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Transactive Memory Systems 1985–2010:
An Integrative Framework of Key Dimensions, Antecedents, and Consequences

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Abstract

Over two decades have passed since Wegner and his co-authors published the groundbreaking paper on transactive memory systems (TMS) in 1985. The concept attracted the interest of management, psychology, and communication scholars who have employed a variety of methods to examine the phenomenon. In this paper, we review 76 papers that examined transactive memory systems and summarize the findings in an integrative framework to show the antecedents and consequences of TMS. Our review also reveals important issues in the literature related to the measurement of TMS, its multidimensional nature, extending TMS from the team level to the organizational level, and the potential role of TMS in explaining the benefits of experience in existing organizations and

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new entrepreneurial ventures. We conclude by calling for future research to examine the dynamic evolution of TMS, TMS in virtual teams, TMS in entrepreneurial ventures, and TMS at the organizational level facilitated with information technologies.

Introduction

Over two decades have passed since Wegner and his collaborators first presented the concept of transactive memory to refer to a collective system that individuals in close relationships use to encode, store, and retrieve knowledge (Wegner, Giuliano, & Hertel, 1985; Wegner, 1987). Over the past two decades, researchers from many disciplines including communication, management, social psychology, and information systems have become interested the concept and its effects in group and organizational settings. The concept has been extended beyond its original context of collective remembering in intimate couples to work groups and organizations (e.g., Liang, Moreland, & Argote, 1995; Jackson & Klobas, 2008; Lewis, 2003). We have also accumulated a large body of literature regarding the antecedents and consequences of transactive memory in dyads and work groups. Much of the insight, nonetheless, remains dispersed in separate studies with limited integration.

In this article, we report findings from a comprehensive review of the transactive memory literature. We summarize the literature in an integrative framework that shows the antecedents, consequences, and factors that moderate the relationship between transactive memory systems (TMS) and various outcomes. Our review suggests four important issues that need to be considered and addressed in future research in terms of (1) using standard scales in measuring transactive memory systems, (2) deciphering the relationships among the dimensions of transactive memory systems, (3) extending transactive memory systems to the organizational level, and (4) investigating the role of TMS in explaining the benefits of experience in existing organizations and new entrepreneurial ventures.

Three observations motivated our decision to conduct a comprehensive review of the literature. First, despite two decades of research, the transactive memory literature remains somewhat fragmented. Researchers choose to study variables of their individual interest and there is little systematic integration such as the input–process–output framework of team effectiveness (Mathieu, Maynard, Rapp, & Gilson, 2008). Although many researchers have examined factors of great interest—such as stress (Ellis, 2006), gender stereotypes (Hollingshead & Fraidin, 2003), and communication (Lewis, 2004), to name just a few—a review is likely to help us integrate accumulated knowledge and identify gaps in the literature for future research.

Second, the growth of the literature increases the likelihood of replicating studies and cross-checking the effects of variables across studies. At the same time, we begin to observe relationships that are inconsistent or even contradict one another across studies. One example is how the relationship between trust and transactive memory is conceived. Kanawattanachai and Yoo (2007) measured cognition-based trust as a key dimension of transactive memory, similar to the task credibility dimension in Lewis's 15-item scale (2003). In contrast, Akgun, Byrne, and Kesin (2005) examined trust as an antecedent to transactive memory systems, whereas Rau (2005) examined trust as a moderator of the relationship between transactive memory systems and top management team performance. A review is likely to help us cross validate insights from different studies and begin to reconcile inconsistencies in the relationships between TMS and other constructs.

Third, we hope the review will serve as a vehicle to bridge the gap between theory and practice. While the benefits of TMS have been consistently demonstrated in small groups, there is not much evidence showing its working and benefits in organizations at large, although many organizations have invested heavily in technological solutions to make better use of their intellectual capital (Moreland & Argote, 2003). Part of the answer may reside in the context of the studies that linked TMS to improved performance and the extent to which these findings generalize beyond small face-to-face groups. A comprehensive review allows us to compare findings across methods and contexts and thereby to identify consistencies and inconsistencies in the literature.

In the rest of the article, we first define the concept of transactive memory and present a representation of its key elements. We then describe how we selected the articles to review, together with basic statistics about the literature. We summarize our findings in an integrative framework about the theoretical antecedents and consequences of transactive memory on group outcomes together with factors that moderate the relationship between transactive memory systems and outcomes. We conclude with a discussion of important issues that need to be addressed and our recommendations for future research.

Transactive Memory Systems Defined

The concept of transactive memory systems was first introduced as a mechanism to illustrate how individuals can rely upon external aids such as books, artifacts, or group members to extend individual memory. Wegner, Giuliano, and Hertel (1985) defined the two components of transactive memory as: (1) organized knowledge contained entirely in the individual memory systems of group members, and (2) a set of transactive processes that occur among group members. A TMS consists of a set of individual memory systems in combination with the communication that takes place between individuals (Wegner, 1987). A commonly used definition of transactive memory system is a shared system that people in relationships develop for encoding, storing, and retrieving information about different substantive domains (Hollingshead, 1998a; Ren, Carley, & Argote, 2006).

A common confusion in the literature is to equate transactive memory with transactive memory systems and use the terms interchangeably. The two concepts are distinct, with transactive memory being a component of a TMS. As Wegner, Giuliano and Hertel (1985) indicated, a TMS has two components: a *structural* component, which shows how transactive memory links individual memories to a collective knowledge network; and three transactive *processes* that can occur during the encoding, storing, and retrieval of information in the group memory. An individual's memory has two components: an individual memory of information the individual possesses, and a transactive memory with *label* and *location* information about what other members know. The second part is also referred to as metaknowledge, which helps individuals to retrieve information from external sources. Although a transactive memory or metaknowledge provides hints about "who knows what," a TMS goes beyond the simple presence of the knowledge and requires dyads or groups to also engage in transactive processes. In 1995, Wegner illustrated the concept using the computer network metaphor and identified three processes related to the development and application of transactive memory systems: directory updating (people learn what others are likely to know); information allocation (new information is communicated to the person whose expertise will facilitate its storage); and retrieval coordination (information on any topic is retrieved based on knowledge of the relative expertise of the individuals in the memory system).

Liang, Moreland, and Argote (1995) extended the TMS concept to the group level of analysis. They identified three indicators or symptoms of groups with established transactive memory systems by analyzing videotapes of groups performing a radio assembly task. These investigators found that, compared with groups whose members were trained individually, groups whose members were trained together tended to specialize in remembering different aspects of the assembly task, to trust each other's expertise, and to coordinate their activities more effectively. These indicators were respectively named memory differentiation, task credibility, and task coordination. Based on this study, Lewis (2003) developed a 15-item scale that has been widely used to measure the presence of transactive memory systems in laboratory and field research.

The concept of transactive memory systems is similar to but distinct from related concepts such as team mental models (Klimoski & Mohammed, 1994), shared-task understanding (He, Butler, & King, 2007) and cross-understanding (Huber & Lewis, 2010). Team mental models have been defined as shared mental representations of aspects of a team's task environment (Klimoski & Mohammed, 1994). The concept of shared-task understanding, which is closely related to the concept of shared mental models, refers to knowledge structures shared by team members about the team's task, goals, strategies and so on (He et al., 2007). The concept of cross-understanding refers to the extent to which group members have an accurate understanding of the mental models of other group members (Huber & Lewis, 2010). What all of these concepts have in common with the concept of transactive memory is that they imply or capture cognitive representations shared among team members. Transactive memory systems differ from these other concepts in two important ways. First, transactive memory systems are narrower in content coverage than the other concepts. Transactive memory systems include knowledge about who knows what, while team mental models and shared-task understandings include additional content such as team goals and strategies, and cross-understanding includes member's beliefs and preferences. Second and most importantly, a TMS is a cooperative division of labor for learning, remembering and communicating knowledge (Wegner, 1987). Thus, groups with a well-developed TMS exhibit differentiation where different members specialize in learning, remembering and sharing different knowledge. By contrast, team mental models, shared-task understandings and cross-understandings do not involve a differentiated memory structure or a division of labor. Thus, in contrast to the other concepts, transactive memory systems involve a differentiated structure where members specialize in remembering knowledge from different domains. A TMS is a retention bin or knowledge repository (Argote & Ingram, 2000) for group or organizational memory (Walsh & Ungson, 1991). A TMS stores knowledge of who knows what, which can influence the future performance of the group or organization (Argote & Miron-Spektor, in press; Levitt & March, 1988).

Literature Search and Review

We searched for research articles in the Web of Science database with the keyword "transactive memory" in the title, abstract, or list of keywords of the paper in three citation databases: Science Citation Index Expanded, Social Sciences Citation Index, and Arts & Humanities Citation Index. Altogether, we found 206 papers. We included papers with a primary focus on transactive memory systems, meaning that TMS was included as an independent variable, a dependent variable, or a mediating variable. We excluded papers that examined TMS only as a moderating variable because incorporating them in our theoretical framework would require the inclusion of the two variables whose relationship is moderated by TMS, and thereby make our theoretical framework more cumbersome. One example is a study by Espinosa, Slaughter, Kraut, and Herbsleb (2007) that investigated three types of coordination needs in software teams—technical, process, and temporal—and how those needs were negatively affected by geographic distance. Transactive memory was examined as a type of shared knowledge that mitigated the negative effects of geographic distance on team coordination needs. Including such studies would require adding variables such as coordination needs to our theoretical framework, which would compromise its parsimonious structure.

