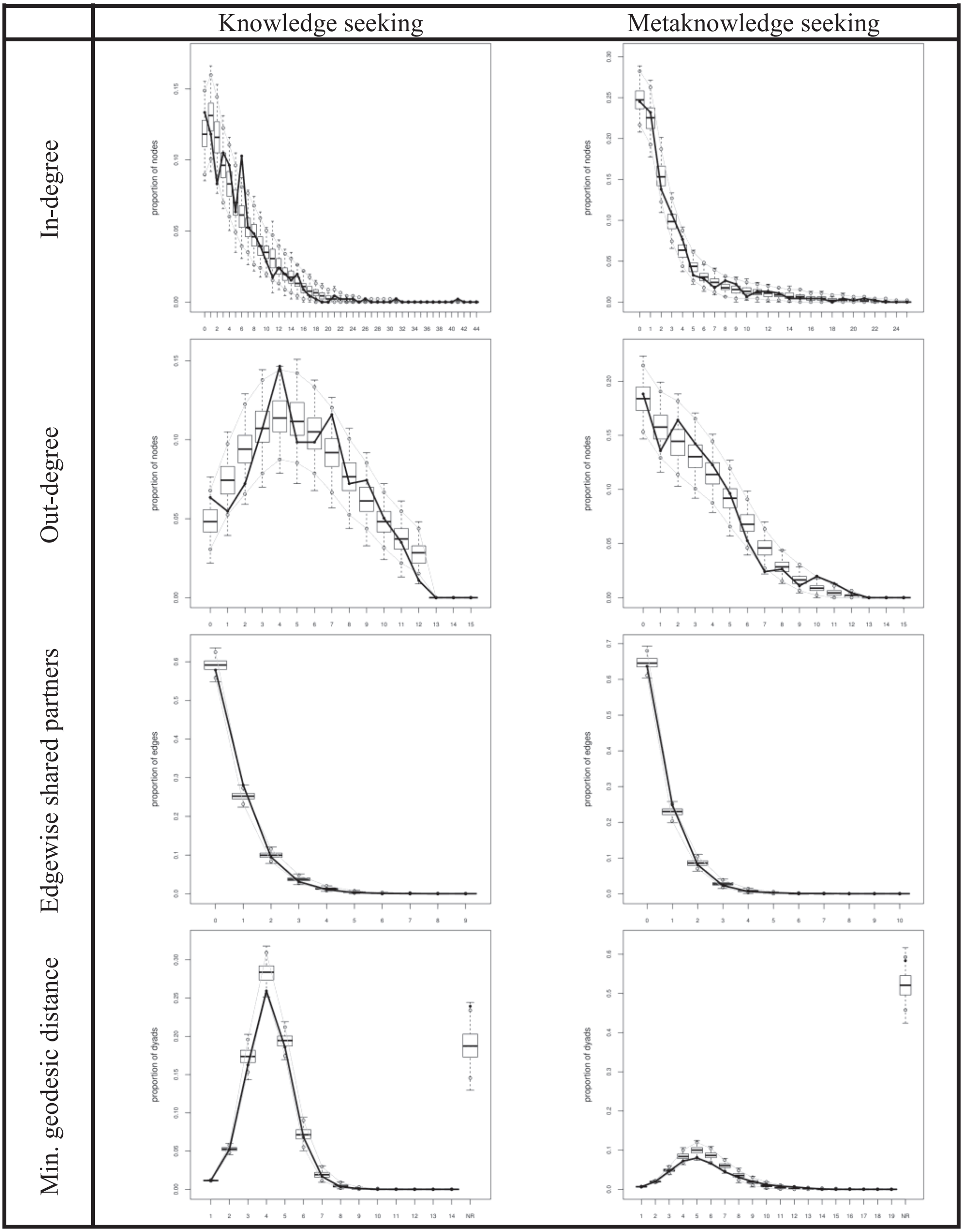
The present study examined the influence of the formal hierarchy of an organization on the informal advice networks within it. Our main conclusion that the formal rank plays a different role in knowledge seeking and metaknowledge seeking networks contributes to a better understanding of the influence of formal structure on informal networks. Furthermore, it holds implications for future research on the joint effects of formal and informal structure on organizational outcomes.

