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AN EXAMINATION OF TEAM SEARCH PATTERNS OVER TIME AS ANTECEDENTS TO TEAM MENTAL MODELS

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ABSTRACT

AN EXAMINATION OF TEAM SEARCH PATTERNS OVER TIME AS ANTECEDENTS TO TEAM MENTAL MODELS

By

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The purpose of this dissertation is to examine how teams develop mental models over time. I contend that teams vary in their search patterns, and that this has important implications for team mental models and team performance. Specifically, teams in which members share their searches will have greater accuracy in their team mental models of the team and their team mental models of the task than teams in which members search independently. Moreover, these relationships vary over time such that teams have the greatest accuracy in their mental models when they engage in shared searches early in a task and independent searches late in a task. Thus, the primary contribution of this dissertation is to extend theory on team mental models to consider the differential influence of search sharedness on team mental models over time.

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INTRODUCTION

Many tasks in organizations are too complex to be performed by an individual. As a result, organizations often assign their most difficult and complex tasks to teams (Hinsz, 1999). Research indicates that about one half of the organizations in the United States use teams (Devine, Clayton, Philips, Dunford, & Melner, 1999). Over the last few decades organizations have increased the usage of teams as a basic building block of structure, making salient their importance in organizations (Ilgen, 1999). Recent literature reviews indicate a corresponding increase in research examining team performance (Kerr & Tindale, 2004; Ilgen, Hollenbeck, Johnson, & Jundt, 2005).

Research examining teams has conceptualized them as information processors (Hinsz, Tindale, & Vollrath, 1997). In this depiction, teams have processing objectives, which influence their attention deployment. Teams gather, encode, store, and retrieve information, process it, and learn from feedback. Team mental models are important emergent states that are products of the information processing system (Marks, Mathieu, & Zaccaro, 2001). Team mental models are defined as knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and, in turn, to coordinate their actions and adapt their behavior to demands of the task and other team members (Cannon-Bowers, Salas, & Converse, 1993). Research has consistently indicated that team mental model accuracy predicts team performance (Edwards, Day, Arthur, & Bell, 2006; Ellis, 2006; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000).

Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000) note that there are two types of team mental models, those with content examining the task domain and those with content examining the team domain. Mathieu and colleagues (2000) note that team mental models of the task describe and organize knowledge about how the task is accomplished, likely contingencies or problems, and environmental conditions. Team mental models of the team contain information about team members, including their knowledge, skills, attitudes, preferences, strengths, and weaknesses. Research indicates that these two types of team mental models are both conceptually and empirically distinct (Mathieu et al., 2000; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005).

This distinction between team mental models of the team and team mental models of the task is important if these two types of team mental models reflect truly different constructs, because the steps teams can take to optimize the development of one may be sub-optimal for developing the other. For example, developing an accurate model of the team may necessitate an internal focus on each member of the team that precludes a simultaneous focus on the larger external task environment. In contrast, developing an accurate mental model of the task may necessitate an external focus on the environment that precludes a simultaneous focus on the strengths and weaknesses of team members. Thus, assuming that teams have finite resources, the manner in which teams seek information may have differential impacts on the two different types of team mental models. Allocating information search resources toward broad external searches may help develop team mental models of the task, but detract from resources available to conduct narrow, internally focused searches that would help develop team mental models of the team.

I contend that if the information search patterns associated with developing accurate mental models of the team are different from those associated with developing accurate mental models of the task, then these alternative models may need to be developed at different times. This is consistent with Gersick's (1988, 1989, 1991) contention that teams generally pursue a consistent strategy in the first half of a task, examine their strategy at the midpoint, and then follow a consistent strategy in the second half which may often be very different than their earlier strategy. If indeed teams should develop team mental models at different times, it is likely that the order in which they are developed matters. Thus, an important question is whether it is better to develop team mental models of the team before team mental models of the task or the other way around. Research examining stages of group development has recognized that time and order matter. Two of the major models of group development imply a temporal differentiation in terms of focus of attention on internal models of team members versus external models of task environment. Tuckman's (1965) model includes development with regards to interpersonal structure and relationships within the team as well as with regards to the task itself. The Kozlowski et al. (1999) theoretical model similarly notes development with regards to the team and the task, but goes further to predict that there is a normative sequence to this process in which order matters.

The purpose of this dissertation is to examine how teams develop mental models over time. I contend that the types of information search processes that teams engage in vary in how they influence team mental models, and that these influences in turn vary over time. Specifically, I contend that early in group development, information search processes that emphasize a shared approach to information gathering will promote the development of accurate mental models of the team, whereas later in group development an independent approach to information search will promote development of accurate mental models of the task. In other words, teams that follow this sequence will have the most accurate mental models.

In this dissertation, I limit my focus to decision-making teams. Moreover, I focus on decision tasks in which have a correct answer, which Laughlin (1999) refers to as intellective tasks. Such tasks either have an answer that can be demonstrated to be correct either prior to implementation or based on the outcome (Barnes & Hollenbeck, In Press). Judgmental tasks—which Laughlin (1999) describes as evaluative, behavioral, or aesthetic judgments for which there is no immediately demonstrably correct answer—lie outside of the scope of this dissertation. Furthermore, in contrast to the previous literature examining team mental models which generally include small (2-4 person) teams, I focus on large teams with greater than 10 members. Moreover, I focus on teams with members that have defined roles structured around specific functional subgroups (Hollenbeck et al., 2002). Finally, I limit my focus to teams performing complex tasks requiring coordination among team members.

TEAM MENTAL MODELS

Historical Origins of the Team Mental Model Construct

Team mental model research owes its origins to research examining mental models at the individual level of analysis. Research in the fields of human factors and cognitive psychology examines mental models of systems that are held by single individuals. In their review of this literature, Rouse and Morris (1986) defined mental models as mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states. Rouse and Morris noted that much of this literature was developed in order to describe and explain contexts of manual control using psychomotor skills as well as contexts where humans have a supervisory role over automated systems. This is apparent in Veldhuyzen and Stassen's (1977) review of the human factors mental models literature. They noted that mental models allow operators to estimate all variables necessary to control a system, adopt strategies necessary to control a system, select proper control actions in relation to a defined strategy, evaluate the potential of control actions that have been initiated, and understand what happens as the task is executed.

Rouse and Morris (1986) are careful to note that in order to predict future states or explain the current state, one must gather, combine, and utilize cues. These are the information building blocks out of which mental models are built. People often either lack information or are biased in putting these building blocks together, leading to inaccuracies in mental models. Rouse and Morris note that training and interventions aimed toward the aid of accurate mental model development have often focused improving the gathering, combination, and utilization of cues. To varying degrees of success, researchers have attempted to aid system operators in this process by conveying the theory behind the operation of a system, providing explicit procedures to guide the cue process, and building expertise through the accumulation of knowledge frameworks.

Drawing explicitly from Rouse and Morris (1986) and Veldhuyzen and Stassen (1977), Cannon-Bowers, Salas, and Converse (1993) took seminal steps in developing this construct conceptually at the team level of analysis. Noting that critical performance in many complex systems depends on coordinated activity within teams, Cannon-Bowers and colleagues contended that effective team performance requires team members to hold common or overlapping cognitive representations of task requirements, procedures, and role responsibilities. Cannon-Bowers and colleagues made the distinction between taskwork, which is focused on the execution of the task, and teamwork, which is focused on functioning effectively as a set of team members. Thus, whereas mental model research conducted at the individual level of analysis focused on task performance (Rouse & Morris, 1986; Veldhuyzen & Stassen, 1977), Cannon-Bowers and colleagues added a focus on team members and how they work together.

This is apparent in how Cannon-Bowers and colleagues (1993) defined team mental models. Drawing explicitly from the Rouse and Morris (1986) definition of mental models, Cannon-Bowers and colleagues defined team mental models as knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and, in turn, to coordinate their actions and adapt their behavior to demands of the task and other team members. The Cannon-Bowers and colleagues definition contains elements of both taskwork and teamwork, and is at the team level of analysis. The impact of this research is apparent when examining citations: a Google Scholar search indicates that this chapter has been cited 351 times.

In transporting the construct of mental models to the team level of analysis, Cannon-Bowers and colleagues (1993) focused primarily on the degree to which knowledge content is overlapping among team members. They note that the role of team mental models is to provide a set of organized descriptions and expectations that are shared by team members. In other words, shared mental models help team members to arrive at common explanations across team members, which aid coordination and team performance. Individual team member mental models that are not shared do not fit this depiction.

Cannon-Bowers and colleagues (1993) note that teams may hold multiple mental models. Specifically, based on their previous experience monitoring teams, Cannon-Bowers and colleagues generated an initial list of four different types of team mental models: equipment model, task model, team interaction model, and team model. The equipment model contains content regarding equipment functioning, operating procedures, equipment limitations, and likely failures. The task model contains content regarding task procedures, likely contingencies, likely scenarios, task strategies, and environmental constraints. The team interaction model contains content regarding roles/responsibilities, information sources, interaction patterns, communication channels, and role interdependencies. The team model contains content regarding teammates' knowledge, skills, abilities, preferences, and tendencies. However, they note that the exact contents of team mental models will be task dependent.

Shortly after the influential Cannon-Bowers and colleagues (1993) book chapter, Klimoski and Mohammed (1994) took further conceptual steps in building the team mental model literature. They examined the label and construct of team mental model, comparing it to other terms. They note that they favor the term team mental models over other terms for three main reasons. First, it makes clear that the locus of interest is the team. Second, it notes that what is being shared is among team members as a collectivity. Third, it allows for the notion of multiple sets or levels of shared knowledge. They contend that these distinctions separate the construct of shared mental model from other constructs such as culture or group mind.

Klimoski and Mohammed (1994) echoed the emphasis of Cannon-Bowers and colleagues (1993) on the sharedness of mental models. However, Klimoski and Mohammed (1994) contended that teams can share content in two very different ways. According to Klimoski and Mohammed, sharing can mean holding knowledge in common, or it can mean dividing up. Therefore, they argue that at one extreme shared mental models can refer to cognitive representations that are identical among team members. At the other extreme, shared mental model can refer to distributed configurations of knowledge where there is no overlap among members. A middle ground depiction of shared mental models is a set of partially overlapping cognitive representations. Thus, whereas Cannon-Bowers and colleagues (1993) depicted team mental models as content that is held by all team members, Klimoski and Mohammed (1994) questioned this assumption. This exploration of sharedness as distributed, non-overlapping knowledge has gone largely ignored by subsequent team mental model research, which has instead focused on team mental models as content that is held by all members of a given team.

A more influential contention put forth by Klimoski and Mohammed (1994) was that time is an important factor in team mental models. They note that team mental model sharedness can change over time, such that teams may initially have diffuse general models that become more specific with experience. Furthermore, they suggest that the manifestation or character of team mental models may reflect the state of group development. Thus, teams may have different content and different levels of sharedness early in development than they do later in development.

Finally, Klimoski and Mohammed (1994) outlined conceptually the mechanisms by which team mental models influence team performance. They note that team mental models allow team members to anticipate and predict the behavior of fellow team members as well as the probabilistic behavior of the group. This allows for the efficient and effective use of team member inputs toward team goals and outputs. Moreover, Klimoski and Mohammed contended that teams that have well developed mental models may be able to implement decisions more quickly and with fewer problems than teams without such mental models. Teams lacking in mental models are forced to devote their attention away from the task and towards processes such as surfacing mutual perceptions, assumptions, options, and preferences. Thus, they proposed that team mental models aid team performance through beneficial effects on team processes.

Early Research on Team Mental Models

Cannon-Bowers and colleagues (1993) and Klimoski and Mohammed (1994) established the construct of team mental model well enough that researchers could begin attempts to place this construct into a larger nomological network. Measurement challenges most notably summarized by Cooke and colleagues (Cooke, Keikel & Helm, 2001; Cooke, Salas, Cannon-Bowers, & Stout, 2000; Cooke, Salas, Keikel, & Bell, 2004; Cooke, Stout, & Salas, 2001) hindered early empirical work. Nevertheless, early research examining team mental models attempted to expand beyond the basic conceptual contention that team mental models benefit team performance. This early research focused on mental models in which all members hold the same content, following the depiction of team mental models outlined by Cannon-Bowers and colleagues (1993).

Hinsz (1995) built on Klimoski and Mohammed's (1994) initial consideration of time in team mental models. Hinz noted that mental models are dynamic, and that one should not expect that a mental model at one point in time would be necessarily relevant for understanding mental models at a different point in time. Thus, team mental models are emergent states that vary over time. Hinsz noted that team mental models are built through experience, based on interaction and learning. Empirical support for this contention was eventually provided by Smith-Jentsch, Campbell, Milanovich, and Reynolds (2001), who found that mental models of more experienced naval officers were more similar to each other than were the mental models of less experienced naval officers.

Gualtieri, Fowlkes, and Ricci (1996) similarly noted that team mental models can change over time as teams learn. However, they extended this logic to contend that researchers and managers can direct changes in team mental models over time by training teams. This contention that teams can be trained to have shared cognitive representations in the team mental models has been echoed by several researchers (Klimoski & Mohammed, 1994; Kraiger & Wenzel, 1997; Mohammed, Klimoski, & Rentsch, 2000; Stout, Cannon-Bowers, & Salas, 1996). Empirical support for this contention was eventually provided by Marks, Zaccaro, and Mathieu (2000), McCann, Baranski, Thompson, & Pigeau (2000), and Smith-Jentsch, Campbell, Milanovich, and Reynolds (2001).

Kraiger and Wenzel (1997) conceptually examined additional antecedents of team mental models. They noted that strong organizational cultures will lead the mental models of team members to be more similar than they would be in weak organizational cultures. They argued that incentive systems which reward team-based actions will lead to more effort allocated toward interaction with the group, benefitting team mental models. Furthermore, concrete tasks lead to specific, well-defined knowledge structures that may be easier for team members to articulate and share that vague tasks and knowledge structures. In one of the only papers exploring the Klimoski and Mohammed (1994) contention that team mental model sharedness can refer to either overlap in knowledge or distributed knowledge, Kraiger and Wenzel (1997) contend that high levels of workload will lead team members to be more likely to distribute information among team members in a non-overlapping manner. Additionally, they suggest that teams with a greater history of success will put more effort into developing team mental models than teams experiencing lower levels of success. In an early conceptual examination of antecedents of team mental models, Kraiger and Wenzel indicate that teams composed of homogeneous members will be more likely to hold shared mental models characterized by overlap in content than teams composed of heterogeneous members.

Kraiger and Wenzel (1997) also added further detail to conceptual arguments as to why team mental models can benefit team performance. They note that team mental models aid team members in approaching a task with similar objectives, a contention that has been more recently echoed by Rico, Sanchez-Manzanares, Gil, and Gibson (2008). Furthermore, Kraiger and Wenzel (1997) note that team mental models facilitate communication in teams, such that there are concise statements of questioning, feedback, and confirmation, as well as low levels of excess chatter. Zohar and Luria (2003) provided field support for the contention that shared mental models in the form of standardized scripted language aided communication.

Blickensderfer, Cannon-Bowers, and Salas (1997) contend that one method for a team to improve its team mental model is to engage in self-correction. Blickensderfer and colleagues define self-correction as a natural mechanism by which team members correct their team attitudes, behaviors, and cognitions without an outside intervention. They note that this process typically occurs during a performance review session. They contend that this self-correction will help teams clarify shared mental models of the task and team by sharing knowledge and expectations, clarifying why problems occurred, and where miscommunications occurred. A similar contention is made by Rasker, Post, and Shraagen (2000). Empirical support for this contention was eventually provided by Gurtner, Tchan, Sernmer, and Nagele (2007), who found that group members had more similar mental models when allowed to engage in an after action review than when they did not engage in this review.

Stout, Cannon-Bowers, Salas, and Milanovich (1999) examined planning as an additional antecedent of team mental models. They hypothesized that high-quality planning would aid team members in forming shared expectations and explanations of each other's informational requirements. In some of the earliest empirical work examining team mental models, they found empirical support for their hypothesis. Specifically, they found that high quality planning led to high levels of overlap in team mental models.

Recent Research on Team Mental Models

At the turn of the century, there were two main developments in the team mental model literature that sparked empirical research and further theoretical extension. One such development was conceptual in nature. Much like how Klimoski and Mohammed

(1994) helped clarify conceptually team mental models early in the development of this literature, Mohammed and Dumville (2001) again addressed the construct of team mental models in the context of other team knowledge constructs. They contended that a team mental model is a super ordinate construct, which includes the subordinate constructs of information sharing, transactive memory, group learning, and cognitive consensus. They further noted that information sharing and transactive memory are especially involved in the taskwork domain, and that group learning is especially involved in the teamwork domain. By helping to establish the domain of team mental models, this conceptual work aided the team mental model literature from splitting into multiple independent literatures.

A second major development in the team mental model literature at this time was a call for empirical research and recommendation for how this should be conducted. Mohammed and Dumville (2001) noted that empirical research had lagged far behind conceptual work in the team mental model literature. Cooke and colleagues (Cooke, Keikel & Helm, 2001; Cooke, Salas, Cannon-Bowers, & Stout, 2000; Cooke, Salas, Keikel, & Bell, 2004; Cooke, Stout, & Salas, 2001) wrote a series of articles examining methods of measuring team mental models, providing suggestions to guide empirical research on team mental models. These included suggestions as to how to operationalize team mental models as well as how to conduct statistical analyses testing propositions put forth by the team mental model literature.

Perhaps spurred in part by these developments, researchers examining team mental models began making empirical contributions to the literature. Among the first of these were Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000). Mathieu and colleagues collapsed the four types of team mental models noted by Cannon-Bowers and colleagues (1993) into two types of team mental models. Mathieu and colleagues (2000) note that team mental models of the task describe and organize knowledge about how the task is accomplished, likely contingencies or problems, and environmental conditions. Team mental models of the team contain information specific to team members, including knowledge, skills, attitudes, preferences, strengths, and weaknesses.

Mathieu and colleagues (2000) built on previous contentions that team mental models aid coordination in the team. They noted that the function of team mental models is to allow team members to draw on their own well-structured knowledge as a basis for selecting actions that are consistent and coordinated with those of their teammates, and that overlap in the mental models of team members enables this coordination. They note that highly similar mental models aid team members in working toward common objectives, where as unshared mental models result in process loss and ineffective team processes.

Mathieu and colleagues (2000) were among the first to conduct empirical work examining outcomes of team mental models. They conducted a laboratory experiment examining the shared mental models of 56 two-person teams engaged in a fighter jet simulation. They found that team mental models of the team and team mental models of the task tapped two qualitatively different content domains. Teams which had high team member similarly in their mental models of the team had higher levels of performance than those which did not. Moreover, strategy formation, cooperation, and communication mediated these effects. They found that similarity among team member mental models of the task predicted strategy formation, cooperation, and communication, but not team performance.

In addition to laboratory research examining team mental models, researchers also examined team mental models in field settings. Rentsch and Klimoski (2001) conducted a field study examining 41 work teams from a U.S. Department of Defense organization. They found that team mental model similarity was positively related to team effectiveness. Moreover, they found that teams with greater experience working together were higher in team mental model similarity than those with lower levels of experience. In a more qualitative study, Waller, Gupta, and Giambatista (2004) conducted a field study examining 14 nuclear power plant control room teams and also found that shared team mental models were positively related to team performance.

A key contribution to the team mental model literature was made by Marks, Zaccaro, and Mathieu (2000). Examining 79 three member teams engaged in a tank simulation, they also found that team mental model similarity was positively related to team performance. Furthermore, they found that team communication partially mediated this effect. However, they extended the team mental model literature by moving beyond similarity in team mental models to examine accuracy in team mental models. They defined accuracy in team mental models as the correctness of the knowledge structured maintained by team members. Marks and colleague noted that just having similar models does not necessarily ensure that this shared model is beneficial to team performance. Teams may agree about knowledge that is incorrect, which could be detrimental to team performance. Marks and colleagues found that accuracy of team mental models was positively related to team performance, and that communication partially mediated this relationship. Marks and colleagues (2000) also examined antecedents of similarity and accuracy of team mental models. They found that teams which received team interaction training developed more similar and accurate team mental models than teams which did not receive such training. They also found that the quality of briefings delivered by leaders prior to the task was positively related to team mental model similarity and accuracy. Also focusing on team mental model accuracy, Lim and Klein (2006) conducted a field study examining 71 armed forces combat teams in Singapore. They found that for both team mental models of the team and team mental models of the task, team mental model similarity and team mental model accuracy both predicted team performance.

Some contemporary research indicates that team mental model sharedness and team mental model accuracy may interact to predict team performance, however these results have been mixed. Mathieu, Heffner, Goodwin, Cannon-Bowers, and Salas (2005) conducted a laboratory experiment examining 70 two person teams engaged in a flight simulator. They found that accuracy in team mental models of the team moderated relationship between team mental model similarity and team processes, such that this relationship was positive when teams had accurate models but neutralized when teams had inaccurate models. However, they did not find this interaction for team mental models of the task. Mathieu and colleagues (2000) also found an interaction between team mental model similarity and team mental model accuracy. However, the form of the interaction was different than that found in Mathieu and colleagues (2005), such that team mental model similarity influence team performance only when teams had inaccurate mental models. Lim and Klein (2006) hypothesized an interaction between team mental model similarity and team mental model accuracy, but failed to find one. Each of these studies utilized less than 100 teams. Future research may benefit from larger samples that will aid the detection of such interactions.