Figure 1 shows the number of papers published each year, with the bottom portion being the ones included in our review. We did not include years before 1999 because the publication of TMS papers remained sparse. Interest in transactive memory has accelerated in the past 10 years. At the same time, the proportion of papers that refer to transactive memory systems but in which TMS is not the core topic of the paper has also grown significantly. These are signs that transactive memory systems are being reified, as with other well-known concepts such as absorptive capacity (Lane, Koka, & Pathak, 2006). In other words, as more people become familiar with the concept, they begin to "take it for granted" and use it conveniently to meet individual research needs, with little consideration of the original assumptions and propositions that define the relationships of the construct with other constructs.

Figure 2 shows the distribution of studies using different research methods. Of the 76 studies reviewed, 18 are conceptual or review papers, 25 are experimental research, 31 are field studies, and two are simulations (Palazzolo,

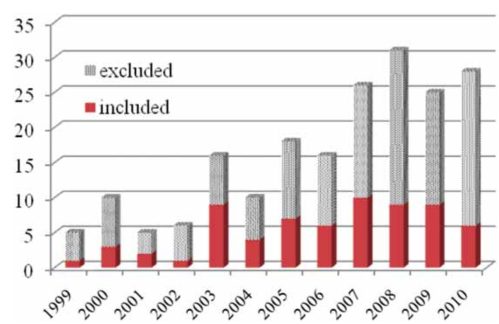

Figure 1 **Transactive Memory Papers Published between 1985 and 2010.**

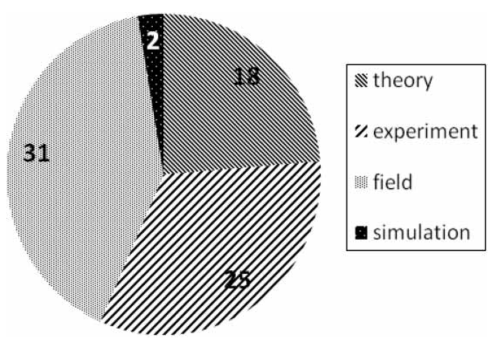

Figure 2 **Review of Types of Paper Published between 1985 and 2010.**

Serb, She, Su, & Contractor, 2006; Ren et al., 2006). Two-thirds of the field studies were published in or after 2006. Of the 31 field studies, 22 surveyed work groups in a variety of real-world organizations including banks, hospitals, manufacturing firms, and high-tech or R&D institutes. Thus, the empirical work is divided almost equally between the laboratory and field.

Figure 3 shows the distribution of studies across different levels of analysis. More than three-quarters of the studies we reviewed examined transactive memory systems at the team or group level (59 or 77.6%). Another 10 studies examined transactive memory systems at the dyadic level. Three studies examined the effects of transactive memory systems at the individual level. For instance, Jarvenpaa and Majchrzak (2008) asked individuals in an inter-organizational network, FBI InfraGard program, to identify the necessary factors for developing transactive memory when congruent interests cannot be assumed. In addition, four studies, including one case study (Jackson & Klobas, 2008), explored the challenges and possibilities of extending the concept of transactive memory system to the organizational level.

To inform our review, we examined the 18 conceptual and review papers to identify emerging patterns or missing links in the literature. Only one paper of the 18 papers is a review of TMS literature, published by Peltokorpi (2008) in the *Review of General Psychology*, while the rest are thought or opinion pieces. Nine of the conceptual papers focused on describing the working of TMS, including the two papers by Wegner (1987, 1995), or the development of TMS as a result of cognitive interdependence (Brandon & Hollingshead, 2004), communication (Hollingshead & Brandon, 2003) or affect (Huang, 2009). Five papers extended the concept to a new level or context such as an organizational level TMS (Anand, Manz, & Glick, 1998; Nevo & Wand, 2005) or emergent groups responding to disasters (Majchrzak, Jarvenpaa, & Hollingshead 2007). Three papers discussed TMS as a mechanism to manage knowledge integration challenges in virtual teams (e.g., Alavi & Tiwana, 2002). The review by Peltokorpi (2008) summarized findings of 28

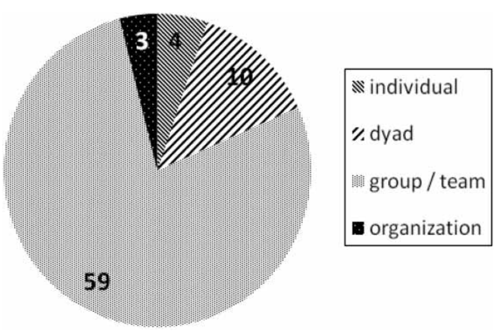

Figure 3 Review of Level of Analysis Published between 1985 and 2010.

studies at dyadic and team levels and identified three interesting directions for future research: the tradeoff between the frequency and quality of communication to form TMS, the effects of team diversity on TMS, and the effects of conflict and power on TMS. What is missing in these papers is a comprehensive review of TMS research conducted in different disciplines and at different levels of analysis and a navigation map of what we have learned so far and what remains unknown, which is what we attempt to deliver in this paper.

An Integrative Framework of Group Transactive Memory Systems

Figure 4 summarizes our review of the antecedents, consequences, and moderating factors of transactive memory in teams and groups research. The antecedents of transactive memory systems that have been studied in previous research are depicted on the left side of the figure. The key components, indicators, and measures of transactive memory systems are depicted in the middle of the figure. Consequences of transactive memory systems—including team learning, creativity, member satisfaction and, most frequently, team performance—are depicted on the right side of the figure. Factors that have been studied as moderators of the relationship between transactive memory systems and outcome variables are depicted in the lower right quadrant as influencing the link between transactive memory systems and outcome variables.

We use the Inputs–Mediators–Outcomes framework presented in Mathieu et al. (2008) to organize the antecedents and consequences of TMS (see also Ilgen, Hollenbeck, Johnson, & Jundt, 2005). We classify TMS antecedents into three levels: member attributes or team composition

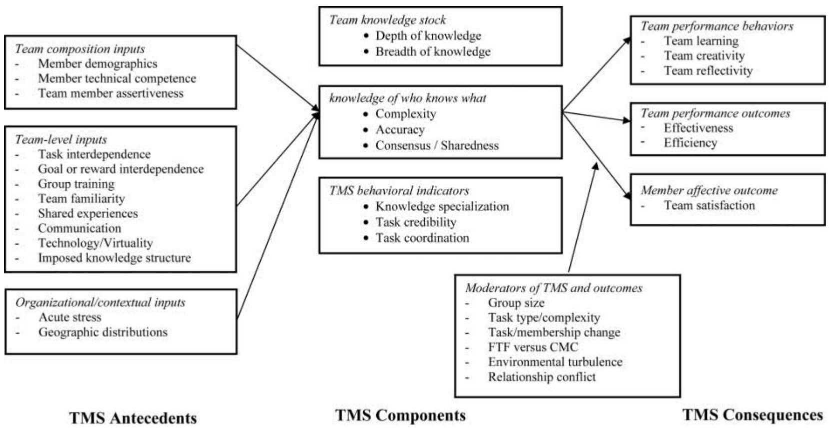

Figure 4 An Integrative Framework of Factors Investigated as Transactive Memory Systems Antecedents and Consequences.

inputs, team-level inputs, and organizational-level input. We classify TMS consequences into team performance behaviors such as team learning, team performance outcomes, and member affective outcomes. We describe each section of the framework in detail. At the end of each section, we identify factors that need to be analyzed in future research, based on the Mathieu et al. (2008) framework, as well as our experiences of conducting and reviewing TMS research.

Antecedents to the Development of Transactive Memory Systems

Based on the team effectiveness framework by Mathieu et al. (2008), the antecedents of TMS can be classified into three levels: team composition inputs (member attributes), team-level inputs, and organizational-level inputs. Team composition inputs include member demographics, competences, and personality traits. Team-level inputs include interdependence, group training, shared experiences, team familiarity, communication (including computer-mediated communication), and imposed knowledge structures. Organizational inputs investigated thus far include acute stress and the effect of geographic distance.

Member demographics and personality traits. Wegner (1995) described four bases for attribution of expertise: surface characteristics such as age, gender, and ethnicity; assignment; exposure to information; and roles or an explicit indication of expertise. Hollingshead and Fraidin (2003) examined gender stereotypes and assumptions about expertise and found that (1) male and female participants shared similar gender stereotypes across knowledge categories and (2) when paired with opposite-sex partners, participants were more likely to assign categories based on gender stereotypes and also to learn more in categories consistent with stereotypes than in categories inconsistent with stereotypes.

