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Relationships Between Externalization Behaviors and Team Cognition Variables in Distributed Teams

Lisa Ann Delise

The University of Tennessee, Knoxville, ldelise@utk.edu

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Joan R. Rentsch, Major Professor

We have read this dissertation and recommend its acceptance:

Michael J. Stahl, Kenneth J. Levine, Eric Sundstrom

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

Relationships Between Externalization Behaviors and Team Cognition Variables in Distributed Teams

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Abstract

Members of distributed teams often have difficulty sharing unique information with their teammates during decision making tasks. These communication problems may hinder the development of cognitions that allow team members to reach a similar understanding of the content and structure of task information. The C-MAP intervention (Rentsch, Delise, & Hutchison, 2008) was designed to assist team members in sharing their information through behaviors that convey the content and structure of information by using specific communication behaviors and developing a knowledge object. In the present study, the knowledge object took the form of a white board where information was posted and organized. The development of the team knowledge object was the focus of the study. Using the knowledge object, team members could post a piece of unique information, highlight it, and organize it into clusters, thereby illustrating the content and structure of information through knowledge object development (KOD) behaviors. The present study evaluated the relationships among four types of KOD behaviors (posting content, highlighting content, conveying structure within domain, and conveying structure across domains) used to externalize pieces of unique information and two team cognition variables (transferred and interoperable knowledge) that develop with respect to each piece of unique information. Results provided evidence that posting content behaviors and highlighting content behaviors were positively related to transferred knowledge. Results also indicated that conveying structure within domain behaviors were negatively related to interoperable knowledge. However, conveying structure across domains behaviors were positively related to interoperable knowledge. Implications of these findings for the C-MAP intervention and suggestions for future research are presented.

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Chapter 1

Introduction

Distributed decision making teams are often assembled with the intent that members will build upon the information they hold in common by compiling the unique information they each hold about the team's task in a way that will lead the team to a high quality decision (e.g., Hertel, Geister, & Konradt, 2005). To do that, team members need to understand the content and structure (i.e., relationships, connections) of the team's available pool of task information and internalize that knowledge into their own cognitions. When team members internalize others' unique content, it becomes *transferred knowledge*. When members internalize relationships and connections among pieces of information in ways that make the information useful and important, it becomes *interoperable knowledge*. These two team cognition variables can encourage high quality decision making in teams (Rentsch, Delise, & Hutchison, 2008).

However, because distributed environments are typified by relatively low-bandwidth communication (e.g., Fussell & Benimoff, 1995), they present several challenges for conveying the content and structure of information. Therefore, teams may benefit from utilizing mechanisms for externally representing their information in textual and figural forms. Two mechanisms that may be particularly useful were proposed by Rentsch et al. (2008) as part of the Collaboration and Meaning Analysis Process (C-MAP) intervention. First, using text-based chat, *schema-enriched communication behaviors* allow team members to discuss information with one another in ways that articulate and elicit the content and structure of information. Second, using a shared virtual information board, *knowledge object development behaviors* allow team members to visually and figurally display the content of their information to all members and to collaboratively organize the information to display its structure. These mechanisms may help team members develop the two team cognition variables mentioned above by explicitly conveying the content and structure of task information. However, little is known about how these behaviors, specifically knowledge object development behaviors, operate to support the development of cognition in distributed teams.

Therefore, the purpose of the present study was to examine behaviors in distributed decision making teams to determine the relationships between knowledge object development behaviors used to externalize knowledge and the internalization of that knowledge (transferred knowledge and interoperable knowledge). The hypotheses tested in the present study were general because there is no direct empirical research and little theory from which to generate specific hypotheses. Therefore, the present study was exploratory and descriptive.

The following sections delineate the theoretical background of the present study. First, challenges of communicating information in distributed teams will be presented. Next, the model upon which the present research is based will be described. Then, the present study is described and the hypotheses are presented.

Chapter 2

Distributed Teams and Team Cognition

Communicating Information in Distributed Teams

A distributed team is defined as two or more individuals working on a task with an interdependent goal, who are spatially dispersed and communicating through technological media (i.e., email, chat, telephone, video conferencing) (e.g., Driskell, Radtke, & Salas, 2003; Hertel et al., 2005). Communication can be difficult in virtual environments, which are impoverished due to a lack of the physical and social cues that facilitate accurate understanding of information in face-to-face environments (Fussell & Benimoff, 1995). As such, virtual environments do not afford opportunities for nonverbal and subtle communications (i.e., nods, eye contact, shrugs), which can make distributed communication of information effortful (Cramton, 2001), slow, and difficult (Driskell et al., 2003). As a result, distributed teams tend to communicate less overall, take longer to make decisions, and make worse decisions than face-to-face teams (e.g., Hiltz, Johnson, & Turhoff, 1986; Hollingshead, 1996b; Kiesler, Siegel, & McGuire, 1984; Kiesler & Sproull, 1992; Straus, 1996; Straus & McGrath, 1994). These negative outcomes may be due to difficulties in sharing the *content* and *structure* of task information available to the team.

Sharing Content

In terms of *content*, distributed teams encounter similar problems as face-to-face teams when sharing distributed (and therefore uniquely held) information. When task information is distributed among members of decision making teams, such that some information is common to all members and other information is uniquely held by only one member, research has shown that teams have difficulty sharing the unique information (e.g., Stasser & Titus, 1985, 1987). In fact, there is a bias against sharing unique information in favor of discussing common information and studies have found that distributed teams mentioned more common and less unique information than face-to-face teams (e.g., Dennis, 1996; Hightower & Sayeed, 1995; Hollingshead, 1996a). This bias can result in teams making poor decisions (e.g., Campbell & Stasser, 2006; Larson, Christensen, Abbott, & Franz, 1996; Larson, Foster-Fishman, & Keys, 1994; Stasser, Stewart, & Wittenbaum, 1995; Stasser & Titus, 1985, 1987; Stasser, Vaughn, & Stewart, 2000; Stewart & Stasser, 1995). The bias is due to the fact that common information is more likely to be discussed simply because more team members have had the opportunity to attend to and encode the information, then retrieve it when relevant to the team's discussion, whereas unique information is only encountered by one team member (Stasser et al., 1995). Also, sharing unique information with others may be difficult because it is often embedded with other unique information from one's own area of expertise, thus requiring additional contextual information to understand it (Carlile, 2002).

Interventions for face-to-face teams involving assignment of expert roles to team members and forewarning members about which team member holds which role are somewhat helpful for combating the common information bias, but they do not completely eradicate it (Stasser et al., 1995; Stasser et al., 2000; Stewart & Stasser, 1995). Nevertheless, teams experiencing these interventions were more likely to recognize unique information on tests and, as a team, to recall pieces of unique information that were mentioned during the discussion (Stewart & Stasser, 1995). In another intervention, Larson et al. (1994) found that training on group decision making methods did not remove the bias against sharing unique information but did prompt team members to mention unique information throughout their discussions, whereas untrained teams mostly mentioned unique information late in the discussions. Because information mentioned later in a discussion can have less effect on the team's decision (e.g., Larson et al., 1996; Stasser & Titus, 2003), information mentioned earlier may be more useful for the team.

In virtual teams, successful interventions included giving teams as much time as necessary to reach a decision, leading them to believe that the task had one demonstrable solution (Campbell & Stasser, 2006), providing team members with smaller information loads and more unique information (Hightower & Sayeed, 1995), and making team members anonymous (McLeod, Baron, Marti, & Yoon, 1997). However, these types of interventions are impractical for real-world distributed teams because the task type, information load, information distribution, and identity of team members are often not variables that can be manipulated. Therefore, although all of these interventions have shown some promise for fostering the sharing of unique information in decision making teams, these teams may also benefit from mechanisms that assist specifically with sharing the *content* of information.

Sharing Structure

In terms of *structure*, it may be difficult for virtual teams to express the importance of information and the underlying relationships among pieces of information. For example, team members may share and attend to information differently depending on how salient they believe it to be to the task. If members do not understand the relevance of a piece of unique information then they will likely ignore it, thereby limiting the information pool available to be considered by the team (Stasser & Titus, 1987). Also, many communication technologies used by distributed teams do not facilitate teams in accurately conveying information (Straus & Olivera, 2000), particularly implicit structural information such as "how" and "why" (Berry & Broadbent, 1984). Therefore, teams may not be able to identify relevant information (Cramton, 2001) or identify and correct errors in transmission and understanding of information (Driskell et al., 2003). Additionally, communication issues make it difficult for distributed team members to develop and maintain common ground (Clark & Brennan, 1991) and mutual knowledge (Cramton, 2001; Thompson & Coovert, 2003) that help team members think similarly about the task information. Therefore, teams may also benefit from mechanisms that assist specifically with the sharing of *structure* information.

Summary

Distributed teams may have difficulty sharing the *content* and *structure* of their unique information due to difficulties of communication in virtual environments. Interventions aimed at improving the team's ability to share *content* of unique information have been only partially successful or are impractical, and distributed communication technologies do not assist teams in overcoming obstacles in sharing the *structure* of their unique information (i.e., importance and relationships with other information). However, despite being difficult to accomplish, sharing information content, explaining relationships among information pieces, and clarifying the relevance of information pieces are essential when distributed team members need to understand one another's unique domains in order to make effective decisions. Therefore, new interventions should directly facilitate team sharing of the *content* and *structure* of unique information.

Model of Development of Team Cognition Variables

Given the difficulties outlined above for distributed teams in which team members are tasked with sharing information and knowledge across specialized areas, Rentsch at al. (2008) developed a model and proposed an intervention to improve information sharing and development of team cognition variables. The Collaboration and Meaning Analysis Process (C-MAP) involves training team members in effective externalization of knowledge through simultaneous use of two channels: 1) the use of schema-enriched communication in text-based synchronous chat and 2) the development of a team knowledge object in a shared team information board where information is posted and organized (see Figure 1). These externalization mechanisms were designed to facilitate the development of two team cognition variables: transferred knowledge and interoperable knowledge. Next, these variables are explained. Then, the two externalization methods are described with an emphasis on knowledge object development behaviors which were the foci of the present study. Finally, the variables are discussed in the context of the present study and hypotheses are delineated.

Chapter 3

Internalization: Team Cognition Variables

The unique information held by one team member can be internalized by other team members in two ways that are of interest to the present study, as transferred knowledge and interoperable knowledge. These two forms of team cognition can be developed through an iterative, cyclical process of team members externalizing and internalizing information (Rentsch, Mello, & Delise, 2010). Internalization is the process of incorporating information into one's schema about a topic, essentially converting explicit knowledge into tacit knowledge (Nonaka, 1994). Conversely, externalization is the process of articulating tacit knowledge from one's schema as explicit knowledge (Nonaka, 1994) that is available to all team members. Before describing the two team cognition variables, a brief explanation of schemas (the foundations of team cognition) is presented.

Schemas

Schemas are cognitive mechanisms that enable individuals to utilize and make sense of information by storing the *content* of information as nodes and the *structure* of information (relationships among pieces) as linkages (Rumelhart & Ortony, 1977). Because information is stored in terms of structured linkages between content nodes, schemas are flexible and can adapt or change their representations of content and relationships among pieces of information (Rumelhart & Ortony, 1977). Hence, schemas allow for encoding new information into already-existing cognitive content and structure. Schema structure supports interaction between old and new information such that memory can be modified and new concepts can be created (Brewer & Nakamura, 1984; Rumelhart & Ortony, 1977). In this way, schemas are particularly useful to team members during discussions as they share unique information and reorganize their cognitions to reflect newly learned knowledge. As team members internalize content and structure of task information, their schemas can change to reflect transferred knowledge and interoperable knowledge.