Appendix

Goodness of Fit Analyses

We tested the goodness of fit for both models using the graphical procedure suggested by Hunter, Goodreau and Handcock (2008). For each model, we simulated five hundred networks according to the fitted ERGM and calculated a number of network statistics from the simulated networks which we compared with the observed original networks. Following Hunter et al., we examined the in- and out-degree distribution, the edgewise shared partner distribution, and the geodesic distance distribution. As elaborated by the authors, this set of statistics captures the main features of a network with respect to degree distribution, centrality, and clustering and provides a good assessment of a model's fit. Figure 6 contains the results of the goodness of fit analyses. The observed statistics are indicated by the solid lines, the boxplots include the median and interquartile range. The light-gray lines indicate the range in which 95% of simulated observations fall. Only few of the observed network statistics fall outside the 95% interval: In the knowledge seeking network it is three out of 37 for in-degree, two out of 13 for out-degree, none out of eleven for edgewise shared partners and one out of 15 for minimum geodesic distance. In the metaknowledge seeking network, none of the 33 in-degree statistics, two of the 13 out-degree statistics, none of the ten edgewise shared partners statistics and 3 of the 24 minimum geodesic distance statistics fall outside the 95% interval. Overall, the fitted models are reasonably well able to reproduce the observed network structures for both networks.

Figure 6. Graphical Goodness of Fit Tests



Note. Simulation results. The observed statistics are indicated by the solid lines, the boxplots include the median and interquartile range. The light-gray lines indicate the range in which 95% of simulated observations fall.

Chapter 5 – General Discussion

The notion that combining the knowledge of multiple individuals is beneficial or often even necessary for solving problems in the most extended sense is not a new one: It is a widely accepted principle, from the proverbial expression that “two heads are better than one” (Heywood, 1546) to the formal proposition that “firms exist as institutions for producing goods and services because they can create conditions under which multiple individuals can integrate their specialist knowledge” in Grant’s (1996b, p. 112) knowledge-based theory of the firm, it is a widely accepted principle. Yet, bringing together people with different knowledge – be it in a small group or in a large firm - is far from a sufficient condition for obtaining the strived for results. The process of knowledge coordination and recombination is fundamentally social in nature (Nahapiet & Ghoshal, 1998; Spender, 1996) and requires interaction: communication, information exchange, and collaborative information processing or elaboration (van Knippenberg et al., 2004) among the people in question.

Albeit the studies contained in this dissertation each have a specific focus, combining multiple theoretical perspectives, levels of analysis and empirical strategies, at the core they share an underlying research question: What factors influence the interactions among individuals that facilitate the combination of the resources contained in individuals’ minds? One factor that the presented studies have in common is metaknowledge, that is, individuals’ knowledge of who knows what (Lewis, 2004).

Summary of the Main Findings and Contributions

Chapter 2 focused on the implications of differences in members’ metaknowledge on knowledge integration and decision making in teams. The findings reported in this chapter constitute first evidence that disparity of metaknowledge levels within the team can, under certain circumstances, be beneficial for team information processing and lead to higher team performance. The reasoning behind this is that - if we hold the average level of metaknowledge constant – in a team with a high disparity of metaknowledge levels or, in our terms, high *TMS centralization*, at least one member has a relatively high level of individual metaknowledge. The presence of such a metaknowledge-central member can act as a catalyst for group information processing, stimulating members to retrieve information from each other and to discuss it more fully, thus helping them to reach better decisions. We also found, however, that this effect was contingent on the requirements of the team's task. Only when information was distributed among members in such a way that posed a particularly high demand on expertise coordination, did teams with a centralized TMS structure outperform teams with a decentralized structure. This chapter's main contribution lies in the domain of TMS theory, advancing a novel perspective on TMS structure that explicitly takes intra-team differences in metaknowledge into consideration. Its implications, however, extend beyond TMS research and into the larger domain of group cognition, suggesting that we can learn more about the effects and dynamics of constructs such as, e.g., shared mental models (Cannon-Bowers, Salas, & Converse, 1993) by considering different configurations of sharedness among group members in addition to its average level.