Bunderson (2003) examined two types of member attributes and how they were used as status cues to infer member expertise. Diffuse status cues include gender and ethnicity. Specific cues include organizational experience and certifications. Bunderson (2003) found that both types of cues were associated with perceived expertise. The association between specific cues and perceived expertise, however, was stronger than the association between diffuse cues and perceived expertise. Only specific cues were associated with intra-group influence, and only the alignment between specific cues and intra-group influence predicted group performance. The difference between the Hollingshead and Fraidin (2003) and the Bunderson (2003) studies can be attributed to the context: gender is more relevant in intimate relationships between couples, and experience and certifications are more relevant in work groups in organizational settings.

We found only one study that examined personality traits of members in conjunction with TMS. Pearsall and Ellis (2006) studied critical team member dispositional assertiveness and found it to be positively related to team performance and team satisfaction. They also found that TMS mediated the effects of critical team member assertiveness on team performance and satisfaction. Assertiveness of critical team members matters because assertive members know how to communicate effectively and share ideas and therefore can work to facilitate the communication and flow of information in team contexts.

Task or reward interdependence. The first paper published on TMS is titled *Cognitive Interdependence in Close Relationships* (Wegner et al., 1985), which illustrates the central role of interdependence to TMS. Interdependence describes the extent to which team members' work outcomes depend on a combination of their own input and the input of other members. Cognitive interdependence develops as group members learn about one another's areas of expertise and become dependent on one another for acquiring, remembering, and generating knowledge (Hollingshead, 2001). In a theoretical paper, Brandon and Hollingshead (2004) presented cognitive interdependence as the most critical prerequisite to the development of a TMS. Cognitive interdependence can result from a reward system or from the structure of group tasks and can influence how knowledge domains and responsibilities are assigned in groups. In a laboratory experiment, Hollingshead (2001) showed that convergent expectations for who will learn what were more likely to develop when there was a match between cognitive interdependence and knowledge expected of a partner. Partners remembered more collectively when they shared perceptions of expertise than when they did not.

We found only one study that empirically tested the role of task and goal interdependence on TMS and group performance. Zhang, Hempel, Han and Tjosvold (2007) assessed "task interdependence" as the extent to which team members believe that they need information, materials, and support from other team members in order to carry out their tasks and "goal interdependence" as members' perception of how their goals are related to other members' goals. Although the two are conceptually different, the researchers found a positive correlation between task and goal interdependence ($r = 0.35$). Both task and goal interdependence led to a higher level of TMS, which led to improved team performance. Hence, TMS was found to mediate between task and goal interdependence, on the one hand, and performance, on the other.

Group training and shared group experience. Numerous studies have shown that groups whose members were trained together developed more advanced transactive memory systems and outperformed groups whose members were trained individually (Liang et al., 1995; Moreland, Argote, & Krishnan, 1996). Group training facilitates the emergence of TMS for at least two reasons. First, it affords members the opportunity to observe one another performing the group task and to store cues about each member's special expertise. Second, it affords members the opportunity to communicate, and thereby to question, claim, and evaluate one another's expertise. Rulke and Rau (2000) coded group conversation during group training into five categories: (1) claiming to have expertise in a certain domain; (2) claiming not to have expertise in a certain domain; (3) asking questions concerning a domain of expertise; (4) planning and coordinating who is to do what in the group; and (5) evaluating the expertise and competence of group members. The researchers observed greater frequency of communication to *claim* and *coordinate* expertise in groups who were trained together than in those who were trained apart. Further, groups with more developed TMS spent more time determining expertise early on than groups with less developed transactive memory systems.

The effects of group training on transactive memory systems and performance go beyond the benefits from team development or familiarity. Moreland, Argote, and Krishnan (1996) conducted an experiment to rule out explanations alternative to transactive memory for the enhanced performance engendered by group training. The experiment included a condition in which a team-building exercise was added after the individual training session (to increase member familiarity and encourage group development) and another condition in which team members trained with a different group from the one they performed with (to disable TMS developed in the training session while preserving learning acquired during training about how to operate as a group) as well as the individual and group training conditions used in the initial study (Liang et al., 1995). The researchers found that participants in neither of these new conditions developed as strong a TMS or performed as well as participants who trained and performed in the same group. The transactive memory scores and performance of participants in these two new conditions did not differ significantly from the performance of participants who were trained as individuals. Further, transactive memory mediated the relationship between training and performance, implying that the primary benefit of group training was the development of TMS.

Gino, Argote, Miron-Spektor, and Todorova (2010) further examined the effects of direct experience on TMS and team creativity. In three laboratory experiments, they manipulated *direct* task experience by having group members practice a task similar to what they would be asked to perform as a team and *indirect* task experience by having group members watch another team perform the similar task. Compared with indirect task experience, direct task experience led to more developed TMS as well as to a greater level of creativity. Further, TMS mediated the effect of experience on creativity.

Prior relationships and familiarity among members. Team familiarity reflects the extent to which members are knowledgeable about one another as a result of prior experiences or interactions. Team familiarity increases the likelihood that members become aware of each other's expertise or past experiences. Several studies have shown a positive impact of team member familiarity or prior experience on the emergence of a TMS, especially in member awareness of expertise location (e.g., Akgun et al., 2005; He et al., 2007). For instance, He et al. (2007) studied undergraduate project teams and found a positive effect of member familiarity on awareness of expertise location. In addition, Littlepage, Robison, and Reddington (1997) found that groups of students who had previously worked with the same group members on a similar task were better able to recognize member expertise, which facilitated group performance.

At the same time, two other studies—by Jackson and Moreland (2009) and Michinov and Michinov (2009)—did not show an effect of member familiarity on the development of transactive memory systems in student projects. Another study, by Lewis (2004) of MBA consulting teams, showed a moderating effect of member familiarity on the relationship between initial expertise distribution and TMS emergence. A stronger relationship between distributed expertise and TMS emergence was observed when familiarity was high than low.

To reconcile the divergent findings, we speculate that team familiarity affects the dimensions of TMS differently. Knowledge about other members from prior experiences is likely to increase general awareness of expertise distribution among members (the structural or content component of TMS), which may or may not affect TMS processes such as knowledge specialization, task credibility, or coordination.

Communication and technology/virtuality. Communication was among the first set of factors linked to the development of transactive memory systems. In the discussion of transactive memory development in intimate couples, Wegner, Giuliano, and Hertel (1985) emphasized the importance of reciprocal self-disclosure through which couples reveal information about themselves to each other. Hollingshead and Brandon (2003) further elaborated the role of communication in helping move individuals from stereotypical perception of expertise, based on gender, for example, to sophisticated and accurate attributions. Group discussion can provide members with an opportunity to discuss and demonstrate their expertise, which in turn allows for greater precision in determining who is an expert in a particular knowledge domain.

Pearsall, Ellis, and Bell (2010) studied role-identification behaviors, when team members either shared information about their specific roles or requested information about their teammates' areas of responsibility. The researchers found that role-identification behaviors were positively related to the emergence of both team mental models and transactive memory, which mediated the effects of role-identification behaviors on team performance.

Several field studies have tested the effect of communication frequency on the development of TMS. The effect of communication frequency has also been investigated in a simulation (Palazzolo et al., 2006). For instance, Lewis' (2004) study of MBA consulting teams found a positive association between the frequency of communication during the planning phase and TMS emergence. She also found that communication channel mattered in addition to communication frequency. Frequent face-to-face communication led to TMS emergence, but communication via other means such as email and telephone conversations had no effect. Similarly, He et al. (2007) studied undergraduate project teams and found that the number of face-to-face meetings and phone calls had significant and positive effects on awareness of expertise location, but emails had no effect.

Despite the general consensus on the importance of communication for the development of transactive memory systems, a few inconsistencies exist in the literature. One study showed no relationship between team communication and TMS (Akgun et al., 2005). Compared with Lewis (2004) and He et al. (2007), who examined impromptu student teams, Akgun et al. (2005) studied new product teams that had existed for at least six months. The reason for the discrepancy may be the time at which team communication was measured: in the planning stage, or in the implementation stage. Kanawattanachai and Yoo (2007) collected three waves of data on transactive memory in student projects and found that task-oriented communication led to expertise location and cognition-based trust two weeks after the teams were formed, but the effects disappeared five or eight weeks into the team's operation. Similarly, Lewis (2004) found that communication frequency during the planning stage facilitated TMS development. Collectively, the studies suggest that the effects of communication on the development of transactive memory are more valuable in early rather than later stages of group operations.

Another discrepancy in the literature concerns the effect of non–face-to-face communication. Contrary to Lewis (2004) and He et al. (2007), Kanawattanachai and Yoo (2007) found a positive effect of computer-mediated communication on members' initial beliefs and trust about others' specialized knowledge. We speculate that the different results regarding the impact of computer-mediated communication on TMS development were due to differences in study contexts. Both Lewis (2004) and He et al. (2007) studied student teams that were located in the same university and thus, could communicate face-to-face. In contrast, Kanawattanachai and Yoo (2007) studied MBA students of ten nationalities taking courses in four different countries. Each team was composed of students from the four countries. There was no chance for members to engage in face-to-face communication and members were expected to communicate only via the Internet. Consequently, members relied solely upon computer-mediated communication to get work done and were able to develop a TMS through computer-mediated communication.