Transferred Knowledge

Transferred knowledge is defined as information that has been shared by one person and internalized by at least one other in such a way that the other can remember the information (Rentsch et al., 2008). In teams where members each have unique information in diverse domains, each team member must transfer his/her own unique knowledge to other team members. The goal is to help others understand the information well enough to integrate it with their own unique information and develop their own understanding (Alavi & Leidner, 2000). Team members need to develop some common ground about the task (e.g., Stahl, 2005) to ensure that they have some common knowledge about the situation before discussing their unique information. Each member's unique information is typically embedded within the jargon and frameworks of that domain (Carlile, 2002), so transmitting unique information requires transferring knowledge rather than just mentioning information. It requires others to attend to the information so they can remember it (Wu, Hsu, & Yeh, 2007). Communicating in a way that transfers knowledge should ease difficulties in retaining new information and applying it to one's existing schema about the task.

Transferring knowledge entails several steps. First, unique information must be mentioned by the person who originally held it. Then, other team members must understand that information well enough to internalize it into their schemas in a way that allows them to remember and recognize it (Rentsch, Mello, & Delise, 2010). Therefore, information does not become transferred knowledge until another team member assimilates the content into his/her own schema about the task. When the *content* is stored, this reflects that the knowledge has been transferred to the receiver, who should be able recognize that information. However, it does not necessarily mean that the information has been *structured* in the schema such that it can be recalled for later use. When all team members are actively involved in sending and receiving knowledge, the team's pool of transferred knowledge should increase, giving team members a greater understanding of the available task information, which should foster positive team outcomes.

Interoperable Knowledge

Although transferred knowledge has been integrated into a team member's schema well enough to recognize or remember it, it is not necessarily useful or meaningful to that member. Interoperable knowledge, on the other hand, is defined as knowledge that has been assimilated into a schema such that an individual can not only recognize and understand it, but can also recall it and use it in some way. For example, interoperable knowledge (another member's unique information) may be used in combination with one's own unique information to identify task constraints, information deficiencies, or potential courses of action toward the team's solution (Rentsch, Mello, & Delise, 2010). Warner, Letsky, and Cowen (2005, p. 1) described the process of developing interoperable knowledge as "the act of exchanging useful, actionable knowledge among team members." Knowledge becomes interoperable through categorizing, organizing, and merging information into a schema (Warner & Letsky, 2008). Therefore, the distinction between transferred knowledge and interoperable knowledge lies in the ability of a team member to recall and use a piece of knowledge after receiving it from a teammate. A team member's knowledge is interoperable when *another* team member can integrate, organize, and use it (Rentsch et al., 2008). The definition of interoperable knowledge implies that the knowledge is embedded in the structure of one's schema, suggesting that a team member has reflected upon the information and determined how it is related to other task knowledge.

The differences between transferred and interoperable knowledge lie in storage and use of information. Cognitive research supports the idea that the differences between recognition and recall of information are reflected in differences in information storage. For example, research has suggested that there is an organizational (i.e., structural) component to information recall such that pairs of similar pieces of information were recalled together more often than pairs of dissimilar information (Schwartz & Humphreys, 1973). Studies have also shown that elaborate processing and coding of information facilitated recall of information, whereas semantic analysis only facilitated recognition (Craik & Lockhart, 1972). Also, changes in schema organization may increase the ability to recall information beyond what would be expected from mere re-exposure to the information (Semb & Ellis, 1994). Hebert and Burt (2004) designated the discrepancies between recognition and recall as a "remember-to-know" shift, highlighting that individuals who performed well on "remember" multiple choice tests did not perform as well on "know" tests that addressed interrelationships among information pieces. Additionally, they indicated that detail-rich experiences can foster development of schemas with complex structures, which can facilitate recall as opposed to recognition. These studies provide support for the theory that interoperable knowledge (which links new information to existing schema information), and transferred knowledge (which can be included in a schema but is not strongly linked with other information) are cognitively distinct concepts. For a piece of information to become interoperable or to be recalled, the team member must elaborate on the information to elucidate its relationships with other pieces of information and the schema must reflect those linkages. Thus, interoperable knowledge is stored differently in memory than transferred knowledge.

Optimally, a piece of knowledge should be interoperable among all team members to promote its effective use in determining a team's solution. However, although individuals are heavily influenced by the team's discussion of information and its meaning, individuals make their own interpretations about the ways new knowledge can be used and *structured* with knowledge that already exists in their schemas (Stahl, 2005). Therefore, one team member being able to utilize the information does not ensure that all team members can use it in the same way, or that they all similarly understand how it is related to the entire pool of task knowledge. Nonetheless, when the team has a large pool of interoperable knowledge, it will increase the amount of information that can be recalled and used by the team, which should foster positive outcomes for the team.

Summary

Schema changes develop as team members externalize and internalize task information. Transferred knowledge represents a piece of uniquely held information that has been transferred to team members who did not originally hold that information. Similarly, interoperable knowledge represents a piece of unique information that has been made interoperable for team members who did not originally hold that information. The difference is that transferred knowledge can be remembered and recognized, whereas interoperable knowledge can be recalled and utilized by team members. The following section describes how the development of these team cognition variables may be achieved by externalizing the *content* and *structure* of information through mechanisms such as schema-enriched communication behaviors and knowledge object development behaviors.

Chapter 4

Externalization: Behaviors to Promote Team Cognition Variables

Externalization mechanisms (e.g., tools, behaviors) can help team members effectively share information about cognitive *content* and *structure* so other members can understand and internalize that information. Externalization mechanisms allow team members to make information explicit and available to all team members and to discuss information until team members think about it in similar ways (Clark & Brennan, 1991; Rentsch et al., 2008). Research indicates that some kinds of externalization behaviors are more effective than others (Baker & Lund, 1997) and that team members can be trained to use effective externalization behaviors to communicate information and relationships among pieces of information via technology (Rentsch, Mello, & Delise, 2010). Technologies that allow team members to visually represent and manipulate information can promote the development of similar interpretations and schemas (Derry & LaJoie, 1993; Jonassen, 1995) if they support externalizing information and questioning or changing the externalizations. Training in the use of effective externalization behaviors should facilitate team member interactions in ways that can lead to development of team cognition variables. Two such externalization mechanisms are schema-enriched communication behaviors made through text chat and knowledge object development behaviors made through figural representations on a team information board. Each type of externalization behavior is described in the following sections.

Schema enriched communication behaviors

Schema-enriched communication is one type of externalization behavior that distributed teams can utilize as an aid for articulating their knowledge in text chat dialogs (Rentsch et al., 2008). Schema-enriched communication (SEC) is the use of certain behaviors to impart and elicit team members' understandings of the team's information pool and the relationships among those pieces of information. The term schema-enriched means that the behaviors communicate the content and structure of each member's schema, therefore enriching what the team knows and understands. SEC behaviors include telling one's own information to teammates and asking teammates for their relevant information. In order to communicate depth of meaning, team members should tell what they know, why they believe it is important to the task, the relationships they see between pieces of information, and whether or not they understand and agree with their teammates. Additionally, team members should seek depth of meaning from their teammates by asking them questions about what they know, why they believe it is important, what are the connections they see among pieces of information, and whether or not they understand and agree with what is being discussed (Rentsch, Delise, Salas, & Letsky, 2010).

Rentsch, McNeese, Pape, Burnett, Menard, and Anesgart (1998) examined the use of SEC behaviors among team members and found that increased use was positively related to team identification of the problem space and consideration of multiple solution alternatives (components of team performance). In terms of relaying *content* information, Mello, Rentsch, Delise, Staniewicz, and Letsky (April 2009) found that the number of SEC behaviors used by a team (particularly telling unique information) predicted the amount of knowledge transferred among distributed team members. In terms of relaying *structure* information, research supports a positive relationship between communication behaviors analogous to telling why and telling connections (e.g., elaborations) and cognitive outcomes (e.g., memory and understanding, Suthers, 2001; memory, Stein & Bransford, 1979; shared knowledge among dyad members, Fischer & Mandl, 2005). Elaborations may improve memory because rather than simply helping individuals remember facts, they help them understand the relevance of information (Stein &

Bransford, 1979). In addition, one study found that members of distributed dyads needed to utilize more behaviors to check their understanding of each others' messages than face-to-face dyads in order to maintain similar performance levels (Doherty-Sneddon, Anderson, O'Malley, Langton, Garrod, & Bruce, 1997). Given this evidence, the use of SEC behaviors should similarly encourage the development of team cognition variables.

Because team members can often forget to relay their information to others in meaningful ways, team discussions should benefit from explicit training on the use of these behaviors. Students trained to communicate with one another using elaboration and explanation methods provided more explanations, asked more task related questions, and made more assertions to counter other team members' arguments than those who did not receive training (Meloth & Deering, 1994). Additionally, students trained to ask their team members questions to reveal and clarify the relevance of information elaborated upon information more effectively and learned more of the task information than those who were not trained (Stein & Bransford, 1979).

Knowledge Object Development Behaviors

The second method for externalizing information, the development of a knowledge object, is of particular interest in the present study. A knowledge object is a depiction team members create about a problem (Warner & Letsky, 2008). Knowledge objects are visual externalizations where team members represent their knowledge to combine their cognitions about the problem so they can understand other members' information. Carlile (2002) suggested that because boundary objects (similar to knowledge objects) are shareable across contexts, team members can use them to represent their knowledge and develop a shared language for communicating about the task. In this way, a knowledge object "sits in the middle" of team members with information from different domains (Star, 1989) and allows them to communicate and coordinate their viewpoints (Fischer, Giaccardi, Eden, Sugimoto, & Ye, 2005). As team members externalize their knowledge visually and figurally, that knowledge becomes accessible to others and is available for the team to analyze (Boland & Tenkasi, 1995). Team members can identify where their thoughts about the task converge or diverge (Nosek, 2004) and engage in discussion to develop shared meaning about the task information (e.g., Ancona, Okhuyson, & Perlow, 2001; Boland & Tenkasi, 1995; Nosek, 2004; Roschelle, 1994; Suthers & Hundhausen, 2003). Knowledge objects also promote perspective taking (Boland & Tenkasi, 1995) such that team members can see where information from their unique domains interact and affect the task (e.g., Ancona, et al., 2001; Scaife & Rogers, 1996) and where dependencies may exist among expert areas (Carlile & Rebentisch, 2003). Knowledge objects represent reality in ways that reduce the complexity (Roth & McGinn, 1998) inherent in situations where team members must utilize knowledge across domains.

Using a knowledge object, team members can communicate about the information each member holds, particularly when each member takes an active part in creating the object using knowledge object development (KOD) behaviors. In the C-MAP intervention, the team's knowledge object was an electronic information board where team members posted and organized the team's information based on training they received. KOD behaviors that team members could use to facilitate the development of the knowledge object and externalization of the team's information about the task were *posting content*, *highlighting content*, *conveying structure within domain*, and *conveying structure across domains*. Posting content refers to posting pieces of information onto the board for the other team members to view. Highlighting content includes placing isolated pieces of information such that the information is not clustered with other pieces and flagging pieces of information by placing a marker to designate the information as being important for the team to remember. Posting, flagging, and placing isolated pieces of information can help teams remember the information *content* without needing to memorize it (e.g., Marcus, Cooper, & Sweller, 1996; Scaife & Rogers, 1996; Suthers & Hundhausen, 2003) and can provide a physical means of referencing information during discussion (e.g., Clark & Brennan, 1991; Suthers & Hundhausen, 2003).