In chapter 3 we moved beyond small groups and considered the role of metaknowledge-central individuals in *intergroup knowledge integration*, that is, group-level relations of acquiring, processing, and utilizing other groups' knowledge. We argued that intergroup knowledge integration would be more likely when groups are connected by boundary spanning knowledge exchange relations that involved individuals who are metaknowledge-central in their own groups. Our findings were consistent with our hypotheses: A group – in our case a business unit – was more likely to report integrating knowledge from another unit when the members seeking knowledge from the other unit and when the members chosen as knowledge sources in the other unit were central in their own unit's TMS structure. Boundary spanning ties between individuals who were peripheral in their own units' TMSs, on the other hand, did not carry additional benefits for intergroup knowledge integration. In providing further evidence for the value of considering individuals' levels of metaknowledge in the examination of knowledge coordination in organizations, this chapter builds upon and extends the previous chapter's contribution to TMS research. This chapter's primary contribution to the literature, however, lies in the domain of boundary spanning. Through integrating boundary spanning research with theories of group cognition and group information processing, we contribute to a better understanding of how the characteristics of boundary spanners shape intergroup relations.

Finally, in chapter 4, we considered interactions involved in knowledge coordination more broadly and examined the factors driving two kinds of advice networks in an organization: knowledge seeking and metaknowledge seeking networks. In particular, we focused on the role of formal hierarchy and argued that formal rank induces specific expectations about individuals' value and accessibility as sources of task knowledge and of metaknowledge. Analyzing the advice networks of a knowledge-intensive organization, we found that while there was no difference in popularity as a source of task knowledge between low and mid-level ranking individuals, high-ranking individuals were significantly less likely to be approached in search for task knowledge than either of the first two groups. In contrast, when individuals were seeking information about whom to ask for task knowledge – i.e. when they were seeking metaknowledge – they were more likely to choose mid-level over low-ranking and high-ranking over mid-level actors as their advisors. This chapter's primary contribution to the literature lies in the area of intraorganizational networks, answering recent calls for research that builds a better understanding of the interplay between formal structures and informal networks (McEvily et al., 2014). Furthermore, this chapter adds to the preceding chapters in providing initial empirical evidence about factors affecting metaknowledge building activities of individuals. This can provide suggestions about potential antecedents of individual differences in metaknowledge levels that are discussed in chapters 2 and 3.

Implications for Future Research

The findings summarized above contribute to the literatures on transactive memory systems and group cognition, intra- and intergroup information exchange and knowledge integration, and intra-organizational networks in multiple ways. While each chapter provides a separate discussion of the specific theoretical and practical implications of each study, in this section I will briefly highlight several broader implications for future research that result from a combined consideration of these studies.

One core contribution of the presented work to TMS research is to add to the predominant preoccupation with groups' average levels of shared knowledge of who knows what a new perspective with a focus on individual metaknowledge and on differences in such. While we have found that disparity in metaknowledge levels can be more productive than homogeneity (chapter 2), an important note that we need to make to forestall misunderstandings is that our findings do not imply that a group with a centralized TMS structure would outperform a group with what could in a more traditional sense be called a "strong TMS", i.e. a group with a high level of shared metaknowledge (Brandon & Hollingshead, 2004). Although the latter would constitute an example of a group with a decentralized TMS structure, as discussed in chapter 2, it also differs from the former on other dimensions such as the average level of metaknowledge. Rather, our combined findings from chapter 2 and 3 can be interpreted in the sense that, where differences in metaknowledge among group members exist, those individuals who have a comparatively higher level of metaknowledge are particularly critical to knowledge coordination processes – within as well as between groups.

Taking into account that such differences can and do exist becomes increasingly important in the changing ecology of teams (Wageman, Gardner, & Mortensen, 2012). Contemporary collaboration conforms less and less to standard definitions that rely on clear boundaries and temporal stability of teams. Instead, structures that involve temporary, recurring, distributed, and overlapping collaboration become increasingly characteristic of the modern workplace. This has two consequences. First, conditions that could allow a team to develop a full and fully converged representation of who knows what become increasingly rare (Brandon & Hollingshead, 2004). Thus, teams with different configurations in metaknowledge become increasingly common and need to be better understood. While in chapters 2 and 3 our focus lies simply on member differences in the levels of metaknowledge, adopting a dyadic or a network perspective, as we suggest in these chapters, can extend to more complex configurations in future research. A network conceptualization of metaknowledge in teams lends itself, for example, to the investigation of "cognitive cliques" within a team – situations in which a team contains subgroups whose members have high levels of metaknowledge about their subgroup members and relatively low levels of metaknowledge about members pertaining to other subgroups.

