Team mental models in a team knowledge framework: expanding theory and measurement across disciplinary boundaries

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Summary

Because research on team mental models is still in its formative stages, there is a need for continued conceptual development of the construct and direct empirical support linking team mental models to team outcomes. Researchers in other fields have developed concepts that are distinct from, but clearly related to team mental models, including information sharing, transactive memory, group learning, and cognitive consensus. Although these research streams currently exist in parallel with little cross-fertilization, there is much to be gained from integration across disciplinary boundaries. Therefore, the purpose of this paper is to enrich the theoretical understanding of team mental models and to broaden the empirical research base by adopting a cross-disciplinary focus and incorporating related team knowledge domains from other literatures. Based on a synthesis of various literatures, we develop a framework that delineates the relationships among team knowledge constructs. Copyright © 2001 John Wiley & Sons, Ltd.

Introduction

The notion of a team mental model was developed to help account for performance differences between teams (Cannon-Bowers and Salas, 1990 – Paper presented at the SIOP, Miami, FL; Rouse et al., 1992) and refers to an organized understanding of relevant knowledge that is shared by team members (Cannon-Bowers et al., 1993; Klimoski and Mohammed, 1994). The general thesis of the shared mental model literature is that team effectiveness will improve if team members have an adequate shared understanding of the task, team, equipment, and situation (e.g., Duncan et al., 1996). As this research is still in its formative stages, there is a need for continued conceptual development of the construct and direct empirical support linking team mental models to team outcomes.

Toward this end, the purpose of the current paper is to enrich the theoretical understanding of team mental models and to broaden the empirical research base by adopting a cross-disciplinary focus and incorporating related team knowledge concepts from other literatures. Although team mental models

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have been investigated primarily by Industrial/Organizational psychologists, researchers in other fields, including social psychology, cognitive psychology, decision making, and organizational behavior have developed concepts that are distinct from, but clearly related to, team mental models. These include information sharing, transactive memory, group learning, and cognitive consensus. Despite the relevance of these topics to mental models, they are not typically cited in the team mental model literature, nor do these literatures commonly cite the existing work on team mental models. Nevertheless, our understanding of team mental models can be significantly enhanced by recognizing, reviewing, and integrating these separate research streams on team knowledge from other disciplines.

The paper is organized in the following manner. After briefly reviewing the literature on team mental models, we summarize the theoretical and empirical research on information sharing, transactive memory, group learning, and cognitive consensus. Following each summary, we discuss the implications of the research for enhancing our understanding of team mental models and suggest potentially fruitful research directions. We then present an integrative synthesis of these parallel research streams.

Team Mental Model Summary

The notion of a shared mental model was introduced by Cannon-Bowers and Salas (1990 – Paper presented at the SIOP meeting, Miami, FL) to account for the fluid, implicit coordination frequently observed in effective teams and to advance the understanding of how teams function in complex, dynamic, and ambiguous situations. Team mental models are team members’ shared, organized understanding and mental representation of knowledge about key elements of the team’s relevant environment (Klimoski and Mohammed, 1994).

Theoretical development

Team mental model content includes shared representations of tasks, equipment, working relationships, and situations (Cannon-Bowers et al., 1993; Duncan et al., 1996; Rouse et al., 1992). In addition, various types of knowledge are represented, such as declarative (knowledge of what), procedural (knowledge of how), and strategic (knowledge of the context and application) (Converse and Kahler, 1992 – unpublished manuscript). Team mental models also fulfill multiple purposes, including description, prediction, and explanation (Rouse et al., 1992). Apart from their essential nature in terms of content, form of representation, and purpose, Kraiger and Wenzel (1997) suggest four categories of determinants: environmental, organizational, team, and individual. With regard to consequences, team mental models bring explanatory power to team performance by directly impacting team processes and enabling members to formulate accurate teamwork and taskwork predictions (e.g., Cannon-Bowers et al., 1993; Klimoski and Mohammed, 1994).

Adopting a multidisciplinary approach, we selected information sharing, transactive memory, group learning, and cognitive consensus because they were potentially useful in the study of team mental models, although not commonly referenced in this literature. Although space constraints forced us to be selective, we acknowledge that there are several other literatures that are clearly relevant to team mental models (e.g., team situation awareness, team decision making, language psychology, computer-mediated communication). In addition, we recognize that many of the team knowledge constructs reviewed in this paper have counterparts at the organizational-level of analysis. For example, literatures exist on organizational memory (e.g., Walsh and Ungson, 1991), organizational learning (e.g., Miller, 1996), and organizational frames/issue interpretation (e.g., Daft and Weick, 1984). However, this paper focuses on group-level research as opposed to organizational-level research.
Empirical research

Although there have been several theoretical papers describing team mental models (e.g., Cannon-Bowers et al., 1993; Klimoski and Mohammed, 1994; Kraiger and Wenzel, 1997; Rentsch and Hall, 1994), empirical work has substantially lagged behind conceptual development. Two reasons offered for this paucity of empirical work include a lack of adequate conceptual development of the construct and confusion over how to measure cognitive structures at the group level (Mohammed et al., 2000). Thus far, the most common methodologies for determining mental model content are similarity ratings (e.g., Mathieu et al., 2000; Stout et al., 1999) and Likert-scale questionnaires (e.g., Blickensderfer et al., 2000 – Paper presented at the APS, Miami, FL). On the other hand, the techniques used most often to capture the relationships between elements in a person’s mind include Pathfinder (e.g., Stout et al., 1999), UCINET (e.g., Mathieu et al., 2000), and concept mapping (e.g., Marks, 1997). As there is no one best technique, researchers must justify their choice of measurement after carefully considering the research question and team context (Mohammed et al., 2000). Because of the complexity and multidimensional nature of team mental models, researchers propose that multiple measures are necessary for thorough assessment (e.g., Kraiger and Wenzel, 1997).