Conveying structure within domain refers to organizing pieces of information into clusters such that the information from one domain is placed near other pieces of information from the same domain to illustrate that those pieces are related to one another. Conveying structure across domains refers to organizing pieces of information into clusters such that the information from one domain is placed near pieces of information from different domains to illustrate that those pieces are related to one another. Conveying structure within and across domains through visual representations of relationships can free team members' cognitive memory resources (Beers, Boshuizen, Kirschner, & Gijselaers, 2006) and promote similar internalization of the information *structure* across team members.

Research provides evidence that knowledge objects can facilitate the development of team cognition variables through their effects on memory, recall, and schema organization. For example, externalizations can reorganize task information in a way that supports recalling information (Levin, Anglin, & Carney, 1987), remembering explanatory information (Mayer, 1989), and when used alongside text, improving comprehension (Hegarty & Just, 1993). They can also reduce inference (Larkin & Simon, 1987; Koedinger & Anderson, 1990) and ambiguity that may exist about relationships among pieces of task information (Winn, 1987). These kinds of knowledge objects can also foster an understanding of the structure or connections among pieces of information (e.g., Levin et al., 1987; Mayer, 1989). Particularly, diagrams can foster the development of interconnected, organized mental models about relationships between concepts from different areas (e.g., learning modules; Fiore, Cuevas, & Oser, 2003), which suggests that knowledge objects help team members identify relationships between unique information pieces from different expert domains. In summary, research indicates that knowledge objects can display *content* and *structure* of information and can help team members develop similar cognitions about task materials.

Although previous research on knowledge objects and other similar externalizations has highlighted their overall effectiveness for team decision making no studies have investigated the effectiveness of particular behaviors used to develop a knowledge object. Regardless, because KOD behaviors are the vehicles through which knowledge objects can represent the *content* and *structure* of team members' schemas, it was expected that the use of trained knowledge object development behaviors would enhance the development of transferred and interoperable knowledge. The following section describes the present study and delineates the expected relationships between knowledge object development behaviors and team cognition variables.

Chapter 5

The Present Study

The present study is part of a larger study in which distributed teams were able to engage in SEC and KOD behaviors. Teams received the Collaboration and Meaning Analysis Process (C-MAP) intervention, which included training on the use of knowledge object development behaviors. They were taught to display, organize, and structure the team's information on an information board using KOD behaviors. Teams utilized their team information board to externalize information while conducting their task discussion via text chat. The entire C-MAP intervention was designed to support the development of transferred and interoperable knowledge.

Studies have found that the C-MAP intervention was successful in face-to-face and distributed teams. Face-to-face teams that received the C-MAP intervention had more transferred knowledge and interoperable knowledge, and higher task performance than teams that did not receive the intervention (Rentsch, Delise, et al., 2010). Distributed teams that received the C-MAP intervention had more transferred knowledge and higher task performance than did teams that did not receive the intervention (Rentsch, Delise, Mello, & Letsky, in preparation). These studies indicated that the entire C-MAP intervention was associated with the development of team cognition variables. However, the authors did not examine how KOD behaviors used to externalize specific pieces of information were related to the transfer of those information pieces to other team members and the interoperability of those pieces for other team members.

Pieces of Information as the Unit of Analysis

Several researchers have studied externalization behaviors in decision making teams by examining changes in patterns of communication behaviors over phases of group interactions (e.g., Bales & Strodtbeck, 1951; Fisher, 1970). However, the present study focused on micro level behaviors involving *single pieces of information* associated with the content and structure of the information being internalized. Because the team cognition outcomes of interest reflected internalization of *pieces* of information as transferred or interoperable, it was logical to investigate externalization behaviors with respect to the pieces of information they explicated. Therefore, the unit of analysis for the present study is the piece of information. The following paragraph highlights research that supports examining team behaviors in this manner.

Research suggests that it is appropriate to examine how teams discuss and utilize their available pieces of information. For example, Poole (1981) coded pairs of action-reaction behaviors among team members, which indicated that the teams progressed through multiple small cycles of decision making that focused around specific topics of information rather than progressing through a single decision making cycle across the entire team discussion. Similarly, Scheidel and Crowell (1964) found that teams experienced multiple small spiral cycles that centered around topics of information in which the teams reached a point where either (a) disagreement about a piece of information led to a different round of discussion of that information or (b) agreement about a piece of information led to another spiral-cycle discussion of a new topic of information. Discussion during each spiral cycle centered on a different topic, so new cycles continued to arise as the team members discussed their information until the team reached a decision. Beers, Boshuizen, Kirschner, and Gijselaers (2005) found that teams negotiated the meaning of information through discussing differences in understanding of information across team members, giving feedback, internalizing new understandings of that information that may have developed through discussion, and continuing that cycle until the team reached an agreement about the information. Research also suggests that teams can go through cycles of determining the usefulness and meaning of information and deciding how to arrange their information within a knowledge object (Smeds, Jaatinen, Hirvensalo, & Kilpio, 2006).

These findings indicate that the behaviors team members use to externalize pieces of information are important in sharing and negotiating *content* and *structure* of information in team discussion and that externalization behaviors may affect how team members internalize information and understanding into their task schemas. Therefore, in the present study, KOD behaviors used to externalize each piece of information were expected to affect a team's transferred knowledge and interoperable knowledge.

Hypotheses

In distributed teams, pieces of information externalized using a knowledge object to represent the content and structure of information are expected to be internalized as transferred knowledge and interoperable knowledge. Knowledge object development (KOD) behaviors in four categories are likely to influence the internalization of transferred knowledge and interoperable knowledge in different ways (see Table 1). Because transferring knowledge to other team members involves the externalization and internalization of *content*, KOD behaviors that convey content of pieces of information were expected to support the transfer of knowledge. Specifically, *posting content* of information pieces should be positively related to transferred knowledge because posting represents the *content* of information on the information board and allows team members to view that content. Moreover, it was expected that for pieces of information that were posted, there would be a positive relationship between *highlighting* the *content* of pieces and those pieces becoming transferred knowledge. Behaviors that highlight content were expected to draw the attention of all team members to pieces of information and therefore help team members to remember or recognize the *content* of that information. Therefore, the following hypotheses were tested.

Hypothesis 1: For each piece of information, *posting content* behaviors will positively predict transferred knowledge.

Hypotheses 2: For pieces of information that were posted, *highlighting content* behaviors will positively predict transferred knowledge.

Because interoperable knowledge represents unique information from one team member that other members organize into a usable *structure*, KOD behaviors that convey *structure* are expected to support interoperability of knowledge (see Table 1). Behaviors that *convey structure* of information pieces *within domain* should be positively related to those pieces becoming interoperable knowledge. These behaviors convey *structure* among pieces of information from the same domain (i.e., unique information from one team member) that are situated and embedded within that domain. In addition, the structure of those within domain relationships may become increasingly salient to team members who are unfamiliar with that domain when they are linked with information from the domains of other team members. Therefore, it was expected that behaviors that *convey structure* of information pieces *across domains* would be positively related to those pieces becoming interoperable knowledge, above and beyond behaviors that *convey structure within domain*. These behaviors convey *structure* across multiple domains to show how information from multiple team members is related. Behaviors that *convey structure across domains* should help team members see where common ground exists across their domains and organize information to show how the pieces can be used together to inform the team's decision making. Illustrating this *structure* may help team members learn how pieces of information from others' domains are relevant and useful with information from their own domains, making those pieces usable and operable for multiple team members. Therefore, the following hypotheses were tested.

Hypothesis 3: For pieces of information that were posted, behaviors that *convey structure within domain* will positively predict interoperable knowledge.

Hypotheses 4: For pieces of information that were posted, behaviors that *convey structure across domains* will positively predict interoperable knowledge, above and beyond behaviors that *convey structure within domain*.

Chapter 6

Method

Research Design

In this laboratory simulation study, 21 teams (each comprised of 3 student volunteers) participated in a simulation of a one-hour meeting of a geographically distributed, virtual rescue-mission planning team. The simulation had three specialized roles, each with specific, unique information. Common information was also available to all three team members. Before the simulation, each team member received approximately 45 minutes of training on information sharing in teams and on using software for communicating via text chat messages. Each team member then received a notebook with a statement of the problem, a description of one role (Weapons, Intelligence, or Environmental), the information uniquely available to that role (41, 21, or 13 pieces of information, respectively), and the common information that all members had (approximately 100 pieces of information). Team members had 45 minutes alone with their notebooks to prepare for the discussion.

In the one-hour meeting, the three team members worked from computer workstations in three separate rooms. They had access to a software system that had two components through which team members could interact: an online text chat area and a shared whiteboard onto which each individual could post personalized pieces of information, flag certain ones for special attention, and move them (for example, into clusters or blank areas). Each simulated team meeting yielded a video recording of everything that happened onscreen during the discussion (all text messages, posting, flagging, and re-positioning information items), which was transcribed. The 21 transcripts provided the data-source for this study, which were content-coded for the elements (see Appendix A) that were combined to create the four types of knowledge object development (KOD) behaviors (see Appendix B) performed on the unique information available to the three role-holders.

After the discussion, team members spent approximately one hour completing measures. Team members completed the interoperable knowledge measure, in which they independently recalled task information that was important to the rescue mission task and each identified the 10 pieces they felt were most important. These data were content coded to determine which pieces of unique, role-specific information were recalled by members who did not initially hold that information. Team members also completed the transferred knowledge measure, in which they individually responded to 75 true-false items that consisted of all the pieces of unique, role-specific information that were distributed across the roles. The items were scored to determine which role-specific items were answered correctly by members who did not initially hold that information. After completing the other measures used in the larger study, team members were debriefed and paid for their participation. Content-coded KOD behaviors, coded interoperable knowledge scores, and transferred knowledge scores for each of the 75 pieces of unique, role-specific information for each team were compiled into a data set.

Participants

The data for the present study were collected as part of a larger study at a large southeastern university. Participants were 63 undergraduate students who were assigned to 21 3-person teams. The sample consisted of 41.3% males. The sample was 85.7% Caucasian. Participant age ranged from 17 to 58 with an average of 20.8 years. Participants received $40 in cash for their participation. The majority of participants also received course credit for their participation. In addition, subjects had the opportunity to win an additional $30 if they were members of the top performing teams or if they were chosen in a random drawing of all participants.

Experimental Task and Intervention

Experimental task. The experimental task was a complex hidden profile task in which team members simulated military teams consisting of three members, each with unique role information in one of three areas (Biron, Burkman, & Warner, 2008). Each team member received the same general background information and different unique information consistent with the assigned role. Teams were instructed to use the information to develop a plan to rescue individuals stranded on an island that had been taken over by rebel forces.

C-MAP intervention. The Collaboration and Meaning Analysis Process (C-MAP) intervention (Rentsch et al., 2008) was used to teach the team members basic principles for sharing their unique role-specific information with one another through externalization methods (schema-enriched communication (SEC) behaviors and knowledge object development (KOD) behaviors) that aid members in understanding the task information and developing transferred and interoperable knowledge. Team members experienced three experimenter-led training activities. First, teams listened to a lecture on SEC behaviors. Second, team members were instructed on ways to externalize task knowledge onto an electronic team information board using KOD behaviors to convey content and to structure pieces of information from all team members. Team members viewed a video describing how to use four types of behaviors to develop a knowledge object: (1) *Posting content* of pieces of information to the board in bubbles color coded for each role, (2) *Highlighting* content of pieces of information by placing isolated pieces of information on the board and flagging pieces as important, (3) *Conveying structure* of information *within domains* by organizing pieces of information from one team member into clusters together, and (4) *Conveying structure* of *information across domains* by organizing pieces of information from multiple team members into clusters together.