Some of the newest research examining team mental models has examined team mental models as a mediator of the influence of other variables on team performance. Edwards, Day, Arthur, and Bell (2006) conducted a laboratory experiment examining 83 two member teams engaged in a low fidelity simulator. They found that both team mental model similarity and team mental model accuracy predicted team performance. However, they note that across two time periods, the relationship between team mental model accuracy and team performance was stronger than the relationship between team mental model similarity and team performance. Moreover, they found that team mental model accuracy partially mediated the relationship between team cognitive ability and team performance. Ellis (2006) conducted a laboratory experiment examining 97 four person teams engaged in a command and control simulation. He found that both team mental model similarity and team mental model accuracy mediated the negative relationship between acute stress and team performance.

It appears that researchers will continue building antecedents, mediators, and moderators into theory examining team mental models. The most recent example is conceptual work by Rico, Sanchez-Manzanares, Gil, and Gibson (2008). They contend that longevity, trust and group efficacy will each positively influence team mental model similarity and accuracy, and that knowledge diversity will negatively influence team mental model similarity and accuracy. Moreover, they extend the contention made by Cannon-Bowers and colleagues (1993) that implicit coordination mediates the influence of team mental model similarity on team performance by adding that implicit coordination should also mediate the influence of team mental model accuracy on team performance. They also echo earlier contentions that team mental models are dynamic over time.

It also appears that much of the focus on team mental models has shifted from team mental model sharedness to team mental model accuracy. Early research examining team mental models, such as Cannon-Bowers and colleagues (1993), Klimoski and Mohammed (1994), and Kraiger and Wenzel (1997) focused entirely on sharedness. However, beginning with Marks and colleagues (2000), researchers have increasingly examined accuracy (Edwards et al., 2005; Ellis, 2006; Lim & Klein, 2006; Mathieu et al., 2005). To the degree that there is a single correct state of a team or task, accurate team mental models of the team necessitate sharedness among members. In other words, teams high in team mental model accuracy are should also be high in team mental model sharedness. Support for this contention is provided by Edwards and colleagues (2006), who conducted 2 empirical studies in which they found correlations between accuracy and sharedness of .61 and .67. Moreover, Edwards and colleagues found that team mental model accuracy had a much greater effect on team performance than did team mental model sharedness. This may lead to an increased focus on accuracy to continue in future research. I contend that this shift in focus to accuracy rather than sharedness makes sense in light of issues regarding levels of analysis. Specifically, if teams are low in mental model sharedness, it is unclear whether or not such mental models are truly at the team level of analysis. Thus, there are both conceptual and empirical reasons to focus on team mental model accuracy rather than team mental model sharedness.

Limitations of Current Theory and Research on Team Mental Models

The literature examining team mental models has evolved at a rapid pace. Although there are many merits of research examining team mental models, there are two main limitations to this research. First, the literature has not taken a systematic approach to information search issues. To date, the emphasis in team mental model research has been on what information is shared and unshared, and what information is accurate and inaccurate. However, there is a dearth of research examining how team members work together to obtain this information. This is problematic, especially considering the contention made by multiple researchers that often time decision makers are not presented with all options in advance of a decision; often times they must obtain information before they can organize and utilize it generate options and make decisions (Fischhoff, 1996; Hinsz et al., 1997; Svenson, 1996). Similarly, Verplanken, Aarts, and Van Knippenberg (1997) note that information search directly influences choices made by groups.

Sorkin and colleagues examined one manner in which groups can gather information (Sorkin & Dai, 1994; Sorkin, Hays, & West, 2001; Sorkin, West, & Robinson, 1998). In this series of studies, groups had the task of perceiving information from the environment. As outlined by Sorkin and Dai (1994), all group members in this series of studies were attempting to perceive the same stimulus in each trial. From this perspective, team members search in a non-distributed, fully overlapping manner. In other words, the search process of each team member is completely redundant with the search process of all other team members. However, a primary purpose of utilizing groups instead of individuals is that groups can consider a greater amount of information from diverse sources than individuals can when working alone (Gigone & Hastie, 1993; Lam & Schaubroek, 2000). Teams in which all members engage in the exact same search may defeat this purpose. Therefore, I contend that teams may vary in the degree to which teams members search the same stimulus. At one extreme teams may search in a manner parallel to the teams in research conducted by Sorkin and colleagues, such that all team members engage in the exact same search. At the other extreme, all team members could engage in non-overlapping independent searches.

Examining the overlap among the knowledge of team members, team mental model researchers have examined team member information sharedness (Cannon-Bowers et al., 1993; Klimoski & Mohammed, 1994). Using parallel logic, I examine search patterns that are shared across team members, and apply the label "search sharedness." Team search patterns are maximally shared when all team members search the same stimulus at the same time. Maximally shared searches are narrow in scope because only one stimulus is examined, but multiple team members obtain information on each stimulus examined. Team search patterns are minimally shared (and maximally independent) when all team members search different stimuli at the same time. Minimally shared searches are high in scope because they examine more stimuli at any given time, but only one team member examines each stimulus. This requires the relaxation of the previous assumption that teams examine only one stimulus at a time (Sorkin & Dai, 1994; Sorkin, Hays, & West, 2001; Sorkin, West, & Robinson, 1998), such that at any given time teams can examine as few as a single stimulus and as many stimuli as there are members in the team.

A five person Ph.D. selection committee can serve as an example that highlights the differences in search patterns along the sharedness continuum. Let the search committee be responsible for examining 100 potential applicants for the program. The committee as a whole makes decisions about each candidate based on candidate information gathered by committee members. Decisions are made at the committee level of analysis, and information is gathered by the team by engaging in various search patterns. One manner in which the committee could gather information about these 100 applicants would be for all five committee members to examine Candidate 1, then for all five committee members to each examine Candidate 2, and continue in this manner until all five committee members have examined all 100 candidates. All committee members would have information about all 100 candidates, but this involves a large number of searches (100 searches in which each member examines each candidate). This would be a maximally shared search. Another option would be for the committee to divide up the work, such that each committee member examined 20 non-overlapping candidates. This involves fewer searches (20 searches in which each committee member examines a different candidate), but any given candidate is examined by only 1 committee member. This would be a minimally shared search. Other search patterns would fall between these extremes on the scale of search sharedness. One option would be to partly divide up the search process but to still maintain some sharedness in the search, such that 2 of the 5 committee members examine each candidate.

A second example would be a four person committee in charge of selecting new business sites. Let the committee be composed of 2 human resources specialists and 2 logistics specialists. As with the previous example, the committee as a whole makes decisions about each potential business site based on information gathered by committee members. Decisions are made at the committee level of analysis, and information is gathered by the team by engaging in various search patterns. One manner for the committee to conduct this search would be engaging in a maximally shared search, where all 4 members to examine each potential site. Another manner would be to engage in a maximally independent search such that each committee member examines a separate site. Such potential variance in search sharedness stands in contrast to previous research which examines only contexts of maximal search sharedness.

A second limitation to the team mental model literature is that, although researchers have acknowledged that that team mental models of the team are separate from team mental models of the task (Mathieu et al., 2000; Mathieu et al., 2005), researchers have not acknowledged that some types of information search may better promote team mental models of the team, while other types of information search may better promote team mental models of the task. Because teams may not be able to optimize their search patterns for both types of mental models simultaneously, teams may need to sequentially pursue one first and then the other. Drawing from the group development literature, especially Gersick's (1988, 1989, 1991) punctuated equilibrium model, I explore how changes in information search influence influences the development of team mental models of the team and team mental models of the task. In doing so, I address sequence issues in such changes in information searches, focusing on how teams can pursue both types of team mental models over time.

SEARCH SHAREDNESS

Jonas and Frey (2003) define information search as the compilation of an evidence base for the purpose of making decisions. As I note in the following paragraphs, researchers have examined the types of information sought by individuals and organizations as well as the amount of information sought by individuals and groups. Researchers have also examined how individuals and groups utilize information once it is obtained. However, researchers have yet to examine how team members choose to overlap or not overlap their searches with other team members. As you may recall, I label overlap among team member searches as search sharedness. Although researchers have not examined search sharedness, I will briefly examine related research that examines search processes. Specifically, I briefly review confirmation bias, search stopping rules, and search location. Moreover, I review cue distribution and information sharing and how they are related to search sharedness.

Several researchers have noted that individuals display a confirmation bias in their search, such that they seek out more information supporting their initial decision than information conflicting with their initial decision (Betsch, Haberstroh, Glockner, Haar, & Fiedler, 2001; Greitemeyer & Schulz-Hardt, 2003; Jonas & Frey, 2003; Jonas, Schulz-Hardt, Frey, & Thelen 2001; Russo, Medvec & Meloy, 1996; Schulz-Hardt, Jochims, & Frey, 2002). Russo, Medvec and Meloy, (1996) note that decision makers need not even have a firm preference in order for confirmation bias to occur; even a mildly held initial preference is sufficient. Russo, Medvec, and Meloy (1996) contend that the desire to maintain consistency and the desire to reduce effort are causal mechanisms for confirmation bias. They argue that confirmation bias is especially like to occur when there is little dissent among members within a group, when groups have strong routines, or when decision-makers are responsible for decisions.

In addition to examining what types of information are sought, researchers have also examined the amount of information sought by individuals making decisions. From a normative standpoint, Kogut (1990) notes that search processes benefit decision makers to the point at which incremental information provides minimal additional benefit. This indicates that decision makers are best served by establishing a stopping point after which they discontinue information search. From a descriptive standpoint, researchers have examined several such stopping rules (Bettman, Johnson, Luce, & Payne, 1993; Gigerenzer & Golstein, 1996; Newell, Weston, & Shanks, 2003; Saad, 1996). Research indicates that different types of decision-makers use different stopping rules, and that these different rules have different levels of effectiveness (Browne & Pitts, 2004; Knight & Nadel, 1986; Weiss & Knight, 1980).

Researchers have even examined the location of information searches, albeit at the firm level of analysis. Research indicates that firms can allocate their search resources toward searching information that is within the firm or outside of the firm. Garg, Walters, and Priem (2003) found that in dynamic environments, firms perform best when CEOs allocated their attention to task-related environmental factors and innovation-related internal functions. Anand, Manz, and Glick (1998) note that firms can meet information demands brought on by dynamic environments by focusing information locating activities outside of the firm rather than inside of the firm. This notion that search can vary from internally focused to externally focused is parallel to my contention in the introduction of this dissertation that internally focused searches may have different consequences for team mental models than externally focused searches.

To date, researchers have yet to directly examine search sharedness. However, researchers examining group decision making have examined different contexts of knowledge distribution that imply different search patterns in search sharedness. A seminal article in this literature is a laboratory experiment examining information sampling in groups conducted by Stasser and Titus (1985). In this study, Stasser and Titus had groups make decisions based on information provided by the experimenters. Specifically, Stasser and Titus manipulated the number of group members who held each particular piece of information. Some bits of information were initially provided to all group members. Other bits of information were initially provided to only 1 member of each group. This same manipulation has been utilized in several information pooling studies (Larson, Christensen, Fransz, & Abbott, 1998; Gigone & Hastie, 1993; Winquist & Larson, 1998; Wittenbaum, Hubbel, & Zuckerman, 1999). Although groups in these studies were not free to engage in various search patterns, these two patterns of information distribution are parallel to different patterns that are likely to occur in search sharedness. Groups that engage in minimal search sharedness have each member examine a different stimulus, which is analogous to the bits of information held by only a single member in the Stasser and Titus study. Groups that engage in maximal search sharedness have all members examine the same stimulus, which could result in the same information being held by all members in a manner analogous to the initially shared information in the Stasser and Titus study. Thus, although Stasser and Titus do not examine how different group search patterns would yield the different conditions of shared and unshared information in their study, variance in search sharedness can be inferred as an important source of different information pooling patterns within groups.

Stasser and Titus (1985) found that different patterns of information pooling were important in determining the performance of groups. Specifically, they found that information that was initially shared by all members in a group was more often discussed and had more influence on group decisions than information that was initially held by only a single group member. Research indicates that unshared information that is not discussed is especially harmful to group performance (Larson, Christensen, Fransz, & Abbott, 1998; Winquist & Larson, 1998). Moreover, the greater effect of shared information than unshared information on group decisions is partially mediated by pre-discussion judgments, such that group members discount information that conflicts with their initial preferences (Gigone & Hastie, 1993). The differential effects of shared and unshared information are attenuated when groups have low levels of information load, assign expert roles that encourage information sharing, or work in computer-mediated environments (Lam & Schaubroek, 2000; Stasser, Vaugh, & Stewart, 2000). This line of research indicates the importance in how information is distributed among group members.

Parallel research indicates that team members can vary in the cue overlap among team members. In the aforementioned research conducted by Sorkin and colleagues, all group members were provided with the same cues relevant to making a decision (Sorkin & Dai, 1994; Sorkin, Hays, & West, 2001; Sorkin, West, & Robinson, 1998). In contrast, in research conducted by Hollenbeck and colleagues, different team members received different cues involved in making a decision (Colquitt, Hollenbeck, Ilgen, LePine, &

Sheppard, 2002; Hollenbeck, Ilgen, LePine, Colquitt, & Hedlund, 1998; Hollenbeck, Ilgen, Sego, Hedlund, Major, & Phillips, 1995). This difference in cue distribution is analogous to variance in search sharedness. Groups that engage in minimal search sharedness have each member examine a different stimulus, which is analogous to the different cues examined in the research conducted by Hollenbeck and colleagues. Groups that engage in maximal search sharedness have all members examine the same stimulus, which is analogous to the research conducted by Sorkin and colleagues in which all group members examined the same cues at the same time.

Other related research examining the distribution of information within groups was conducted by Laughlin and colleagues (Laughlin, 1986, 1988, 1999; Laughlin & Ellis, 1986; Laughlin & Hollingshead, 1995). However, rather than focusing on how groups obtain raw information, Laughlin and colleagues focused on the generation and exchange of correct and incorrect hypotheses. However, the distribution of correct and incorrect hypotheses was parallel in nature to that of variance in search sharedness. Laughlin and colleagues examined contexts in which only a single member held the correct hypotheses. This is analogous to minimally shared searches in which only a single member examines a given stimulus. Laughlin and colleagues also examined contexts in which the majority of group members held the correct hypothesis. This is analogous to shared searches in which a majority of group members examine a given stimulus. Laughlin and colleagues additionally examined contexts in which two group members held a correct hypothesis. This is analogous to a point between maximally and minimally shared searches.

Laughlin and colleagues note that these differences in how correct hypotheses are distributed in groups have important implications for groups (Laughlin, 1986, 1988, 1999; Laughlin & Ellis, 1986; Laughlin & Hollingshead, 1995). Specifically, the more group members which hold the correct hypothesis, the more likely it is that the group will accept the correct hypothesis. This is consistent with research by Stasser and Titus (1985) indicating that the more group members hold a given piece of information, the more likely that information will be utilized. An application of this logic to team search processes indicates that groups will have different outcomes when high in search sharedness than when low in search sharedness.

Laughlin and Shupe (1996) extended this research paradigm to examine the hypothesis exchange between multiple subgroups working together. They conducted a laboratory experiment in which they structured subgroups to work semi-independently, with occasional exchanges of hypotheses. They found that the exchange of correct hypotheses between subgroups helped the performance of each subgroup. Specifically, they found that a subgroup holding an incorrect hypothesis was especially likely to switch to the correct hypothesis when receiving that correct hypothesis from the other subgroup. Subgroups holding a correct hypothesis and receiving that same correct hypothesis from other subgroups were especially likely to avoid switching to an incorrect hypothesis.

Laughlin and Shupe's (1996) research indicates the importance of information exchange between subgroups. Management researchers suggest that in organizational teams, team members are often assigned to sub-teams functioning under an overarching team structure (DeChurch, & Marks, 2006; Marks, DeChurch, Mathieu, Panzer, &

Alonso, 2005). An especially important form of subgrouping is based on function served by each subgroup (Burns & Stalker, 1961; Hollenbeck, Moon, Ellis, West, Ilgen, Sheppard, Porter, & Wagner, 2002). In functional subgrouping, organizations structure personnel such that those doing similar tasks are grouped together based on their function, minimizing redundancy across units and maximizing efficiency through specialization (Hollenbeck et al., 2002). Thus, different functional groups have access to different types of information and expertise. Hollenbeck and colleagues indicate that such structures of subgroups are important in teams (Ellis, Hollenbeck, Ilgen, Porter, West, & Moon, 2003; Hollenbeck et al., 2002; Moon et al., 2004), where team members are placed into different subgroups that each serve a different function.

In the context of search sharedness, when teams are structured such that they have subgroups, I contend that there are two types of search sharedness on which a given search can be measured: within-function search sharedness, and cross-functional search sharedness. A team search is high in within-functional search sharedness when multiple team members from the same subgroup examine the same stimulus. A team search is high in cross-functional search sharedness when multiple team members from different functional subgroups examine the same stimulus. Thus, both types of search sharedness share the characteristic of multiple team members examining the same stimulus. The difference between the two is which members are searching together.

A return to the working example of the business site selection committee will illustrate these types of sharedness. Recall that the business site selection committee is composed of 2 human resources specialists and 2 logistics specialists. Thus, there are 2 functional subgroups: human resources and logistics. A team search would be high in within-function search sharedness if both human resources specialists examine Potential Site 1 and both logistics specialists examine Potential Site 2. A search would be high in cross-function search sharedness if 1 member from each of the functions examined Potential Site 1, and the other member from each of the functions examined Potential Site 2. A team search would be low on both within-function search sharedness and cross-function search sharedness if each of the 4 committee members examined 4 separate sites. A team search would be high on both within-function search sharedness and cross-function search sharedness if all 4 committee members examined Potential Site 1. It is important to note that the level of analysis is the team search, which is a pattern that can be high or low in within-functional search sharedness and high or low in cross-functional search sharedness.

An additional example that might highlight these differences is a team of consultants working together on a project to improve profitability of a client organization. Such a team may have multiple functional subgroups. These might include a subgroup of supply chain specialists, a subgroup of machine operations specialists, and a subgroup of worker safety specialists. Within-function search sharedness would involve multiple supply chain specialists examining the same work procedure. Cross-function search sharedness would involve a supply chain specialist, a machine operations specialist, and a worker safety specialist all examining the same work procedure. The fact that multiple team members examine the same work procedure holds for both examples, thus they are both forms of search sharedness. However, they differ in whether members of a shared search are in the same function or different functions.

In summary, although researchers have not yet directly examined team search sharedness, an examination of these literatures examining patterns of distribution in search and information provide a logical precedent for different patterns in team information searches. In a manner analogous to variance in search sharedness ranging from minimally shared searches to maximally shared searches, previous research indicates that groups have similar variance in overlap in group members with regards to information (Stasser & Titus, 1985), cues (Hollenbeck et al., 1995; Sorkin & Dai, 1994), and hypotheses (Laughlin, 1999). Moreover, previous research indicates that structures that delineate subgroups are important to examine, suggesting the differentiation between within-function sharedness and cross-function sharedness.

GROUP DEVELOPMENT: TEMPORAL ASPECTS OF INFORMATION SEARCH

Group Development: History

Research examining teams over time has often taken a developmental perspective. Initially, researchers examined team development over the course of the lifetime of teams that might function for years at a time (Tuckman, 1965; Tuckman & Jensen, 1977). Since then, researchers have zoomed in with the lens of team development. Marks, Mathieu, and Zaccaro (2001) focused on what occurs in a single task episode that may occur in a series of task episodes. Gersick (1988, 1989, 1991) zoomed in even further, focusing on changes in groups between the first half and second half of task episodes. In this section, I will briefly summarize these models of group development, and note their relevance to the development of team mental models.

In a literature review and theoretical distillation of development in groups, Tuckman (1965) generated a seminal descriptive model of stages in group development over time. Tuckman (1965) indicates that there are two main characteristics on which groups develop: the relationships and interpersonal structure within the group, and the manner in which the group works on the task. Note that this is parallel to the distinction made between the team and the task noted by team mental model researchers (Cannon-Bowers et al., 1993; Mathieu et al., 2000). Tuckman contends that there are 4 stages of team development and 4 stages of task development. With regards to the team, the first stage is referred to as testing and dependence. In this stage, group members attempt to discover what interpersonal behaviors are acceptable in the group, based on the reactions of other group members. In the second stage, members become hostile toward one another as a means of expressing their individuality and resisting the formation of group structure. The third phase is labeled as the development of group cohesion. In this stage, group members accept the group and the idiosyncrasies of fellow members. The group becomes an entity by virtue of its acceptance by the members, their desire to maintain the group, and the establishment of new group-generated norms to insure the group's existence. Harmony is of maximum importance in this stage, and task conflicts are avoided to insure harmony. The fourth phase of labeled as functional role-relatedness. In this phase, the group becomes a problem-solving instrument. At this point, members can adopt and play roles that will enhance the task activities of the group, since they have learned to relate to one another as social entities in the preceding stage. Role structure is an instrument which can now be directed at the task.