To understand the role of communication in transactive memory, it is also important to examine communication in the utilization of transactive memory (Littlepage, Hollingshead, Drake, & Littlepage, 2008). Research on the role of communication in the *utilization* of shared knowledge is not entirely consistent. Some studies have shown that communication can facilitate transactive retrieval, especially when dyads share information face-to-face, which allows them to use nonverbal and paralinguistic cues to signal and combine their knowledge effectively (Hollingshead, 1998b). Compared with members of face-to-face dyads, members of dyads using the computer were less likely to explain their answers and less likely to solicit task-relevant information from their partners. Other studies show that groups with a shared agreement of member knowledge can coordinate transactive retrieval to improve performance without explicit communication (Hollingshead, 2001; Wegner, Erber, & Raymond, 1991).

O'Leary and Mortensen (2010) found that the effect of geographic distribution on the development of transactive memory systems in virtual teams depended on the configuration or number of team members at each location. Totally dispersed teams with only one member at each geographic location developed stronger transactive memory systems than teams with two or more members per location. Further, an unequal number of members per location led to more negative outcomes than balanced subgroups.

Written communication and imposed knowledge structure. Transactive memory systems can be created artificially, either by assigning members to specific domains or by providing members with information about others' expertise. Wegner et al. (1991) found that stranger dyads recalled more items than natural couples when provided with an explicit memory assignment. Without the explicit scheme for learning words in different domains, intimate couples recalled more words than strangers. The imposed organizational structure thus inhibited the performance of intimate couples because it interfered with the implicit encoding system they had developed over the course of their relationships and yet aided strangers who did not have such a system.

Moreland and Myaskovsky (2000) created "artificial" transactive memory systems by giving written feedback about members' specialty to groups whose members were trained individually and found those groups performed as well as groups whose members were trained together and better than groups whose members were trained apart. Similarly, Stasser, Stewart, and Wittenbaum (1995) examined the effects of forewarning and role assignment on awareness of expertise and decision quality in solving a hidden-profile case. Results suggest that simply telling or reminding members that each has distinct information is insufficient to increase expertise recognition. Specific information about members' expertise needs to be provided for members to take notice and leverage the information. In addition to increased expertise recognition, another advantage of providing specific information about members' expertise is enabling the allocation of tasks to match member expertise (Littlepage et al., 2008). We thus expect such knowledge to affect not only the structure of TMS, but also transactive processes such as knowledge retrieval and task coordination.

Team environment such as acute stress. Ellis and her collaborators (2006, 2009) found that acute stress negatively affected transactive memory processes such as directory updating, information allocation, and retrieval coordination, which mediated the negative effects of acute stress on team performance. A later study (Pearsall, Ellis, & Stein, 2009) examined two types of stressors: *challenge* stressors, manipulated as time pressure, and *hindrance* stressors, manipulated as role ambiguity. The results show a subtle effect of different types of stressors on the development of transactive memory systems. Although a challenge stressor led to both more advanced transactive memory systems and better performance than no stressor, a hindrance stressor prohibited the development of transactive memory systems and reduced performance relative to the no stressor condition.

Summary and future directions. We found considerable work examining the effects of communication, group training, team familiarity, shared experience, and imposed knowledge structures on the development of transactive memory systems. We found a moderate amount of research on how member demographics and stress affect TMS development. The effects of interdependence and personality characteristics have been investigated in only a very small number of studies. Thus, of the three levels of antecedents to TMS development shown in our theoretical framework, team-level inputs have received significantly more attention than member attributes and organizational-level inputs. Future research should pay more attention to the effects of team composition inputs such as member diversity (Williams & O'Reilly, 1998) and faultlines (Lau & Murnighan, 1998) and the effects of organizational context such as culture and HR practices on TMS development. The former is important because it is likely to affect the ease with which members communicate and exchange information; the latter is important because it is likely to affect members' motivation to engage in collective processing of information.

Many of the factors examined as antecedents of TMS, such as training or communication, are likely to affect members' abilities to develop a TMS and to a lesser extent their opportunities to do so. Understanding team member's motivation to develop a TMS is also important (Wittenbaum, Hollingshead, & Botero, 2004). Thus, we encourage additional research on how motivational factors affect the development of transactive memory systems. A factor that is likely to affect members' motivation is the extent to which group members identify with the group. In groups where members identify with the group, they are more likely to invest in developing the specialized division of labor that is a defining characteristic of transactive memory systems. That is, members are more likely to divide areas of expertise, rely on each other, and share knowledge when they identify with the group than when they do not. Future research should examine how motivational factors affect the development of transactive memory systems.

Further research is also needed on factors affecting the opportunity to develop a TMS. Social networks can affect the opportunities members have to be exposed to each other's expertise and to develop a shared division of cognitive labor. For instance, Yuan et al. (2010b) surveyed 218 people in 18 teams and found a positive relationship between communication tie strength and expertise exchange at both the individual and team level. New technologies such as "telepresence systems," whereby members can interact with others in geographically dispersed locations, also hold promise for affording distributed groups the opportunities to develop a shared cognitive division of labor.

Another important issue that would benefit from research attention is the role of forgetting and the extent to which transactive memory systems decay. Because transactive memory systems include knowledge in individuals' memories and the transactive processes that occur between individuals, understanding knowledge decay involves analyzing individual and transactive processes. Concerning individual memories, research on the development of TMS has focused primarily on gaining knowledge of who knows what while at the same time, members may forget such knowledge if it remains unused for a substantial period of time (Ren et al., 2006). Knowledge about who knows what is declarative knowledge (know-what) and may decay at a faster rate than procedural knowledge or know-how (Cohen & Bacdayan, 1994). Further, aspects of an individual's transactive memory may become obsolete if members' areas of expertise change. For example, a team member may acquire new knowledge and skills of which other team members are not aware. The decay and obsolescence of transactive memories are less of a concern in small and collocated groups where members interact frequently, but may be exacerbated in large groups and groups consisting of geographically dispersed members.

Concerning the transactive component of transactive memory systems, membership change or turnover can disrupt transactive processes. If a team member departs, other members will not be able to rely on his or her expertise. Networks such as transactive memory systems can also decay through not being used. A couple of studies have investigated the role of turnover in the utilization of transactive memory systems. When all members of a team turnover from one period to the next, the TMS of the team is totally disabled and thus confers no performance benefits (Moreland, Argote, & Krishnan, 1996). When turnover is not total from one period to the next, transactive memory systems can retain some value (Lewis, Belliveau, & Herndon, 2007), although not as much value as when there is no turnover.

Conceiving of transactive memory systems as member–task links (McGrath & Argote, 2001) or task–expertise–person links (Brandon & Hollingshead, 2004) enables us to understand when turnover will be more or less harmful in teams. To the extent that the new team member has expertise similar to the departing member, turnover will have a less deleterious effect on transactive memory systems and subsequent performance. Team members will have to learn about the new member's expertise, but will not have to reconfigure their transactive structures and processes. As the new member's expertise differs more from that of the departing member, group members will have to reconfigure more links in their TMS, learning what they can and cannot count on the new member to know, finding alternative sources to the knowledge that the new member does not possess, and/or changing their and the newcomer's expertise. In the short term, this will be very disruptive to the group. In the long run, the effect of new members with expertise different from departing members will depend on the quality of the new member's knowledge and how the group adapts to it. Further work is needed on the dynamics of transactive memory systems, with attention to both how these systems develop and how they decay at the level of transactive processes as well as individual memories.

Consequences of Transactive Memory Systems on Group Outcomes

Based on the team effectiveness framework by Mathieu et al. (2008), the consequences of TMS can be classified into three types: team performance behaviors, team performance outcomes, and member affective outcomes. Team performance behaviors are actions that are relevant to achieving team goals such as team learning, creativity, and reflectivity. Team performance outcomes are the results of performance behaviors such as effectiveness and efficiency. Member affective outcomes include member commitment and satisfaction.

Compared with the antecedents to transactive memory systems, findings are much more consistent about the impact of transactive memory systems on group outcomes. Numerous studies have shown the positive effects of transactive memory systems on a variety of group outcomes such as group learning, team creativity, effectiveness, and member satisfaction (e.g., Austin, 2003; Faraj & Sproull, 2000; Lewis, 2003; Liang et al., 1995; Michinov et al., 2008). Accurate expertise recognition improves team performance because it facilitates the division of cognitive labor among members, the search and location of required knowledge, the match of problems with the person with the requisite expertise to solve the problems, the coordination of group activities, and better decisions through the evaluation and integration of knowledge contributed by group members (Moreland, 1999).