Measures

Knowledge object development behaviors. Each piece in a pool of 75 pieces of task information was coded for the KOD behaviors the teams used to externalize that information piece on the team information board. There were four categories of KOD behaviors: posting content, highlighting content, conveying structure within domain, and conveying structure across domains. See Appendix A for a full list of codes that were combined to create KOD behaviors. The author of the present study coded the KOD behaviors for all teams and two research assistants each coded half of the teams. After coding independently, the author and the research assistants compared their ratings and discussed discrepancies until a consensus rating was reached (e.g., Smith-Jentsch et al., 2001). Simple interrater agreement between the author and each of the research assistants, calculated using methods consistent with agreement calculation techniques used by Rentsch, Delise, et al. (2010), was high (93.3% and 94.6%, respectively). These codes were combined to create the following variables, which were aggregated and labeled in two ways: (1) to the piece of information level, in which the variable values for each piece of information were aggregated across the 21 teams to create a mean score and labeled with (P) (e.g., for a given piece of information, posting content scores were aggregated across the 21 teams and referred to as posting content(P)) and (2) to the team level, in which the variable values were aggregated across all 75 pieces of information to create a mean score for each team and was labeled with (T) (e.g., for a given team, posting content scores were aggregated across all 75 items and referred to as posting content(T)). See Appendix B for an explanation of how the codes from Appendix A were combined to create each of the following variables.

Posting Content. Posting content was calculated as a sum of how many times a piece of information was posted or reposted. Typically, each piece of information was posted once, but a piece of information could be posted again by another team member, or could be deleted and reposted, thereby increasing the posting content value. At the unaggregated level, Posting content ranged from 0 to 3 with a mean of .42 and a standard deviation of .61. Therefore, when Posting content values for each piece of information were aggregated to the piece of information level by averaging across teams, Posting content(P) ranged from 0 to 1.24, with a mean of .42 and a standard deviation of .31.

Highlighting Content. Highlighting content was calculated as a sum of how many times behaviors that call attention to content were used on each piece of information, such as placing an isolated piece of information on the information board and flagging a piece of information as important for the team's discussion. At the unaggregated level, Highlighting content ranged from 0 to 6 with a mean of 1.07 and a standard deviation of 1.06. Therefore, when Highlighting content values for each piece of information were aggregated to the piece of information level by averaging across teams, Highlighting content(P) ranged from 0 to 2.00, with a mean of .97 and a standard deviation of .47.

Conveying Structure Within Domain. Conveying structure within domain was calculated as a sum of how many times a piece of information was clustered or moved simultaneously with at least one other piece of information from the same content domain. At the unaggregated level, Conveying structure within domain ranged from 0 to 20 with a mean of 3.73 and a standard deviation of 2.81. Therefore, when Conveying structure within domain values for each piece of information were aggregated to the piece of information level by averaging across teams, Conveying structure within domain(P) ranged from 0 to 8.33, with a mean of 3.68 and a standard deviation of 1.73.

Conveying Structure Across Domains. Conveying structure across domains was calculated as a sum of how many times a piece of information was clustered or moved simultaneously with at least one piece of information from a different content domain. At the unaggregated level, Conveying structure across domains ranged from 0 to 24 with a mean of 1.89 and a standard deviation of 3.23. Therefore, when Conveying structure across domains values for each piece of information were aggregated to the piece of information level by averaging across teams, Conveying structure across domains(P) ranged from 0 to 5.75, with a mean of 1.76 and a standard deviation of 1.02.

Team cognition variables. For each piece of information, transferred knowledge scores and interoperable knowledge scores were aggregated and labeled in two ways: (1) to the piece of information level, in which the variables values for each piece of information were aggregated across the 21 teams to create a mean score and labeled (P) and (2) to the team level, in which the variable values were aggregated across all 75 pieces of information to create a mean score for each team and labeled with (T).

Transferred knowledge. As part of the larger study, transferred knowledge was assessed using a 75-item test (Rentsch, Delise, Mello, Staniewicz, & Scott, 2008). Each *true/false/don't know* item addressed one piece of role-specific, unique information that was important to developing the optimal task solution. The transferred knowledge score for each piece of information was calculated by determining if the team member who originally held that piece of unique information responded correctly, then determining if either of the other teammates responded to the information correctly. If either teammate responded correctly, the knowledge was transferred. If a piece of information was not transferred to either teammate, it received a value of 0, if it was transferred to one other teammate, it received a value of 1, and if it was transferred to both other teammates, it received a value of 2. At the unaggregated level, Transferred knowledge ranged from 0 to 2 with a mean of 1.06 and a standard deviation of .86. Therefore, when Transferred knowledge values for each piece of information were aggregated to the piece of information level by averaging across teams, Transferred knowledge(P) had a mean of 1.04, a standard deviation of .60, and a range of 0 to 2.00.

Interoperable knowledge. Interoperable knowledge was assessed using a recall procedure (Rentsch et al., 2008). During a 10-minute period, team members recalled pieces of information they believed to be important to the team in planning the rescue mission and entered them into a Microsoft Word document. Then, each team member selected the 10 pieces of information from his or her own list that he or she believed were most important to the development of the team's plan.

The ability to recall *unique* information initially held only by another expert indicated that the information was incorporated into one's schema in such a way that it had become interoperable among the team members. By recalling information initially held solely by another team member, team members revealed that they understood the information, encoded it in such a way that it was recalled rather than just recognized, and integrated it with the other knowledge used to form the team's rescue plan. The 75 pieces of information assessed in the transferred knowledge measure were also assessed for interoperability. If either team member who did not originally hold the piece of information recalled it, the knowledge was interoperable. If a piece of information was not interoperable for either teammate, it received a value of 0, if it was interoperable for one other teammate, it received a value of 1, and if it was interoperable for both other teammates, it received a value of 2. At the unaggregated level, Interoperable knowledge ranged from 0 to 2 with a mean of .39 and a standard deviation of .67. Therefore, when Interoperable knowledge values for each piece of information were aggregated to the piece of information level by averaging across teams, Interoperable knowledge had a mean of .27, a standard deviation of .29, and a range of 0 to 1.06.

Data Collection Procedure

Team members were randomly assigned to teams and were given information about the team's task. Team members then received SEC and KOD behavior training and participated in an example illustrating the use of both types of behaviors in conjunction. Team members were distributed in three different rooms and had 45 minutes to review task information. After reviewing the information, the team used computer software to discuss the task and post information to the team information board for an hour to determine a solution. After the task, team members completed the interoperable knowledge and transferred knowledge measures, along with additional measures used in the larger study.

Present Study Procedure

For the present study, data from 21 teams that received the C-MAP intervention were transcribed and coded. Each team's one-hour task session (chat discussion and team information board use) was recorded using Camtasia (video screen capture software). The team's one-hour chat was also recorded and saved as a Microsoft Word document. Using Transana video transcription software, a complete transcript of the team's externalization behaviors during discussion was created using the screen capture video and the text chat. The text chat was used as a base transcript. The author of the present study and two research assistants blind to the study's hypotheses created a complete externalization behavior transcript for each team. The transcribers watched the team discussion video and amended the chat transcript to include behaviors that occurred on the team information board. The transcript containing the text chat and information board behaviors is referred to as the complete transcript.

Knowledge object development (KOD) behaviors that occurred on the team information board were coded by the author of the present study and second coded by two research assistants who each coded half of the teams. After the KOD coding scheme was established, the research assistants were trained to the criterion through discussion of the specific codes in the scheme and the process to use for assigning those codes and through jointly coding a practice team with the author of the present study. Next, each second rater coded one team, both of which were coded by the author of the present study, and the ratings were compared for agreement.

When one of the 75 pieces of information was externalized on the information board and was logged in the complete externalization transcript, it was coded with a number representing that piece of information. This allowed the researcher to identify which KOD behaviors were used to externalize each piece and to link the KOD behaviors with the transferred and interoperable knowledge scores for each piece of information. After the KOD variables (e.g., posting content, conveying structure across domains) were computed, the data for each information piece were compiled, producing 1,575 cases (pieces of information) with one value for each predictor and criterion variable. Then, values for each piece of information were aggregated across the 21 teams to produce a data set with 75 cases (pieces of information) and across pieces of information within each team to produce a data set with 21 cases (teams).

Chapter 7

Results

Analysis of Data Aggregated by Piece of Information

The hypotheses were tested at $p < .05$ and only results significant at that level are reported below. Correlations, means, and standard deviations for variables aggregated to the piece of information level are presented in Table 2. Results at this level provided information about the relationships between the average KOD behaviors performed on a specific piece of information across all teams and the average transfer or interoperability scores for those aggregated items, therefore providing a test of the hypotheses irrespective of which team externalized the information. Correlations showed that posting content(P) was positively related to all other KOD behaviors. These strong positive relationships are to be expected because a piece of information must be posted before any other behaviors can be used to externalize the content and structure of that piece of information. The correlations between posting content and the team cognition variables were lower, but significant. Posting content(P) was correlated with interoperable knowledge(P) ($r = .74$) indicating that pieces of information that were posted were more likely to become interoperable than pieces that were not posted. Correlations also indicated a positive relationship between posting content(P) and transferred knowledge(P), as suggested in Hypothesis 1, which was tested by regressing transferred knowledge(P) on posting content(P). Hypothesis 1 was supported. Posting content positively predicted transferred knowledge ($\beta = .34$, $F_{(1, 73)} = 9.30$; see Table 3).

Hypotheses 2-4 were tested using data for the pieces of information that were posted for each team. Hypothesis 2 was tested by regressing transferred knowledge(P) on highlighting content(P). Hypothesis 2 was not supported. Highlighting content did not predict transferred knowledge (see Table 3). In addition to the two hypothesized relationships involving transferred knowledge, correlations indicated that transferred knowledge was significantly negatively correlated with conveying structure within domain(P) (r = -.26) and conveying structure across domain(P) (r = -.21).

Hypotheses 3 and 4 were tested using hierarchical regression (see Table 4). In Step 1, interoperable knowledge(P) was regressed on conveying structure within domain(P). In Step 2, conveying structure across domains(P) was entered into the equation. Hypothesis 3 was not supported. Conveying structure within domain did not predict interoperable knowledge. Additionally, Hypothesis 4 was not supported. Conveying structure across domains did not predict interoperable knowledge.

Examination of curvilinear relationships. Post hoc regressions were conducted to examine curvilinear relationships between the KOD variables and the team cognition variables because it was suspected that a moderate amount of behaviors may be associated with high cognition values but too few or too many behaviors may be associated with low cognition values. In order to reduce the multicollinearity between the original variables and the quadratic variables in the regression equations, the original variables were centered before squaring them to form the quadratic variables (Cohen & Cohen, 1983). The centered variables and their squares were utilized in each regression equation testing for curvilinear relationships.

The relationship between posting content and transferred knowledge was examined by regressing transferred knowledge(P) on posting content(P) and the quadratic term of posting content(P). The results revealed that posting content(P) (β = .47) and the quadratic term of posting content(P) (β = -.25) predicted transferred knowledge (R^2 = .16, $F_{(2, 72)}$ = 6.88; see Table 5).