Although much of the earlier research simply used team mental models as a post hoc explanation for performance differences between teams (e.g., Kleinman and Serfaty, 1989), recent work is attempting to measure the construct more directly. For example, Mathieu et al. (2000) examined the effect of shared mental model convergence on team processes and performance using two-person, undergraduate teams performing a PC-based flight/combat simulation. Results indicated that both teamwork and taskwork mental models related positively to team process and performance, and that team processes fully mediated the relationship between shared mental models and performance (Mathieu et al., 2000). Other research has found that team planning (Stout et al., 1999), self-correction training (Blickensderfer et al., 1997), and computer-based instruction (Smith-Jentsch et al., 1999 – Paper presented at the 14th SIOP conference, Atlanta, GA) foster the development of team mental model convergence.

Because the existing work on team mental models is in its infancy, the current paper seeks to enrich and expand theoretical and empirical research in this area by incorporating team knowledge concepts from other disciplines. Toward this end, the literatures on information sharing, transactive memory, group learning, and cognitive consensus will be reviewed.

Information Sharing Summary

Introduced by Stasser and Titus (1985), the information sharing literature examines information pooling behaviors in groups. In principle, groups are capable of producing better decisions by pooling information. In practice, however, collective sampling dynamics promote the rehashing of shared information at the expense of pooling unshared information (e.g., Gigone and Hastie, 1993; Stasser et al., 1989).

Theoretical development

Research in the area of information sharing revolves around the biased sampling model of group discussion, which is restricted to unstructured, face-to-face discussion with the goal of consensus (Stasser and Titus, 1985, 1987). According to the model, discussion is biased in favor of shared information, as shared information is more likely to enter discussion than unshared information. Shared information is held by all group members before discussion begins, whereas unshared information is only held by one
group member prior to discussion (Stasser and Titus, 1985). Thus, in this literature, the terms shared and unshared refer only to the distribution of the information prior to discussion, and do not imply that information designated as such will or will not be shared during discussion. Taking its limitations into account, the information sampling model has been shown to be successful when equal-status members have comparable information loads, shared and unshared items are similar in content and task relevance, and no cues in the decision environment allow members to distinguish shared from unshared items (e.g., Stasser and Titus, 1985, 1987; Stasser et al., 1989).

Empirical research

Following the prototype of Stasser and Titus’ (1985, 1987) seminal work, information sharing effects have been primarily examined using a hypothetical, hidden profile task (i.e., murder mystery; select the best candidate), where information that supports a superior option is unshared, whereas information that supports an inferior option is predominantly shared. The hidden profile and the best decision have the potential to be discovered, but only if group members pool their unshared information effectively. Suggesting a robust effect, numerous studies have supported the bias of shared information over unshared information (e.g., Gigone and Hastie, 1993; Stasser et al., 1989; Stasser et al., 1995). Shared information not only has a sampling advantage, but it also has a repetition and recall advantage over unshared information (Larson et al., 1996; Stasser et al., 1989; Stewart and Stasser, 1998).

Temporal, social, and task environment variables are three categories of effects that have been found to influence information sharing (Wittenbaum and Stasser, 1996). With regard to temporal patterns, shared information tends to be discussed earlier than unshared information and information discussed later in the discussion frequently has less impact on the decision (e.g., Larson et al., 1994). Social variables affecting information sharing include leadership (e.g., Larson et al., 1996, 1998), status (Hollingshead, 1996a), and expertise (Stasser et al., 1995). In addition, various aspects of the task environment have been found to impact the information sharing process, including information load (e.g., Stasser and Titus, 1987), intellective versus judgement tasks (e.g., Stasser and Stewart, 1992), and recall versus choice demands (e.g., Hollingshead, 1996b; Stewart and Stasser, 1998).

Overview

Over the past 15 years, the information sharing literature has produced a rather homogeneous body of empirical research showing that face-to-face groups are better at discussing widely shared information than they are at pooling diverse information. Although the collective information sampling model (Stasser and Titus, 1985, 1987) provided a solid foundation for theoretical development in this literature, there have been few conceptual advances beyond the original model. Therefore, theoretical work has lagged behind empirical findings, and an advanced framework would be helpful in describing the interpersonal dynamics of group discussion and interconnecting the nearly two dozen variables influencing information sharing. As most studies are direct variations of Stasser and Titus (1985, 1987) and use intellective, hidden profile tasks in ad hoc laboratory groups, there is a need to expand the research to intact organizational teams. In addition, researchers should examine how frequently hidden profiles occur in field settings.