Group learning, team creativity, and team reflectivity. Transactive memory systems have been shown to improve group learning and team creativity. Akgun et al. (2006) surveyed Turkish new project development teams and found a positive effect of TMS on team learning that was further linked to new product success. Similarly, Dayan and Basarir's (2010) study of Turkish new product teams revealed a positive association between transactive memory and team reflexivity, conceived as the extent to which group members reflect upon the group's objectives, strategies, and processes and adapt them to environmental circumstances. Dayan and Basarir (2010) further showed a link from team reflexivity to product success. In a laboratory experiment, Gino et al. (2010) found that groups with more developed transactive memory systems demonstrated a higher level of creativity in creating products than groups with less developed transactive memory systems.

Team performance outcomes. When the concept of transactive memory was first presented, Wegner (1987) predicted that a group with a smoothly functioning transactive memory system would be effective in reaching its goals and satisfying its members. The statement has received wide support in laboratory experiments, field studies, and simulation models. Two common tasks in laboratory experiments are collective remembering and recall of words from different domains (Wegner et al., 1991; Hollingshead, 1998a) and product assembly (Liang et al., 1995; Lewis, Lange, & Gillis, 2005). It has been repeatedly shown that dyads with transactive memory systems recall more words collectively and recall more unique or non-overlapping words than dyads lacking transactive memory systems (Hollingshead, 1998a, 1998b). It has also been repeatedly shown that members trained as a group recalled more knowledge about product assembly and made fewer errors than members who were trained individually, and that the relationship between training and performance was fully mediated by transactive memory systems (Moreland, Argote, & Krishnan, 1998). In comparison, transactive memory systems did not seem to predict greater speed to complete assembly tasks—at least, not in laboratory experiments.

In field studies, transactive memory systems have shown positive associations with team performance measured in many ways. Faraj and Sproull (2000) found that team members' knowledge of who knows what (location or recognition of team expertise) had a positive association with team effectiveness assessed by work quality, team operations, ability to meet project goals, extent of meeting design objectives, and reputation of work excellence, as well as team efficiency measured as time to completion and cost of the projects. Rau (2005) found that awareness of expertise location positively influenced top management team performance measured as return on average assets of banks. Other studies have linked transactive memory systems to performance assessed as new product success, speed to market (Akgun et al., 2005), decision quality (Littlepage et al., 2008), and customer service quality (Peltokorpi, 2004).

Team member satisfaction. The relationship between transactive memory and satisfaction was first shown in an experiment of 60 heterosexual couples who completed a questionnaire (Wegner, Giuliano, & Hertel, 1985). A couple's agreement on self- versus other-expertise judgments was significantly correlated with each member's assessment of satisfaction with the relationship. The association between transactive memory systems and satisfaction has also been confirmed in field studies. Michinov et al. (2008) surveyed nurse and physician anesthetists working in French hospitals and found that higher scores of TMS were correlated with stronger perceptions of team effectiveness and job satisfaction as well as team identification.

Summary and future directions. Team performance measures of recall and errors have consistently shown a positive relationship with TMS. Performance measures of time to complete tasks have not been associated with TMS in laboratory studies. Indirect evidence from field studies suggests that TMS might reduce the time required to complete tasks. For example, although they did not measure TMS directly, Reagans, Argote, and Brooks (2005) found that team experience reduced procedure completion time for orthopedic surgeries.

Compared with team performance outcomes such as assembly errors and work quality, there is less research on the effects of TMS on performance behaviors and member affective outcomes. A promising new direction is the inclusion of creativity as an outcome. Most groups are concerned with being creative as well as being effective and efficient, so including creativity as an outcome is a useful development. Yet we found only one study that examined the effects of TMS on creativity. Further, investigating the relationship between TMS and creativity promises to open up new avenues in creativity research, which examines how knowledge is recombined in new ways (Kogut & Zander, 1992). Because groups with well-developed transactive memory systems have knowledge of members' expertise, they are in a better position to envision how members' expertise can be combined in new ways to create new products and services than teams with less developed transactive memory systems.

Another promising direction to explore is the effects of performance on the elaboration of TMS—a feedback loop from team outcomes to team mediators or process depicted in the Mathieu et al. (2008) framework. Most studies we reviewed are cross-sectional and assume a linear causal relationship from antecedents to TMS to its consequences. In real life, the connections may be recursive, and performance could affect the future development of TMS. Members of high-performing teams are likely to maintain and reinforce their TMS such as member specialization, whereas members of low-performing teams are likely to challenge and modify their TMS by reallocating work assignments or reducing their reliance upon others for information. We found only one study—by Kanawattanachai and Yoo (2007)—that investigated the effects of team performance feedback on subsequent TMS development. Past performance reinforced expertise location or members' metaknowledge of others' expertise, but did not affect trust or task–knowledge coordination. More research, especially experimental work with greater control of performance feedback, is needed to understand how performance feedback affects TMS development.

Moderators of the Relationship between TMS and Performance

It has been speculated that the effects of transactive memory systems on group outcomes vary across group context such as group size, type of tasks, environmental turbulence, membership change, and geographic dispersion or technologies. Alternations in membership (e.g., old-timers leaving or newcomers joining) and changes in group tasks or goals disrupt the working of existing transactive memory systems and prompt members to reexamine or renegotiate their roles, responsibilities, or assumed expertise in the group (London, Polzer, & Omoregie, 2005). As a result, these changes can alter the relationship between transactive memory systems and group performance.

Group membership change. The group training experiments showed the importance of team stability or conversely the detrimental effects of membership change on transactive memory systems. Teams whose membership was totally changed from one period to the next did not perform as well as teams whose membership was stable from one period to the next (Moreland, Argote, & Krishnan, 1996).

To more fully understand the impact of membership change on TMS and group performance, Lewis et al. (2007) conducted a laboratory experiment that compared the performance of intact groups, partially intact groups, and totally reconstituted groups. The researchers found that although there was no significant difference between TMS structure stability in partially intact groups and intact groups, partially intact groups had lower TMS process efficiency scores (i.e., performed worse in utilizing member knowledge) than did intact groups, and did not differ significantly from totally reconstituted groups. The group's expertise structure remained largely stable in partially intact groups because newcomers adapted and changed their specializations to substitute for departing members. Members of partially intact groups tended to rely on the TMS structure that old-timers developed in the original group, which turned out to be detrimental to group performance because it created inefficient TMS processes (Lewis et al., 2007).

Task change. Lewis et al. (2005) studied the effects of task change and the extent to which transactive memory systems developed in one task generalize to a similar, yet different, task. The researchers hypothesized that groups that had previously developed and utilized a TMS on one task would perform better on a subsequent, similar task than would groups with no prior TMS. Groups with a prior TMS were more likely to demonstrate abstract, generalized knowledge about the underlying principles relevant to the task than groups that had never developed a TMS. The researchers manipulated task change by asking a group to first perform a telephone assembly task and then perform a stereo assembly task. Experimental results showed that performance on the telephone assembly task was higher in groups with full access to the TMS they developed during training. Surprisingly, groups that had developed and utilized a TMS on a previous task (the telephone assembly task) did not perform better on a transfer task (the stereo assembly task). There was evidence, however, that groups with an established TMS demonstrated better knowledge of the underlying principles of the task domain than those without an established TMS. A prior TMS had the most beneficial effect on learning transfer for members of groups who had been reassigned for the transfer task and who had maintained either a medium or a high degree of expertise stability across tasks.

Transactive memory systems in virtual teams. Although only a few studies have empirically examined transactive memory systems in virtual teams (e.g., see Kanawattanachai & Yoo, 2007; O'Leary & Mortensen, 2010), several researchers have speculated about the impact of geographic dispersion or computer-mediated communication on the development and utilization of transactive memory systems. For instance, Alavi and Tiwana (2002) suggested that physical distance, technology-mediated interactions, a lack of antecedent collaborative history, and the typical diversity in expertise and backgrounds of virtual team members are likely to constrain the development and maintenance of transactive memory in virtual settings. Cordery and Soo (2008: 491) identified the failure to develop an effective TMS as a common barrier to virtual team success. They further commented: "The boundaries created by virtuality, in the form of geographic, cultural, and temporal–spatial separations; the lack of 'richness' in many electronically mediated forms of communication; and the fluctuating membership of virtual team structures pose particular challenges to team knowledge development and information sharing."

Griffith, Sawyer, and Neale (2003) proposed that TMS development can be more difficult when groups work apart and are located in different environments, because geographic distance reduces the opportunity for groups to gain shared experiences, develop common language, or engage in joint decision-making (Hollingshead, 1998b). Griffith et al. (2003) further proposed that the use of information technologies to facilitate communication and sharing of personal information mitigates the negative relationship between working in virtual teams and the development of transactive memory systems.

Hollingshead (1998a) suggested that face-to-face communication plays a crucial role not only in the development of transactive memory systems, but also in their utilization. When working face to face to answer questions, intimate couples were able to use nonverbal cues to figure out which partner knew the correct answer on questions where only one member was correct prior to discussion. Compared with strangers who worked face to face, intimate couples looked at one another more and worked together more to remember information, which improved their performance. Hence, communication media affects not only the development of TMS but also the extent to which TMS can be leveraged to improve performance.