Second, in a context where teams emerge from a latent pool or network of potential members, continually assembling, disbanding, and reassembling in new configurations to tackle new tasks and projects (Contractor, 2013), a view of TMSs that is primarily geared towards understanding the functioning of small, stable groups will soon become constraining. As we strive to understand TMSs in larger collectives or networks - for instance, at the organizational level – we will likely increasingly consider the role of central people who “manage expertise recognition” (Garner, 2006, p. 334), the interplay between TMSs in small groups and communication links between such groups (Ren & Argote, 2011), and activities that individuals undertake in order to obtain metaknowledge (Galunic et al., 2014). Chapters 2, 3, and 4 of this dissertation contribute to these different lines of thought.

Recognizing the impact of what we have called “metaknowledge-central” individuals, another natural next question for future research is to explore factors that can explain or predict differences in metaknowledge among individuals. There are at least three groups of likely candidates for such factors. The first group contains factors inherent in an organization’s formal structure, e.g. roles, responsibilities, or workflow interdependence structures. For example, chapters 3 and 4 discuss differences in metaknowledge associated with formal leadership roles. The second group contains factors relating to the social context surrounding individuals, e.g. group composition, communication networks, or geographical distribution (O’Leary & Mortensen, 2009; Su, 2012). Finally, the third group contains factors identifying individual differences in motivations, personality, or cognitive abilities. For instance, individuals who have a high level of learning goal orientation (VandeWalle, 1997) may be more attuned to cues that help them build an accurate understanding of what expertise they can learn from which colleagues than individuals with low learning goal orientation.

Conclusion

Coordinating knowledge – locating, transferring, and integrating the knowledge resources distributed among individuals’ minds – is a critical activity for groups and organizations that engage in knowledge-intensive work. Metaknowledge as the back bone of transactive memory systems is a key factor in this process. Viewing metaknowledge as an individual resource that can differ among individuals, this dissertation has aimed to shed light onto the role of such differences within small groups as well as in larger collectives or networks. In three empirical studies we have found that a) teams that contain a member with an above-average level of metaknowledge can outperform teams in which metaknowledge is more evenly distributed, b) individuals with a high level of metaknowledge are particularly effective in the role of informational boundary spanners between organizational units, and c) informal social networks through which task knowledge and metaknowledge are exchanged are to a considerable extent influenced by the formal organizational structures in which such interactions take place. Naturally, each of the chapters raises new questions. We thus hope that the perspectives presented and insights gained in this work will inspire future research, furthering our understanding on the role that metaknowledge and social cognition more broadly play in knowledge coordination.

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Summary

Knowledge coordination, the process of locating, transferring, and integrating the specialized knowledge of multiple individuals, is a critical prerequisite for organizations to make fuller use of one of their most important resources: the knowledge of their employees. Yet, knowledge coordination is as challenging as it is important. This dissertation aims to further our understanding of how groups and larger collectives process information and integrate their knowledge and what factors influence the social interactions at the core of this process. More specifically, in three studies this dissertation examines the role of individuals' metaknowledge, i.e. the knowledge of who knows what, in knowledge coordination processes in groups and across group boundaries.

The first study examined the implications of differences in members' metaknowledge on knowledge integration and decision making in teams. We predicted that a team that contains at least one member with an above-average level of metaknowledge – even though this implies below-average metaknowledge the other members – can outperform a team in which the same amount of metaknowledge is evenly distributed among the team members. In a laboratory experiment we found that in situations that posed high demands on knowledge coordination, teams in which metaknowledge was centralized in one member processed information more deeply and reached better collective decisions than teams in which the same amount of metaknowledge was evenly distributed among members.