The remaining proposed relationships were examined using only pieces of information that were posted for each team. The relationship between highlighting content and transferred knowledge was tested by regressing transferred knowledge(P) on highlighting content(P) and the quadratic term of highlighting content(P). Highlighting content(P) ($\beta = .71$) and the quadratic term ($\beta = -.69$) predicted transferred knowledge ($R^2 = .13$, $F_{(2, 70)} = 4.85$; see Table 5).

The relationships between conveying structure within domain and across domains and interoperable knowledge were tested using hierarchical regression (see Table 6). In Step 1, interoperable knowledge(P) was regressed on conveying structure within domain(P) and the quadratic term of conveying structure within domain(P). In Step 2, conveying structure across domains(P) and the quadratic term of conveying structure across domains(P), were entered into the equation. Neither relationship was supported.

Analysis of KOD components. Because each of the KOD variables was composed of components which may differentially contribute to the predictive ability of the variables, a set of analyses was conducted to investigate the relationships of the component variables with transferred knowledge(P) and with interoperable knowledge(P). The components are listed in Appendix B. For example, posting content has two components, (1) posting and (2) reposting, and conveying structure within domain has five components, (1) moving a piece of information simultaneously with one or more pieces of information from the same domain, (2) initially placing a piece of information near information from the same domain, (3) initially placing a piece of reposted information near information from the same domain, (4) moving a piece of information near information from the same domain, and (5) a piece of information attracting a piece of information from the same domain). Correlations, means, and standard deviations for component variables are presented in Table 7.

The proposed relationships were explored using the same technique described above with the components substituted for the original KOD variables. The relationship between posting content and transferred knowledge was tested using simultaneous regression to determine if the components of posting content(P) predicted transferred knowledge(P). Posting information (β = .35) predicted transferred knowledge(P), but reposting information did not (R^2 = .12, $F_{(2, 72)}$ = 4.85; see Table 8).

The remaining proposed relationships were examined using only pieces of information that were posted for each team. The relationship between highlighting content and transferred knowledge was evaluated using simultaneous regression to determine if the components of highlighting content(P) predicted transferred knowledge(P). The model as a whole did not predict transferred knowledge(P) (see Table 8) and three components (flagging information, initially placing reposted information in a blank area, and moving information to a blank area) had nonsignificant betas. However, bivariate correlations revealed that initially placing information in a blank area significantly predicted transferred knowledge(P) (r = .29; see Table 7).

The relationships between conveying structure within domain and across domains and interoperable knowledge were tested using hierarchical regression (see Table 9). In Step 1, interoperable knowledge(P) was regressed on the components of conveying structure within domain(P). In Step 2, the components of conveying structure within domain(P) were added to the model to determine if any of these components predicted above and beyond the within domain components. The model in Step 1 predicted interoperable knowledge (R^2 = .24), and one component, initially placing a piece of reposted information near information from the same domain, had a significant beta ($\beta = .38$). However, the model in Step 2 did not predict interoperable knowledge beyond the within domain components.

Exploratory Analysis of Data Aggregated by Team

Two series of exploratory analyses were conducted to further investigate the hypothesized relationships. First, the proposed relationships between cognition variables and KOD variables were analyzed using data aggregated to the team level. Second, the proposed relationships between cognition variables KOD variables and their components were analyzed using unaggregated data. The same regression procedures conducted above for hypothesis testing were also used to examine each set of relationships in the exploratory analyses. The relationship between posting content and transferred knowledge was examined by regressing transferred knowledge on posting content variables. The remaining relationships were examined using only data from the pieces of information that were posted by each team. The relationship between highlighting content and transferred knowledge was examined by regressing transferred knowledge on highlighting content variables. The relationships between the conveying structure variables and interoperable knowledge were examined using hierarchical linear regression. In Step 1 of each analysis, interoperable knowledge was regressed on conveying structure within domain variables. In Step 2, conveying structure across domains variables were entered into the model to determine if they accounted for variance in interoperable knowledge above and beyond conveying structure within domain behaviors. For these exploratory analyses, relationships were tested at $p < .05$ and only results significant at that level are reported below.

First, the proposed relationships were examined at the team level of analysis. These results provided information about the relationships between the average KOD behaviors performed by each team across all unique items and the average degree of transfer or interoperability across those items. Correlations, means, and standard deviations for variables aggregated to the team level are presented in Table 10.

Results indicated that neither posting content(T) nor highlighting content(T) predicted transferred knowledge(T) (see Table 11), although correlations indicated a negative relationship between transferred knowledge and highlighting content ($r = -.37$). In addition to the two proposed relationships involving transferred knowledge, correlations indicated that transferred knowledge was also significantly, negatively related to conveying structure within domain(T) ($r = -.48$). Additionally, conveying structure within domain and conveying structure across domains did not predict interoperable knowledge (see Table 12). Therefore, no support was found for any of the proposed relationships at the team level.

Exploratory Analysis of Unaggregated Data

Second, a set of exploratory analyses was conducted to investigate the hypothesized relationships using the unaggregated data. These results provided information about the relationships between the KOD behaviors used to externalize each item and the degree of transfer or interoperability of each item, therefore providing a test of the relationships irrespective of which item is being externalized by the behavior. Correlations, means, and standard deviations for unaggregated variables are presented in Table 13.

Because KOD values for items externalized by a team are not independent, a vector of nominal dummy-coded variables (referred to here as “team identification variables”) were included in the analyses of the unaggregated data to determine whether differences between teams may have explained some of the variance in the individual level cognition outcomes for pieces of information. James and Williams (2000) delineated that a set of team identification variables can be utilized in regressions to examine team level effects when predictor variables of interest (e.g., posting content, conveying structure within) and the criterion variable (e.g., transferred knowledge) are at the individual level. In the following hierarchical regressions using unaggregated data, the team identification variables were entered as the first step of the regression, then the appropriate KOD variable(s) were entered in subsequent steps to investigate if the KOD variables explained variance in the team cognition variables above and beyond between-teams effects.

Exploratory analysis with team identification vector. The hypothesized relationships were examined using linear regression in a similar manner as the above regressions, with the team identification vector entered in Step 1 of each regression. Posting content predicted transferred knowledge above and beyond team ($\beta = .29$, $F_{\text{change } (1, 1{,}500)} = 142.84$, see Table 14), but highlighting content did not explain additional variance in transferred knowledge beyond team (see Table 15). When controlling for team, conveying structure within domain did not significantly predict interoperable knowledge in Step 2 of the model. However, in Step 3 conveying structure across domains ($\beta = .23$) significantly predicted interoperable knowledge beyond conveying structure within domain and team ($\Delta R^2 = .04$, $F_{\text{change } (1, 544)} = 21.75$, see Table 16). Additionally, when conveying structure across domains is entered into the model, conveying structure within domain has a significant beta ($\beta = -.18$).

Exploratory analysis of KOD components with team identification vector. Next, regressions were conducted on the unaggregated data using the components of the KOD variables, as described above for the aggregated piece of information level, after first controlling for team with the vector of team identification variables. Correlations, means, and standard deviations for the component variables are presented in Table 17.

Posting information predicted transferred knowledge (β = .29; ΔR^2 = .08, $F_{\text{change}\ (2,\ 1{,}500)}$ = 142.84) above and beyond team effects, but reposting information did not (see Table 18). None of the highlighting content components explained additional variance in transferred knowledge above and beyond team (see Table 19).

When controlling for team level effects, none of the components of conveying structure within domains significantly predicted interoperable knowledge (see Table 20). However, when controlling for team and conveying structure within components, conveying structure across domains components accounted for additional variance in interoperable knowledge (ΔR^2 = .04, $F_{\text{change}\ (4,\ 544)}$ = 5.98). Specifically, two conveying structure across domains components (moving a piece of information near a piece of information from a different content domain (β = .13) and attracting a piece of information from a different content domain (β = .15)) positively predicted interoperable knowledge beyond the within domain components. Also, one additional conveying structure across domains component (simultaneously moving a piece from one domain with a piece from a different domain) had a *p* value of .05 (β = .09).

Chapter 8

Discussion

The purpose of the present study was to examine the relationships between knowledge object development (KOD) behaviors and team cognition variables (transferred knowledge and interoperable knowledge) in distributed teams. A summary of results is presented in Table 21. First, results supported the proposed relationship between posting content and transferred knowledge, indicating that posting unique information to the knowledge object was related to team members who did not initially possess it being able to recognize it later. Second, a curvilinear relationship between highlighting content and transferred knowledge was found, indicating that performing a moderate amount of highlighting behaviors was related to helping team members internalize and recognize other members' unique information. Third, the predicted positive relationship between conveying structure within domain behaviors and interoperable knowledge was supported for only one within domain component. Fourth, exploratory results at the unaggregated level were consistent with the hypothesis that conveying structure across domains behaviors would positively predict interoperable knowledge beyond conveying structure within domain behaviors. Results are discussed in the following section.

Hypothesized Relationships Between KOD Behaviors and Team Cognition Variables

The test of Hypothesis 1 showed that posting content behaviors had linear and curvilinear relationships with knowledge transfer at the piece of information level. It was expected that posting the content of information would predict transferred knowledge because it would afford visualization of information (e.g., Marcus et al., 1996; Scaife & Rogers, 1996; Suthers & Hundhausen, 2003) and common ground (Nosek, 2004) that assisted in the internalization and transfer of information to team members who did not initially possess it. The curvilinear relationship that was found indicated that there may be an optimal level of posting pieces of information that promotes transfer of knowledge. However, failure to post a piece will likely hinder its transfer because it was not available for the team to view. Additionally, posting a piece of information multiple times (through deleting and reposting the same piece of information or through multiple team members posting the same piece of information) may also hinder knowledge transfer, perhaps because team members may become confused about which pieces of information are important enough to be remembered. Upon further exploration, results for the unaggregated data also revealed a linear relationship between posting content and transferred knowledge. Overall, results support the notion that posting information to the knowledge object (at least once) can promote the transfer of knowledge between team members.

The test of Hypothesis 2 did not support a linear relationship between highlighting content and transferred knowledge. However, post hoc analyses indicated that there was a curvilinear relationship between highlighting content and transferred knowledge at the piece of information level. The existence of a curvilinear relationship may explain why the results of linear regressions using highlighting content and its components were nonsignificant. It was expected that highlighting content behaviors would draw the attention of team members which would help them to recognize highlighted information pieces more often than nonhighlighted pieces. The curvilinear relationship suggests that transferred knowledge may be best supported by a moderate amount of highlighting content behaviors. Thus, highlighting behaviors that draw attention to important pieces of information should perhaps be utilized sparingly. Although regressions at the team level revealed no linear or curvilinear relationships, correlations at that level indicated that teams that performed more highlighting behaviors had less transferred knowledge than teams that performed fewer highlighting behaviors. That correlation suggests that when teams highlight many pieces of information team members may have their attention diverted in many directions, which may distract them from key pieces of information and may decrease the transfer of knowledge to multiple team members. In general, the results indicated that failure to highlight a piece of information may deter its transfer, but also that highlighting a single piece multiple times and highlighting many pieces within a team's knowledge object may also hinder knowledge transfer.