The first stage of task activity development is labeled as orientation to the task (Tuckman, 1965). Group members attempt to identify the task in terms of its relevant parameters and the manner in which the group experience will be used to accomplish the task. The group decides upon the type of information they need in dealing with the task and how this information is to be obtained. Emotional response to task demands is the second stage of task-activity development. In this stage, group members react emotionally to the task as a form of resistance to the discrepancy between the individual's personal orientation and that demanded by the task. The third stage of task activity development is the open exchange of opinions. The fourth stage is identified as the emergence of solutions. It is in this stage that groups attempt successful task completion, with an emphasis on constructive action.

In an integration of these stages of development in group member relationships and task activity, Tuckman (1965) summarized these in four overall stages. He noted that groups initially concern themselves with orientation accomplished primarily through testing. This testing serves to identify the boundaries of both interpersonal and task behaviors. Tuckman notes orientation, testing, and dependence constitute the group process of "forming." The second phase in the sequence is characterized by conflict and polarization around interpersonal issues, with emotional responses in the task sphere. Tuckman notes that these behaviors serve as resistance to group influence and task requirements, labeled this phase as "storming." Resistance is overcome in the third stage in which group feelings and cohesiveness develop, new standards evolve, and new roles are adopted. In the task realm, intimate, personal opinions are expressed as well. Tuckman referred to this stage as "norming." Finally, the group attains the fourth stage in which interpersonal structure becomes the tool of task activities. Roles in the group become flexible and functional, and group energy is channeled into the task. Issues about structure have been resolved, and structure can now become supportive of task performance. Tuckman labeled this stage as "performing."

Following this seminal work, Tuckman and Jensen (1977) noted that the end of relationships within groups is an important issue throughout the life of groups. They note that strong interpersonal feelings among group members may have developed throughout the group's cycle. The end of the group and release of ties among members signifies the end of the cycles of group development. Consequentially, Tuckman and Jensen (1977) label this stage as "adjourning" and added it as the fifth and final stage of group development.

Kozlowski, Gully, Nason, and Smith (1999) added further detail to stages in group development over time, and took a more normative approach in their theoretical description of team development. Similar to the Tuckman (1965) model, Kozlowski and colleagues (1999) predict that team formation is the first phase of team development. In this phase, individuals seek information to reduce ambiguity about interpersonal issues that will govern the team. Team members also begin to seek information about the basic nature of the team, its purpose, and their place in it. At this point there is no common understanding exists among team members regarding perceptions, affect, and behavior. Kozlowski and colleagues contend that the acquisition of interpersonal knowledge during this initial stage of team formation leads to improved task performance later in the developmental process. The acquisition of interpersonal knowledge noted by Kozlowski and colleagues is comparable to early stages in the process of building team mental models of the team, in which teams figure out the knowledge, skills, attitudes, strengths, and weaknesses of team members. Indeed, interpersonal knowledge is the major content of team mental models of the team. Thus, an extension to the Kozlowski et al. model in the context of team mental models suggests that team members will begin building team mental models of the team early, even before the task compilation stage. Task compilation is the second stage of team development in the Kozlowski and colleagues model. In this stage, there a focus on demonstrating task competency. In the context of team mental models, this focus on tasks is analogous to early efforts toward building team mental models of the task. Thus, Kozlowski and colleagues note that interpersonal knowledge, which is focused toward team mental models of the team, will precede task compilation, which is focused toward team mental models of the task. Role compilation is the third stage, in which team members elaborate dyadic relationships. Having already established basic task knowledge, team members begin to probe their dyadic links with others, with a focus on enacting horizontal role linkages that are necessary to accomplish particular team tasks. In this phase, team members come to understand how their task outputs and pacing affect those with whom they directly interact. Thus, the focus of this phase is on both the team and the task. Team compilation is the fourth phase. In this phase, the focal level is the entire team. Team members learn how to improve their network of roles continuously to deal with routine, normative situations.

Similar to the logic inherent in Tuckman's (1965) work, Kozlowski and colleagues (1999) contend that effective teams are not created full-blown and mature, but rather they form, establish regulatory mechanisms, and evolve through a series of recognizable changes over time. However, Kozlowski and colleagues take this a step further to contend that certain behaviors and capabilities are appropriate at certain phases of development. Thus, the Kozlowski and colleagues (1999) model of group development has more of a normative stance than the previous Tuckman (1965) work, noting that teams should initially focus on team members and then later focus on the task.

Research by Hollenbeck and colleagues is consistent with the contention that not only does time matter, but teams which engage in different actions at different times have different performance outcomes. Moon, Hollenbeck, Humphrey, Ilgen, West, Ellis, and Porter (2004) found that teams which initially performed in divisional structures in which each member worked independently in a specific geographic region carried such independent actions over even when switching to functional structures in which interdependent actions were more appropriate. Similarly, Johnson, Hollenbeck, Humphrey, Ilgen, Jundt, and Meyer (2006) conducted a laboratory experiment in which they found that teams which initially performed under a competitive reward structure tended to behave competitively even when switching to a cooperative reward structure in which cooperative behaviors were more appropriate than competitive behaviors. Thus, beyond the contention by Kozlowski and colleagues (1999) that certain behaviors are more appropriate at some points in time than others in the development of a group, Hollenbeck and colleagues found that the order of time sequences is important in determining team behaviors and outcomes.

As noted above, Marks and colleagues (2001) took a different approach to examining teams over time. Rather than focusing on macro development over the lifespan of teams, they focused on multiple iterations of task episodes. Marks and colleagues define task episodes as distinguishable periods of time over which performance accrues and feedback is available. They note that task episodes constitute rhythms of task performance for teams, and are marked by identifiable periods of action and transition periods between action periods. They define action phases as periods in time when teams are engaged in acts that contribute directly to goal accomplishment, and transition phases as periods of time when teams focus primarily on evaluation and/or planning activities to guide their accomplishment of a team goal or objective.

Marks and colleagues (2001) note that certain processes are especially likely at different points in this recurrent phase model. Specifically, coordination and monitoring processes are likely to dominate action phases. Mission analysis formation and planning, goal specification, and strategy formulations are likely to dominate transition phases. However, certain interpersonal processes occur throughout both action and transition phases, and typically lay the foundation of effectiveness of other processes. These processes include conflict management, motivation and confidence building, and affect management.

Marks and colleagues (2001) also note that task episodes are often segmented into sections or sub-periods of more limited scope or duration that contribute towards the larger effort. This directs attention to development that occurs within an action period. Gersick's (1988, 1989, 1991) punctuated equilibrium model of group development examines that very topic, and is the focus of the next section.

Punctuated Equilibrium: Early Versus Late Differences

Examining teams engaged in a single task episode, Gersick (1988, 1989) noted that time matters in groups even over the time scale of different halves of the same project. She began with an inductive qualitative field study in which she examined 8 groups of several different types, each of which lasted between 7 days and 6 months, and each of which met between 4 and 25 times (Gersick, 1988). She noted that every group conformed to a distinctive approach as soon as it began the project, and stayed with that approach through a period of inertia that lasted for half of its allotted time. Following that, every group underwent a major transition, in which through a concentrated burst of changes, groups dropped old patterns, reengaged with outside supervisors, adopted new perspectives on their work, and made dramatic progress. These changes resulted in a new approach in the project, which were carried through a second major phase of internal activity consisting of the execution of plans created at their transition. Gersick (1989) noted that an especially interesting finding was that each group experienced its transition at the same point in its calendar: precisely halfway between its first meeting and its official deadline. This occurred despite wide variation in the amounts of time the teams were allotted for their projects. Gersick (1988) referred to this model as the punctuated equilibrium model of group development.

Following her inductive qualitative study, Gersick (1989) conducted a second qualitative study examining eight groups of MBA students engaged in an open ended creative task in a laboratory setting. Similar to her previous work, Gersick (1989) found that all eight groups displayed explicit attention to time, accompanied by efforts to conclude an initial phase of the work and efforts to shift ahead. She found that this transition occurred at the midpoint of the groups' allotted time for 6 of the 8 groups. This transition occurred near the midpoint for the other 2 groups. Thus, as with her previous work, she found that halfway through their allotted time is the most likely moment at which at least one group member will call attention to time or pacing, prompting the rapid change that characterizes the punctuated equilibrium model.

Gersick followed these qualitative studies with a conceptual piece further detailing the punctuated equilibrium paradigm (Gersick, 1991). In this work, she notes that not just groups, but often organizations in general have relatively long periods of stability (equilibrium), punctuated by compact periods of qualitative, metamorphic change (revolution). She notes that cognitive frameworks, motivational barriers, inertial constraints of obligations among stakeholders, and previous benefits from persistence are mechanisms driving inertia during periods of equilibria. Internal changes that pull parts and actions out of alignment with each other or the environment and environmental changes that threaten the system's ability to obtain resources drive the compact periods of revolution. The beginnings of such periods of revolution are triggered by the attraction of newcomers to crisis situations and the system's arrival at key temporal milestones (such as halfway between the inception and deadline of a project). Often times, these revolutions change from confusion to clarity, pivoting on the insight around which new equilibria crystallize.

An application of the normative prescriptions from the Kozlowski et al. (1999) model of team development to Gersick's (1988, 1989, 1991) model of punctuated equilibria over the course of tasks indicates that teams will perform best if the focus on team members in the first half of a task episode and focus on their task in the second half of a task episode. Such a path of group development would entail team members first learning about the roles of their fellow team members and interdependence among team members in the first half, aiding in the understanding of how team members can work together as a team. At the midpoint of the time allotted for their task, such teams would then change their approach to focus on the task itself and how knowledge of the team can be leveraged to complete the task. During the second half of the task, teams would focus on the task itself. Having briefly reviewed the group development literature, especially from the Gersick (1988, 1989, 1991) punctuated equilibrium model viewed normatively from the Kozlowski et al. (1999) normative model, I will delineate the model and hypotheses of my dissertation.

MODEL AND HYPOTHESES

As noted in the introduction, the purpose of this dissertation is to examine how teams develop team mental models over time. In doing so, I focus on different patterns of information search and how they differentially influence team mental models of the team and team mental models of the task. Thus, the primary contribution of this dissertation, as encapsulated by the model in Figure 1, is to extend theory on team mental models to consider the differential influence of search sharedness on team mental models over time. In the next sections of this dissertation, I examine this model in detail.

As indicated by my earlier review of the group development literature, time is an important variable in the context of teams. As noted by Gersick (1988, 1989), over the course of a task episode teams tend to have an initial period of inertia lasting until halfway between the beginning and deadline of a task. At the halfway point, they have a brief burst of revolution in which they alter their strategy and behaviors, and then implement their new plan during a second period of inertia that occurs for the duration of the second half of the task. Hypotheses 8 and 9 explicitly focus on comparing behaviors early in a task and late in a task. In the hypotheses leading up to Hypotheses 8 and 9, there are no differential predictions for early versus late in the task. However, in order to be consistent and complete with of my hypotheses, I will explicitly examine search sharedness in both halves of a task episode. For those hypotheses where there is no differential prediction for early versus late, early and late hypotheses are listed individually but in a parallel manner. This will help lay the foundation for later hypotheses which do focus on differences early versus late in the task.

Search Sharedness and Team Mental Models over Time

As noted above, search sharedness refers to the number of team members searching the same stimulus at the same time. The decision of how the team will search is essentially a search allocation decision. When engaging in a maximally shared search, teams only examine a single stimulus at any given time. However, all team members are examining that stimulus, giving the team multiple sources of data for that stimulus. Much like research conducted by Sorkin and colleagues (Sorkin & Dai, 1994; Sorkin, Hays, & West, 2001; Sorkin, West, & Robinson, 1998), teams with a maximally shared search can compare and weight the perceptions of team members. In contrast, when teams engage in a maximally independent search, at any given time they can examine as many stimuli as there are team members. However, each stimulus is examined by only a single team member.

Sorkin and Dai (1994) conducted a mathematical analysis of signal detection in groups in which they examined the number of detectors as an important determinant of signal detection. A primary conclusion of this work was that the greater the number of group members examining a stimulus, the greater their ability to accurately identify said stimulus. However, each additional perceiver provided a smaller margin of benefit. This research was intended to compare different groups consisting of different numbers of group members. However the same logic applies to variance in search sharedness. That is, for any given stimulus, the greater the search sharedness (i.e., the greater the number of team members examining that stimulus), the greater the likelihood that the team will accurately identify a given stimulus.

As indicated by Sorkin and Dai (1994), each additional team member examining a given stimulus provides a smaller increase in accuracy. This indicates that for a single stimulus, search sharedness will be positively related to accuracy in detecting that stimulus. However, whereas Sorkin and Dai focused on contexts comprised of only a single stimulus at a time, my dissertation focuses on complex tasks composed of many stimuli. In such complex tasks, both marginal and absolute gains in accuracy should be taken into account. Marginal gains to accuracy focus on how much more accurate a team can detect a single stimulus by increasing the number of team members examining that stimulus. According to Sorkin and Dai, there will always be marginal gains in accuracy from adding another team member to a search of a given stimulus.

However, this marginal gain will diminish with each additional team member. This is important with respect to absolute gains in accuracy. In a complex task composed of many stimuli to be examined, the more team members examining a single stimulus, the fewer stimuli can be examined at any given point in time. Holding overall search resources constant, the more maximally shared searches conducted, the fewer minimally shared searches can be conducted. Maximally shared searches, in which all team members examine a single stimulus, leave no search resources to examine other stimuli. This results in all other stimuli being left unexamined. Unexamined stimuli result in missing information for team mental models of the task, detracting from the accuracy of team mental models of the task. Because the first team member to examine a stimulus provides the greatest absolute gain in accuracy, the greatest gain in absolute accuracy will be achieved when each team member examines a different stimulus. When each team member examines a separate stimulus, each individual stimulus examined may not be as accurately examined as when all team members examine the same stimulus. However, more stimuli are examined, with each team member providing a greater jump in accuracy. In other words, an extension of Sorkin and Dai's logic indicates that the benefit to team mental models of the task by marginally increased accuracy in detecting a stimulus by having multiple team members examine it is more than offset by the loss in absolute accuracy detection by examining fewer stimuli. Therefore, Hypotheses 1 and 2 indicate that search sharedness will be negatively related to the accuracy of team mental models of the task.

Hypothesis 1: Early search sharedness will be negatively related to the accuracy of the early team mental models of the task.

Hypothesis 2: Late search sharedness will be negatively related to the accuracy of the late team mental models of the task.

In addition to influencing team mental models of the task, I contend that search sharedness will also influence the accuracy of team mental models of the team. I define accuracy in team mental models of the team as the correctness of information about team members, including their knowledge, skills, attitudes, preferences, strengths, and weaknesses. I contend that when teams are high in search sharedness, they have multiple opportunities to compare their search results with each other. Such comparison presents the opportunity for tracking down conflicting information and learning about the members of the team. If our business site search committee engages in a maximally shared search in which all four committee members examine each potential site, the committee members can compare information. They may find out that Human Resource Specialist 1 has a very informative interpersonal network in Australia, aiding the information search of that team member in that region. Thus, the team can delineate expert roles among members. They may also find out that the same team member is ineffective at obtaining information about business sites in Eastern European states. In other words, the team could also delineate weaknesses and shortcomings among members. In contrast, if each committee member were to examine a different candidate, there would be less of an opportunity to compare their information and learn about the strengths and weaknesses of each committee member than if multiple committee members examine the same candidate.

Previous research lends indirect support to my contentions that search sharedness provides teams with opportunities to compare their search results of different team members to learn about the team members. Rasker, Post, and Schraagen (2000) conducted a laboratory experiment in which they manipulated information about the task execution of each team member. Teams that had access to this information developed better team mental models of the team than those that did not. Similarly, Gurtner, Tschan, Semmer, and Nagele (2007) conducted a laboratory experiment in which they manipulated the opportunity to reflect on their processes and performance prior to a second task episode. Teams that engaged in this process of comparing information developed better team mental models in the next task episode. Both of these studies are consistent with the logic presented above, in that teams received information about the efforts and results of team members and were able to learn about members to develop better team mental models. Accordingly, I hypothesize that search sharedness a will be positively related to the accuracy of team mental models of the team.

Hypothesis 3: Early search sharedness will be positively related to the accuracy of the early team mental models of the team.

Hypothesis 4: Late search sharedness will be positively related to the accuracy of the late team mental models of the team.

As noted above, subgroups are often designed into the structure of a team, such that team members are assigned to sub-teams functioning under an overarching team structure (DeChurch, & Marks, 2006; Marks, DeChurch, Mathieu, Panzer, & Alonso, 2005). Common formal dividing lines that may be drawn among subgroups include the function that is served by each subgroup or region that is served by each subgroup (Hollenbeck, Moon, Ellis, West, Ilgen, Shepperd, Porter, & Wagner, 2002). This method of subgroup formation may result in differences between subgroups that influence the results of search sharedness, which presents important implications for signal detection in teams.

Sorkin and Dai (1994) note that to the degree that different group members engaged in a signal detection task have identical information, the incremental value provided by each team member is minimal. This is because no new information is presented that can influence the decision of the group. In contrast, the greater the differences between the information presented by each group member, the greater the incremental value of each group member. Sorkin and Dai found that, holding the overall accuracy of each group member constant, adding group members was most beneficial to group signal detection when the correlations among the perceptions of the group members was lowest. As noted above, Sorkin and Dai's (1994) research was intended for comparing groups of different sizes. However, the same logic applies in comparing the same group utilizing all of its members to investigate the same stimulus (high search sharedness), or only 1 team member to investigate a stimulus (low search sharedness). To the degree that each additional team member examining a given stimulus differs from other team members examining that stimulus, the accuracy of detecting a given stimulus increases.

Research on the topic of group decision making provides further support for this contention. Sniezek and Buckley (1995) contend that when multiple group members receive the same information, there is little opportunity for process gain in which the group outperforms the average of its members. However, when there is conflicting information, group members can more closely examine their data to reach a more accurate conclusion. They contend that, all else equal, conflicting information among group members leads to better performance. Consistent with this logic, Sniezek and Henry (1989) conducted a laboratory experiment examining group decision making.

They found that the greater the disagreement in the judgment of group members, the more accurate the decision of the group. Indeed, they found that 30% of the group decisions were more accurate than the group's most accurate member. Such accuracy gain did not occur when all members had similar initial judgments.

Indirect support for this contention is provided by Turner and Pratkanis' (1998) review and re-conceptualization of the groupthink literature. They note that groupthink entails a process of concurrence seeking that is directed at maintaining a positive view of the group. Disagreement within the group can be a threat to the positive view of the group, so groups often suppress such dissent. The suppression of dissent leads to premature consensus in the decision-making process, which often detracts from the quality of the decision reached. Extending this logic to teams composed of subgroups suggests that team members within the same subgroup may suppress dissention within subgroups. To the degree that team members identify more strongly with their own subgroup than with other subgroups within their own team, they will be more likely to suppress dissention in decision processes within subgroups than between subgroups. This suggests that the limitations to decision quality posed by premature consensus should be weaker when teams engage in high levels of cross-function search sharedness than when teams engage in high levels of within-function search sharedness.

Consistent with this work is an experiment conducted by Schulz-Hardt, Jochims, and Frey (2002). They examined 201 German civil servant engaged in a decision task. Schulz-Hardt and colleagues found that information heterogeneity, such as that found when members from different functions work together, is effective at preventing confirmatory bias in information seeking. Indeed, they found information heterogeneity to be a more effective tool for this purpose than devils advocacy. Similarly, Ng and Van Dyne (2001) found that individuals exposed to a minority perspective demonstrated improvement in the quality of their decisions.

I contend that there will be more similarity in the perceptions of members from different functional subgroups than in the perceptions of members from the same functional subgroup. Therefore, cross-function search sharedness should result in more accurate team mental models than within-function search sharedness. Accordingly, Hypotheses 5 and 6 examine the differential strength of the influence of within-functional search sharedness and cross-functional search sharedness on team mental models of the task and team mental models of the team.

Hypothesis 5a: The negative relationship between early within-function search sharedness and early accuracy in team mental models of the task will be stronger than the negative relationship between early cross-function search sharedness and early accuracy in team mental models of the task.

Hypothesis 5b: The negative relationship between late within-function search sharedness and late accuracy in team mental models of the task will be stronger than the negative relationship between late cross-function search sharedness and late accuracy in team mental models of the task.

Hypothesis 6a: The positive relationship between early cross-function search sharedness and the accuracy of the early team mental model of the team will be stronger than the positive relationship between early within-function search sharedness and the accuracy of the early team mental model of the team.

Hypothesis 6b: The positive relationship between late cross-function search sharedness and the accuracy of the late team mental model of the team will be stronger than the positive relationship between late within-function search sharedness and the accuracy of the late team mental model of the team.