Information sharing and team mental models

A number of important differences exist between the literatures on information sharing and team mental models. Because information sampling focuses exclusively on the discussion of information,
the primary dependent variables of interest are the number of times shared/unshared information is mentioned/repeated, free recall, and the decision that is reached. In contrast, team mental model research broadens beyond decision making to examine the impact of knowledge convergence on various team processes and team performance. In addition, most of the information sharing research uses ‘extreme’ distributions in which either all information is shared by all group members or unshared information is held by only one member. Rather than being dichotomous in orientation, the team mental model literature focuses on the degrees of sharing that often exist between completely identical and completely idiosyncratic cognitive representations. Moreover, whereas information sharing addresses the communication of distinct pieces of information, the emphasis of mental models is on the organization and interconnectedness of items of information. That is, measures of team mental models not only reveal the degree of convergence among members with regard to the content of known elements, but the structure of data or the relationships between elements (e.g., Mohammed et al., 2000).

Despite these differences, there are several ways in which the information sharing research can contribute to an enriched understanding of team mental models. Although the theoretical work on team mental models does acknowledge the potential benefits of diverse structures (e.g., Cannon-Bowers et al., 1993), the empirical emphasis has been on the convergence or similarity of team member knowledge (e.g., Mathieu et al., 2000). However, the work on information sharing warns of the danger of focusing exclusively on shared information. Distinct team roles often require that members possess unique information, and this information should not only be mentioned, but also actively considered. In order to experience the benefits of group membership, individuals must have mutually recognized and complimentary domains of expertise. Therefore, team mental model research should give increased attention to what is known about effective information pooling behaviors and the factors that undermine the opportunity for group members to discuss diverse knowledge.

Team mental model studies could also benefit from greater emphasis on group discussion and the dynamics of information exchange. Utilizing various analysis techniques, aircrew communications research has found that communication sequences differ between effective and ineffective flight crews (e.g., Bowers et al., 1998). Thus, information sharing and team communications research could be combined to better explain how team members develop accurate expectations of team behavior. In addition, whereas much of the information sharing empirical research examines the variables that increase the probability that unshared information will be mentioned, existing team mental model work has not focused on antecedents or developmental processes. However, potentially fruitful directions include examining the impact of temporal environment, leadership, member status, and task environment on mental model convergence. Furthermore, as team mental model research is in its infancy, it could benefit from the example of systematic, programmatic research utilizing a common task and a similar research design. Although failure to expand to new samples, tasks, and research approaches can lead to an empirical rut over time, homogeneity in methodology and a well-accepted paradigm early on can be beneficial in launching an area of research.

Transactive Memory Summary

Transactive memory is a relatively new concept that was introduced by Wegner (1987) to explain aspects of the behavior of intimate couples (e.g., Wegner et al., 1991), but has also been recently applied to groups (e.g., Moreland, 2000). It refers to the idea that memory is a social phenomenon, and individuals in continuing relationships often utilize each other as external memory aids to supplement their own limited and unreliable memories.
Theoretical development

Transactive memory is a set of individual memory systems which combines the knowledge possessed by particular members with a shared awareness of who knows what (Wegner, 1987). The analogy is that of a computer network in which each computer memory contains its own directory and also a directory of the other computer memories in the system (Wegner, 1995). A cognitively interdependent system for encoding, storing, and retrieving information is developed to ensure that important details are not forgotten (Wegner, 1987). That is, each member keeps current on who knows what, channels incoming information to the appropriate person, and has a strategy for accessing the information. In addition to knowing who is the expert in different knowledge areas, transactive memory also involves storing incoming information with individuals who have matching domains of expertise and accessing relevant material from others in the system (Wegner, 1987, 1995). Through the encoding and information allocation processes, individual memories become progressively more specialized and are fashioned into a differentiated collective memory that is useful to the group.

The specialization of knowledge that individuals develop within a transactive memory system can reduce the cognitive load of each individual, provide access to an expanded pool of expertise, and decrease redundancy of effort (Hollingshead, 1998b). On the other hand, the complexity of transactive memory can create confusion, especially when expertise is in dispute and important information falls through the cracks (Wegner, 1987).

Empirical research

Because the notion of a transactive memory system was introduced to explain aspects of the behavior of intimate couples, much of the empirical research has continued in the tradition of examining dyads (e.g., Hollingshead, 1998a, 1998b; Wegner et al., 1991). However, Moreland and colleagues have conducted a series of experiments investigating the operation of transactive memory in laboratory work groups. In the first experiment (Liang et al., 1995), undergraduates were trained to assemble a radio either individually or in groups and were later tested with their original group or in a newly formed group. Evidencing stronger transactive memory systems, members of groups trained together specialized in remembering different aspects of the task, coordinated behaviors more effectively, and displayed greater trust in each other’s expertise. In addition, the effects of group training on task performance were mediated by the operation of transactive memory. In follow-up work utilizing a similar design and task, transactive memory was measured more directly through the complexity of group members’ beliefs about one another’s radio expertise, the accuracy of those beliefs, and within-group agreement about the distribution of expertise (Moreland, 2000). Addressing the need to investigate the developmental process of transactive memory, qualitative research has also examined the sequence by which encoding unfolds over time (Rulke and Rau, 1997). Recent work has also begun to validate field measures and establish the link between transactive memory and team performance in organizational settings (e.g., Lewis, 2000 – Paper presented at the Academy of Management, Toronto).