The test of Hypotheses 3 did not reveal a relationship between conveying structure within domain and interoperable knowledge at the piece of information level. However, one component of conveying structure within domain (initially placing a reposted piece of information near information from the same domain) positively predicted interoperable knowledge. It was expected that conveying structure within domain behaviors could be used to illustrate how information from a particular domain could be structured. These behaviors may assist team members who did not initially possess that information in understanding (and perhaps similarly internalizing) the domain structure held by the team member who did initially possess the information. Team members may help others develop and internalize similar structures by organizing externalized information to illustrate connections between pieces in a way that would promote information recall (e.g., Levin et al., 1987; Mayer, 1989). The significant finding for reposted information suggests that clustering reposted information with information from the same domain may promote interoperability by 1) illustrating the importance of the reposted piece and 2) by structuring the reposted piece in a way that reinforces its relationships with other pieces of information in its domain. Exploratory results at the unaggregated level revealed no significant relationships between conveying structure within or any of its components and interoperable knowledge when controlling for team level effects.

The test of Hypotheses 4 did not reveal a relationship between conveying structure across domains and interoperable knowledge at the piece of information level. It was expected that conveying structure across domains would indicate where information from different domains intersects and where domains may be interdependent (e.g., Ancona, et al., 2001; Carlile & Rebentisch, 2003; Scaife & Rogers, 1996). Externalizing the across domains connections should increase interoperability beyond conveying structure within domain because it may increase the salience of information from other domains. Team members can then store that salient information in a useful manner that emphasizes relationships between pieces. Although no support was found for the relationship at the piece of information level, exploratory analyses at the unaggregated level revealed support for this prediction when controlling for team level effects. Also, two across domains components (moving a piece of information into a cluster with information from a different domain and attracting a piece of information from a different domain) positively predicted additional variance in interoperable knowledge. In addition, the significance value was .05 for a third across domains component, simultaneously moving a piece on information from one domain with a piece of information from another domain. These behaviors may identify relationships that span the unique roles of the team members by clearly clustering pieces from different domains and emphasizing places where information from multiple domains can work together to help the team develop an understanding of the whole task. Exploratory findings at the unaggregated level revealed that, when controlling for team level effects, conveying structure across domains behaviors positively predicted interoperable knowledge and that externalization of structure in those ways should perhaps be encouraged during the development of a team knowledge object.

Overall, the results suggested that distributed team members developing a knowledge object through externalization behaviors should be encouraged to post content and highlight content with moderation in order to increase transferred knowledge and to convey structure across domains by clustering together information from different roles to increase interoperable knowledge.

Other Relationships Among KOD Behaviors and Team Cognition Variables

Correlations revealed some interesting relationships among the KOD variables. First, posting content was significantly related to the other three KOD behaviors and to both cognition variables at the piece of information level and the unaggregated level. Posting content was also significantly related to highlighting content and conveying structure within domain at the team level of analysis. These correlations indicated that pieces of information that were posted were often also externalized using the other KOD behaviors and that those posted pieces were more likely to be transferred and interoperable than pieces that were not posted. Anecdotally, the norms teams developed about how to use the information board may explain these correlations. Often, especially at the beginning of a discussion, pieces were posted then moved into blank areas, therefore isolating those pieces, which may explain the correlation across all levels of analysis between posting and highlighting content. Also, some teams developed norms in which each team member posted his/her unique information to the board, then clustered it together without immediately clustering information from different domains together. Therefore, if teams followed those typical practices of posting their pieces of information in blank areas (a highlighting content behavior) then placing them in same-domain clusters (a conveying structure within domain behavior), the team level correlations between posting content and highlighting content and between posting content and conveying structure within domain may be explained.

It should be noted that this pattern of behaviors may also explain the high team level correlation between highlighting content and conveying structure within domain, which was much higher at the team level (*r* = .76) than the correlation between those two variables at the aggregated piece of information level (*r* = .20) or the unaggregated level (*r* = .39).

Second, there were surprising findings regarding the conveying structure KOD behaviors. Conveying structure within domain and conveying structure across domains were moderately correlated at the piece of information level (*r* = .66), team level (*r* = .63), and unaggregated level (*r* = .50). A possible explanation for these correlations is that pieces of information often were not clustered with only pieces of their same domain information (even though they may have been initially for some teams) or clustered only with pieces of different domain information. Often, pieces of information were moved several times during the discussion, which likely included movement into clusters with information from the same and different domains, not just into same-domain-only clusters and different-domain-only clusters. Interestingly, conveying structure within domain behaviors were negatively related to the transfer of knowledge at all three levels of analysis and conveying structure across domains was negatively related to transfer at the aggregated piece of information level. Perhaps conveying structure promoted team members to think about pieces of information in terms of the pieces that surrounded them in a cluster. Thinking about those types of relationships would promote recall of information by team members (often in their own words) and perhaps hinder the rote memorization of facts that would facilitate correct responses on the true-false transferred knowledge measure (e.g., Craik & Lockhart, 1972; Hebert & Burt, 2004; Schwartz & Humphreys, 1973; Semb & Ellis, 1994). Also, unlike posting content and highlighting content, the conveying structure behaviors did not show curvilinear relationships with transferred and interoperable knowledge at the piece of information level of analysis, indicating that there may not be a point when performing additional clustering behaviors on a piece of information becomes detrimental to team members' abilities to encode and recall that piece.

Limitations

The present study has several limitations, including some threats for generalizing the results to full-time organizational teams. The first threat was that the sample consisted of undergraduate students. However, 42.9% of the students held jobs at the time of the study, with 59.3% of those students having held their job for over a year and 51.9% of them working 20 hours a week or more. Additionally, 54.8% of the students indicated they had been a member of five or more teams. The work and team experience of these participants suggested that this student sample may be somewhat generalizable to samples from work organizations. However, the participants in this study were engaged in a military task, although they had little to no military experience. Therefore they may have had limited understanding of their information, which may have been detrimental to their ability to understand, externalize, and internalize the task information.

A second threat was that the study was conducted in a laboratory environment. That environment can seem artificial compared to a work environment within an organization where training and subsequent team discussions may occur. However, because the C-MAP was a new intervention that was being tested for the first time with distributed teams and because KOD behaviors had never before been examined, internal validity was of greater importance for the present study than external validity for generalizing to organizational populations. Hackman (1987) delineated that lab studies are appropriate for this type of research in which concepts are being initially tested. Therefore, a controlled laboratory environment was utilized where a carefully designed study could be implemented to investigate new concepts.

In addition to these threats to external validity, a relatively small number of teams (n = 21) was examined in the present study, which may have affected the power to find results at the team level of analysis. However, it is not uncommon for team studies to utilize sample sizes of 20 or less (e.g., Buller & Bell, 1986; Eden, 1986; Entin & Serfaty, 1999; Ibbetson & Newell, 1996; Liang, Moreland, & Argote, 1995). In contrast, the sample size at the aggregated piece of information level was larger (n = 71), but still relatively modest. Additionally, the sample size was larger when examining the unaggregated data (n = 1,500 for analyses using posting content variables and n = 544 for all other unaggregated analyses). Although the smaller samples provide information about how team members convey the content and structure of information using a knowledge object, the aggregated findings should be interpreted with caution. Thus, future research should examine effects at the team level and for specific pieces of information across teams with larger samples. Also, the number of interoperable knowledge pieces was relatively small (n = 154) compared to the number of transferred knowledge pieces (n = 371) and to the total number of pieces of information that were posted to the information board (n = 564). This finding may illustrate the difficulty team members faced in recalling unique information from another's domain. With this small baseline of interoperable responses, the findings for regressions predicting interoperable knowledge should also be interpreted cautiously.

Contributions

The present study makes several contributions to the literature on communication in distributed teams. First, this study contributes to the knowledge object literature. To this author's knowledge, no study has coded pieces of information with respect to the behaviors used to externalize them within a knowledge object. The knowledge object literature has not focused specifically on behaviors used to externalize pieces of information or on cognitive outcomes for specific pieces of information. Most studies in that area have not explicated how knowledge objects function (Carlile, 2004). Also, because knowledge object studies are typically qualitative and are often case studies, the present study may be the first quantitative study of the specific behaviors used to develop knowledge objects and how those behaviors are related to team cognition outcomes. The results of the present study begin to address Carlile's (2002) question as to what constitutes a "good" knowledge object and how a "good" knowledge object can be distinguished from a "bad" one.

Additionally, the present study addresses calls by Salas, Cooke, and Rosen (2008) to extend the focus of team research to understanding complex team tasks (including communication and information sharing) and by Mesmer-Magnus and DeChurch (2009) to conduct additional research on information sharing and processing in distributed teams. The present study focuses on externalizing and internalizing unique information across team roles in distributed teams, which includes information sharing in the traditional sense (i.e., presenting information to the team) and processes that go beyond simple information sharing into visually conveying structure and content of information in ways that other team members can understand, remember, and recall it. These processes are not often examined in traditional information sharing studies. Therefore, the present study provides a unique way of investigating team process behaviors that occur during complex team tasks.

Implications and Suggestions for Future Research

The present study provides implications for future research regarding distributed team communication using knowledge objects to externalize and internalize task information. First, the findings of the present study suggested some specific behaviors that can be incorporated into a training module for the Collaboration and Meaning Analysis Process (C-MAP) intervention to teach team members how to use a team information board to present and organize their information effectively. Specifically, training may illustrate how team members can post information content and reasonably highlight the content of information pieces to increase the transfer of that knowledge to team members. Additionally, training can demonstrate effective ways of structuring knowledge across domains (such as moving pieces of information from different domains into clusters together to illuminate relationships and indicate how information from different roles can be utilized together) and admonish against ineffective ways of structuring information within domain (such as simultaneously moving pieces from the same domain or clustering pieces of information from the same domain).

Future research should also examine the pattern of KOD behaviors across a team's discussion period. The present study was designed under the assumption that teams discuss topics in micro level cycles and that the KOD behaviors used to externalize each piece of information would follow micro level patterns to effectively foster transferred and interoperable knowledge. However, future research should test for the existence of macro level patterns of KOD behaviors, such as temporal phases in the use of KOD behaviors that may occur as the knowledge object is developed. If such patterns exist, research should examine whether micro or macro patterns of KOD behaviors are more effective in promoting team cognition outcomes.

Finally, given the large number of information pieces that team members were asked to study and externalize, paired with the demands of managing and attending to the team information board and text chat, future research should investigate the effects of cognitive load (e.g., Cramton, 2001; Tindale, & Sheffey, 2002; van Bruggen, Kirschner, & Jochems, 2002), multitasking ability (e.g., Dresner & Barak, 2009), divided attention (e.g., Wickens, Goh, Helleberg, Horrey, & Talleur, 2003), and bounded rationality (e. g., Nelson, 2008) on the effective use of KOD behaviors in a team information board. Additionally, researchers should examine how team members utilize KOD behaviors while operating in different types of organizational cultures, as culture may affect team members' ability and motivation to share information (e.g., Milne, 2007; Wilkesmann, Wilkesmann, & Virgillito, 2009). For example, team members with incentives to cooperate may utilize KOD behaviors differently than team members whose roles promote competition or self-interest. Therefore, future research should examine situational factors with regard to technology, cognitive ability, and organizational culture.

Chapter 9

Conclusion

Members of distributed teams often have difficulty sharing the content and structure of their information. The Collaboration and Meaning Analysis Process (C-MAP; Rentsch et al., 2008) was developed to assist team members in sharing their information content and structure through schema-enriched communication behaviors and knowledge object development (KOD) behaviors. The present study examined the relationships between four types of KOD behaviors and two team cognition variables (transferred knowledge and interoperable knowledge). Results indicated that posting and highlighting content behaviors were positively related to transferred knowledge and conveying structure across domains positively predicted more variance in interoperable knowledge than within domain behaviors. Findings can be applied to revising the C-MAP intervention to train team members to perform the specific behaviors that positively predicted team cognition outcomes.