Group size. Most laboratory studies have examined dyads or groups consisting of three or four members. There are several field studies that surveyed project teams consisting of four or more members, but group size was only included as a control variable. Two studies of student project groups reported the effects of group size on transactive memory. Michinov and Michinov (2009) found that group size was negatively correlated with the coordination dimension of transactive memory systems: groups of two students were able to coordinate better than groups of three. Jackson and Moreland (2009) studied student projects consistent of three, four, or five members and found that smaller group size was associated with stronger transactive memory and therefore better performance.

The effects of group size on TMS and group performance were examined in two simulation studies. Palazzolo et al. (2006) simulated network sizes of 4 and 20 and found that smaller networks had higher communication density and greater TMS accuracy and specialization. Ren, Carley, and Argote (2006) simulated group sizes ranging between 3 and 35 and found that although groups of all sizes benefited from an established TMS, transactive memory systems were more beneficial to larger groups in terms of efficiency or speed of performance and more beneficial to smaller groups in terms of decision quality.

Task type. Although many researchers have speculated that the effects of transactive memory on performance vary by types of task (Lewis & Herndon, in press), we found only one study that tested the hypothesis empirically. Akgun et al. (2005) examined the moderating effect of task complexity in new product teams. Task complexity can originate from two dimensions: repetitiveness of a task, and whether the task requires established bodies of knowledge versus novel solution. Akgun et al. (2005) found that the impact of TMS on product outcomes was greater when the task was more complex (i.e., less repetitive and requiring more novel knowledge).

Environmental turbulence. Environmental turbulence, reflected in changes associated with new product technologies or the composition of customers and their preferences, is likely to render some knowledge obsolete and thus alter the effect of an established TMS (Akgun et al., 2006). In a field study of new product teams, Akgun et al. (2006) found that greater environmental turbulence, measured as rapid changes in technologies and customer preferences, significantly weakened the relationship between TMS and team learning as well as speed-to-market. Ren, Carley, and Argote (2006) also simulated the impact of two types of turbulence: task volatility and knowledge volatility. The researchers found that while teams in stable environments outperformed groups in volatile environments, transactive memory systems were more beneficial to groups in volatile environments with high task volatility or high knowledge volatility. The discrepancy between the two studies can be attributed to the level of turbulence. Environmental turbulence in Akgun et al. (2006) rendered some *team* knowledge obsolete and forced the team to search for new knowledge to address the change. Consequently, TMS became less useful with high environmental turbulence. In contrast, task and knowledge volatility in the study by Ren et al. (2006) rendered some *individual* knowledge obsolete and forced the individuals to search for knowledge in the rest of the team. Consequently, TMS become more valuable with high task or knowledge turbulence.

Relationship conflict and trust. Rau (2005) examined relationship conflict and trust as two moderators of the relationship between transactive memory and performance. She defined relationship conflict as interpersonal incompatibility that includes tension, annoyance, and animosity among team members and trust as expectations, assumptions, or beliefs about the likelihood that another's future actions will be beneficial, favorable, or at least not detrimental to one's interests. Survey results show that relationship conflict negatively moderated the effects of awareness of expertise location on performance, such that awareness of expertise location was not associated with performance under high conflict. In contrast, trust was not found to moderate the effects of TMS on performance.

Summary and future directions. Changes in tasks, membership, communication channels, group dynamics, and environments are all likely to affect the working of transactive memory systems and their impact on performance. A fruitful direction for future research is to explore managerial and technological interventions to assist teams in dynamic settings to function effectively. Because members of dynamic organizations move in and out of project teams frequently, transactive memory systems at the team level may be weaker than those in traditional organizations (Moreland & Argote, 2003). Lewis et al. (2007) suggested promising possible interventions to help team members cope with membership change. When old-timers of partially intact groups were given information to reflect upon their own specializations and the specializations of other members, they proactively adjusted their specializations to the addition of a newcomer, which improved the efficiency of TMS processes and group performance.

Four Observations and Recommendations for Future Research

We observed interesting patterns in reviewing the literature. Several suggest how anomalies in the literature can be reconciled, while others suggest fruitful directions for future research. These patterns relate to conceptual and measurement issues associated with TMS, the level of analysis at which TMS is studied, and the promise of TMS for explaining the benefits of experience in both established and new firms. Below, we discuss each of these observations in turn.

Consistency in measuring TMS

In spite of general convergence in defining the concept of transactive memory systems, we observed significant divergence in measuring the concept. We identified five sets of established measures of transactive memory systems in the literature. One is particular to dyadic studies (Hollingshead, 1998a, 1998b; Wegner et al., 1991) where pairs of participants were asked to complete a questionnaire about how well they knew the areas of expertise of their partners. Four other measures were developed to assess transactive memory systems in small groups, including Austin (2003), Faraj and Sproull (2000), Lewis (2003), and Liang et al. (1995). Among those, the measures of Austin (2003) and Faraj and Sproull (2000) have been used primarily in field studies. The Liang et al. measurement approach (1995) has been used primarily in laboratory experiments. The Lewis (2003) measure can be adapted to use in both the laboratory and the field.

Among these measures, Liang et al. (1995) was the first to assess TMS in the context of small groups. The researchers identified three behavioral indicators of TMS as memory differentiation (tendency for members to specialize in remembering distinct knowledge), task credibility (how much members trust each other's knowledge), and task coordination (ability of members to work together smoothly). Judges who were blind to the research hypotheses watched videotapes of groups working together and rated the extent to which the groups demonstrated the three behaviors. In addition, participants individually completed a questionnaire with items about their own and other members' expertise, which were used to calculate three direct measures of TMS as complexity, accuracy, and agreement among members about others' expertise. The correlations between direct and indirect, behavioral measures were positive and significant (Moreland, 1999).

The Austin (2003) and Lewis (2003) measures were developed on the basis of Liang et al. (1995) to be used in field studies. Austin (2003) built on the direct measures and included four components: knowledge stock (combination of individual knowledge), consensus about knowledge sources (agreement), specialization of expertise, and accuracy of knowledge identification. Lewis (2003) built on the behavioral measures and included three dimensions: knowledge specialization, task credibility, and task coordination. Table 1 shows the three measures by Lewis (2003), Austin (2003), and Faraj and Sproull (2000).

Among the established measures, Lewis (2003) has been the most widely adopted. As shown in Table 1, the Austin (2003) measure is labor intensive for both researchers and respondents. To construct the questionnaire, researchers need to conduct preliminary interviews to identify all skills or areas of knowledge that are relevant to the team being studied. For each skill or area of knowledge, respondents rate the ability level of all members. For example, for a team with 10 members and 12 skills, each respondent is required to fill out $10 \times 12 = 120$ cells. Decisions about which measure to use depend, of course, on study goals and the empirical context. An advantage of the Lewis (2003) measure is that it can be used in studies that include different kinds of groups. By contrast, the Austin measure is constructed based on detailed knowledge of the skills and knowledge that is relevant in a particular group. Its fine-grained assessment of knowledge and skills enables one to determine, for example, where perceptions of expertise are more or less accurate, which in turn can enable interventions to strengthen TMS.

Our review suggests convergence in using standard measures, especially Lewis (2003), to assess TMS. Out of the 31 field studies we reviewed, 27 included measures of TMS (two were case studies and the other two did not provide details of how they measured TMS). Among the 27 studies, 12 used the 15-item scale developed by Lewis (2003), three used the expertise location and bringing expertise to use measure by Faraj and Sproull (200), and one used the Austin (2003) measure. The remaining 11 studies used self-developed measures that do not correspond well to the established measures. Using standard measures is valuable in promoting the accumulation of knowledge. If researchers believe that the standard measures are not appropriate for their theory or empirical context and want to develop new measures, we advocate using a standard measure in addition to the new measure and comparing the two measures. Such comparisons can lead to refinements or elaborations of measurement approaches and enable the field to progress by promoting the accumulation of knowledge.

TMS as a multidimensional construct

In spite of consensus about the multidimensional nature of transactive memory systems, there is great divergence in the conceptualization of the

Table 1 Established Measurements of Transactive Memory Systems

Lewis (2003) measures

Specialization

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

Credibility

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

Coordination

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

Faraj & Sproull (2000) measures

Expertise location

The team has a good "map" of each other's talents and skills.
Team members are assigned to tasks commensurate with their task-relevant knowledge and skill.
Team members know what task-related skills and knowledge they each possess.
Team members know who on the team has specialized skills and knowledge that is relevant to their work.

Bring expertise to bear

People in our team share their special knowledge and expertise with one another.
If someone in our team has some special knowledge about how to perform the team task, he or she is not likely to tell the other member about it.
There is virtually no exchange of information knowledge or sharing of skills among members. (reversed)
More knowledgeable team members freely provide other members with hard-to-find knowledge or specialized skills.