Overview

In contrast to the information sharing literature, empirical research on transactive memory lags behind theoretical development. The current work has provided evidence of the existence of transactive memory (Moreland, 2000; Wegner et al., 1991) as well as the encoding, storage, and retrieval mechanisms through which it operates (Hollingshead, 1998a, 1998b; Rulke and Rau, 1997). However, much of this
research involves couples rather than groups and has been conducted in the laboratory using contrived tasks. Recent work has begun to utilize organizational teams, but more research examining how transactive memory systems emerge and are maintained in field contexts is needed.

**Transactive memory, information sharing, and team mental models**

Although there is not much cross-fertilization across the three literatures, the notion of transactive memory is clearly related to the construct of a team mental model and information sharing behaviors in groups. In order to overcome some of the barriers to communicating and using unique knowledge, Stasser (1991) recommends that each group member be made aware that he or she may have distinctive information and that members be informed of the types of unique information that others may have. Therefore, the development of a transactive memory system may overcome the tendency in groups to rehash shared information at the expense of pooling unshared information.

Whereas transactive memory emphasizes task-oriented domains of expertise, team mental models incorporate a wider array of content, including shared representations of working relationships and teamwork. In addition, because of the focus on the encoding, storage, and retrieval of information, recall is usually the primary dependent variable measured in empirical work on transactive memory. In contrast, the emphasis in team mental model research is on examining the impact of knowledge convergence on team processes (e.g., communication, coordination, performance monitoring) and performance.

To date, team mental model research has emphasized the convergence/similarity/agreement/compatibility/overlap among team member knowledge as an important predictor of team effectiveness (e.g., Cannon-Bowers et al., 1993; Mathieu et al., 2000). However, the definition of sharing encompasses not only having in common (e.g., share the equipment), but dividing (e.g., share the workload) (Klimoski and Mohammed, 1994). That is, shared knowledge incorporates both overlapping and complimentary perspectives. According to Cooke et al. (2000), the latter definition of sharing is most appropriate for heterogeneous teams where distinct team roles require information unique to particular individuals. Clearly, many teams fall into this category. On a legal defense team, for example, there is information and areas of expertise that are held in common by all team members, but there is also information and expertise that is distributed unevenly within the team.

Similar to the notion of transactive memory, some team mental model researchers have discussed the importance of knowing who knows what, given the distribution of roles within a team. For example, Cooke et al. (2000) emphasize the need for measures of interpositional accuracy (accuracy associated with roles other than your own) and knowledge distribution metrics (gaps in individual knowledge can be compensated for by the knowledge of other team members). In addition, Jenkins and Rentsch (1995 – Symposium presented at the SIOP meeting, Orlando, FL) have examined schema accuracy (accurate knowledge about another’s knowledge). However, the team mental model literature, by and large, has overemphasized the overlapping perspective of sharing and underemphasized the complementary perspective of sharing. The majority of the empirical research examines the similarity among all team members’ understanding of the relationships between concepts. Interestingly, several of these studies have failed to find significant relationships between measures of convergence of mental models and various dimensions of team performance (e.g., Adelman et al., 1986; Blickensderfer et al., 2000 – Paper presented at the APS, Miami, FL; Stout et al., 1999).

Perhaps one reason for these weak linkages is the failure to consider the distributed definition of sharing. Overlapping knowledge in teams with distinct roles may be inefficient, create a redundancy of effort, and contribute to a less than optimal use of resources. Therefore, rather than measuring similarity globally and assuming that all team members need to have common knowledge in all domains,
future research should work toward specifying the domains and conditions under which distributed and common knowledge will aid or hinder team performance. In addition, in situations where overlapping knowledge is required, it is important to delineate which team roles need to share what information. In a surgical team, for example, there will be some knowledge that needs to be held in common by all team members (identical), some knowledge that needs to overlap among various dyads or triads (e.g., nurse and surgeon, surgeon and anaesthesiologist), and some knowledge that will be unique to individual roles within the team (complementary).

In addition to an increased emphasis on the distributed definition of sharing, team mental model research could also benefit from transactive memory’s attention to the basic cognitive mechanisms of the encoding, storage, and retrieval of information. Although it has been identified as an important dependent variable (e.g., Mathieu et al., 2000), accuracy is measured to a greater extent in the empirical research on transactive memory as compared to team mental models. Furthermore, it may prove useful to investigate turnover (Moreland, 2000) and communication media (e.g., face-to-face versus computer networked environments, Hollingshead, 1998a) as antecedents of team mental model development.