To date, team mental model researchers have devoted more attention toward conceptually differentiating team mental models of the task from team mental models of the team than examining relationships between the two (c.f. Mathieu et al., 2000; Mathieu et al., 2005). However, I contend that although they are conceptually distinct, there is nevertheless an important relationship between them. Accurate team mental models of the team aid team members by providing information about team member knowledge, skills, strengths, and weaknesses (Mathieu et al., 2000). Teams with accurate mental models of the team will have a better understanding of how to develop their searches so as to utilize the strengths and expertise of each team member. Moreover, team members can learn about the decision criteria of each other. This information aids in weighting the inputs of each team member. Some team members may have very conservative decision criteria, such that they will only report a stimulus as present when they have overwhelming evidence. Teams may benefit from accepting stimulus reports from such conservative members by heavily weighting decisions that are strongly supported by evidence, but discounting reports by that member that no stimulus is present. Other team members may have less conservative decision criteria, such that they will report a stimulus as present if even a hint of supporting data is present. Teams may benefit from discounting stimulus reports from such members, but accepting reports by that member that no stimulus is present. Indirect empirical support for this process is provided by Hollenbeck and colleagues (1995, 1998). They found that team leaders who learned the detection tendencies of their fellow team members were able to use this information to weight the input of their team members in a manner that aided detection decisions.

Recall that in the business site search committee example, the team found out that Human Resource Specialist 1 has a well developed network in Australia, aiding the information search of that member in that region. They also found out that the same team member is especially ineffective at gathering information about potential sites in Eastern Europe. This committee could alter their search pattern such that the Human Resource Specialist 1 is utilized in many of the searches of sites in Australia and not utilized in searches of sites in Eastern Europe. This would aid the committee in avoiding errors and accurately gathering information. Returning to the Ph.D. candidate selection committee example, the team may learn that Committee Member 3 has a very conservative decision criterion, such that he or she only advocates selecting candidates with a constellation of very high test scores, a very strong research background, and very strong letters of recommendation. The committee may learn to heavily weight recommendation of acceptance by that member, aiding their selection process. However, such a conservative decision criterion utilized by Committee Member 3 leads him or her to be prone to miss potentially successfully candidates. Thus, the committee may learn to discount rejection recommendations made by Committee Member 3.

Previous research conducted by Lim and Klein (2006) provide supports for my contention that accurate team mental models of the team aid team mental models of the task. In their field study examining 71 military teams, Lim and Klein found a correlation of .40 between the accuracy of team mental models of the team (measured as the similarity between the team mental model of the team and an expert model) and the accuracy of team mental models of the task (measured as the similarity between the team mental model of the task and an expert model). Thus, Hypothesis 7 indicates that the accuracy of team mental models of the team will be positively related to the accuracy of team mental models of the task.

Hypothesis 7: The accuracy of team mental models of the team will be positively related to the accuracy of team mental models of the task.

Now that I have explicated the relationships of search sharedness on team mental models, I will address a major purpose of this dissertation and examine how these relationships change over time. As noted in the section in which I briefly reviewed the group development literature, Kozlowski and colleagues (1999) contend that the acquisition of interpersonal knowledge during the initial stage of team formation leads to improved task performance later in the developmental process. The reverse relationship, where the acquisition of task knowledge might aid interpersonal knowledge, was not a part of their model. Rather, Kozlowski and colleagues propose that initial investments in interpersonal knowledge eventually pay off in the form of task performance. An application of the normative prescriptions from the Kozlowski et al. (1999) model of team development to Gersick's (1988, 1989, 1991) model of punctuated equilibria over the course of tasks indicates that teams will perform best if the focus on team members in the first half of a task episode and focus on their task in the second half of a task episode.

I extend this contention to team mental models, such that teams will have the most accurate mental models when pursuing actions focused on team mental models of the team prior to pursuing actions focused on team mental models of the task. In other words, teams will have the most accurate team mental model of the task and the most accurate team mental models of the team when engaging in high levels of search sharedness early in a task and low levels of search sharedness late in a task. This will occur because teams which pursue high levels of search sharedness will build accurate mental models of the team early. Once teams have accurate mental models of the team, they will no longer need to engage in high levels of search sharedness, and can then alter their search patterns to cover more stimuli (with fewer team members examining each stimuli) without the high levels of errors that would occur without an accurate team mental model of the team. In other words, early shared searches allow later independent searches to be conducted with high levels of accuracy.

This logic suggests that once a team has built an accurate team mental model of the team, there is minimal benefit to the team mental model of the team from the process of gathering further information. Returning to the business site search committee example, once the team has discovered that Human Resource Specialist 1 is especially effective at gathering information about business sites in Australia and especially ineffective at gathering information about business sites in Eastern Europe, there is little benefit from further checking whether or not that committee member gathers accurate information from those regions. Such checking would not result in new information, but would detract from information gathering resources that could be employed elsewhere.

Research examining stopping rules in information search provides indirect support for this contention. Kogut (1990) notes that search processes benefit decision makers to the point at which incremental information provides minimal additional benefit. Specifically, Kogut (1990) notes that continued search loses its value at the point at which the marginal cost of engaging in further search exceeds the marginal benefit. Similarly, Rapoport, Lissitz, and McAllister (1972) note that detectors will not receive further benefit from searching once they have found the correct answer. Empirical research provides support for the contention that decision makers who continue to engage in search after they have discovered correct solution do not increase the accuracy of their decision (Brickman, 1972).

In the context of the current topic, engaging in high levels of search sharedness is a primary means of gathering and comparing information that can be utilized to generate the team mental model of the team. I contend that if a team has not generated an accurate mental model of the team early in a task, engaging in high levels of search sharedness late in the task will be positively related to the accuracy of the team mental model of the team late in the task. This is the same reasoning utilized in Hypotheses 4, in that search sharedness allows the team to compare the actions and results of team members. However, I contend that if a team has generated an accurate team mental model of the team early in a task, engaging in further shared searches will provide redundant information and will not increase the accuracy of the team mental model of the task. In other words, highly accurate early team mental models of the team neutralize the relationship between late search sharedness and late team mental models of the team.

In summary, there is theoretical research suggesting that teams should pursue interpersonal knowledge before pursuing task knowledge (Kozlowski et al., 1999). There is research supporting the contention that once teams generate accurate team mental models of the team, there is little value in further searching for information about team mental models of the team (Kogut, 1990; Rapoport, Lissitz, & McAllister, 1972). And there is research indicating that accurate team mental models of the team are accompanied by accurate team mental models of the task (Lim & Klein, 2006). Drawing from this body of research, I contend that teams have most accurate team mental models of the task and team when they engage in high levels of search sharedness early in a task and low levels of search sharedness late in a task. Hypotheses 8 and 9 address these contentions.

Hypothesis 8: Time moderates the negative relationship between search sharedness and accuracy in team mental models of the task, such that teams will have the most accurate mental models of the task when engaging in high levels of search sharedness early in the task and low levels of search sharedness late in the task.

Hypothesis 9: Time moderates the positive relationship between search sharedness and accuracy in team mental models of the team, such that teams will have the most accurate mental models of the team when engaging in high levels of search sharedness early in the task and low levels of search sharedness late in the task.

Research examining the topic of team mental models has indicated that there are several benefits to teams for having accurate team mental models. Stout, Cannon-Bowers, Salas, and Milanovich (1999) contend that team mental models of the team aid teams by providing an understanding of what information requirements are for each role, allowing team members to get the information that they need. Teams that have a more accurate awareness of each other's roles and actions can communicate more efficiently—more frequently transferring appropriate information without being asked (MacMillan et al., 2004). Teams with accurate mental models of the team will have a diminished need for explicit communication, leaving more available resources and open channels of communication for completing the task (Smith-Jentsch, Campbell, Milanovich, & Reynolds, 2001). Additionally, teams with accurate team mental models of the team can better anticipate the actions of the team members, aiding coordination such that teams can adapt their behavior to demands of the task and other team members (Cannon-Bowers et al., 1993; Mathieu et al., 2000). Rico, Sanchez-Manzanares, and Gibson (2008) note that this anticipation and dynamic adjustment contribute positively to team performance. Accuracy in the team mental models of the task should aid teams by enabling the prediction of contingencies in the environment, problems that need to be addressed, and how to accomplish the task (c.f. Mathieu et al., 2000). This allows teams to interact with the environment to accomplish goals. Specifically, this information will aid teams in matching their resources to the demands of the task.

Several researchers have examined the relationship between team mental models of the team and team performance. Field research by Lim and Klein (2006) and laboratory research by Ellis (2006), Edwards et al. (2006), Gurtner, Tschan, Semmer, and Nagele (2007), and Zhang, Hempel, Han, and Tjosvold (2007) provide direct empirical support for the contention that both team mental models of the team and team mental models of the task are positively related to team performance. Indirect support for the beneficial influence of team mental models of the team on team performance is provided by Hollenbeck, Ilgen, Sego, Hedlund, Major, and Phillips (1995) and Hollenbeck, Ilgen, LePine, Colquitt, and Hedlund, (1998). In their laboratory experiments examining hierarchical decision teams, they found that teams performed better when leaders were able to determine which team members had the most valid information for that particular task. Such leaders were able to place heavier weights on the decisions of those team members than other team members. An extension of this logic suggests that if the same teams were engaged in an additional task or subtask, teams would also benefit from finding out which team members were most effective at that task or subtask. Thus, such teams could then allocate people to tasks in a manner that best utilizes the strengths of their members. This understanding of which team member does which task well is an important component of the team mental model of the team.

Building from theory and research examining team mental models and team performance, Hypotheses 10-11 note the relationships between team mental models of the task and team performance as well as between team mental models of the team and team performance.

Hypothesis 10: The accuracy of team mental models of the task will be positively related to team performance.

Hypothesis 11: The accuracy of team mental models of the team will be positively related to team performance.

Method Issues in Team Mental Model Research

Prior to describing the empirical investigations conducted in this dissertation, it is necessary to review the current state of team mental model methods. In so doing, I will highlight limitations that have been present to date. I will then delineate potential solutions to these limitations. Following that, I will describe an empirical study which employs my proposed advances to team mental model research methods.

One shortcoming of research examining team mental models of the task is the one-dimensional approach that researchers have taken in examining accuracy. Several researchers have conceptually depicted the accuracy of team mental models of the task as high when teams are low in errors and low when teams are high in errors (c.f. Lim & Klein, 2006; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005). However, signal detection theory indicates that when groups are detecting stimuli in their environment—as is the case in generating team mental models of the task—there is a more complex depiction of accuracy and errors (Green & Swets, 1966; Sorkin & Dai, 1994; Sorkin, Hays, & West, 2001; Sorkin, West, & Robinson, 1998). Specifically, there are two types of accurate responses (hits and correct rejections) and two types of inaccurate responses (misses and false alarms).

Signal detection theory, developed initially in the field of psychophysics, is designed to describe situations in which a perceiver is attempting to detect a specific stimulus, which is referred to as a signal (Green & Swets, 1966). Signal detection theory assumes that there is a dichotomously defined state of the environment, such that either the signal is present or it is not. The perceiver is presented with a stimulus, which may either be the signal for which the perceiver is searching, or which may be a different stimulus (noise). The perceiver then makes a judgment regarding whether or not the signal was present, comparing his or her perception against his or her decision rule. If his or her perception exceeds the decision rule, he or she reports the signal as present. For example, if trying to detect the number 11, the decision rule may be to report the presence of a signal if two lines of similar length are within 5 degrees or less of being parallel. If he or she perceives two lines of similar length that are within 3 degrees of being parallel, he or she will report the presence of the signal.

Signal detection theory posits that people imperfectly perceive stimuli in their environment, in part because of difficulty between discriminating between target stimuli (signal) and distracter stimuli (noise). There are four potential outcomes that may result from attempting to detect a target stimulus from distracter stimuli. If a target stimulus is presented, accurately detected through the noise, and the perceiver reports the presence of the signal, this is referred to as a "hit." The Ph.D. committee selection task can provide a helpful illustration. If we simplify the candidate pool into a two sets of candidates, those who will perform well in the program and those who will not, this task has property of a dichotomously defined environment as assumed by signal detection theory. Using this example, if Candidate #8 would perform well in the program and is selected, this would be a hit. If a stimulus is not presented but the person reports a signal, this is referred to as a "false alarm." In our example, a candidate who would perform poorly but is still selected would be a false alarm. If a target stimulus is presented but not detected, this is referred to as a "miss." In our example, a candidate who would perform well and is not selected would be a miss. If a person is presented with noise without a signal and does not report a signal, this is referred to as a "correct rejection." In our example, a candidate who would not perform well and is not selected would be a correct rejection.

Signal detection theory was initially developed for research on perception and sensation conducted at the individual level of analysis (c.f. Green and Swets, 1966). However, Sorkin and colleagues apply signal detection theory to the group level of analysis as well (Sorkin & Dai, 1994; Sorkin, Hays, & West, 2001; Sorkin, West, & Robinson, 1998). Sorkin and Dai (1994) outline this application. They note that the process of signal detection at the individual level of analysis consists of an individual who is presented with either a signal or noise. That individual compares his or her perception with his or her decision criterion, and if the perception that a signal is present exceeds this criterion, the individual reports perceiving a signal. The process of signal detection is similar at the group level of analysis, but with an additional step. Much like perception at the individual level of analysis, group members are presented with either a signal or noise. Each member compares his or her perception with his or her criterion, and decides whether or not he or she perceived a signal. However, the added step in groups is that group members combine their judgments to make a single final group decision regarding whether or not there was a signal. Sorkin, West, and Robinson (1998) and Sorkin, Hays, and West (2001) note that there are different decision rules that may be used in combining individual level judgments, including a majority vote, total consensus, and weighted sums. However, the end of the process results in a single group-level decision regarding the presence or absence of a signal.

Green and Swets (1966) note that although signal detection theory indicates four outcomes for each decision that correspond to four cells (signal present/absent; reported as present/absent), there are actually only two degrees of freedom in this matrix. This is because of the relationships within pairs of cells. Given a signal, the proportion of hits plus the proportion of misses sum to 1. In other words, given the number of stimuli presented, one can determine the number of misses by subtracting the hits. Given noise without a signal, the proportion of false alarms plus the proportion of correct rejections also sum to 1. Put more simply, information about misses is redundant with information about hits, and information about correct rejections is redundant with information about false alarms. Accordingly, signal detection theory focuses on hits and false alarms, ignoring the redundant data presented by misses and correct rejections (c.f., Sorkin & Dai, 1994; Sorkin, West, & Robinson, 1998). I will follow this precedent and consider only hits and false alarms.

Because hits are correct decisions (which indicate accuracy) and false alarms are incorrect decisions (which indicate inaccuracy), a sum of hits and false alarms would not be meaningful. If hits and false alarms were strongly negatively correlated, it might be conceptually reasonable to reverse code false alarms and add them to hits to create a potentially meaningful construct of overall accuracy. In such a depiction, some teams would be high in hits and low in false alarms, fitting the label of high in accuracy. Other teams would be low in hits and high in false alarms, fitting the label of low in accuracy. The rest would be somewhere in the middle. That would not be inconsistent with a unidimensional depiction of team mental model of the task accuracy.

However, signal detection theory contends that hits are a monotonically increasing function of false alarms, and vice versa (Green & Swets, 1966). This is because perceivers vary in their decision criterion. Those with a strict decision criterion will be conservative in their reporting of signals. They will have few false alarms, but also few hits. Those with a liberal decision criterion will be less conservative in their reporting of signals, such that even a hint of a signal will be reported. They will have many hits, but also many false alarms. Thus, signal detection theory indicates that researchers examining team mental models of the task are losing information when they combine hits and false alarms into a single construct. Moreover, because of the positive relationship between hits and false alarms, there are tradeoffs inherent in trying to maximize hits or trying to minimize false alarms. Specifically, actions taken to maximize hits will also tend to increase false alarms, and actions taken to minimize false alarms will also suppress hits. Therefore, I contend that research examining team mental models of the task should consider both hits and false alarms.

A second shortcoming of team mental model research is that current methods collect data at the individual level of analysis. Indeed, several researchers have noted this shortcomings of current research methods (Cooke, Salas, Cannon-Bowers, & Stout, 2000; Cooke, Stout, & Salas, 2001). For example, Mathieu et al. (2000) conducted a laboratory experiment in which 56 two-person teams were engaged in a flight simulation. Team mental models were measured by collecting individual team member knowledge and analyzing the overlap of this individual-level data. Edwards (2006) used a similar analysis of individual-level team member knowledge in his laboratory experiment examining 83 two-person teams engaged in a computer simulation. Conducting research in which the theoretical unit of analysis is the team but the empirical unit of analysis is the individual borders on committing what Rousseau (1985) refers to as a misspecification error, limiting the inferences that can be drawn from such research.

A third shortcoming is that team knowledge research to date has generally measured this knowledge during transition phases (i.e., before and after the task). The above mentioned Mathieu et al. (2000) study measured team mental models after each of 6 iterations of a task. Similarly, Ellis (2006) conducted an investigation of 97 four-person teams engaged in a command and control simulation. Team mental models were measured after completion of the task, in what would fit into the category of transition phase if the teams would have then engaged in another task episode. However, Cooke et al. (2000) and Rico et al. (2008) note that team mental models are fleeting and dynamic during the time teams are engaged in a task. This suggests that team mental models are primarily created and modified during action phases (i.e., during the task). Indeed, Cooke et al. (2000) explicitly call for methods in which data are collected continuously and synchronously with task performance.

Accordingly, a primary purpose of this section is to address these issues. Building from the suggestions put forth by Cooke et al. (2000) and Cooke et al. (2004), I contend that computer simulations can be used to address many of these issues and can enable a method of measuring team mental models that more closely resembles its theoretical conceptualization. I then present the Leadership Development Simulator as an example of a platform for such research, and an empirical examination utilizing this simulation. This method measures team mental models at the team level of analysis throughout the action phase. Furthermore, I contend that team mental models of the task should include both hits and false alarms. Is it hoped that the method presented here will facilitate empirical research in the field of team mental models such that new theoretical advances can be tested.

Prior Guidance for Team Mental Model Methods

Researchers have proposed guidance and solutions to some of the methods issues noted above. Cooke et al. (2000) contend that because team knowledge is thought to be more than the sum of individual team members' knowledge, holistic approaches to measurement are needed that elicit knowledge from the team as a whole. They further contend that whereas the collective approach targets the knowledge of individual team members and then aggregates this information, the holistic approach targets the team knowledge that results from the application of team process behaviors to the collective knowledge. Cooke et al. (2004) summarize this position by noting that holistic measures of team knowledge more directly reflect the theoretical construct of team knowledge than do aggregations of individual knowledge.

Cooke et al. (2000) note that one method for obtaining team level data would be to interview the team as a whole. The benefit of team interviewing techniques would be that teams could confer and agree on the content of their team mental model. However, as noted by Langan-Fox, Code, and Langfield-Smith (2000), interviewing techniques can be subject to retrospective distortions, and they rely heavily on the interviewer's interpretations of participant responses. Moreover, the views of more influential or extraverted group members can dominate the discussion and distort the team knowledge (Langan-Fox, Code, & Langfield-Smith, 2000). Cooke et al. (2004) further note that the public nature of the consensus may overshadow private disagreements. Additional problems noted by Rouse and Morris (1986) are that experts may not be able to verbalize their expertise that self-reports may reflect what they expect the inquirer wants rather what the participants actually perceive.

Patrick, James, Ahmed, and Halliday (2006), suggest an alternative method, noting that it is feasible to utilize observer ratings of team mental models for specific events when teams engage in dynamic scenarios. However, as noted by Cooke et al. (2004), such a method is vulnerable to measurement errors and limited experimenter attention resources. Thus, rather than difficulties due to participant self-report biases and shortcoming, researchers would instead deal with experimenter biases and shortcomings.

A final alternative is provided by Cooke et al. (2004). They propose that team mental models should be measured during action phases with objective metrics generated through participant interaction with computer simulations. This allows for the use of embedded measures of team mental models that gather data during tasks, as it is necessary to measure that knowledge in the context of the situation at the moment when momentary knowledge occurs. They further argue that automating measures and embedding them within the task can reduce task disruption due to measurement, along with experimenter measurement errors and experimenter resources. Similarly, embedded objective measures minimize biases inherent in self-report methods.

I propose that this solution of embedded measures contained within computer simulations utilized by teams has an additional benefit in the context of measuring mental model accuracy: objectively correct knowledge can be defined and measured. Measurements of team mental models can then be compared to what has been programmed by researchers. In the next section, I describe further how this research method can be applied to the measurement of team mental models. I then describe the application of such a method in a simulation platform called the Leadership Development Simulator (LDS).

Simulation Methods for Measuring Team Mental Models

I posit that what makes Cooke et al.'s (2004) suggestion to use measures embedded within simulations compelling is that this method can serve as a vector for obtaining team-level data on team mental models. In this section, I will describe a process to do just that. Later in the empirical investigation, I will describe an example platform, the LDS, in more detail. Moreover, this platform is used in the series of empirical investigations described later.