Table 1 Established Measurements of Transactive Memory Systems (Continued)

Lewis (2003) measures
Austin (2003) measures
Group task knowledge stock
Preliminary interviews to identify all skill/knowledge areas. Each group member is required to rate their ability and other members' ability in all skill/knowledge areas using a 5-point Likert scale (a matrix of $P \times N$ with P equal to the number of members in the group and N equal to the number of skill/knowledge areas).
Task knowledge specialization
Take the $P \times N$ matrix. Count the number of times each person is identified as an expert (a number ranging from 0 to N). The standard deviation of counts across skills for each individual is the person's knowledge specialization score.
Transactive memory consensus
Take the $P \times N$ matrix. For each skill, write the name of the team member that you believe is most knowledgeable. For each skill, check the frequency at which a person is named as the most knowledgeable member and assign 1 to the most frequently identified expert, 2 to the next most frequently, and so on. The standard deviation for each skill indicates group consensus on identification of experts for that skill.
Transactive memory accuracy
Self-report expertise scores (e.g., Person B reported a skill level of 5 in area 1) are linked with identified expert scores (e.g., Person A rated Person B as the expertise in area 1) to create accuracy score for each individual and skill (therefore Person A's accuracy of skill area 1 is 5). Skill accuracy scores are averaged to an individual accuracy score.

relationships among its dimensions. Two common approaches are to either combine all dimensions into one construct or to examine each dimension as a separate construct and relate it to criterion variables. The first approach was started by Liang et al. (1995) and reinforced by Lewis (2003). Typically, the authors concluded that because the three behavioral measures of transactive memory systems or the three dimensions were strongly correlated, their scores were averaged to create a composite index to measure TMS as a whole. Lewis and Herndon (in press) further defined specialization, credibility, and coordination as manifestations of a latent TMS variable, meaning that (1) when a TMS exists, it causes specialized knowledge, mutual trust in others' knowledge, and smooth, coordinated task processing; and (2) specialization, credibility, and coordination co-vary because they have a common cause.

Another less common approach is to examine the dimensions and relate them to criterion variables separately. The implication is that the dimensions of transactive memory systems are not always highly correlated with one another to justify their combination. For instance, Austin (2003) found the strongest correlation between consensus and specialization (0.65), probably because both develop as group members gain experience working with each other. Accuracy was correlated with consensus (0.34) and specialization (0.18), but not as strongly as the correlation between consensus and specialization. Further, Austin (2003) found that transactive memory accuracy was the most significant predictor of group performance, knowledge specialization was related to external and internal evaluations, and consensus was not significantly related to performance.

Table 2 shows correlations between the dimensions of TMS in three field studies. As can be seen from the table, the magnitudes of the correlations vary from no correlation to moderate correlation. A key difference between these studies and the many studies that have reported high correlations among the dimensions is the type of groups and length of time groups have worked together. The studies shown in the table examined mature, established teams in organizational settings such as product teams, hospital teams, and software development teams. Members of these groups often developed their specializations in another context through training, education, or prior project experiences. These groups can still vary greatly in the recognition of expertise, trust of each other's expertise and coordination. The correlation between the dimensions of transactive memory systems, however, may not be as strong as in newly created groups where specialization, credibility and coordination develop together.

Researchers have also speculated that the dimensions of transactive memory might follow different evolutionary paths. For example, Brandon and Hollingshead (2004) proposed three stages of transactive memory development. They suggested that a benefit of group interaction is the development of perceptions of expertise over time from crude perceptions based on surface characteristics, such as gender, to more accurate perceptions of group member expertise. Knowledge of what others know first becomes complex (gaining the knowledge or making inferences from individual characteristics), then accurate (modifying and refining knowledge to match reality), and finally shared or

Table 2 Correlations among TMS Dimensions

References	*r*(specialization, credibility)	*r*(specialization, coordination)	*r*(credibility, coordination)
Akgun et al. (2005)	0.26 ($p < 0.05$)	0.29 ($p < 0.05$)	0.30 ($p < 0.01$)
Faraj & Sproull (2000)	0.31 ($p < 0.05$)	0.17 (N.S.)	0.56 ($p < 0.01$)
Michinov et al. (2008)	0.15 (N.S.)	−0.005 (N.S.)	0.41 ($p < 0.01$)

Note: We equated expertise presence in Faraj & Sproull (2000) to specialization in Lewis (2003), expertise location to task credibility, and bring expertise to bear to task coordination. N.S., not significant.

convergent (through validation). According to Brandon and Hollingshead (2004), the optimal state of a transactive memory system is convergence where all members have similar representations of the TMS that accurately reflect relative knowledge in the group.

We recommend that future studies report not only TMS as a construct, but also the value of different dimensions and their intercorrelations. Most studies we reviewed did not provide such statistics, which makes it hard to compare across contexts.

Another reason to think more deeply about the relationships among the dimensions is that several researchers have proposed and found that different dimensions have different levels of influence on performance. For example, Michinov et al. (2008) found a high contribution of coordination to team effectiveness and satisfaction, a small contribution of credibility, and no effect of specialization. Kanawattanachai and Yoo (2007) found that expertise location and cognition-based trust affected performance through task–knowledge coordination. The researchers also observed that the three dimensions of TMS did not follow the same evolutionary path, with expertise location and cognition-based trust being stable once initially formed and task–knowledge coordination being more dynamic and emergent.

We agree with the position of Lewis and Herndon (in press) that one needs some degree of both specialization and coordination for a TMS to exist. What is unique about the concept of transactive memory is that it combines specialization and coordination: not only do members of groups with well-developed transactive memory systems specialize in remembering different knowledge, they also know who knows what and coordinate their knowledge effectively. The dimensions of specialization and coordination correspond to the original theorizing of Wegner et al. (1985) about the two components of transactive memory systems: knowledge in individual memories, and the transactive processes that link the knowledge in individual memories. Examining the separate as well as the interactive effects of specialization and coordination on task performance and the conditions under which each variable is positively related to task performance will advance our understanding of transactive memory systems.

The role of trust in the concept of transactive memory systems needs to be sharpened. Trust has been conceived as an antecedent (Akgun et al., 2005) or dimension (Kanawattanachai & You, 2007) of transactive memory systems as well as a moderator of the relationship between transactive memory systems and performance (Rau, 2005). Trust itself is a multidimensionsal construct (McEvily, in press). It can be based on assessment of different characteristics of a trustee such as ability, benevolence, and integrity (Mayer et al., 1995) or different sources such as knowledge about the trustee (cognition-based) or emotional bonds with the trustee (affect-based) (McAllister, 1995). The type of trust that is most closely related to transactive memory systems is knowledge of and trust in member's expertise or what researchers have termed task credibility (Liang et al., 1995; Lewis, 2003). Our review suggests that the relationship between trust and TMS is complicated and requires further research.

An organizational-level TMS

The current literature focuses primarily on teams and how transactive memory systems develop and affect team performance. There is very limited research on the presence or impact of transactive memory systems at the organizational level. Our review suggests that the concept can be generalized to the organizational level, yet the generalization requires substantial elaboration to the theory.

Several researchers have written about the challenges of generalizing TMS to the organizational level. First, organizations are usually larger than work groups, so their transactive memory systems should contain more (and more varied) sources of task knowledge (Moreland, 1999). As a result, members might have more trouble identifying who knows what in organizations than in small work groups. Second, organizations consist of multiple *subgroups* with less communication and knowledge sharing across subgroup boundaries (Anand et al., 1998). Third, organizations are increasingly geographically distributed and rely upon advanced *technologies* to locate and share information. Fourth, it is easier to share tacit knowledge in a small group, but when the tacit knowledge is available in a distal part of the organization, retrieval becomes challenging (Nevo & Wand, 2005).

How do transactive memory systems operate in organizations? The options can be divided into two broad categories (Moreland, 1999): interpersonal and technological. The general goal of the interpersonal approach is to locate a specific person in the organization and obtain whatever information is needed from him or her. The general goal of the technological approach is to obtain whatever information is needed through the use of tools such as computers. The latter approach can be elaborated into two forms: knowledge provided through repositories, or knowledge provided by connections mediated through computers. Although empirical evidence on the effects of knowledge repositories on organizational performance is mixed (Haas & Hansen, 2005; Kim, 2008), repositories and directories have the potential to build transactive memory systems by providing pointers to who knows what in the organization.

With old technologies such as Intranet and corporate "yellow pages," employees are often reluctant to use these technologies because they need to regularly upload their latest CVs or list their recent projects to keep the information up to date. Current approaches to knowledge management such as those enabled by Web 2.0 provide the capability to connect people as well as to capture knowledge in repositories. Further, the communication capabilities afforded by Web 2.0 technologies such as wikis, blogs, and online social networks have the potential to automatically populate directories of who knows what while members edit their personal profiles or post documents about their work activities (Majchrzak, Cherbakov, & Ives, 2009). Companies can install tools to mine emails, instant messaging, and virtual space usage to automatically infer expertise and identify social networks. Not only does the system provide information about who knows what, it can also display social networks for a particular topic and calculate degrees of separation between the employee and all others in their network, so that the employee can find a route to reach a remote source of information through direct contacts. Another useful tool for knowledge integration is a wiki, a website that anyone can edit. The name wiki came from the Hawaiian word meaning "quick." Wikis are used typically by multiple users to codify their knowledge and co-generate useful content. As employees communicate and collaborate using these new technologies, the records can be automatically analyzed to derive information about who knows what and who is interested in what. Thus, these new technologies have "affordances" that enable the development of transactive memory systems without members being in the same location. The affordances provide opportunities (Zammuto, Griffith, Majchrzak, Dougherty, & Faraj, 2007). Whether the opportunities are realized depends on how the tools are used, a topic on which additional research is needed.