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Appendices

Appendix A

This coding scheme requires codes in eight categories that were used to create KOD behaviors.

A. <u>Behavior Type</u>

1. Post
2. Initial Placement
3. Move
4. Delete
5. Repost - Post
6. Repost - Initial Placement
7. Repost – Move
8. Rearrange
9. Amend

B. <u>*Originating Role</u>

1. Weapons (blue)
2. Intelligence (pink)
3. Environmental (green)

99. N/A (flag or grey)

C. <u>Content Domain</u>

1. Weapons-specific
2. Intelligence-specific
3. Environmental-specific
4. General (accessible to all roles)
5. Final Plan
6. Other
7. Flag

99. N/A

D. <u>Simultaneous with</u>

0. None (posted alone)
1. One other bubble
2. Cluster of bubbles
3. One other piece in same bubble
4. Multiple other pieces in same bubble
5. Other piece(s) in bubble and with other pieces in other bubbles

99. N/A

E. <u>Content in Simultaneous Piece(s)</u>

i. *Weapons content* (0 – no; 1 – yes)
ii. *Intelligence content* (0 – no; 1 – yes)
iii. *Environmental content* (0 – no; 1 – yes)
iv. *General content* (0 – no; 1 – yes)
v. *Final Plan content* (0 – no; 1 – yes)
vi. *Other content* (0 – no; 1 – yes)

F. <u>Location</u>

0. Blank Area
1. Near one other piece
2. Near cluster of pieces

99. N/A

G. <u>Content in Same Location Pieces</u>

i. *Weapons content* (0 – no; 1 – yes)
ii. *Intelligence content* (0 – no; 1 – yes)
iii. *Environmental content* (0 – no; 1 – yes)
iv. *General content* (0 – no; 1 – yes)
v. *Final Plan content* (0 – no; 1 – yes)
vi. *Other content* (0 – no; 1 – yes)

H. <u>Content of Attracted Pieces (pieces moved near a stationary piece)</u>

i. *Weapons content* (0 – no; 1 – yes)
ii. *Intelligence content* (0 – no; 1 – yes)
iii. *Environmental content* (0 – no; 1 – yes)
iv. *General content* (0 – no; 1 – yes)
v. *Final Plan content* (0 – no; 1 – yes)
vi. *Other content* (0 – no; 1 – yes)
vii. *Flag* (0 – no; 1 – yes)

* Used only in the larger study

Appendix B

Each time a piece of information is externalized, codes were given in each category listed in Appendix A. These codes were used in combination to determine if each externalization qualifies as a KOD behavior. This chart indicates how codes were combined. Each piece may have been externalized using one or more KOD behaviors, or may not have been externalized at all. For each piece of information, the KOD behaviors used to externalize that piece were summed to determine how many times each type of behavior (posting content, highlighting content, conveying structure within domain, and conveying structure across domains) was used on that piece.

<table>
<tr><th>KOD Behavior</th><th colspan="2">Codes Combined*</th></tr>
<tr><td>Posting Content</td><td colspan="2">Behavior Type
• Post
• Repost</td></tr>
<tr><td rowspan="2">Highlighting Content</td><td colspan="2">Content of Attracted is Flag</td></tr>
<tr><td>Behavior Type (any one)
• Initial Placement
• Move
• Repost–Initial Placement
• Repost–Move</td><td>Location is Blank Area</td></tr>
<tr><td rowspan="3">Conveying Structure Within Domain</td><td>Simultaneous With (any one)
• One other piece in bubble
• Multiple others in bubble
• Others in bubble and others in other bubbles</td><td>Content Domain and Content of Simultaneous Pieces are the same</td></tr>
<tr><td>Behavior Type (any one)
• Initial Placement
• Move
• Repost–Initial Placement
• Repost–Move</td><td>Content Domain and Content in Same Location are the same</td></tr>
<tr><td colspan="2">Content Domain and Content of Attracted Pieces are the same</td></tr>
<tr><td rowspan="3">Conveying Structure Across Domains</td><td>Behavior Type (any one)
• Initial Placement
• Move
• Repost–Initial Placement
• Repost–Move</td><td>Content Domain and Content in Same Location are different</td></tr>
<tr><td>Simultaneous With
• One other piece in bubble
• Multiple others in bubble
• Others in bubble and others in other bubbles</td><td>Content Domain and Content of Simultaneous Pieces are different</td></tr>
<tr><td colspan="2">Content Domain and Content of Attracted Pieces are different</td></tr>
</table>

*If codes are listed in two columns, requirements in both columns must be fulfilled to qualify.

Appendix C

Table 1

Knowledge Object Development Behavior Features Supporting the Development of Team Cognition Variables

Team Cognition Variable Supported	**Knowledge Object Development Behavior**	**Method of Externalizing Cognition**
Transferred Knowledge	Posting content	Presents content to team members
	Highlighting content	Draws others' attention to content
Interoperable Knowledge	Conveying structure within domain	Illustrates relationships among pieces of information within the same domain
	Conveying structure across domains	Illustrates relationships among pieces of information across different domains

Table 2

Correlations Among KOD and Team Cognitive Outcome Variables at the Piece of Information Level

Variables	1[a]	2	3	4	5	6
1. Posting Content	-					
2. Highlighting Content	.88**	-				
3. Structure Within Domain	.87**	.20*	-			
4. Structure Across Domains	.89**	.08	.66**	-		
5. Transferred Knowledge	.34**	.11	-.26*	-.21*	-	
6. Interoperable Knowledge	.74**	.19	-.05	.05	.04	-
Mean	.42	.97	3.68	1.76	1.04	.27
SD	.31	.47	1.73	1.02	.60	.29

[a]Correlations and descriptive statistics for posting content are based on all pieces of information. All other correlations and statistics are based only on pieces of information that were posted by each team.

$n = 71$

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

Table 3
Regressions for Content Variables Predicting Transferred Knowledge at the Piece of Information Level

Transferred Knowledge	Unstandardized Coefficients		β	R^2	t-test	Sig.
	B	SE B				
Posting Content[a]	.49	.16	.34	.11	3.05	.00**
Highlighting Content	.13	.15	.11	.01	.87	.39

[a]Regressions with posting content as a predictor were conducted using all pieces of information. All other regressions were conducted using only on pieces of information that were posted by each team.
$n = 71$.
*$p < .05$. **$p < .01$.

Table 4

Hierarchical Regression for Structure Variables Predicting Interoperable Knowledge at the Piece of Information Level

	Step 1			Step 2		
Variable	B	SE B	β	B	SE B	B
Structure Within Domain	-.01	.02	-.05	-.03	.03	-.15
Structure Across Domains				.04	.05	.15
R		.05			.13	
ΔR^2		.00			.02	
$F\ \Delta R^2$		.19			.34	

n = 71.

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

Table 5

Polynomial Regressions for Content Variables Predicting Transferred Knowledge at the Piece of Information Level

Transferred Knowledge	Unstandardized Coefficients		β	R^2	t-test	Sig.
	B	SE B				
Posting Content[a, b]	.68	.18	.47		3.71	.00**
Posting Content Squared	-.94	.46	-.25		-2.02	.05*
				.16**		
Highlighting Content	.89	.29	.71		3.05	.00**
Highlighting Content Squared	-.66	.22	-.69		-2.97	.00**
				.13*		

[a]Regressions with posting content as a predictor were conducted using all pieces of information. All other regressions were conducted using only on pieces of information that were posted by each team.
[b]Variables were centered before being squared to form quadratic variables.
$n = 71$.
$*p < .05$. $**p < .01$.

Table 6

Hierarchical Polynomial Regression for Content Variables Predicting Transferred Knowledge at the Piece of Information Level

	Step 1			Step 2		
Variable	B	SE B	β	B	SE B	β
Structure Within Domain[a]	.04	.05	.21	.00	.05	.09
Structure Within Domain Squared	-.01	.01	-.29	-.01	.01	-.20
Structure Across Domains				.14	.07	.49
Structure Across Domains Squared				-.03	.02	-.37
R		.13			.26	
ΔR^2		.02			.05	
$F\ \Delta R^2$		.60			1.80	

[a]Variables were centered before being squared to form quadratic variables.

$n = 71$.

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

Table 7

Correlations Among KOD Components and Team Cognitive Outcome Variables at the Piece of Information Level

Variables	1[a]	2	3	4	5	6	7	8	9
1. Posting Information	-								
2. Reposting Information	.18	-							
3. Flagging Information	.20*	.41**	-						
4. Initially Placing piece in blank area	.92**	.21*	.00	-					
5. Initially Placing reposted in blank area	.12	.69**	.30**	.11	-				
6. Moving piece to blank area	.74**	.17	.48**	-.01	.19	-			
7. Initially placing near same content	.81**	.03	-.22*	-.56**	-.19	-.12	-		
8. Initially placing reposted near same content	.18	.50**	-.06	-.01	-.05	.08	.04	-	
9. Moving near same content	.69**	.27	.28*	.00	.05	.28**	.03	.03	-
10. Simultaneously moving with same content	.73**	.14	.20*	-.02	.20*	.23*	.29**	-.13	.09
11. Attracting same content	.92**	.19	.05	-.02	-.01	.13	.35**	.04	.32**
12. Initially placing near different content	.72**	.00	.02	-.38**	-.03	.09	.57**	-.14	.18
13. Moving near different content	.73**	.33**	.16	.07	.19	.22*	-.03	-.11	.79**
14. Simultaneously moving with different content	.58**	.13	.00	-.15	.12	.09	-.02	-.07	.15
15. Attracting different content	.90**	.14	.00	.18	.03	.05	-.02	-.02	.20*
16. Transferred knowledge	.34**	.00	-.06	.29*	.00	-.06	-.34**	-.03	-.05
17. Interoperable knowledge	.73**	.30**	-.14	.19	-.02	.16	-.13	.39**	.24*
Mean	.41	.30	.04	.48	.01	.43	.50	.01	.38
SD	.01	.02	.09	.26	.03	.34	.03	.02	.30

Table 7

Correlations Among KOD Components and Team Cognitive Outcome Variables at the Piece of Information Level (cont.)

Variables	10	11	12	13	14	15	16	17
10. Simultaneously moving with same content	-							
11. Attracting same content	.55**	-						
12. Initially placing near different content	.51**	.38**	-					
13. Moving near different content	.20	.29**	.21*	-				
14. Simultaneously moving with different content	.44**	.19	.34**	.14	-			
15. Attracting different content	.30**	.52**	.33**	.15	.28**	-		
16. Transferred knowledge	-.27*	-.08	-.26*	-.11	-.20*	.09	-	
17. Interoperable knowledge	-.12	.07	-.15	.23*	-.06	.13	.04	-
Mean	2.65	.63	.41	.40	.53	.50	1.04	.27
SD	1.68	.28	.30	.35	.69	.29	.60	.29

[a]Correlations and descriptive statistics for posting content are based on all pieces of information. All other correlations and statistics are based only on pieces of information that were posted by each team.

$n = 71$

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

Table 8

Simultaneous Regressions for Content Components Predicting Transferred Knowledge at the Piece of Information Level

Transferred Knowledge	Unstandardized Coefficients		β	R^2	t-test	Sig.
	B	SE B				
Posting Information	.52	.17	.35		3.11	.00**
Reposting Information	-1.29	2.63	-.06		-.49	.62
				.12*		
Flagging Information	-.30	.97	-.04		-.31	.76
Initially Placing piece in blank area	.66	.27	.29		2.43	.02*
Initially Placing reposted piece in blank area	-.19	2.86	-.01		-.07	.95
Moving piece to blank area	-.06	.24	-.03		-.26	.80
				.30		

[a]Regressions with posting content components as predictors were conducted using all pieces of information. All other regressions were conducted using only on pieces of information that were posted by each team.