In their seminal work on mental models, Rouse and Morris (1986) note that the human information system is particularly adept at processing spatially oriented information, and, hence, may tend to store information in that manner. Accordingly, they propose that mental knowledge is often pictorial or image-like rather than symbolic in a list-processing sense. This suggests that teams may store information about the task in a spatial image that matches their perceptions of entity locations within the environment. Extending this logic, I propose that team mental model researchers can depict a representation of the environment in which teams record the perceived current locations of environmental entities, as well as the perceived identity of such entities. For teams engaged with a computer simulation, this representation of the environment can serve the dual purposes of containing the team's information about the environment for the team's use as well as recording these data for the use of researchers. This avoids the problem of interrupting team behaviors with measurements of team mental models. Indeed, it turns a research data collection tool into a helpful tool for the use of participants in their process of generating, modifying, and maintaining their model of the task.

A key characteristic of this team representation of the environmental conditions, likely contingencies, and problems is that it should be generated at the team level of analysis. Rather than collecting data at the individual level of analysis, researchers should instruct teams to construct one single representation. For example, two different team members to have directly contradictory information which they compare and weight in the process of making a decision regarding what they believe to be correct.

Having described a method of measuring team mental models, I will now move on to describe an empirical investigation which utilizes this method. In doing so, I will include a detailed description of the LDS.

Method

Sample

The sample was composed of 3,374 Air Force Captains who had 4-8 years experience as junior officers in the United States Air Force. These officers were drawn from every career field in the officer ranks, and were attending a 5 week leadership course. The course was offered approximately every 7 weeks. Students were assigned to cohorts based approximately on the amount of time they had accumulated as an officer.

At the beginning of each of 5 cohorts, participants were assigned to 14 person teams (241 teams total) which were held intact until the end of the course. Field limitations prevented the random assignment of individuals to teams or teams to conditions. However, cohorts were drawn from equivalent officer pools that were on average time lagged by approximately 7 weeks. Leaders at the field site provided assurance that significant effort was directed toward constructing the teams such that career fields were approximately balanced across teams. Moreover, the individuals responsible for assigning individuals to cohorts and teams were blind to the hypotheses of this study. Thus, it is reasonable to assume that the participants in each cohort are equivalent.

Leadership Development Simulator

Overview. As part of a larger program of research, a new simulator was developed with the purpose of enabling team research in general, including research that objectively measures team mental models. This simulator, called the Leadership Development Simulator (LDS), is designed to engage teams of 14 people in the common task of discovering and interacting with targets in a defined environment. These teams are responsible for integrating multiple sources of information in the process of finding and engaging targets, which include both threats and opportunities. Team members are free to talk with each other throughout the simulation. Each team member has a defined role with assigned responsibilities (see Figure 2). These roles are arranged in a hierarchical structure containing three subgroups: two groups of staff members and 1 group of command members. How the roles of the staff members depend on which structure is used. In this study, a functional structure was utilized.

This simulation was designed to be a complex task in which teams must manage a large number of resources (48 assets in each round) in a short amount of time (9 minutes per round). Team members must negotiate collaborative efforts to achieve certain objectives (such as attacking a large target or verifying intelligence). The simulation contains several objective metrics that can be used to test the hypotheses in this dissertation. The greatest strength of utilizing the LDS in this dissertation is that it will collect objective team-level data regarding the team mental model constructs.

Team Objectives. Teams have the objective of maximizing their score, which is influenced by four types of events: capitalization on an opportunity, threat destruction by escort assets, asset destruction by a threat, and failure to protect the base from a threat. Teams lose 8 points for each asset destroyed by a threat. Teams lost 8 points each turn for each threat that is adjacent to a base. Teams score 4 points for capitalizing on a small opportunity and 16 points for capitalizing on a large opportunity. Teams score 2 points for destroying a small threat and 4 points for destroying a large threat.

Team Member Roles. Following research on team structure (Hollenbeck, Moon, Ellis, West, Ilgen, Sheppard, Porter, & Wagner, 2002; Moon, Hollenbeck, Humphrey, Ilgen, West, Ellis, & Porter, 2004), the LDS has two different horizontal role structures: functional and divisional. As noted above, in this study the functional structure was utilized. In the functional structure, staff members have narrowly defined specialized roles, and are responsible for fulfilling their roles throughout the entire environment (see Figure 2).

In the LDS, staff members are responsible for two primary actions: gathering information and engaging environmental entities. Staff members who primarily gather information about the environment are labeled as "Intelligence" team members, and staff members who engage environmental entities and gather information are labeled as "Operations' team members. Each Intelligence team member has 8 assets to work with. There are four different types of assets: Visual, Communications, Human, and Allied. Each intelligence asset is effective in a different region of the environment. Each intelligence asset is deployed to a single location, and gathers probabilistic information regarding that area of the environment. In the functional structure, each Intel player has 8 assets of 1 type (e.g., the Visual Intelligence player controls 8 Visual Intelligence assets), and each Intel player was responsible for using their assets in the entire environment. A final characteristic of Intelligence assets is that they only observe the environment, and thus are never lost when deployed to the environment. In other words, Visual assets deployed for gathering information will not be destroyed by environmental entities.

In contrast to Intelligence assets, Operations assets directly engage the environment, and thus can be destroyed by entities in the environment. However, information gathered by Operations assets is not probabilistic, instead it is perfectly accurate. Operations assets team members have four different types of assets: Strike, Escort, Refuel, and Info. Strike assets have the capability of capitalizing on opportunities. Escort assets have the capability of destroying threats. Refuel assets enable other assets to reach distant portions of the environment. Info assets gather information from areas that are larger than can be investigated by Intelligence assets. In the functional structure, each Operations member has 4 assets of 1 type (e.g., Strike has 4 strike assets), and is responsible for utilizing their assets in the entire environment.

The command structure is composed of 6 individuals: the Commander, the Vice Commander, the two Directors, and the two Assistant Directors. In both structures, the Commander is the highest level of authority, and approves or modifies all actions taken by team members. The Vice Commander has two primary roles: assisting the Commander, and updating the team's representation of the environment, which is referred to as the Common Operating Picture (COP).

Like the Commander, Directors either approve or modify the actions taken by their staff members. There are two directors: the Director of Operations, who is responsible for all of the operations staff members and their actions taken, and the Director of Intelligence, who is responsible for all of the intelligence staff members and their actions taken. Assistant Directors are responsible for ensuring that the teams assign confidence levels to each threat and opportunity placed on the COP, as well as aiding the Directors. Figure 2 depicts the roles within the LDS.

Simulation Environment. The environment in the LDS consists of a grid, 16 rows (1-16) by 16 columns (A-P), totaling 256 squares. At the start of the simulation, teams are presented with a blank grid. However, hidden throughout the grid are threats and opportunities, which can be either small or large and either fixed or mobile. As mentioned above, threats attack assets and bases, costing the team points. Opportunities may be capitalized upon, gaining the team points. Teams only need a single asset to engage a small target, but they must engage large targets with two assets. Fixed targets remain in the same square throughout the entire simulation. Mobile targets move about the grid throughout the simulation.

Teams engage the simulation in a round-based fashion, much like the game of chess. At the beginning of each round, team members deploy their assets, and at the end of each round, team members see the results of their asset deployments. This is how they build their representation of the task. Each team member receives information revealed by their asset. During each round, there is the potential for information returns from 48 different assets. Moreover, the majority of this information must be processed in order to be useful to the team, and the team has only a few minutes to integrate this information into the representation of the task before the round proceeds to asset allocation for the next round. Accordingly, no single team member acquires and processes all of the team's information. Instead, team members collaborate to build a common representation of the task, which is referred to as the Common Operating Picture (COP). Figure 3 depicts a sample COP.

Procedure

First, teams received training material for the Leadership Development Simulator. This included a 4 page overview description, a 45 minute slide presentation, and 15 minutes of hand-on simulation training. Prior to the simulation, teams engaged in a 10 minute planning session in which teams determined goals and mission priorities. Following the planning session, teams participated in the Leadership Development Simulator for 90 minutes, followed by a 30 minute performance feedback session.

Measures and Manipulations

Search Sharedness. The simulation tracked the search of each team member. Any time multiple team members searched the same square at the same time, this was counted as a shared search. Within-function search sharedness was operationalized as the total number of times multiple team members from within the same subgroup searched the same square at the same time. Cross-function search sharedness was operationalized as the total number of times team members from different functional subgroups (i.e., an Intelligence staff member and an Operations staff member) searched the same square at the same time.

Accuracy of Team Mental Models of the Task. The Leadership Development Simulator contains 8 types of targets, defined by crossing three dimensions: Potential for gain (opportunity) or loss (threat), mobile or fixed, and small or large. As noted above, teams were responsible for locating and identifying these targets in the simulation. Each Intelligence and Operations player gathered information about threats and opportunities in the 16 by 16 grid which composed their environment.

The COP was the primary tool for measuring the team's mental model of the task. This is the central system for integrating information from the 14 team members into a single team-level representation. Once team members have perceptions about stimuli from the environment, they discuss this information with their team members. After the teams made decisions about these perceptions, they pass information about their representation of the environment to the Vice Commander, who was the conduit for updating the COP. It is important to note that the COP is not generated solely by the Vice Commander, but that the Vice Commander served as conduit for placing team representations on the COP. The COP was continually updated as teams processed information.

As noted earlier, both hits and false alarms are important components of team mental models of the task. To measure hits and false alarms in team mental models of the task, the simulation made comparisons of each of these perceptions with the actual threats and opportunities programmed in the grid. Hits in team mental models of the task were measured as the number of times teams placed a representation of a threat or opportunity in a square in which a threat or opportunity existed. False alarms in team mental models of the task were measured as the number of times teams placed a representation of a threat or opportunity in a square in which a threat or opportunity did not exist.

To create a measure of the team mental model of the task that utilizes both hits and false alarms, I created a difference score consisting of false alarms subtracted from hits. As noted by Edwards and Parry (1993), difference scores can be problematic because they mask the main effects of each of the components of the difference score such that it is not possible to determine whether the effect is due primarily to one or the other of the components. However, Edwards (1995) delineated a decomposition technique that addresses this issue. This decomposition technique entails breaking down the effects of the independent variable on the components of the difference score. Phillips, Hollenbeck, and Ilgen (1996) provide an example of this technique. Accordingly, I include hits, false alarms, and hits minus false alarms as measures for examining accuracy in team mental models of the task.

Accuracy of Team Mental Models of the Team. Each Intelligence staff member could obtain accurate information in 8 of the 16 rows of the grid (in which the information provided by their asset was correct 95% of the time), and inaccurate information in the other 8 rows (in which the information provided by their asset was correct 5% of the time). Visual was accurate in rows 5-12, Communications was accurate in rows 1-4 and 13-16, Allied was accurate in rows 1-8, and Human was accurate in rows 9-16.

A key component of the team mental model of the team was the discovery of which team member was accurate in which 8 rows of the grid. Accuracy in team mental model of the team was operationalized as the number of times each team allocated team member search resources where they were accurate.

Team Performance. Team performance was also measured objectively with a metric embedded within the LDS. Teams were scored based on the rules contained within Table 1. Teams received +16 points each time they capitalize on a large opportunity, +4 points each time they capitalize on a small opportunity, +4 points each time they destroy a large threat, +2 points each time the destroy a small threat, -8 points each time they lose an Operations asset, and -8 points per turn for each threat that is adjacent to a base (i.e., in Row 1). Early performance was the total score in rounds 1-5. Late performance was the total score in rounds 6-10.

Results

Hypotheses 1 and 2 note the expectation that search sharedness will be negatively related to the accuracy of team mental models of the task. As noted earlier, consistent with Edwards's (1995) decomposition technique, I contend that in addition to the difference between hits and false alarms, hits and false alarms should independently be examined as components of accuracy. As indicated by Tables 3-5, the correlation between early search sharedness and early hits minus false alarms was .06 (p=.331). The correlation between early search sharedness and early hits was -.10 (*p*=.135). The correlation between early search sharedness and early false alarms was -.19 (*p*=.003). These findings do not support Hypotheses 1. Also indicated by Tables 3-5, the correlation between late search sharedness and late hits minus false alarms was -.28 (*p*<.001). The correlation between late search sharedness and late hits was -.33 (*p*<.001). The correlation between late search sharedness and late false alarms was .05 (*p*=.464). These findings generally support Hypotheses 2.

Hypotheses 3 and 4 note the expectation that search sharedness will be positively related to the accuracy of team mental models of the team. As indicated by Tables 3-5, the correlation between early search sharedness and early team mental models of the team was .02 (*p*=.755). This finding does not support Hypotheses 3. The correlation between late search sharedness and late team mental models of the team was -.22 (*p*=.001). This finding does not support Hypotheses 4.

Hypothesis 5a notes the expectation that the negative relationship between early within-function search sharedness and the accuracy of early team mental models of the task will be stronger than the negative relationship between early cross-function search sharedness and the accuracy of early team mental models of the task. Table 6 shows the regressions for this hypothesis. A beta difference test based on a sample size of 241 indicates that for the composite measure of early hits minus early false alarms, the beta for early within-function search sharedness (β=-.139, *p*=.064) and the beta for early cross-function search sharedness (β=.234, *p*=.002) were significantly different (*p*<.01). For early hits in team mental models of the task, the beta for early within-function search sharedness (β=-.175, *p*=.021) and the beta for early cross-function search sharedness

(β=.081, p=.285) were significantly different (p<.01). For early false alarms in team mental models of the task, the beta for early within-function search sharedness (β=.007, p=.925) and the beta for early cross-function search sharedness (β=-.242, p<.01) were significantly different (p<.01). Taken together, these results generally support Hypothesis 5a.

Indeed, these results go beyond Hypothesis 5a. I expected that both types of search sharedness would have negative effects on team mental models of the task, but that negative effect would be stronger for within-function search sharedness than cross-function search sharedness. Consistent with this expectation, early within-function search sharedness had some negative effects on team mental models of the task. However, the effects of cross-function search sharedness were so much less negative that it actually had beneficial effects on false alarms and the composite measure of hits minus false alarms.

Hypothesis 5b notes the expectation that the negative relationship between late within-function search sharedness and the accuracy of late team mental models of the task will be stronger than the negative relationship between late cross-function search sharedness and the accuracy of late team mental models of the task. Table 7 shows the regressions for this hypothesis. A beta difference test based on a sample size of 241 indicates that for the composite measure of late hits minus late false alarms, the difference between the beta for late within-function search sharedness and late cross-function search sharedness was in the direction hypothesized but not significant (p=.713). For late hits in team mental models of the task, the difference between the beta for late within-function search sharedness and late cross-function search sharedness was also in the direction hypothesized but not significant (p=.844). For late false alarms in team mental models of the task, the difference between the beta for late within-function search sharedness and late cross-function search sharedness was not significant (p=.968). Taken together, these results do not support Hypothesis 5b.

Hypothesis 6a notes the expectation that the positive relationship between early cross-function search sharedness and the accuracy of early team mental models of the team will be stronger than the positive relationship between early within-function search sharedness and the accuracy of early team mental models of the team. Table 8 shows the regression for this hypothesis. A beta difference test based on a sample size of 241 indicates a significant difference (p<.01) between the beta for early cross-function search sharedness (β=.141, p=.063) and the beta for early within-function search sharedness (β= -.103, p=.174). Moreover, this effect was in the hypothesized direction, supporting Hypothesis 6a.

Hypothesis 6b notes the expectation that the positive relationship between late cross-function search sharedness and the accuracy of late team mental models of the team will be stronger than the positive relationship between late within-function search sharedness and the accuracy of late team mental models of the team. Table 8 shows the regressions for this hypothesis. A beta difference test based on a sample size of 241 indicates a marginal difference (p=.054) between the beta for late cross-function search sharedness (β=.018, p=.264) and the beta for late within-function search sharedness (β= -.246, p<.01). Moreover, this effect was in the hypothesized direction, in that the effect for late cross-function search sharedness was more positive than that for late within-function search sharedness. However, neither effect was significantly positive. Indeed, the effect for late within-function search sharedness was significantly negative. Thus, Hypothesis 6b was only partially supported.

Together, Hypotheses 5 and 6 indicate that, at least early in a task, teams benefit more from engaging in cross-function search sharedness than within-function search sharedness. In other words, having multiple team members from different functions examine the same stimulus has better effects on team mental models than does having multiple team members from the same stimulus. That these different types of search sharedness have different effects is especially interesting considering that within-function search sharedness and cross-function search sharedness are moderately correlated with each other both early in the task (r=.52, p<.01) and late in the task (r=.40, p<.01).

Hypothesis 7 notes the expectation that the accuracy of the team mental model of the team will be positively related to the accuracy of team mental model of the task. As indicated by Table 3, the correlation between the composite hits minus false alarms measure of accuracy in team mental models of the task and accuracy in team mental models of the team was .390 (p<.001). The correlation between hits in team mental models of the task and accuracy in team mental models of the team was .433 (p<.001). The correlation between false alarms in team mental models of the task and accuracy in team mental models of the team was -.104 (p=.109). These findings generally support Hypothesis 7.

Hypothesis 8 notes the expectation that time moderates the negative relationship between search sharedness and accuracy in team mental models of the task, such that teams will have the most accurate mental models of the task when engaging in high levels of search sharedness early in the task and low levels of search sharedness late in the task. As indicated by Table 10, the interaction term had a coefficient of .023 (p=.723) on the composite hits minus false alarms measure of team mental models of the task. The interaction term had a coefficient of .033 (p=.607) on hits in team mental models of the task. The interaction term had a coefficient of less than .001 (p=.999) on false alarms in team mental models of the task. These findings do not support Hypothesis 8.

Hypothesis 9 notes the expectation that time moderates the positive relationship between search sharedness and accuracy in team mental models of the team, such that teams will have the most accurate mental models of the team when engaging in high levels of search sharedness early in the task and low levels of search sharedness late in the task. As indicated by Table 11, the interaction term had a coefficient of .081 (p=.232). This does not support Hypothesis 9.

Hypothesis 10 notes the expectation that the accuracy of team mental models of the task will be positively related to team performance. As indicated by Table 12, the regression weight of hits in team mental models of the task on team performance was .14 (p=.026). The regression weight of false alarms in team mental models of the task on team performance was -.192 (p=.002). These findings support Hypothesis 10. No interaction between hits and false alarms was hypothesized, and the interaction between hits and false alarms was not significant (β=.013, p=.828).

Hypothesis 11 notes the expectation that the accuracy of team mental models of the team will be positively related to team performance. Also indicated by Table 8, the regression weight of accuracy of team mental models of the team on team performance was .285 (p<.001). This supports Hypothesis 11.

Supplemental Analyses

The analyses above are appropriate to test the hypotheses put forth in this dissertation. However, they do not include control variables that may potentially be important in uncovering the hypothesized effects. This dissertation focuses on search sharedness. However, this focus leaves out unshared searches. Unshared searches are searches conducted by individual team members, where no other team members examine the same stimulus at the same time. Whereas shared searches are interdependent actions by teams, unshared searches are independent actions by individual team members. Like shared searches, unshared searches can provide information that can inform team mental models. Thus, unshared searches is a variable that might be important in building team mental models. Therefore, in this supplemental analysis section, I will re-examine the analyses that include search sharedness as an independent variable to include unshared searches as a control variable.

As noted earlier, the simulation tracked the search of each team member. Any time only a single team member searched a given square at a given time, this was counted as an unshared search. The negative correlation between search sharedness and unshared searches in both early in the task (-.704, $p<.01$) and late in the task (-.511, $p<.01$) provides empirical support for my contention that the more a team engages in search sharedness, the fewer search resources available to engage in unshared searches. In other words, search sharedness limits the number of stimuli that can be examined. This provides additional support for the reasoning behind Hypotheses 1 and 2, which indicated that the marginal gains to accuracy from adding additional team members to the search of a single stimulus will be more than offset by that loss to absolute accuracy due to the examination of fewer stimuli.

Early unshared searches were positively correlated with early hits in the team mental models of the task (r=.189, p<.01), early false alarms in team mental models of the task (r=.212, p<.01), and early accuracy in team mental models of the team (r=.414, p<.01). Early unshared searches were not significantly correlated with early team performance (r=.016, p=.799). Late unshared searches were positively correlated with late hits in the team mental models of the task (r=.283, p<.01), but not significantly correlated with late false alarms in team mental models of the task (r=.046, p<.480). Late unshared searches were positively correlated with late accuracy in team mental models of the team (r=.585, p<.01) and late team performance (r=.206, p<.01).

Table 13 shows the supplemental analysis of Hypothesis 8, examining the changing effects of search sharedness on the accuracy of team mental models of the task over time. The coefficients for the interaction terms are almost identical in Table 13 (.024, .038, .003 for hits minus false alarms, hits, and false alarms, respectively) as to the original coefficients noted in Table 10 (.023, .033, .000 for hits minus false alarms, hits, and false alarms, respectively). This indicates that controlling for unshared searches does not change the results of the tests of Hypothesis 8.

Table 14 shows the supplemental analysis of Hypothesis 9, examining the changing effects of search sharedness on the accuracy of team mental models of the team over time. The coefficient for the interaction term is almost identical in Table 14 (β=.101) to the value in Table 11 (β=.081). This indicates that controlling for unshared searches does not change the results of the tests of Hypothesis 9. However, including unshared searches as a control variable does alter the main effects of search sharedness on the accuracy of team mental models of the team. Whereas in table 11, early search sharedness had no significant effect (β=.066, p=.309) and late search sharedness had a negative main effect (β=-.243, p<.001) on the accuracy of team mental models of the team, controlling for unshared searches results in a positive effect of early search sharedness (β=.357, p<.001) and no significant effect for late search sharedness (β=.008, p=.864). These results support Hypothesis 3.