**Group Learning Summary**

In recent years, the concept of organizational learning (e.g., Miller, 1996) has grown in popularity. In addition, a related, but distinct literature has emerged on group or collective learning, which involves the construction of new knowledge by a group. In contrast to research at the organizational level, studies of group learning focus on internal group processes such as communication and influence in mostly laboratory settings (e.g., Argote et al., 1999).

**Theoretical development**

Group learning is defined in terms of both processes and outcomes of group interaction (Argote et al., 1999). Emphasizing processes, Edmondson (1999) conceptualizes learning as ‘an ‘ongoing process of reflection and action, characterized by asking questions, seeking feedback, experimenting, reflecting on results, and discussing errors’ (p. 353). As an outcome, group learning refers to relatively permanent changes in the knowledge and performance of an interdependent set of individuals associated with experience (Devadas and Argote, 1995 – Paper presented at the midwestern Psychological Association, Chicago). For example, Argote et al. (1995) examined learning curves, which refer to groups and organizations improving productivity as they gain experience in production. Because not all knowledge manifests itself in performance changes, and knowledge is difficult to measure directly, both changes in knowledge and behavior are useful indicators of group learning (Devadas and Argote, 1995 – Midwestern Psychological Association). Highlighting the paradoxical nature of the group learning process, a group of skilled individual learners will not necessarily result in a learning team in which collective learning occurs (Argote et al., 1999).

Edmondson (1999) proposed a model of team learning in which psychological safety (shared belief that the team is safe for interpersonal risk taking) contributes to team learning behaviors, such as seeking feedback, sharing information, experimenting, asking for help, and talking about errors. These learning behaviors, in turn, facilitate effective performance by allowing the team to shift directions as situations change and discover unexpected implications of team actions (Edmondson, 1999).
Adopting a different approach, Argote et al. (1999) embed the notion of collective learning within a CORE framework describing Construction, Operation, Reconstruction, and External relations processes in groups. Viewed from this perspective, learning plays a key role across a group’s life span, from initial establishment to task execution to project modification to the management of external sources.

**Empirical research**

There are only a few examples of empirical research specifically investigating group learning. Argote et al. (1995) examined the effects of turnover and task complexity on group learning in a laboratory setting. Supporting the existence of a group-level learning curve, the performance of the groups making origami birds increased significantly over the six periods, and this increase in performance occurred at a decreasing rate. In addition, turnover and task complexity were detrimental to performance, and the differences between turnover and no turnover groups as well as simple task and complex task groups were amplified as the groups gained experience over time. In a follow-up study using a similar experimental paradigm, Devadas and Argote (1995 – Midwestern Psychological Association) replicated previous results regarding a group-level learning curve and turnover, but also examined task structure. When there was turnover, low structure groups performed less well than high structure groups because the low structure groups had more difficulty accessing existing knowledge, lost knowledge, and had to keep reorganizing when members left the group. Using organizational work teams, Edmondson (1999) tested her model of team learning using both quantitative (surveys) and qualitative (interviews and observations) methods of data collection. As hypothesized, team psychological safety positively affected learning behaviors, which in turn, positively affected team performance. A follow-up field study also found that learning oriented beliefs promoted group performance and that effective coaching, clear direction, and a supportive work context were antecedents of group learning (Cannon and Edmondson, 2000 – Paper presented at the Academy of Management Conference, Toronto, Canada).

**Overview**

Although primarily laboratory based, recent work on group learning is beginning to explore field and qualitative applications (e.g., Edmondson, 1999). However, as this literature is in its formative stages, there are a number of areas in need of increased attention. Given the multidimensional and complex nature of the construct, further theoretical development is clearly warranted as to what constitutes group learning. Although claiming to measure the same phenomenon, the lack of overlap between conceptual models is quite striking (e.g., Argote et al., 1999; Edmondson, 1999). In addition, the distinctions made between antecedent variables, contextual factors, and components of the construct itself are ambiguous. In contrast to the homogeneity of the information sharing literature, the group learning literature suffers from the problem of insufficient cohesion. Greater consensus in the development of a theoretical framework would be helpful in generating more empirical research.

**Group Learning and Team Mental Models**

Failure to share unique information and develop a transactive memory system creates problems for learning in groups. In addition, in order for a team to achieve a shared, organized understanding of
knowledge about key elements in the relevant environment, changes in the knowledge and/or behavior of team members will most likely occur. Therefore, group learning plays a significant role in the development, modification, and reinforcement of mental models and can be viewed as a sub-set of the broader concept of team mental models.

Similar to Edmondson's (1999) consideration of corrective feedback and group reflection as critical team learning behaviors, team self-correction has been identified as an important contributor of team mental models (e.g., Blickensderfer et al., 1997). Specifically, team self-correction refers to the natural tendency of a team to debrief following a performance event by correcting team attitudes, behaviors, and cognitions (Blickensderfer et al., 1997). Clearly, the error identification, problem solving and feedback that characterize team self-correction serve as important resources for team learning. However, team mental model research could benefit from increased attention to the important role that group learning plays in the development of a team mental model.