Jackson and Klobas (2008) conducted a case study to identify TMS processes in organizations and explore ways to design systems to improve the functioning of organizational TMS. In terms of *directories and directory maintenance*, they found organizational members employed a variety of directory structures, informal and formal, internal and external, primitive and high-tech, which pointed them to information sources or "someone who might know someone." Managers and administrators functioned as keepers of directories or gatekeepers. In addition, two organization-level information systems supported directories: a portal through which employees could report their activities and search a curriculum vitae database, and a file management system from which directory information could be obtained by identifying the individuals who wrote documents on various topics. The researchers noted that physical separation led to fewer opportunities to maintain directories of "who knows what" in the organization. Being given information by others was a minor source of knowledge in the case study organization. Knowledge was gained mostly on the job and by one's own research. Compared with members of small groups, members of a large organization seem less motivated and have less opportunity to actively allocate or direct knowledge to relevant experts.

The rotation of individuals throughout the organization can be an effective mechanism for building an organizational-level TMS. Such rotation exposes members in recipient groups to the knowledge and skills of rotating members, and thereby spreads knowledge of individuals' capabilities throughout the organization. The rotation of individuals is especially likely to spread knowledge when organizational members share a strong superordinate identity

(Kane, Argote, & Levine, 2005). Further, member rotation is a mechanism for spreading tacit as well as explicit knowledge (Berry & Broadbent, 1984, 1987). Although member rotation can disrupt the operation of a group's TMS, the disruption can be minimized by keeping the proportion of rotated members small and by providing the group with information about the new member's knowledge and skills (Lewis et al., 2007).

In addition to knowing and trusting others' expertise, studies have shown the importance of accessibility or cost of access in facilitating information seeking and sharing in organizations. Borgatti and Cross (2003) suggested that the likelihood of seeking information from another person is a function of knowing and valuing what the person knows, getting timely access to that person, and the perceived cost of the information-seeking effort. Similarly, in a field study of hospital nurses, Hofmann, Lie, and Grant (2009) found that the decision to seek help from others depended on help-seekers' perceptions of experts' accessibility and trustworthiness. In a study of a geographically distributed sales team, Yuan et al. (2010a) found that expertise retrieval was affected by awareness of expertise distribution and social accessibility. Although these studies do not explicitly discuss an organizational-level TMS, they do illustrate the working of the expertise retrieval process at the organizational level.

Overall, the concept of transactive memory systems shows promise for being generalized to the organizational level, although our understanding of how an organizational TMS functions remains limited. How an organizational TMS functions and manifests, with the assistance of social networks and information technologies, is a fruitful future research direction.

The relationship between group and organizational transactive memory systems also offers a promising direction for future research. Do strong transactive memory systems at the group level of analysis that are linked through social mechanisms as well as technological mechanisms enable a strong transactive memory at the organizational level? For example, building strong transactive memory systems at the group level of analysis and linking groups through a small world network could enable a strong TMS at the organizational level of analysis. The simulation results of Fang, Lee, and Schilling (2010) about organizational learning support this conjecture.

Alternatively, do strong transactive memory systems at the group level of analysis interfere with building a strong TMS at the organizational level of analysis? To the extent that factors that facilitate building a strong transactive memory at the group level of analysis, such as membership stability, are negatively related to the factors that facilitate building a strong TMS at the organizational level of analysis, such as member rotation across groups, a negative relationship between the strength of transactive memory systems at group and organizational levels can develop. If such a negative relationship between group and organizational-level transactive memory systems exists, we suggest focusing on building a TMS at the level of analysis where task interdependence is reciprocal (Thompson, 1967) and timing of the articulation of team member skills and knowledge is most critical. For example, in situations where task interdependencies are very strong within groups and weaker between groups, such as surgical teams within a hospital (Reagans et al., 2005) or flight crews within an airline (Hackman, 2003), and coordination of member skills at particular moments in time is critical to successful task performance, we suggest focusing primarily on building a TMS at the team level. Conversely, if the precise coordination of member skills at a particular point in time is less important than access to a large and varied pool of expertise, such as in consulting organizations, then focusing on building an organizational-level TMS would be desirable. Future research is needed to determine the relationship between transactive memory systems at group and organizational levels.

How TMS can explain the benefits of experience in groups and opportunities for full cycle research

Much of the research on TMS so far has been theory driven, and researchers rely primarily upon theoretical insights to guide their research. For example, theory suggested that cognitive interdependence, communication, and gender stereotypes led to the development of TMS and researchers conducted experiments to test the causal connections. This theory-driven approach has been a fruitful path for TMS research. We argue that the literature can also benefit from a shift toward practice-driven research by encouraging researchers to observe TMS in action in natural settings and understand its interactions with other variables. Both individual researchers and the research community would benefit from engaging in full-cycle research (Chatman & Flynn, 2005) that alternates between field observations to formulate theories and experimental tests of these theories and uses the two to complement one another. A good candidate for such an approach is the interplay between experience and performance for both established and new entrepreneurial ventures.

There is considerable evidence that group performance improves with experience. Hospital surgical teams (Reagans et al., 2005), software development groups (Boh, Slaughter, & Espinosa, 2007) and product assembly teams (Argote & Epple, 1990) have all been shown to improve their performance with increases in group experience. We hypothesize that transactive memory is a mechanism through which group experience improves performance. With experience working together, group members learn who is good at what and how to coordinate their expertise. Thus, we hypothesize that experience working together enables groups to develop transactive memory systems, which in turn improve their performance. Future research on the role of experience in facilitating group performance would benefit from including transactive memory systems as a mediator of the relationship.

There is also considerable evidence that new ventures that spin out of existing firms generally perform better than *de novo* firms or new entrants to an industry (Klepper & Sleeper, 2005; Sørensen & Fassiotto, in press). New entrepreneurial ventures are excellent contexts to study transactive memory systems because researchers can chart the development of those systems from the start of the firms. We hypothesize that the performance benefits of *de alio* firms that spin out of existing ventures are due to the operation of transactive memory systems that members developed in the parent firm.

Many studies have shown that experience working together improves the performance of new firms. Carroll, Bigelow, Seidel, and Tsai (1996) found that *de novo* firms with preproduction experience performed better initially than *de novo* firms without preproduction experience or *de alio* firms that developed from firms in a related industry. Similarly, Phillips (2002) found that the failure rate of new law firms decreased as the proportion of founding team members from a particular parent firm increased. Along similar lines, Groysberg and Lee (2009) found that financial analysts who moved with their teams to a new firm performed better than those who moved solo.

By contrast, the greater productivity of *de alio* firms that spin out of existing firms does not seem to be due to transferring technologies from the parent firm. For example, Carroll et al. (1996) reported that the experience of parent firms with new automotive technologies did not seem to improve the performance of their progeny.

We hypothesize that experience working together enabled firms whose members had previous experience working together to develop a TMS that they transferred to the new organization. Through experience working together, team members had already learned who was good at what and how to coordinate that knowledge effectively. Thus, they were able to transfer the cognitive division of labor or the Task–Expertise–Person links that they developed working together in one organization to another. The transactive memory systems they developed enabled them to perform better than firms whose members did not have previous experience working together. Further, a TMS can enable new ventures whose members had previous experience working together to be more innovative than their counterparts lacking previous experience (see Gino et al., 2010). We conjecture that their transactive memory systems enabled them to recombine their individual competencies in new ways and thereby create new products and services.

Research is needed to test our conjectures and determine whether transactive memory is a mechanism that accounts for the beneficial effects of experience working together on the performance of new or established firms. Research is also needed to determine the boundary conditions for this effect. For example, how similar do tasks have to be for the effect to hold? Research is also needed to determine the best way to grow entrepreneurial ventures from the seeds or Task–Expertise–Person links of transactive memory systems.

Conclusion

A TMS is a powerful concept for explaining the performance of groups. Studies in a variety of empirical contexts have shown that transactive memory systems contribute positively to team performance. Progress has been made on understanding how to build transactive memory systems and on identifying the conditions under which they are most valuable. More research is needed, however, on understanding the predictors of transactive memory systems and factors that moderate the relationship between transactive memory systems and team performance. Although most of the research on transactive memory systems has been conducted at the group level, extending research on transactive memory to the organizational level is a promising research direction. We have suggested that both social and technological factors can facilitate building an organization-wide TMS. Another promising research area involves understanding whether transactive memory systems explain the benefits of experience working together observed in established organizations and newly created ones. We have hypothesized that transactive memory systems can provide seeds, or Task–Expertise–Person links that can grow into successful new entrepreneurial ventures. We believe that this hypothesis, and the other directions that we have identified, are worthy of future research.

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