A more direct way to examine time as a potential moderator of the influence of search sharedness on team mental models is to conduct a moderation analysis. Rather than comparing the effects of search sharedness in the first half against search sharedness in the second half, this involves including each half of the task as nested within teams and examining the interaction between search sharedness and time. However, this involves treating each half of the task as the unit of analysis and utilizing 2 observations per team (first half and second half). Because halves that are nested within teams are likely to be nonindependent, conducting these analyses with OLS regressions would violate assumptions of independence of observations. Therefore, I conducted this analysis using Hierarchical Linear Modeling, which accounts for non-independence of observations within teams by placing each observation at Level 1 and each team identifier at Level 2. There are no substantive analyses at Level 2; the sole purpose of Level 2 is to account for non-independence of observations nested within teams. As with the other exploratory analyses, I included unshared searches as a control variable to account for the effects of unshared searches on both types of team mental models.

As indicated by Table 15, time had a positive relationship with both team mental model of the task hits (β=.274, p<.001) and false alarms (β=.374, p<.001). Search sharedness had a negative relationship with team mental model of the task hits (β=-.274,

$p<.001$), but not team mental model of the task false alarms ($\beta=.018, p=.879$). Time moderated the relationship between search sharedness and team mental model of the task hits ($\beta=.230, p=.003$). Moreover, for form of this interaction indicates that search sharedness has very little relationship with team mental model of the task hits early in the task, but a strong negative relationship late in the task (see Figure 4). This is consistent with the correlation analyses mentioned above. In contrast, time did not moderate the relationship between search sharedness and team mental model of the task false alarms ($\beta=.057, p=.555$).

As indicated by Table 16, time had a positive relationship with the accuracy of team mental models of the team ($\beta=.388, p<.001$). Search sharedness also had a positive relationship with team mental models of the team ($\beta=.374, p<.001$). There was no significant interaction between time and search sharedness ($\beta=-.085, p<.284$), indicating that time did not moderate the relationship between search sharedness and team mental models of the team.

Discussion

The purpose of this dissertation is to examine how teams develop mental models over time. Several sets of analyses indicate that the manner in which teams engage in team searches is related to their team mental models. As hypothesized, search sharedness was negatively related to the accuracy of team mental models of the task, although primarily when it is within-functional in nature or when it is late in a task. As suggested by the logic supporting Hypotheses 1 and 2, high levels of these types of search sharedness limit the number of stimuli that can be examined by a team, thereby limiting the accuracy of their mental models of the task.

The fact that late search sharedness was negatively related to team mental models of the task but early search sharedness was not related to team mental models of the task suggests that time plays an important role in determining this relationship. Indeed, exploratory analyses specifically examining time as a moderator of the influence of search sharedness on team mental models in nested halves within teams indicated that time moderated the influence of search sharedness on team mental model of the task hits (but not false alarms). This supplemental analysis indicates that team search sharedness has very little relationship with team mental model of the task hits early in a task, but a much stronger negative relationship with hits in the team mental model of the task late in a task.

Also as hypothesized, search sharedness was positively related to the accuracy of team mental models of the team, although only early in a task. As suggested by the logic supporting Hypotheses 3 and 4, engaging in shared searches appears to present opportunities for team members to compare the information they obtain in their searches to uncover the strengths and weaknesses of the members of the team. However, the fact that this relationship was not significant late in a task is consistent with the contention that there are diminishing returns to this process (Brickman, 1972; Kogut, 1990; Rapoport, Lissitz, & McAllister, 1972).

Many teams may discover the strengths and limitations of team members by the midpoint of the task, and thus not gain further accuracy in their team mental model of the team by engaging in further search sharedness. Alternatively, many teams may simply not be able to piece together information from shared searches, and similarly not benefit from further search sharedness. As with team mental models of the task, regression analyses suggested that time plays an important role in determining the relationship between search sharedness and team mental models of the team. However, exploratory analyses that more directly examined time as a moderator of the influence of search sharedness on team mental models in nested halves within teams did not reveal a significant interaction between time and search sharedness on team mental models of the team. These inconsistent results make it difficult to determine the roles of search sharedness and time in determining team mental models of the team.

I expected that in comparison to within-function search sharedness, cross-functional search sharedness would have a stronger positive relationship with the accuracy of team mental models of the team and a weaker negative relationship with the accuracy of team mental models of the task. These hypotheses were generally supported early in a task, but generally not supported late in a task. This indicates that, at least early in a task, cross-function search sharedness can have the benefit of aiding team mental models of the team without hindering team mental models of the task.

There were no differences in the effects of within-function search sharedness and cross-function search sharedness late in a task. It appears that many teams engaging in cross-function search sharedness stopped capitalizing on the relatively more diverse sources of information than in within-function search sharedness. This could be because late in the task, people from different functions ignored the search results of others who engaged in shared searches with them, offsetting the potential benefits of cross-function search sharedness. It is also possible that there is an important moderator shaping these relationships that should be examined in future research.

Based on the logic of the hypotheses of this dissertation, and the results of Hypotheses 1-4, it seemed reasonable to expect that the specific sequence of team searches would be an important determinant of team mental models. Specifically, Hypotheses 8 and 9 indicate that teams will have the most accurate mental models of the team and the task when they engage in high levels of search sharedness early and low levels of search sharedness late. However, these hypotheses were not supported. This suggests that there may be more complex relationships than the moderated relationships depicted in Hypotheses 8 and 9. Perhaps some teams do benefit by engaging in high search sharedness early and low search sharedness late, but others are not systematic enough in their team mental model development to benefit from this process.

As hypothesized, the accuracy of team mental models of the team and the accuracy of team mental models of the task were positively related. Moreover, in agreement with previous research establishing the two types of team mental models as related but distinct constructs (Mathieu et al., 2000), in this dissertation they were moderately related ($r=.39$, $p<.01$). This indicates that teams that tended to have accurate mental models of the team also had accurate mental models of the task, although actions that aided one type of team mental model did not always aid the other type of team mental model.

Furthermore, both the accuracy of team mental models of the team and the accuracy of team mental models of the task were related to team performance, and contributed independently to the explanation of team performance. A decomposition of the accuracy of team mental models of the task into hits and false alarms indicates that both hits and false alarms are important determinants of team performance. Consistent with previous research examining signal detection (Green & Swets, 1966), hits and false alarms were significantly positively correlated (r=.16, p<.05). Nevertheless, they had opposite relationships with team performance. Thus, in order to perform well teams must promote hits and suppress false alarms, which is difficult considering that hits and false alarms are positively related.

Strengths and Limitations

There are a few important limitations to this study that should be acknowledged. First, the task utilized in this study was a synthetic simulation task. Readers may call into question the generalizability of the findings generated by such a task in the same manner that is often done with laboratory studies. Readers may have questions as to whether or not participants are motivated to perform well in a synthetic task and whether team members worked together.

One way to check if team members worked together in this study is to examine whether or not information held by one team member was shared with other team members. As noted earlier, one component of this task was to discover where each Intelligence staff member was accurate. If team members did not work together, then if an Intelligence staff member figure out where they were accurate, their fellow team members would be no more likely to figure this out than would other members from other teams. However, there were significant ICC(1) and ICC(2) values of .32 and .67 (p<.01) indicating that there was clustering within teams. In other words, team members shared information and worked together.

Readers may also call into question whether or not search sharedness was intentional, or whether it was purely by chance. In the LDS, there were 256 total squares that can be investigated in each of the 10 rounds. There were 48 search assets total that could be used each round. Any given square had a probability of .1875 of being investigated. The probably of a given square being investigated by 2 search assets was $.1875^2$=.00352. Multiplying this probability by 256 squares reveals that each round, random chance alone would lead to multiple assets investigating the same square 0.9 times each round. In other words, random chance alone would on average lead to search sharedness 9 times total across all 10 rounds of a single task. As indicated by Table 2, the mean search sharedness for teams in this dissertation engaged was 90.03 (s = 45.23). Only a single team engaged in 9 or less shared searches; all others ranged from 13 to 300. This strongly indicates that the overwhelming majority of search sharedness observed in this dissertation was due to something other than chance.

Readers may question whether or not the Gersick (1988, 1989, 1991) model of punctuated equilibriums in groups was applicable to this dissertation. The Gersick model highlights how many teams alter their strategies at the midpoint of their task, such that their behaviors are different in the second half than they were in the first half. Table 2 reveals that teams in this dissertation engaged in different levels of search sharedness in early than they did late, consistent with utilizing the punctuated equilibrium model. Teams engaged in more unshared searches (p<.01) in the second half (mean=127.67, s=18.14) than in the first half (mean=87.26, s=32.51). Teams engaged in less search sharedness (p<.01) in the second half (mean=18.89, s=14.74) than in the first half (mean=71.14, s=40.09). This is consistent with the expectation that most teams would in a change at or near the midpoint of the task. In this particular context, teams decreased their search sharedness and increased their unshared searches.

Readers may question whether or not participants were actively engaged in the task. Previous research indicates that research participants have found other synthetic tasks to be engaging (Hollenbeck, Moon, Ellis, West, Ilgen, Sheppard, Porter, & Wagner, 2002). Moreover, teams in this organization were ranked on their performance of the simulation, with the rankings publicly available. The setting of these teams was a training organization that posts performance on tasks publicly in order to encourage competition between teams. Therefore, it is reasonable to assume that participants were motivated to put significant effort into the task.

Readers may also question whether the teams included in this dissertation have important characteristics that limit their generalizability to other teams. Thus, one boundary condition of this dissertation is that it focused on teams that are larger than is normally found in teams research. However, whereas large teams are not common in research, they are common in actual organizations. For example, many sales teams have a dozen or more members, and all National Football League professional football teams have 53 team members. Nevertheless, future research should relax this boundary condition and examine teams of different sizes.

A second boundary condition of this dissertation is that the teams were composed of military officers. The American military is among the largest organizations in the world. With well over a million employees, it is safe to assume that military teams are common. However, the norms and values of military officers may not be identical to members of civilian teams. Future research should examine teams from different types of organizations, including civilian organizations.

A third boundary condition is that team were composed of individuals from a very diverse set of careers and jobs within their organization. Cross-functional teams are very common in organizations, such as the consulting team example which I used earlier in this dissertation. However, cross-functional teams may build their team mental models differently than teams composed of members that are entirely from the same function. Future research should consider how search sharedness may influence team mental models when team members are all drawn from the same career field.

A fourth boundary condition of this dissertation is that these teams were engaged in a novel task. Although they received training prior to the start of the task, this was the only exposure any of them had ever had to this task. Novel tasks are common in organizations. Newly assembled teams are especially likely to engage in novel tasks, because many of them are composed of members low in experience. Furthermore, dynamic environments lead to changes in tasks that may introduce novelty even for experienced teams. However, future research should consider how teams build mental models in tasks that are less novel.

A fifth boundary condition is that these teams were newly assembled when they engaged in their task. All teams are newly assembled at some point in their existence. However, teams may change over time in ways that influence the manner in which they build their team mental models. Future research should examine teams at different point of their existence, including teams that have multiple years of experience as a team.

A final boundary condition is that these teams were engaged in a task with a 90 minute duration. Many teams in organizations engage in tasks that are of this duration or even less, such as the football teams mentioned above. However, teams may change in how they build their mental models over the course of longer duration tasks. Future research should examine such long duration tasks, such as project teams working on a single task for several months or years.

Mook (1983) notes that when assessing the relevance of external validity, one needs to keep the nature of the research question in mind. In this dissertation, I am less interested in actual command and control situations and the mundane realism (Berkowitz & Donnerstein, 1982) that would come from an experimental setting and procedure that are nearly identical to what people would face in these situations. My purpose is not to estimate population parameters that can be applied to all different types of teams, in all contexts, and at all points in time.

The question of interest is how teams develop their mental models over time, and the simulation task utilized in this study provided the opportunity to develop mental models over time. My purpose was to extend theory on team mental models, and then test that theory. Although there are boundary conditions to the sample which was utilized to test this theoretical extension, there were no boundary conditions included in the theory itself that would preclude my sample from being an appropriate sample with which to test this theory. Thus, my sample was as appropriate as many others would have been, including non-military, longer tenured, smaller teams engaged in longer duration, less novel tasks. Also important to note is that research conducted in laboratory-like settings using simulated or simplified tasks generally agree with research that is conducted in field settings and highly realistic contexts. Anderson, Lindsay, and Bushman (1999) conducted a large survey of laboratory and field studies and found that the correlations between effect sizes obtained in laboratory settings and field settings generally exceed .70, indicating the similarity between hypothesis tests using field and laboratory studies.

Despite the potential boundary conditions and limitations of my dissertation, there are important strengths that should be noted. First, this is the first study that measures both hits and false alarms in team mental models of the task. In addition to the theoretical implications to be discussed below, measuring both hits and false alarms provides an example of a contribution to research methods in the topic of team mental models. Future research can build from this extension to methods to further advance empirical research examining team mental models.

Second, the simulation task allows for the objective measurement of team mental models in a manner that follows recommendations put forth by Cooke and colleagues (Cooke, Keikel & Helm, 2001; Cooke, Salas, Cannon-Bowers, & Stout, 2000; Cooke, Salas, Keikel, & Bell, 2004; Cooke, Stout, & Salas, 2001). The objective nature of the measures in this dissertation avoids many of the difficulties that often accompany self-report measures (c.f. Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Moreover, this method avoids many of the difficulties in measuring team mental models noted by Cooke and colleagues, such as single dominant team members reporting a team mental model that is not endorsed by the rest of the team and limited attentional resources of researchers.

Moreover, the nature of the simulation allowed for the objective measurement of team mental models over time, allowing for the investigation of team mental models in a manner not previously seen in research which aggregates all time points into a single measurement. This represents a second example of an advance in methods for examining team mental models, which will hopefully promote further empirical advances in these topics.

Finally, my dissertation included teams composed of 14 members. Previous research examining teams has focused on teams with 2-5 team members. Teams composed of 10 or more members have been understudied in the theoretical and empirical literature. My dissertation is among the very few studies focusing large teams, and will hopefully direct attention toward studying large teams in the future.

Theoretical Implications

There are several important theoretical implications that can be derived from this dissertation. One is the extension to theory and research examining information search in team contexts. As noted above, previous research examining search behavior has focused primarily at either the individual level of analysis (Betsch, Haberstroh, Glockner, Haar, & Fiedler, 2001; Greitemeyer & Schulz-Hardt, 2003; Jonas & Frey, 2003; Jonas, Schulz-Hardt, Frey, & Thelen 2001; Russo, Medvec & Meloy, 1996; Schulz-Hardt, Jochims, & Frey, 2002) or the firm level of analysis (Anand, Manz, & Glick, 1998; Garg, Walters, & Priem, 2003). Theories of information search have largely overlooked the team level of analysis.

This dissertation extended these theoretical foundations by focusing on search patterns at the team level of analysis. In doing so, I defined the construct of search sharedness. Team search patterns are maximally shared when all team members search the same stimulus at the same time, and minimally shared when all team members search different stimuli at the same time. This new construct provides a new means for established models of team performance and decision making to more fully examine how information enters groups rather than treating information within groups as a given constant.

For example, the groups as information processors model of group decision making focuses on how information enters groups by becoming the focus of attention (Hinsz, Tindale, & Vollrath, 1997). However, Hinsz and colleagues (1997) do not specify how groups actively deploy group members to obtain information. Indeed, by leaving group information searches out of their model and treating the information that a group has as a given, Hinsz and colleagues promote the assumption that it does not matter how groups engage in information searches.

My dissertation refutes that assumption, indicating that groups vary in how they search for information and that this variance has important implications for how they perform. The construct of search sharedness can be integrated into the groups as information processors model in order to determine how broadly or redundantly groups employ the searches of team members. Specifically, search sharedness can be a determinant of the accuracy of information that comes to the attention to the team, as well as what type of information comes to the attention to the team. Maximally shared searches can direct group attention to information about the groups themselves, especially regarding the strengths and weaknesses of each member. Minimally shared searches can direct group attention more toward the task.

Moreover, what type of information is brought to the attention of the group may vary based on when groups engage in search sharedness. In this dissertation, search sharedness decreased over the course of the task. This finding suggests that teams may direct less attention toward the team over time throughout the duration of a task. Although time is not a primary component of the groups as information processors model, this dissertation suggests that extensions to the groups as information processors model should give greater focus to the role of time.

The development of the construct of search sharedness also provides several extensions to theory and research examining team mental models. To date, team mental model theory and research has focused on antecedents of team mental models that occur either during transition phases between tasks or that occur through the accumulation of experience over multiple tasks (c.f. Marks, Mathieu, & Zacarro, 2001). Such research has examined training (Marks, Zaccaro, & Mathieu, 2000; McCann, Baranski, Thompson, & Pigeau, 2000; Smith-Jentsch, Campbell, Milanovich, & Reynolds, 2001), job experience (Hinsz, 1995; Smith-Jentsch, Campbell, Milanovich, & Reynolds, 2001), and organizational culture (Kraiger & Wenzel, 1997).

However, theory and research examining team mental models has not examined antecedents to mental models that occur during action phases that occur during tasks. By ignoring the development of team mental models during action phases, this body of research may promote the assumption that team mental models are not developed during action phases. This dissertation counters that assumption and extends team mental model theory and research by placing team search sharedness as an important antecedent to both team mental models of the team and team mental models of the task. My dissertation highlights the fact that teams may vary in how they search for information as they build their mental models during tasks, that search sharedness can have opposing relationships with team mental models of the team and team mental models of the task, and that these relationships vary over the duration of a task. The inclusion of an action phase antecedent to team mental models helps to extend the nomological network of burgeoning theory on team mental models and helps researchers better understand how teams can develop mental models.

An additional theoretical extension to research examining team mental models is the further development of the construct of accuracy in team mental models of the task. Previous theory and research examining team mental models of the task has taken a uni-dimensional approach in conceptualizing accuracy. Several researchers have conceptually depicted the accuracy of team mental models of the task as high when teams are low in errors and low when teams are high in errors (c.f. Lim & Klein, 2006; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005). However, signal detection theory indicates that when groups are detecting stimuli in their environment—as is the case in generating team mental models of the task—there is a more complex depiction of accuracy and errors (Green & Swets, 1966; Sorkin & Dai, 1994; Sorkin, Hays, & West, 2001; Sorkin, West, & Robinson, 1998).

Specifically, there are two types of accurate responses (hits and correct rejections) and two types of inaccurate responses (misses and false alarms). Because of redundancy in information contained in hits and misses as well as correct rejections and false alarms, signal detection researchers have focused on hits and false alarms (c.f. Sorkin & Dai, 1994; Sorkin, Hays, & West, 2001; Sorkin, West, & Robinson, 1998). Signal detection theory provides clear conceptual and empirical support for the contention that hits and false alarms are positively related (Green & Swets, 1966). Such a positive relationship is inconsistent with any attempt to place them at the opposite ends of a single continuum of accuracy.

The application of signal detection theory to theory examining team mental models highlights the shortcomings of how team mental model research had previously conceptualized accuracy in team mental models of the task, and provides an extension to that conceptualization that addresses these shortcomings. Indeed, the fact that in this dissertation hits and false alarms provided independent prediction of team performance indicates the value of including both hits and false alarms in theory examining team mental models of the task. This is most apparent when examining variance in team performance accounted for by hits and false alarms in team mental models of the task. As a sole predictor, hits account for 5.6% of the variance in team performance (β=.236). However, adding false alarms as an additional predictor of team performance accounts for an additional 5.7% of the variance (β=-.243).

This dissertation provides an extension to signal detection theory as well. Recent theoretical extensions to signal detection theory have focused on groups as the level of analysis (Sorkin & Dai, 1994; Sorkin, Hays, & West, 2001; Sorkin, West, & Robinson, 1998). However, this work by Sorkin and colleagues has focused entirely on maximally shared searches, with no notice of minimally shared searches or searches that lie between the two extremes of the continuum. The approach taken by Sorkin and colleagues makes the assumption that all groups search with all members examining the same stimuli. My dissertation counters this assumption by conceptually considering search sharedness as a continuous construct, and then showing evidence of variance in this construct. Moreover, as noted above, search sharedness has important outcomes for how teams gather information.

Applying this extension back to signal detection theory indicates that groups will have different signal detection outcomes (e.g., hits and false alarms) based on whether groups engage in maximally shared searches or minimally shared searches, and these relationships will change over the course of multiple detection trials. Whereas previously Sorkin and colleagues assumed that all group members examine the same stimulus, my dissertation indicates that signal detection groups may benefit from changing their level of search sharedness midway through a set of trials in a manner parallel to the pattern suggested by Figure 4 of this dissertation.