Whereas the information sharing and transactive memory literatures emphasize the distributed definition of sharing, the group learning and team mental model literatures emphasize the 'held in common' definition of sharing. The issue of whether the learning of a few, the majority, or all team members constitutes group learning is usually not discussed explicitly, and team mental model research has wrestled with similar issues. Consequently, there is still progress to be made in specifying exactly what constitutes a shared understanding of team-related phenomenon. Requiring all team members to learn all aspects of mental model content would undermine several of the benefits of constructing a team in the first place, including a division of labor and diversity of expertise. Rather, in order to achieve a high level of team effectiveness, there is some knowledge that will need to be collectively learned by all team members, some knowledge that will need to overlap among various dyads or triads, and some knowledge that will uniquely be held by particular individuals within the team. Therefore, future research must begin to specify which team knowledge content needs to be identical, overlapping, and distributed among team members for maximum team performance. As the optimum mix of complementary and overlapping knowledge will depend on several factors, researchers should carefully consider variables such as the team context and team task.

Cognitive Consensus Summary

Many groups such as governing boards, cross-functional teams, and task forces involve the participation of decision makers from diverse functional backgrounds, multiple departments, and organizational levels. Therefore, individuals often enter the group setting with different perspectives and interpretations of the issues involved. Through interaction and discussion, members are confronted with the conflicting views of their colleagues and must seek to reconcile dissimilar assumptions underlying the issues. Cognitive consensus refers to similarity among group members regarding how key issues are defined and conceptualized (Mohammed and Ringseis, in press).

Theoretical development

Although most of the decision making research has focused on how groups negotiate to reach consensus on decisions, much less is known about how group members negotiate to reach cognitive consensus on the interpretations of issues (e.g., Brehmer, 1976; Bettenhausen, 1991). Nevertheless, an integral part of the group effort is dedicated to resolving differences in how members conceptualize problems,
and without active consideration given to conflicts caused by cognitive factors, there is not likely to be any conflict resolution (Brehmer, 1976). Researchers representing different fields of study have examined various aspects of cognitive diversity in groups. For example, the psychology literature has focused on frames of reference in terms of gain/loss perspectives and disagreements in cue weighting (e.g., Brehmer, 1976; Tindale et al., 1993). More diverse in its treatment of cognitive diversity, the management literature has examined variables such as attributions concerning organizational success and failure (Kilduff et al., 2000), belief structures (Walsh et al., 1988), and issue certainty, controllability, and scope (Fiol, 1994).

Group members may attempt to resolve these types of diversity and develop collective representations of decision issues. Cognitive consensus refers to similarity among group members regarding how key issues are defined and conceptualized. Groups that have more cognitive consensus are likely to attend to, interpret, and communicate about issues more similarly than individuals who have less cognitive consensus (Mohammed and Ringseis, in press). Although decision making tasks have traditionally focused on outcomes, cognitive consensus primarily attends to characteristics of individual judgment processing. Whereas decision preferences reveal what members want out of the decision process, cognitive representations help to explain the reasons underlying the preferences (e.g., Tindale et al., 1993).

Depending on the situation, scholars contend that both cognitive diversity and cognitive consensus can contribute to effective performance in decision making groups (e.g., Kilduff et al., 2000; Walsh et al., 1988). For example, multiple member perspectives have been shown to contribute to creative solutions, but may also cause problems due to miscommunication and disorganization (e.g., Jackson, 1992). Therefore, cognitive diversity can assist a group in operating as a unified structure, but becomes a liability when the uniqueness of individual contributions is lost. Because extreme diversity and consensus in collective representations are generally viewed as dysfunctional for many situations, a delicate balance of both agreement and disagreement is required (e.g., Fiol, 1994). However, the optimal level of consensus and dissensus in framing perspectives that will contribute to effective group process dynamics and decision outcomes will depend upon a number of factors, including the specific environment in which a group operates, the level of interdependence among members, the nature of the task, and where the group is in the decision making process.

**Empirical research**

Scattered throughout various literatures, several authors have explored the notion of cognitive consensus utilizing different terminology and focusing on diverse aspects of the phenomenon. For example, Walsh et al. (1988) found that realized coverage (the range of belief structures voiced during a discussion) and realized consensus (level of similarity among team members’ individual belief structures) were systematically related to product and firm performance by student groups participating in a business simulation. On the other hand, Tindale et al. (1993) showed that variations in gain/loss perspectives among group members influenced decision processes.

Operationalizing cognitive consensus as shared assumptions underlying decision issues, Mohammed and Ringseis (in press) investigated the antecedents, processes, and consequences of cognitive consensus. Utilizing student groups participating in a multi-issue decision making exercise, results revealed that unanimity decision rule groups achieved more cognitive consensus than majority rule groups. In addition, groups whose members inquired concerning the reasons underlying others’ decision preferences, accepted others’ viewpoints as legitimate, and incorporated others’ perspectives into their own interpretations of the issues arrived at a greater degree of cognitive consensus than groups whose members engaged in less of these behaviors. With regard to consequences, cognitive consensus positively influenced expectations regarding decision implementation and satisfaction.
Kilduff et al. (2000) found that the most successful teams of managers participating in a business simulation started out with diversity among members regarding attributions of organizational success and failure, but developed more consensus over time. Therefore, cognitive diversity at the beginning of a decision making task, integrated with cognitive consensus by the end of the task, is one way for teams to foster both equivocality and mutual understanding. Also emphasizing the need for both a ‘divergence and convergence of meanings’ (p. 404), Fiol (1994) concluded that agreement around a broad frame of interpretations provided the common meaning needed to move toward action in new venture teams, regardless of differing views on issue content.