$n = 71$.

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

Table 9

Hierarchical Regression for Structure Components Predicting Interoperable Knowledge at the Piece of Information Level

	Step 1			Step 2		
Variable	B	SE B	β	B	SE B	β
Initially placing near same content	-.15	.12	-.15	-.02	.16	-.02
Initially placing reposted near same content	4.61	1.36	.38*	4.92	1.39	.40*
Moving near same content	.20	.11	.21	-.01	.18	-.01
Simultaneously moving with same content	-.02	.02	-.11	-.01	.03	-.08
Attracting same content	.11	.15	.10	-.01	.17	-.01
Initially placing near different content				-.14	.16	-.14
Moving near different content				.26	.16	.32
Simultaneously moving with different content				-.02	.06	-.04
Attracting different content				.17	.14	.17
R		.49			.54	
ΔR^2		.24			.05	
$F\ \Delta R^2$		4.05**			1.04	

$n = 71$.
*$p < .05$. **$p < .01$.

Table 10
Correlations Among KOD and Team Cognitive Outcome Variables at the Team Level

Variables	1[a]	2	3	4	5	6
1. Posting Content	-					
2. Highlighting Content	.52**	-				
3. Structure Within Domain	.50**	.76**	-			
4. Structure Across Domains	.23	.41*	.63**	-		
5. Transferred Knowledge	.37	-.37*	-.48*	-.15	-	
6. Interoperable Knowledge	-.09	-.12	-.17	-.09	.35	-
Mean	.42	1.07	3.71	1.89	1.05	.40
SD	.10	.43	1.26	1.06	.25	.23

[a]Correlations and descriptive statistics for posting content are based on all pieces of information. All other correlations and statistics are based only on pieces of information that were posted by each team.
$n = 21$
* $p < .05$, ** $p < .01$

Table 11

Regressions for Content Variables Predicting Transferred Knowledge at the Team Level

Transferred Knowledge	Unstandardized Coefficients		β	R^2	t-test	Sig.
	B	SE B				
Posting Content[a]	.59	.35	.37	.13	1.72	.10
Highlighting Content	-.22	.13	-.37	.14	-1.73	.10

[a]Regressions with posting content as a predictor were conducted using all pieces of information. All other regressions were conducted using only on pieces of information that were posted by each team.

$n = 21$.

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

Table 12

Hierarchical Regression for Structure Variables Predicting Interoperable Knowledge at the Team Level

	Step 1			Step 2		
Variable	B	SE B	β	B	SE B	β
Structure Within Domain	-.03	.04	-.17	-.04	.05	-.20
Structure Across Domains				.01	.07	.03
R		.17			.18	
ΔR^2		.03			.00	
$F\ \Delta R^2$		.60			.01	

$n = 21$.

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

Table 13

Correlations Among KOD and Team Cognitive Outcome Variables for Unaggregated Data

Variables	1[a]	2	3	4	5	6
1. Posting Content	-					
2. Highlighting Content	.64**	-				
3. Structure Within Domain	.79**	.39**	-			
4. Structure Across Domains	.59**	.14**	.50**	-		
5. Transferred Knowledge	.29**	.03	-.09*	.06	-	
6. Interoperable Knowledge	.32**	.00	-.08*	.11**	.08*	-
Mean	.42	1.07	3.73	1.89	1.06	.39
SD	.61	1.06	2.81	2.32	.86	.69

[a]Correlations and descriptive statistics for posting content are based on all pieces of information (n = 1, 575). All other correlations and statistics are based only on pieces of information that were posted by each team (n = 564).

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

Table 14

Hierarchical Regression for Posting Content Predicting Transferred Knowledge using Unaggregated Data

	Step 1			Step 2		
Variable	B	SE B	β	B	SE B	Β
Team Identification Variables						
Posting Content				.40	.03	.29**
R		.19			.34	
ΔR^2		.04			.08	
$F\ \Delta R^2$		2.85**			142.84**	

n = 1,500.

***p* < .01.

Table 15

Hierarchical Regression for Highlighting Content Predicting Transferred Knowledge using Unaggregated Data

	Step 1			Step 2		
Variable	B	SE B	β	B	SE B	β
Team Identification Variables						
Highlighting Content				.06	.04	.07
R		.28			.28	
ΔR^2		.08			.00	
$F\ \Delta R^2$		2.23**			2.43	

$n = 544$.

**$p < .01$.

Table 16

Hierarchical Regression for Structure Variables Predicting Interoperable Knowledge using Unaggregated Data

	Step 1			Step 2			Step 3		
Variable	B	SE B	β	B	SE B	β	B	SE B	β
Team Identification Variables									
Structure Within Domain				-.02	.01	-.07	-.04	.01	-.18**
Structure Across Domains							.07	.02	.23**
R		.32			.32			.37	
ΔR^2		.10			.00			.04	
$F\ \Delta R^2$		2.99**			2.68			21.75**	

n = 544.
**p < .01.

Table 17

Correlations Among KOD Components and Team Cognitive Outcome Variables for Unaggregated Data

Variables	1[a]	2	3	4	5	6	7	8	9
1. Posting Information	-								
2. Reposting Information	.09	-							
3. Flagging Information	.14**	.10**	-						
4. Initially Placing piece in blank area	.62**	.08**	.00	-					
5. Initially Placing reposted in blank area	.04	.64**	.08*	.07	-				
6. Moving piece to blank area	.41**	.04	.04	.00	-.05	-			
7. Initially placing near same content	.59**	.03	-.06	-.62**	-.07	.02	-		
8. Initially placing reposted near same content	.07**	.58**	-.02	.00	-.01	-.03	.04	-	
9. Moving near same content	.40**	.06**	.05	-.05	.01	.18**	.04	-.05	-
10. Simultaneously moving with same content	.66**	.11**	.03	.18**	.09*	.37**	.05	.02	.08*
11. Attracting same content	.69**	.03	.04	.02	-.05	.05	.23	.01	-.01
12. Initially placing near different content	.54**	.02	-.01	-.55**	-.06	.02	.52**	-.02	.06
13. Moving near different content	.39**	.04	.03	-.02	.00	.28**	.00	-.05	.61**
14. Simultaneously moving with different content	.28**	.06*	-.05	.03	-.03	.22**	-.06	-.03	.18**
15. Attracting different content	.60**	.06**	.08*	-.07	-.04	.12**	.20**	.06	.01
16. Transferred knowledge	.29**	.04	-.02	.07	-.01	-.01	-.14**	-.01	.01
17. Interoperable knowledge	.33**	.00	-.01	-.02	-.02	.01	-.02	-.02	.05
Mean	.41	.01	.05	.53	.01	.49	.47	.01	.44
SD	.60	.09	.21	.60	.08	.83	.60	.08	.78

Table 17

Correlations Among KOD Components and Team Cognitive Outcome Variables for Unaggregated Data (cont.)

Variables	10	11	12	13	14	15	16	17
10. Simultaneously moving with same content	-							
11. Attracting same content	.17**	-						
12. Initially placing near different content	.12**	.11**	-					
13. Moving near different content	.20**	-.01	.08**	-				
14. Simultaneously moving with different content	.35**	-.04	.07*	.28**	-			
15. Attracting different content	.24**	.40**	.30**	.09*	.19**	-		
16. Transferred knowledge	-.12**	.02	-.02	.01	.08*	.04	-	
17. Interoperable knowledge	-.09*	-.06	-.01	.12**	.07*	.09*	.08*	-
Mean	2.62	.65	.40	.49	.55	.54	1.06	.39
SD	2.81	.64	.59	.92	1.75	.65	.86	.69

[a]Correlations and descriptive statistics for posting content components are based on all pieces of information (n = 1, 575). All other correlations and statistics are based only on pieces of information that were posted by each team (n = 564).

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

Table 18
Hierarchical Regression for Posting Content Components Predicting Transferred Knowledge using Unaggregated Data

	Step 1			Step 2		
Variable	B	SE B	β	B	SE B	β
Team Identification Variables						
Posting Information				.40	.03	.29**
Reposting Information				.12	.23	.01
R		.19			.34	
ΔR^2		.04			.08	
$F\ \Delta R^2$		2.85**			142.84**	

n = 1,500.
**$p < .01$.

Table 19

Hierarchical Regression for Highlighting Content Components Predicting Transferred Knowledge using Unaggregated Data

	Step 1			Step 2		
Variable	B	SE B	β	B	SE B	β
Team Identification Variables						
Flagging Information				.00	.18	.00
Initially Placing piece in blank area				.04	.06	.03
Initially Placing reposted piece in blank area				.06	.44	.01
Moving piece to blank area				.07	.05	.07
R		.28			.28	
ΔR^2		.08			.00	
$F\ \Delta R^2$		2.23**			.66	

n = 544.
**$p < .01$.

Table 20

Hierarchical Regression for Structure Variable Components Predicting Interoperable Knowledge using Unaggregated Data

	Step 1			Step 2			Step 3		
Variable	B	SE B	β	B	SE B	β	B	SE B	β
Team Identification Variables									
Initially placing near same content				.00	.05	.00	.01	.06	.01
Initially placing reposted near same content				-.12	.34	-.02	-.16	.33	-.02
Moving near same content				.04	.04	.05	-.03	.05	-.04
Simultaneously moving with same content				-.01	.01	-.05	-.03	.01	-.13*
Attracting same content				-.10	.05	-.09	-.14	.05	-.13*
Initially placing near different content							-.02	.06	-.02
Moving near different content							.10	.04	.13*
Simultaneously moving with different content							.04	.02	.09†
Attracting different content							.16	.06	.15**
R		.32			.33			.39	
ΔR^2		.10			.01			.04	
$F\ \Delta R^2$		2.99**			1.41			5.98**	

n = 544.

†*p* = .05. **p* < .05. ***p* < .01.

Table 21
Summary of Results

Relationships	Piece of Information Level	Team Level	Unaggregated Level with Team Identification Vector
Hypothesis 1: Posting content predicts TK[a]			
Relationships supported	Linear & Curvilinear	None	Linear
Predictive components	Posting information	None	Posting information
Hypothesis 2: Highlighting content predicts TK			
Relationships supported	Curvilinear	None	None
Predictive components	Initially placing piece into blank area	None	None
Hypothesis 3: Structure within domain predicts IK[b]			
Relationships supported	None	None	Linear (*negatively predicts)*
Predictive components	Initially placing reposted piece near same domain piece	None	None
H4: Structure across domains predicts IK			
Relationships supported	None	None	Linear
Predictive components	None	None	Moving piece near different domain piece; Attracting different domain piece; Simultaneously moving with different domain piece[c]

[a]TK = Transferred knowledge
[b]IK = Interoperable knowledge
[c]$p = .05$ for the simultaneous component

Vita

Lisa Ann Delise was born in New Orleans, Louisiana and lived in Arabi, Louisiana for 23 years. She graduated from Andrew Jackson Fundamental Magnet High School in May 1997. She then graduated magna cum laude from the Newcomb College of Tulane University in May 2001. She is currently pursuing her doctorate in Industrial/Organizational Psychology at the University of Tennessee, Knoxville.