The primary purpose of this paper was to focus on team mental models of the team and team mental models of the task. However, it may also have implications for transactive memory theory (Austin, 2003; Lewis, 2003; 2004). Transactive memory is a construct that is related to team mental models of the task, in that it focuses on team members. However, the content of transactive memory is which team member holds which bit of information (e.g., which person in our team knows the capital of Uruguay), whereas the content of team mental models of the team focus on the strengths and weaknesses (e.g., what task is Member 1 most qualified to do?). Transactive memory is intended to allow teams to distribute their memory among team members in a non-redundant manner, yet maintain a directory that allows information to be retrieved when needed. Team mental models of the team are intended to aid team member coordination and team member utilization.

Although transactive memory and team mental models of the team are conceptually distinct, search sharedness may have similar implications for transactive memory as it does for team mental models of the team. Because search sharedness allows team members to compare search results, this may allow team members to better understand what information is held by which team member. If two team members share a search, they have conflicting information, and determine that one of them is correct and the other is incorrect, the incorrect team member may remember that the correct member has information about that particular stimulus. Even if the incorrect team member forgets later on the details of that stimulus, they may remember that the correct team member has the information. In contrast, unshared searches do not provide this opportunity for indexing information among team members. Unshared searches may promote distributed knowledge that is characteristic of transactive memory, but without the index indicating who knows what it is difficult to develop transactive memory that can be effectively utilized.

Practical Implications

This dissertation reveals important practical implications for managers and members of teams in organizations. First, teams that are new to a task or environment should develop accurate team mental models of the team by engaging in shared searches that allows for team members to compare and contrast their results in order to determine the strengths and weaknesses of each member. By doing so, teams will learn how they can best deploy each member of the team, for the benefit of team mental models of the task. This will also work best when teams focus more on cross-function search sharedness than within-function search sharedness.

This is an especially important lesson for teams performing in stressful contexts or when teams must accomplish a lot of work in a short amount of time. Such contexts may put pressure on teams to perform immediately, which may shift the team's focus to the task in order to achieve short term gains. This may push teams toward engaging in low levels of search sharedness, so that they can minimize redundancy and collect as much information as possible in as short of a time period as possible. However, low levels of search sharedness present few opportunities to compare bits of information from different team members, which makes it difficult to learn the strengths and weaknesses of different team members. Thus, pressure to perform quickly may lead teams to skip search sharedness that would likely benefit their team mental models of the team later in the task.

Once these team mental models of the team have been developed, teams should alter their search patterns such that team members search different stimuli. This dissertation indicates that late in a task, search sharedness has a negative relationship with team mental models of the task. Engaging in minimally shared searches in the second half of a task will allow teams to maximize the amount of stimuli examined, providing the widest search possible. This is consistent with contentions by Tuckman (1965) that teams focus first on team members and then on the task.

Although future research should further investigate this topic, this dissertation suggests that the sequence of team searches may be important in determining team performance. There can be costs and benefits of high levels of search sharedness and low levels of search sharedness, namely the opposing effects on the two different types of team mental models. However, teams may best be able to balance these costs and benefits by sequencing their search processes such that they engage in high levels of search sharedness early and low levels of search sharedness late. Teams may also be able to minimize the tradeoffs involved by focusing more on cross-function searches than within-function searches, because cross-function searches seem to maximize the benefits of search sharedness and minimize the costs.

An additional practical implication is that teams should be trained to develop a moderately strict decision criterion for determining what information to include in their team mental models of the task. Both signal detection theory (Green & Swets, 1966) and this dissertation indicate that hits and false alarms are positively related. This suggests that teams generally have a choice as to (1) including a lot of information in their team mental model of the task, but accepting that some of it will be incorrect, (2) restricting the amount of information in their team mental model of the task in order to minimize errors, but accepting that accurate information will be left out of their team mental model, or (3) compromising between the two. Holding constant the context, because both team mental model of the task hits and team mental model of the task false alarms predict team performance, teams may be best off with the compromise strategy.

However, the costs and benefits associated with hits and false alarms may vary from context to context (Barkan, 2002). Therefore, teams may be even better off matching their criterion for what information to include to the costs and benefits of hits and false alarms. For example, in a nuclear reactor, missing the cue that a meltdown is imminent is an especially costly mistake that is likely to outweigh the cost of calling a false alarm. Therefore, groups working in nuclear reactors might do well to follow the strategy of having a liberal criterion that includes a lot of information (even if some of it is false) in order to prevent the expense of a meltdown.

A related practical application involves how feedback is utilized. Managers of teams may have the opportunity to engage in review sessions after a task in order to provide helpful feedback that will improve performance in the next task (Ellis & Davidi, 2005). If such after event reviews focus primarily on how teams had low levels of hits in their team mental model of the task (e.g., a high level of misses), this may encourage teams to shift their decision criterion to include more information in their team mental model of the task. Such a decision criterion shift will likely be accompanied by more false alarms. If such after event reviews focus primarily on how teams had high levels of false alarms in their team mental model of the task, teams will likely shift their criterion in the opposite direction, resulting in fewer hits. This dissertation suggests, ceteris paribus, managers should provide feedback on both hits and false alarms in order to balance their costs and benefits.

Another related practical application involves compensation practices. Compensation practices that reward high levels of hits in team mental models of the task may promote liberal decision criteria in a manner similar to feedback that is focused on hits. Compensation practices that reward low levels of false alarms in team mental models of the task may promote strict decision criteria in a manner similar to feedback that is focused on false alarms. Thus, ceteris paribus, managers may want to design compensation systems that provide rewards for both high levels of hits and low levels of false alarms in order to keep decision criteria from being too liberal or too strict. Alternatively, managers may want to design compensation systems to provide rewards most heavily weighted toward what they consider to be the most important, whether that is hits or false alarms. Whatever the reward policy, it is likely that it will influence the proportion of hits to false alarms.

Future Research

The findings of this dissertation present multiple avenues for future research. In this section, I organize these possibilities around three main themes: (1) time, (2) task characteristics, (3) and team characteristics.

Time. As indicated in the discussion section, it appears that the benefit to team mental models for search sharedness varies over time within a given task. Future research should examine changes over time over the course of longer time periods involving multiple tasks. As noted earlier, theory examining team development over time indicates that teams perform best when they focus on the team early in their development and on the task later in development (Kozlowski, Gully, Nason, & Smith, 1999; Tuckman, 1965). An integration with research examining search sharedness over longer periods of time, such as the development of a team over the course of a year, may find that teams in different stages of development may differentially benefit from search sharedness. Extending the reasoning of this dissertation to longer periods of time, it may still be that team mental models of the team benefit from search sharedness early in the development of the team but not as much later in the development of the team. Similarly, search sharedness may be more harmful to team mental models of the task later in the development of a team than early in the development of the team. Stability in team membership may have a similar moderating role, such that teams with high levels of turnover benefit more from search sharedness than teams with stable membership.

Another avenue for future research in the context of time is with regards to action and transition phases. In the Marks et al. (2001) taxonomy of team processes, team timelines are divided into action phases and transition phases. This phase model treats teams as if they were dichotomously defined as in one phase or another. However, the boundaries between action phases and transition phases may often be blurry. Search sharedness conducted during the height of activity may be analyzed during a period of lesser activity. The lower activity period may be considered a transition phase because teams are not as engaged in the task, or it may still be considered an action phase because teams are analyzing data from their search. Future research should examine the possibility that this is not a dichotomous distinction.

Furthermore, future research should consider the possibility that there are sub-phases nested within action or transition phases. For example, during an action phase, there may be multiple periods of feedback that may prompt analysis, goal setting, and planning that resemble transition phase processes. Indeed, the punctuated equilibrium model (Gersick, 1988, 1989, 1991) suggests that the midpoint of a task would be a time when groups would engage in such processes. Future research should consider in what ways action phases can be divided into multiple action/transition phases, and how search sharedness from one such sub-phase can influence search sharedness from other sub-phases.

Task characteristics. Another avenue for future research would be to examine different types of tasks. Because this was an initial step in extending theory examining search sharedness and team mental models, in this dissertation, task type was held constant. However, previous research reveals important dimensions on which tasks may vary (Laughlin, 1999; McGrath, 1984; Steiner, 1972). An important dimension of team tasks which was held constant in this dissertation is task demonstrability. Task demonstrability refers to how possible it is for a group member who has an accurate bit of information to demonstrate to others the correctness of that information (Laughlin, 1986; Laughlin & Hollinghead, 1995). Intellective tasks, such as the task utilized in this dissertation, are on the high end of the task demonstrability continuum.

In contrast, judgment tasks are on the low end of the task demonstrability continuum. Future research may find that the relationship between search sharedness and team mental models is different with judgment tasks than with intellective tasks. Specifically, the benefit of comparing search results in shared searches may be attenuated in judgment tasks. Because it is usually difficult or impossible to demonstrate the correctness of a bit of information in judgment tasks, comparing search results may be more confusing than helpful. Thus, future research should examine team task type as a potentially important moderator of the influence of search sharedness on team mental models.

Similarly, task dynamicity was held constant in this dissertation. However, this too may be an important moderator. Future researchers may find that search sharedness is more beneficial to team mental models of the team in dynamic environments and in dynamic tasks than in stable environments and tasks. It may be that such changing circumstances make team member knowledge about each other in the context of that specific task to be obsolete, creating a continual need for comparison of search results among team members to check for accuracy.

Team characteristics. Team structure was constant in this dissertation. However, previous research reveals different methods of structuring teams that have important implications for team processes (Budescu, Rantilla, Yu, & Karelitz, 2003; Hollenbeck, Ilgen, Sego, Hedlund, Major, & Phillips, 1995; Hollenbeck, Moon, Ellis, West, Ilgen, Sheppard, Porter, & Wagner, 2002; McGrath, 1984). Horizontal structure, in particular, may have important implications for the relationship between search sharedness and team mental models. Previous research indicates that teams which are structured functionally, such that each team member has narrow specialized roles for which they are responsible over broad regions, have different levels of interdependence among members than do teams with broad roles that are constrained to narrower regions (Hollenbeck et al., 2002). Future research may find that the greater communication requirements that accompany functionally structured teams provide a natural conduit for comparing information and inferences among team members. In contrast, teams which are structured divisionally have naturally lower communication requirements, which may leave team members less likely to make such comparisons. Because the benefit to team mental models from engaging in shared searches is proposed to come from these comparisons, this may mean that divisionally structured teams are less affected by shared searches than are functionally structured teams.

As noted earlier, the participants in the sample utilized in this dissertation were all drawn from the same organization, the United States Air Force. Although the jobs held by the participants of this study were extremely varied, military organizations have relatively strong organizational cultures and norms. Kraiger and Wenzel (1997) contend that strong organizational cultures will promote team mental models. This suggests that future research should examine the relationships among search sharedness and team mental models in organizations with relatively weaker cultures and norms. Researchers may find that teams working in weak cultures may have more difficulty comparing search results from shared searches. In other words, strength of organizational culture and norms may moderate the relationship between team search sharedness and team mental models.

Future research may also find that the manner in which teams utilize information can influence the relationships between search sharedness and team mental models. Some team members may be reluctant to share disconfirming bits of information with the team, negating many of the benefits of search sharedness. Alternatively, certain team members may be consistently ignored when they attempt to bring their search results to the group, mitigating the beneficial effects of search sharedness on various outcomes such as team mental models. Future research may reveal that promoting productive conflict through the allowance of dissent is necessary in order to capture benefit from shared searches (c.f. Schulz-Hardt, Jochims, & Frey, 2002). In other words, shared searches may be more effective where dissent is valued.

There are potentially several reasons that team members may not be willing to share disconfirming bits of information. One reason might be that some teams engage in groupthink (Esser, 1998; Turner & Pratkanis, 1998). Teams aiming to protect their identity as a team may generate strong norms for suppressing the release of disconfirming information, and for quickly discrediting disconfirming information when it is released. Indeed, in such groups sharing or supporting disconfirming information may be perceived as a sign of disloyalty to the group. Thus, groupthink may attenuate the relationships between search sharedness and team mental models.

A second potentially related reason may be that psychological safety, which is defined as the "shared belief that the team is safe for interpersonal risk taking" (Edmondson, 1999: 354). In contrast to teams that are high in psychological safety, teams that are low in psychological safety are more concerned about others' negative reactions to actions that have the potential to embarrass or threaten a member (Edmondson, 1999). In teams with low psychological safety, team members may be less likely to compare their search results for fear of making themselves or someone else look bad. Unwillingness to compare search results may undercut some of the benefits of search sharedness.

A third reason that team members may not be willing or able to share disconfirming bits of information is conflict within teams. Previous research that both task and relationship conflict can have detrimental effects on team processes (De Dreu & Weingart, 2003). Relationship conflict, in particular, may lead team members to either discredit information coming from other members with whom they have disagreements, or be less willing to share disconfirming information that might reopen old arguments. Moreover, lines of conflict can stack along several dimensions, such that standing faultlines may develop within teams that lead to repeated conflicts among specific subgroups within teams (Lau & Murnighan, 1998, 2003). To the degree that such conflict prevents the comparison of potentially conflicting information, the benefit of search sharedness may be eroded. Thus, team conflict may moderate the influence of search sharedness on team mental models.

Perhaps one method of promoting productive dissent that allows teams to capture the benefit of shared searches might be to structure special roles into teams that specifically seek disconfirming information, known as devil's advocates (c.f. Greitemeyer, Schulz-Hardt, Brodbeck, & Frey, 2006; Schweiger, Sandberg, & Ragan, 1986; Schweiger, Sandberg, & Rechner, 1989). By formalizing the role of seeking disconfirming information, teams may be more likely to engage in shared searches, more likely to pay attention to conflicting information in shared searches, and more likely to direct attention to resolving conflicting bits of information. This may enhance the beneficial effects of shared searches on team mental models.

Previous research indicates that team composition has important effects on team processes (Campion, Medsker, & Higgs, 1993; Campion, Papper, & Medsker, 1996; Humphrey, Hollenbeck, Meyer, & Ilgen, 2007). One such character of composition that has recently gained research attention is goal orientation. In their seminal review of the literature on achievement orientation, Dweck and Leggett (1988) noted two types of goals that create a framework within which individuals interpret and react to events: learning goals and performance goals. According to Dweck and Leggett, learning goals emphasize opportunities to increase competence and acquire skills, and performance goals emphasize the establishment of adequacy of ability and avoidance of evidence of inadequacy. Although many researchers initially treated learning goals and performance goals as mutually exclusive goals, Button, Mathieu, and Zajac (1996) conducted a series of four empirical studies which provided convincing empirical support for the contention that learning goals and performance goals are neither mutually exclusive nor contradictory.

Recent research has examined goal orientation at the team level of analysis (Bunderson & Sutcliffe, 2003; LePine, 2005; Porter, 2005), indicating that teams can vary in goal orientation. In the context of search sharedness and team mental models, future research may reveal that teams with high learning goal orientation are especially likely to learn from the comparison of different search results that can occur in search sharedness. Because such teams seek to improve their competence, they will be especially motivated to find the strengths of their team members. This may accentuate the beneficial effects of search sharedness on team mental models of the team, suggesting a moderating effect of learning orientation. In contrast, performance goals emphasize the avoidance of evidence of inadequacy. Because conflicting results obtained from different team members engaged in shared searches may be seen as suggesting that certain team members are incorrect and potentially inadequate, teams high in performance orientation may seek to avoid such opportunities for comparison. In other words, performance orientation may inhibit search sharedness.

Alternatively, goal orientation may be an important antecedent of search sharedness. As noted above, search sharedness involves examining fewer stimuli, limiting the amount of information that can be included in team mental models of the task. As indicated by this dissertation, early search sharedness had a negative correlation with early team performance (r= -.14). However, early search sharedness allow teams to build accurate early mental models of the team (β=.14). Thus, search sharedness involves engaging in an action that has negative short term effects on performance but aids teams in building accurate mental models of the team. Because learning goal orientations focus on increasing skills and capabilities more so that immediately performing well, learning goals may be more likely than performance goals to lead teams to engage in high levels of search sharedness.

Future research may find that search sharedness can moderate the effects of other team characteristics on team mental models. Previous research indicates that stressful contexts lead to decrements in team mental models (Ellis, 2005). Stress leads to the breakdown of team mental models as team members miss bits of information, do not combine bits of information, forget information, and forget where information resides within their team. Search sharedness may provide some redundancy in the search process that can alleviate these problems, with beneficial results to team mental models in stressful contexts.

Similarly, teams may have team members who are overburdened (Barnes, Hollenbeck, Wagner, DeRue, Nahrgang, & Schwind, 2008; Porter, Hollenbeck, Ilgen, Ellis, West, & Moon, 2003), fatigued (Barnes & Hollenbeck, 2009; Barnes & Van Dyne, 2009), or lacking required expertise (Budescu, Rantilla, Yu, & Karelitz, 2003) who attempt to gather information that is important to the team. Search sharedness may be a way for other team members who are not as overburdened, fatigued, or lacking in expertise to work with such team members in order to help them to avoid missing important information or gathering inaccurate information. In other words, search sharedness may mitigate the influence of workload, fatigue, or expertise on team mental models. This moderating effect may work in the opposite direction on other variables. For example, search sharedness presents the opportunity for multiple team members to have conflicting information. This is especially true when there are conflicting cues in the environment. Thus, search sharedness may increase the influence of conflicting information on team conflict.

Future research may reveal that another antecedent of team search sharedness is team trust. Previous research indicates that teams with high levels of trust are more reluctant to monitor team members than are teams with low levels of trust (Langfred, 2004). To the degree that teams engage in search sharedness as a means of monitoring the accuracy of the information obtained by team members, high levels of team trust may inhibit shared search. A similar effect may be found for team member empowerment. Team member empowerment is defined as increased task motivation that is due to team members' positive assessments of their organizational tasks (Kirkman & Rosen, 1999; 2000). Of particular relevance to the current discussion is the dimension of autonomy, which is defined as the degree to which team members believe they have the freedom to make decisions (Kirkman, Rosen, Tesluk, & Gibson, 2004). Teams with members high in empowerment, especially the autonomy component, may be especially likely to engage in unshared searches in an independent manner. In contrast, teams lower in empowerment and autonomy may be more likely to engage in shared searches in which they are more coordinated with fellow team members.

Conclusion

The purpose of this dissertation was to examine how teams develop mental models over time. Seeking to extend current theoretical foundations of research examining team mental models, I drew from theory examining team development to contend that teams vary in their search patterns and that this would have important implications for team mental models and team performance. I found that search sharedness was negatively related to the accuracy of team mental models of the task, although only late in a task. In contrast, search sharedness was positively related to the accuracy of team mental models of the team, although only early in a task. Also, as expected, both types of team mental models were beneficial to team performance. This dissertation indicates that search sharedness is an important determinant of team mental models, and that these relationships vary over time.

TABLE A1:

List of Hypotheses

Hypothesis 1: Early search sharedness will be negatively related to the accuracy of the early team mental models of the task.

Hypothesis 2: Late search sharedness will be negatively related to the accuracy of the late team mental models of the task.

Hypothesis 3: Early search sharedness will be positively related to the accuracy of the early team mental models of the team.

Hypothesis 4: Late search sharedness will be positively related to the accuracy of the late team mental models of the team.

Hypothesis 5a: The negative relationship between early within-function search sharedness and early accuracy in team mental models of the task will be stronger than the negative relationship between early cross-function search sharedness and early accuracy in team mental models of the task.

Hypothesis 5b: The negative relationship between late within-function search sharedness and late accuracy in team mental models of the task will be stronger than the negative relationship between late cross-function search sharedness and late accuracy in team mental models of the task.

Hypothesis 6a: The positive relationship between early cross-function search sharedness and the accuracy of the early team mental model of the team will be stronger than the positive relationship between early within-function search sharedness and the accuracy of the early team mental model of the team.

Hypothesis 6b: The positive relationship between late cross-function search sharedness and the accuracy of the late team mental model of the team will be stronger than the positive relationship between late within-function search sharedness and the accuracy of the late team mental model of the team.

Hypothesis 7: The accuracy of team mental models of the team will be positively related to the accuracy of team mental models of the task.

Hypothesis 8: Time moderates the negative relationship between search sharedness and accuracy in team mental models of the task, such that teams will have the most accurate mental models of the task when engaging in high levels of search sharedness early in the task and low levels of search sharedness late in the task.

Hypothesis 9: Time moderates the positive relationship between search sharedness and accuracy in team mental models of the team, such that teams will have the most accurate mental models of the team when engaging in high levels of search sharedness early in the task and low levels of search sharedness late in the task.

Hypothesis 10: The accuracy of team mental models of the task will be positively related to team performance.

Hypothesis 11: The accuracy of team mental models of the team will be positively related to team performance.