Overview

The concept of cognitive consensus provides a valuable means for understanding how decision makers collectively make sense of ill-structured issues in a group setting and is conceptually appealing because it integrates group, cognitive, negotiation, and decision making literatures. However, the extant body of research devoted to the construct is fragmented and scattered across various literatures. Recent work by Mohammed (1997 – Paper presented at the Academy of Management Meeting, Boston, MA) has attempted to consolidate and integrate what has been learned about cognitive consensus into a foundation upon which future work can be based, but there are still many unanswered questions that must be addressed both conceptually and empirically. Particularly salient is the need for insight into processes that contribute to the development of cognitive consensus and how groups can achieve an optimal mix of diversity and consensus in group-level interpretations.

Cognitive consensus and team mental models

Whereas both teamwork and taskwork are implicated in the notion of a team mental model, cognitive consensus narrows the focus to collective representations of key issues faced by the group. In addition, cognitive consensus references evaluate belief structures, while information sharing, transactive memory, group learning, and team mental models reference knowledge structures. In contrast to knowledge structures, which concern descriptive states of nature that one knows or thinks to be true, belief structures concern desired states of nature that one prefers or expects (Mohammed et al., 2000). Rather than focusing on raw information content, cognitive consensus deals with the interpretation of the information, how it is viewed by the group, and the opinions that are held about it. Therefore, it is likely that knowledge structures will occur more readily than the development of cognitive consensus. Furthermore, ‘correctness’ or accuracy is an important variable in the study of knowledge structures, but would be problematic with cognitive consensus because of its subjective and evaluative nature.

Although the existing work on team mental models has referenced shared knowledge structures, the cognitive consensus literature can assist in expanding the construct to include belief structures as well. We would argue that the team mental model construct should allow for the notion of shared interpretations and viewpoints of strategic issues. Not only is it important that team members share an adequate knowledge of taskwork and teamwork, but that they also have a common conception of the assumptions underlying issues of significance. In addition to including belief structures, team mental model research could also benefit from the work on cognitive consensus by incorporating key political realities inherent in many group contexts. Despite the fact that political mechanisms are often overlooked in team research (Walsh et al., 1988), recognizing the presence of divergent viewpoints, as well as conflicting motives to both compete and cooperate, could enrich team mental model research.
Development of an Integrative Framework

In examining the constructs of team mental models, information sharing, transactive memory, group learning, and cognitive consensus, this paper reflects the variety of perspectives that emerge when multidisciplinary scholars examine the broad concept of team knowledge. Collectively, these literatures provide considerable insights into shared cognition processes at the group-level. However, the diversity also provides a considerable challenge in that there are many ways to view the multifaceted nature of team knowledge.

Table 1 summarizes the team knowledge domains that have been reviewed in the current paper according to their academic roots, definitions, methodologies, antecedents, and criterion variables. Unfortunately, these literatures have progressed in parallel with little cross-fertilization, and researchers do not commonly cite each other's work. However, because all of these areas are in the formative stages of research development, there is much to be gained from integration across disciplinary boundaries. Therefore, the current paper seeks to enhance and expand understanding of team mental models by reviewing and assimilating these separate research streams on team knowledge.

Integrating across all of the literature reviewed, one of the primary distinctions separating the research on team mental models from the research on information sharing, transactive memory, group learning, and cognitive consensus is that the former references teams, while the latter references groups. Specifically, team mental models are generally discussed in the context of command and control or military teams, where the task is highly structured, roles are clearly differentiated, and coordinated patterns of interdependence are specified (e.g., Cannon-Bowers et al., 1993; Mathieu et al., 2000). On the other hand, the other team knowledge domains have primarily been implicated in groups, which are characterized by ambiguous task contexts, unspecified roles, and the absence of explicit task interaction demands (Salas et al., 1992). As the previous review demonstrates, much of the work on groups has been conducted in laboratories with undergraduate students doing tasks (e.g., murder mystery; making origami birds) that are far removed from the complex, multidimensional context typical of 'real world' military, medical, or process control teams. Therefore, caution should be exercised in applying theories and empirical findings based on groups to teams, and the integrative sections of the paper have taken these important differences into account when drawing connections to team mental model research.

With that qualifier in mind, however, we do feel that group literature, with its longer history and greater volume, has much to offer team research. Indeed, although the empirical research has been primarily limited to groups in laboratory settings, there is nothing inherent in the phenomenon of information sharing, transactive memory, group learning, and cognitive consensus that prevents their applicability to teams. For example, recent work by Lewis (2000 – Paper presented at the Academy of Management Toronto, Canada) has shown that transactive memory systems predict the performance of consulting teams. Also breaking away from the traditional lab-based research, group learning behaviors have been measured in organizational teams (Edmondson, 1999; Cannon and Edmondson, 2000. Paper presented at the Academy of Management Conference, Toronto, Canada). Hopefully, these applied research trends will continue.