The second study examined the role of metaknowledge in communication across group boundaries. In this study we suggested that while intergroup knowledge integration relies on knowledge exchange ties between individual members of the groups, not all members are equally effective boundary spanners. In a field survey of knowledge workers in an engineering firm, we found that the extent to which individuals' knowledge exchange ties across business unit boundaries contributed to knowledge integration between units depended on the extent of their metaknowledge about their own units.

The third study focused on the antecedents of informal networks of knowledge seeking and metaknowledge seeking in a knowledge intensive organization. In particular, we argued that formal rank induces different expectations about individuals' value and accessibility as sources of task knowledge and of metaknowledge. We found that while increasing rank increased an individual's popularity as a source of metaknowledge, high-ranking individuals were less likely to be sought out for task knowledge.

Samenvatting (Dutch Summary)

Kenniscoördinatie, oftewel het lokaliseren, overdragen en integreren van de specialistische kennis van meerdere individuen, is een vereiste voor organisaties die vollediger gebruik willen maken van een van hun belangrijkste vormen van kapitaal: de kennis van werknemers. Kenniscoördinatie is echter even uitdagend als belangrijk. Deze dissertatie heeft als doel inzicht te bieden in hoe groepen en grote collectieven informatie verwerken en kennis integreren en de factoren die van invloed zijn op de sociale interacties die aan de basis staan van dit proces. De dissertatie omvat drie studies waarin wordt onderzocht welke rol metakennis van individuen, d.w.z. de kennis over wie wat weet, heeft in kenniscoördinatieprocessen binnen groepen en tussen groepen.

De eerste studie onderzoekt de consequenties van verschillen in metakennis onder groepsleden voor de kennisintegratie en besluitvorming in teams. We voorspellen dat een team dat ten minste een groepslid heeft met bovengemiddelde metakennis – ook al impliceert dit dat de metakennis van andere groepsleden onder het gemiddelde ligt – beter kan presenteren dan een team waarin dezelfde hoeveelheid metakennis evenredig verdeeld is tussen teamleden. Uit een laboratoriumexperiment kwam naar voren dat in situaties die veel kenniscoördinatie behoeven, de informatieverwerking fijnzinniger is en de collectieve besluitvorming beter is bij teams waarin de metakennis bij een persoon ligt dan in teams waarin dezelfde hoeveelheid metakennis evenredig is verdeeld onder de teamleden.

De tweede studie richt zich op de rol van metakennis in communicatie waarin de grenzen van groepen worden overschreden. In deze studie stellen wij dat, terwijl kennisintegratie tussen groepen afhankelijk is van kennisintegratie tussen individuele leden van de groepen, niet alle groepsleden even effectief zijn in het slaan van bruggen tussen groepen. Uit een veldonderzoek van kenniswerkers in een ingenieursbureau kwam naar voren dat de mate waarin de kennisuitwisselingsbanden van individuen tussen business units bijdraagt aan de kennisintegratie tussen deze groepen, afhankelijk is van de hoeveelheid metakennis van deze individuen over hun eigen business unit.

De derde studie richt zich op de antecedenten van informele netwerken voor het zoeken naar kennis en metakennis in een kennisintensieve organisatie. We stellen dat de informele rang andere verwachtingen creëert ten aanzien van de waarde en toegankelijkheid van een individu als bron van taakkennis en metakennis. Uit het onderzoek blijkt dat, terwijl met een hogere formele positie in de organisatie de populariteit van het individu als bron van metakennis toeneemt, hogergeplaatste individuen minder vaak worden benaderd voor taakkennis.

About the Author

Julija Nia Mell (1987) received her Diploma (Master's) degree in Psychology from Humboldt University Berlin in 2010. She started her PhD at Rotterdam School of Management in January 2011 and was a visiting PhD at Northwestern University in 2013 and 2014. Currently, she is an Assistant Professor of Management at ESSEC Business School.

Julija's research lies at the intersection between group cognition and social networks in organizations. Her dissertation examines the role of individuals' metaknowledge, i.e. the knowledge of who knows what, in knowledge coordination processes in groups and across group boundaries. Her work has appeared in the Academy of Management Journal, Group Processes and Intergroup Relations, and Economica. Julija is a member of the Academy of Management, the Interdisciplinary Network for Group Research, and the International Network for Social Network Analysis.

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Connecting Minds

On the Role of Metaknowledge in Knowledge Coordination