TABLE A2:

Simulation Scoring

Event	**Points**
2 Strikes capitalize on 1 large opportunity	+16
1 Strike capitalizes on 1 small opportunity	+4
2 Escorts destroy 1 large threat	+4
1 Escort destroys 1 small threat	+2
Each asset lost	-8
Each threat adjacent to a base	-8 per turn

TABLE A3:

Correlations Part 1

	Mean	SD	1	2	3	4	5	6
1. Early within-function search sharedness	40.27	27.04						
2. Late within-function search sharedness	7.95	11.68	0.23**					
3. Overall within-function search sharedness	48.22	31.79	0.93**	0.56**				
4. Early between-function search sharedness	30.87	18.65	0.52**	0.01	0.45**			
5. Late between-function search sharedness	10.93	5.48	0.16*	0.40**	0.28**	0.13*		
6. Overall between-function search sharedness	41.80	20.11	0.53**	0.12	0.49**	0.96**	0.39**	
7. Early total search sharedness	71.14	40.09	0.92**	0.16*	0.84**	0.82**	0.17**	0.81**
8. Late total search sharedness	18.89	14.74	0.24**	0.94**	0.55**	0.06	0.69**	0.24**
9. Overall total search sharedness	90.03	45.23	0.89**	0.45**	0.92**	0.74**	0.37**	0.79**
10. Accuracy of early team mental model of the team	86.01	20.43	-0.03	-0.17**	-0.09	0.09	-0.08	0.06
11. Accuracy of late team mental model of the team	119.32	27.16	-0.03	-0.24**	-0.12	0.08	-0.08	0.05
12. Accuracy of overall team mental model of the team	205.33	40.50	-0.04	-0.25**	-0.12	0.10	-0.09	0.07
13. Early hits in team mental model of the task	23.87	10.89	-0.13*	-0.20**	-0.19**	-0.01	-0.12	-0.04
14. Late hits in team mental model of the task	41.14	16.56	-0.03	-0.30**	-0.14*	0.09	-0.23**	0.03
15. Overall hits in team mental model of the task	65.01	22.87	-0.09	-0.32**	-0.19**	0.06	-0.23**	0.00
16. Early false alarms in team mental model of the task	14.75	10.11	-0.12	0.04	-0.09	-0.24**	0.02	-0.22**
17. Late false alarms in team mental model of the task	26.81	19.63	-0.04	0.04	-0.01	-0.08	0.04	-0.06
18. Overall false alarms in team mental model of the task	41.56	27.30	-0.07	0.04	-0.04	-0.15*	0.04	-0.13*
19. Early hits minus false alarms	9.12	14.23	-0.02	-0.18**	-0.08	0.16*	-0.10	0.12
20. Late hits minus false alarms	14.33	22.85	0.01	-0.26**	-0.09	0.14	-0.20**	0.07
21. Overall hits minus false alarms	23.45	32.68	0.00	-0.26**	-0.10	0.17**	-0.19**	0.10
22. Early team performance	52.90	37.83	-0.02	0.12	0.03	-0.15*	0.11	-0.11
23. Late team performance	95.89	36.97	-0.06	-0.36**	-0.19**	0.07	-0.37**	-0.03
24. Overall team performance	148.79	47.05	-0.06	-0.19**	-0.12	-0.07	-0.20**	-0.12

n=241

* $p < .05$. ** $p < .01$.

TABLE A4:

Correlations Part 2

	7	8	9	10	11	12	13	14
1. Early within-function search sharedness								
2. Late within-function search sharedness								
3. Overall within-function search sharedness								
4. Early between-function search sharedness								
5. Late between-function search sharedness								
6. Overall between-function search sharedness								
7. Early total search sharedness								
8. Late total search sharedness	0.19**							
9. Overall total search sharedness	0.95**	0.49**						
10. Accuracy of early team mental model of the team	0.02	-0.17**	-0.04					
11. Accuracy of late team mental model of the team	0.01	-0.22**	-0.06	0.44**				
12. Accuracy of overall team mental model of the team	0.02	-0.23**	-0.06	0.80**	0.89**			
13. Early hits in team mental model of the task	-0.10	-0.20**	-0.15*	0.35**	0.23**	0.33**		
14. Late hits in team mental model of the task	0.02	-0.33**	-0.09	0.25**	0.38**	0.38**	0.36**	
15. Overall hits in team mental model of the task	-0.03	-0.33**	-0.13*	0.35**	0.39**	0.43**	0.74**	0.90**
16. Early false alarms in team mental model of the task	-0.19**	0.03	-0.16*	0.01	-0.11	-0.07	0.08	0.10
17. Late false alarms in team mental model of the task	-0.06	0.05	-0.04	-0.04	-0.13*	-0.11	0.02	0.21**
18. Overall false alarms in team mental model of the task	-0.12	0.05	-0.09	-0.03	-0.13*	-0.10	0.05	0.19**
19. Early hits minus false alarms	0.06	-0.18**	0.00	0.26**	0.25**	0.30**	0.71**	0.20**
20. Late hits minus false alarms	0.07	-0.28**	-0.03	0.22**	0.39**	0.37**	0.24**	0.54**
21. Overall hits minus false alarms	0.08	-0.27**	-0.02	0.27**	0.38**	0.39**	0.48**	0.47**
22. Early team performance	-0.08	0.14*	-0.03	0.14*	0.04	0.10	0.13*	-0.32**
23. Late team performance	-0.01	-0.43**	-0.15*	0.24**	0.37**	0.37**	0.30**	0.45**
24. Overall team performance	-0.07	-0.22**	-0.14*	0.30**	0.32**	0.37**	0.34**	0.10

n=241

* $p < .05$. ** $p < .01$.

TABLE A5:

Correlations Part 3

	15	16	17	18	19	20	21	22	23
1. Early within-function search sharedness									
2. Late within-function search sharedness									
3. Overall within-function search sharedness									
4. Early between-function search sharedness									
5. Late between-function search sharedness									
6. Overall between-function search sharedness									
7. Early total search sharedness									
8. Late total search sharedness									
9. Overall total search sharedness									
10. Accuracy of early team mental model of the team									
11. Accuracy of late team mental model of the team									
12. Accuracy of overall team mental model of the team									
13. Early hits in team mental model of the task									
14. Late hits in team mental model of the task									
15. Overall hits in team mental model of the task									
16. Early false alarms in team mental model of the task	0.11								
17. Late false alarms in team mental model of the task	0.16*	0.65**							
18. Overall false alarms in team mental model of the task	0.16*	0.84**	0.96**						
19. Early hits minus false alarms	0.48**	-0.65**	-0.44**	-0.56**					
20. Late hits minus false alarms	0.51**	-0.48**	-0.71**	-0.69**	0.53**				
21. Overall hits minus false alarms	0.57**	-0.62**	-0.69**	-0.72**	0.80**	0.93**			
22. Early team performance	-0.17**	-0.09	-0.01	-0.04	0.17**	-0.22**	-0.08		
23. Late team performance	0.47**	-0.08	-0.25**	-0.21**	0.29**	0.55**	0.51**	-0.21**	
24. Overall team performance	0.24**	-0.14*	-0.21**	-0.20**	0.36**	0.25**	0.33**	0.64**	0.62**

n=241

* $p < .05$. ** $p < .01$.

TABLE A6:

Results of Regression Analysis Testing Hypothesis 5a

Regression of Early Accuracy in Team Mental Models of the Task on Early Within- and Cross-Functional Team Search Sharedness

Independent Variable	Beta for Hits Minus False Alarms	Beta for Hits	Beta for False Alarms
Early Within-Function Search Sharedness	-.139†	-.175*	.007
Early Cross-Function Search Sharedness	.234**	.081	-.242**
R^2	.040	.022	.057
F	4.946	2.729	7.192

n=241

† $p < .10$ * $p < .05$. ** $p < .01$.

TABLE A7:

Results of Regression Analysis Testing Hypothesis 5b

Regression of Late Accuracy in Team Mental Models of the Task on Late Within- and Cross-Functional Team Search Sharedness

Independent Variable	Beta for Hits Minus False Alarms	Beta for Hits	Beta for False Alarms
Late Within-Function Search Sharedness	-.207**	-.252**	.028
Late Cross-Function Search Sharedness	-.123†	-.132*	.031
R^2	.078	.107	.002
F	10.056	14.289	.296

n=241

† $p<.10$ * $p<.05$. ** $p<.01$.

TABLE A8:

Results of Regression Analysis Testing Hypothesis 6a

Regression of Early Accuracy in Team Mental Models of the Team on Early Within- and Cross-Functional Team Search Sharedness

Independent Variable	Beta
Early Within-Function Search Sharedness	-.103
Early Cross-Function Search Sharedness	.141†
R^2	.015
F	1.852

n=241

† $p < .10$ * $p < .05$. ** $p < .01$.

TABLE A9:

Results of Regression Analysis Testing Hypothesis 6b

Regression of Late Accuracy in Team Mental Models of the Team on Late Within- and Cross-Functional Team Search Sharedness

Independent Variable	Beta
Late Within-Function Search Sharedness	-.246**
Late Cross-Function Search Sharedness	.018
R^2	.057
F	7.251

n=241

† $p<.10$ * $p<.05$. ** $p<.01$.

TABLE A10:

Results of Regression Analysis Testing Hypothesis 8

Regression of Accuracy in Team Mental Models of the Task on Team Search Sharedness, as Moderated by Time

Independent Variable	Beta for Hits Minus False Alarms		Beta for Hits		Beta for False Alarms	
	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2
Early search sharedness	.131*	.130*	.034	.032	-.128	-.128
Late search sharedness	-.298**	-.306**	-.340**	-.352**	.071	.071
Early search sharedness X Late Search Sharedness		.023		.033		.000
R^2	.091	.092	.112	.113	.018	.018
ΔR^2		.001		.001		<.001
F	11.937	7.969	15.069	10.099	2.201	1.461

n=241

* $p < .05$. ** $p < .01$.

TABLE A11:

Results of Regression Analysis Testing Hypothesis 9

Regression of Accuracy in Team Mental Models of the Team on Team Search Sharedness, as Moderated by Time

Independent Variable	Beta Step 1	Beta Step 2
Early search sharedness	.066	.060
Late search sharedness	-.243**	-.272**
Early search sharedness X Late Search Sharedness		.081
R^2	.057	.063
ΔR^2		.008
F	7.258	5.324

n=241

* $p < .05$. ** $p < .01$.

TABLE A12

Results of Regression Analysis Testing Hypotheses 10-11

Regression of Team Performance on Team Mental Models

Independent Variable	Beta
Hits in team mental models of the task	.143*
False alarms in team mental model of the task	-.192**
Accuracy of team mental models of the team	.285**
R^2	.177
F	16.934

n=241

* $p < .05$. ** $p < .01$.

TABLE A13

Results of Supplemental Regression Analysis Testing Hypothesis 8

Regression of Accuracy in Team Mental Models of the Task on Team Search Sharedness, as Moderated by Time

Independent Variable	Beta for Hits Minus False Alarms		Beta for Hits		Beta for False Alarms	
	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2
Early unshared searches	.022	.022	.167†	.166†	.113	.113
Late unshared searches	.010	.011	.109	.110	.080	.080
Early search sharedness	.147	.145	.152	.149	-.048	-.049
Late search sharedness	-.293**	-.301**	-.284**	-.297**	.112	.111
Early search sharedness X Late Search Sharedness		.024		.038		.003
R^2	.092	.092	.142	.143	.032	.032
ΔR^2		<.001		.001		<.001
F	5.946	4.764	9.733	7.833	1.984	1.581

n=241

† $p < .10$

* $p < .05$ ** $p < .01$

TABLE A14:

Results of Supplemental Regression Analysis Testing Hypothesis 9

Supplemental Regression of Accuracy in Team Mental Models of the Team on Team Search Sharedness, as Moderated by Time

Independent Variable	Beta Step 1	Beta Step 2
Early unshared searches	.411**	.410**
Late unshared searches	.492**	.497**
Early search sharedness	.357**	.349**
Late search sharedness	.008	-.026
Early search sharedness X Late Search Sharedness		.101
R^2	.394	.403
ΔR^2		.009
F	38.369	31.691

n=241

* $p < .05$. ** $p < .01$.

TABLE A15:

Results of Supplemental HLM Analyses Examining Time as a Moderator of Search Sharedness on Team Mental Models of the Task

	Hits	False Alarms
	Standardized Coefficient	Standardized Coefficient
Total Unshared Searches	0.120	-0.004
Time	0.274**	0.375**
Total Shared Searches	-0.272**	0.018
Total Shared Searches X Time	-0.230**	0.057

n=482 observations

* $p < .05$. ** $p < .01$.

TABLE A16:

Results of Supplemental HLM Analyses Examining Time as a Moderator of Search Sharedness on Team Mental Models of the Team

	Step 1
	Standardized Coefficient
Total Unshared Searches	0.700**
Time	0.388**
Total Shared Searches	0.373**
Total Shared Searches X Time	-0.085

n=482 observations

* $p < .05$. ** $p < .01$.

FIGURE B1

Conceptual Model

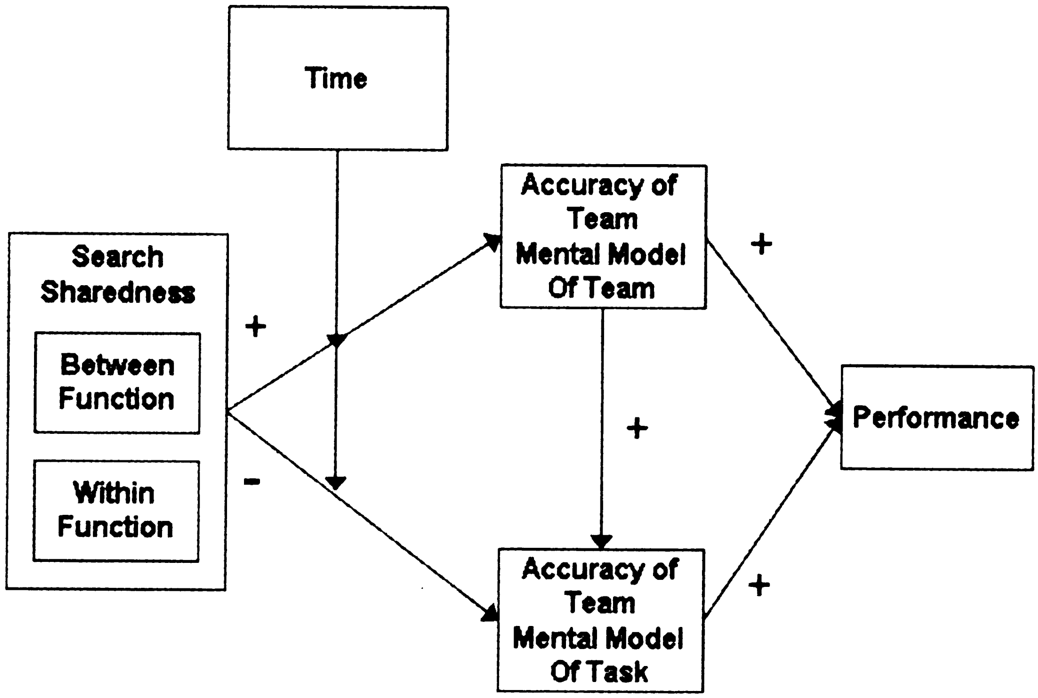


FIGURE B2

Leadership Development Simulator Roles

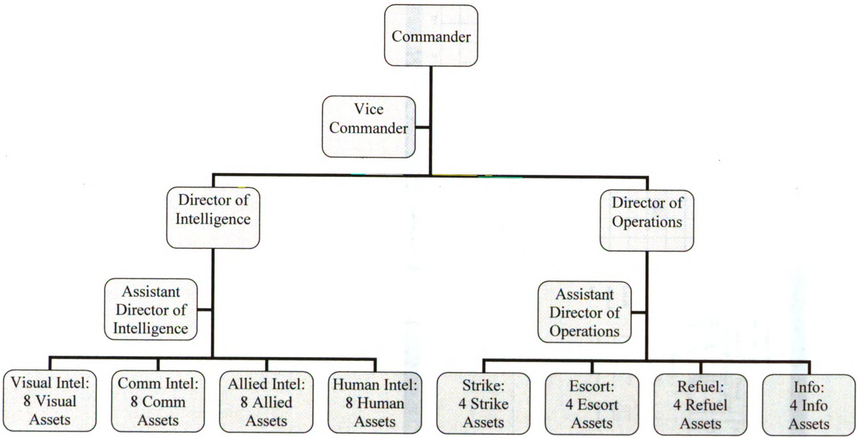


FIGURE B3

Sample Common Operating Picture

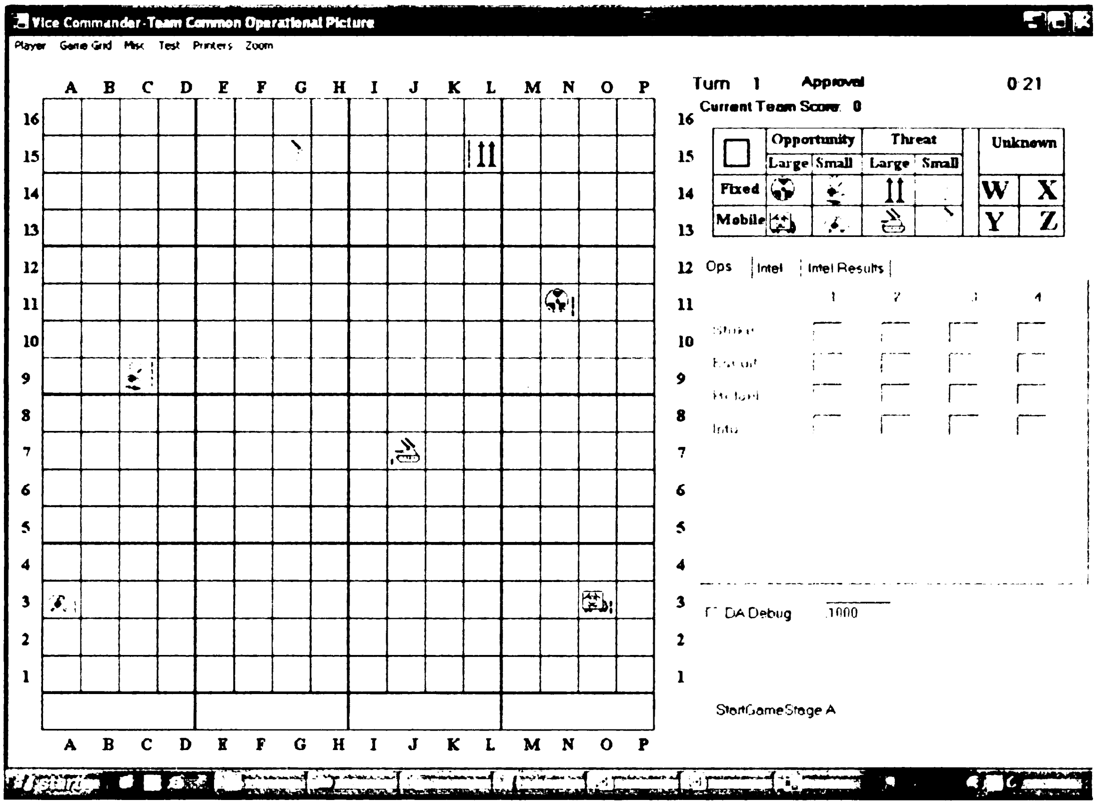
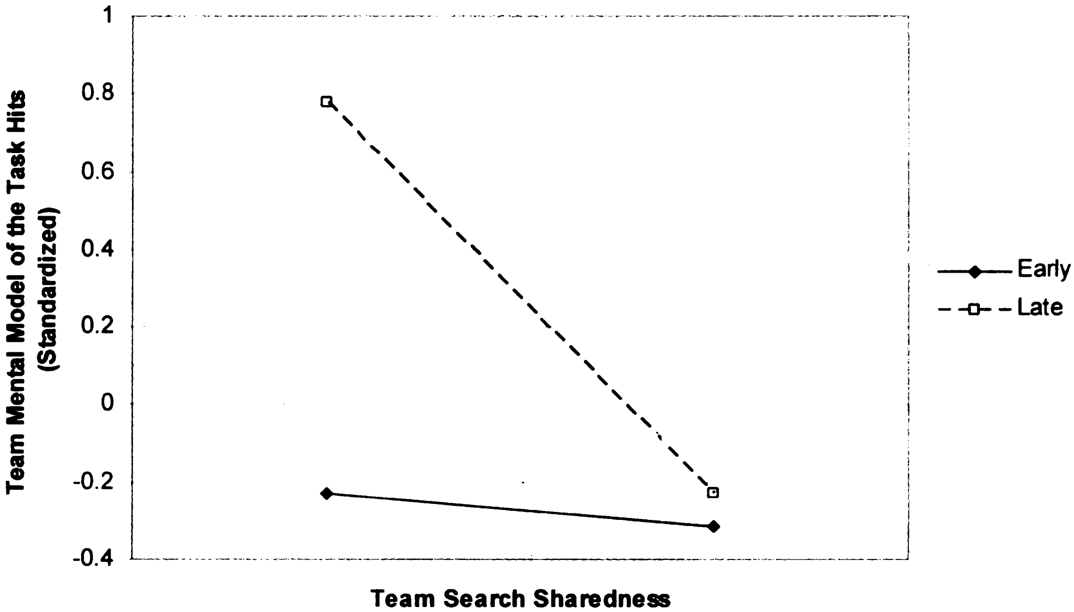


FIGURE B4

Time as a Moderator of the Relationship between Search Sharedness and Team Mental Model of the Task Hits



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