Several themes have emerged from the review of the various team knowledge literatures. First, based on how the various constructs have been conceptualized and operationalized, it appears that the notion of a team mental model is the broader term that encompasses the specific dimensions of information sharing, transactive memory, group learning, and cognitive consensus. Second, these various team knowledge domains feature different content domains, such as taskwork, teamwork, and belief systems. Third, the concepts reflect varying degrees of emphasis with regard to the definition of 'shared' as overlapping/held in common versus complementary/distributed. Figure 1 portrays
<table>
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<th>Construct/Phenomenon Description</th>
<th>Methodology</th>
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<td>Team mental model</td>
<td>Human factors Industrial/organizational psychology Cognitive psychology Social psychology Communication</td>
<td>Team members' shared, organized understanding of knowledge about key elements in the team's relevant environment (e.g., teamwork, taskwork)</td>
<td>Flight simulations (e.g., TANDEM) Similarity ratings, pathfinder, UCINET, concept mapping Intellecitive hidden profile task (e.g., murder mystery) Laboratory-based</td>
<td>Team training Planning</td>
<td>Team processes (e.g., communication, coordination Team performance</td>
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<tr>
<td>Information sharing</td>
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<tr>
<td>Transactive memory</td>
<td>Social psychology Cognitive psychology</td>
<td>Cognitively interdependent system for encoding, storing and retrieving information that combines the knowledge possessed by individual members with a shared awareness of who knows what</td>
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<tr>
<td>Cognitive consensus</td>
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<td>Similarity in the way that group members conceptualize and define key issues</td>
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Table 1. Summary of team knowledge literature
these themes by positioning the team mental model construct within a larger team knowledge framework.

As previously discussed, the information sharing and transactive memory literatures have clearly been task-oriented, focusing on the discussion of information and knowledge concerning members’ domains of expertise. Within the context of heterogeneous teams in which distinct roles require information unique to particular individuals, it is argued that knowledge concerning the task should primarily be distributed among team members. Although there is some taskwork knowledge that all team members will need to hold in common in every team, too much overlap will create redundancies and inefficiencies that result in sub-optimal use of team resources. Therefore, the majority of taskwork information should be unique to individual roles or be held in common among specified dyads or triads within the team.

In contrast to the information sharing and transactive memory literatures, the group learning area has emphasized the overlapping definition of sharing. It is argued that knowledge reflecting how the team will function together and communication processes should primarily be held in common by all team members. Given the distributed nature of taskwork knowledge recommended in heterogeneous teams, overlapping teamwork knowledge would be necessary to provide adequate coordination for the team to function smoothly as a collective entity. Uneven distribution of teamwork knowledge would undermine the development of accurate expectations of team behavior and effective team coordination. Therefore, group learning efforts involving all members of the team should be oriented toward dimensions of teamwork in heterogeneous teams.

Whereas teamwork and taskwork reflect knowledge structures, varying interpretations and perspectives regarding key team issues reflect belief structures. Although team mental models have traditionally measured knowledge structures, it is argued that the construct should allow for the notion of evaluative belief structures, and the work on cognitive consensus can assist in this regard. A delicate balance between both overlapping and complementary sharing perspectives is needed with respect to belief structures. With completely divergent belief structures, group member interactions will likely involve a high degree of miscommunication and misunderstanding. However, because multiple perspectives are one of the advantages of a group context, overlap in team member interpretations to the point of groupthink becomes a liability. Therefore, group members must simultaneously agree and disagree in order to maintain both unity and diversity in equilibrium. Members of the group may even be in agreement on the need to disagree, respect divergent perspectives, and permit conflict.
Furthermore, within a single group, there may be coalitions of shared beliefs, with all individuals sharing some beliefs, but only a sub-set of members sharing other beliefs. The optimal level of consensus and dissensus in framing perspectives that will contribute to effective outcomes will depend upon a number of moderating variables such as where the group is in the decision making process.

With regard to recommendations for future research, the integrative framework proposed in Figure 1 highlights the need for team mental model researchers to clearly articulate the particular content domain being considered and the sharing perspective hypothesized. Given the multifaceted nature of the construct, team mental models should not be referenced in the abstract without specifying whether the focus is on teamwork/taskwork/representations of issues, and whether a distributed/common notion of sharing is being considered. In addition, the degree to which a team’s mental model spans across both knowledge and belief structure domains should be incorporated as a relevant criterion variable in research. Whereas some teams may have a well developed task mental model, a poorly developed teamwork mental model, and wide divergence on belief structures, other teams may experience just the opposite.

Based on the literature reviewed in this paper, we would expect that a team mental model with primarily distributed taskwork knowledge, primarily overlapping teamwork knowledge, and a balance of diversity and consensus in belief structures would result in higher collective performance for heterogeneous teams where distinct team roles require information unique to particular individuals. However, for other types of teams and tasks, a different configuration may be superior. The optimal degree of sharing across content domains will depend upon factors such as the specific environment in which a team operates, the level of interdependence among members, the nature of the task, and where the group is in terms of development.

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