Towards a Team Mental Model of Collaborative Information Seeking during Team Decision-Making

Article · October 2014

DOI: 10.1177/1541931214581069

3 authors, including:

Nathan J. McNeese
Clemson University
64 PUBLICATIONS **310** CITATIONS
SEE PROFILE

Madhu C. Reddy
Northwestern University
98 PUBLICATIONS **2,527** CITATIONS
SEE PROFILE

TOWARDS A TEAM MENTAL MODEL OF COLLABORATIVE INFORMATION SEEKING DURING TEAM DECISION-MAKING

Nathan J. McNeese, Madhu C. Reddy, Evan M. Friedenberg
College of Information Sciences and Technology
The Pennsylvania State University

Team decision-making (TDM) is composed of many activities. One important aspect of TDM is information seeking, particularly collaborative information seeking (CIS). Within CIS research, the role of team cognition and the development of team mental models (TMMs) have not been well-studied. In this paper, we examine the development of TMMs during CIS activities. Utilizing qualitative knowledge elicitation methods, we conducted an exploratory laboratory-based study of student teams working on CIS tasks. We report on how the teams describe TMM development, the teamwork and taskwork aspects of the TMM, and the attributes supporting TMM development. The results highlight that the process of TMM development during CIS is similar to TMM development research reported in other studies. Furthermore, to the best of our knowledge, this is the first research to attempt to understand the role of team cognition in CIS and describe the development of a TMM specific to CIS.

INTRODUCTION

Team decision-making (TDM) is a highly complex process dependent on multiple steps. One critical step in successful TDM is information seeking (Lipshitz, et al., 2001), in particular collaborative information seeking (CIS). CIS is defined as "*the study of the systems and practices that enable individuals to collaborate during the seeking, searching, and retrieval of information*" (Foster, 2006). We view CIS as an important aspect of TDM. If a team fails to find the needed information, it is more than likely that their TDM process will suffer. However, CIS has not been a focus of study within the TDM community. Consequently, we need to better understand this important aspect of TDM.

CIS is a relatively new research area that is starting to be explored in greater detail (Reddy & Jansen, 2008). Traditionally, researchers have focused on CIS from an interactional perspective (i.e., investigating how people interact with each other during these activities). Consequently, very little research has examined the role of cognition in CIS. A recent review of the CIS literature by Shah (2010a) highlights that most CIS research has focused on social and technical perspectives. Cognitive work is rarely mentioned in the review, and when it is, cognition is often explored from an individual level, and not a team perspective. Although, there are many factors that can impact the success of a team's CIS activity, one significant factor is team cognition. Therefore, we have been studying CIS from a team cognitive perspective. Often, the development of team cognition can positively improve the TDM process (Cooke et al., 2003). Consequently, understanding CIS from a team cognitive perspective has the potential to lead to improvements in CIS, which in turn could improve TDM.

One of the most effective means to study CIS from this perspective is through identifying and understanding the development of a team mental model (TMM). TMMs were first introduced in 1990 (Canon-Bowers et al.) to better understand and study implicit communication and coordination within a team. Although there are multiple definitions of TMMs, we use Klimoski & Mohammed's (1994) definition, which describes the model as "*organized mental representations of the key elements within a team's relevant environment that are shared across team members.*" The opportunity to share and interpret information based on commonality (description), the ability to share assumptions and expectations of what will happen in the future (predictability), and the ability to understand together how an event happened (explanation) are all affordances of a TMM (Rouse et al., 1992). As Mohammed et al. (2010) have noted, TMMs help a team acquire the knowledge of "what" is currently happening and will happen, and "why" it is happening. TMMs are generally viewed as being composed of two different sub-models: taskwork and teamwork (Mathieu et al., 2000). Taskwork models usually focus on the actual work of the team, whereas teamwork models focus on the interpersonal relationships within the team and the emotional responses that are elicited.

To address the gap in the CIS literature on the role of team cognition during CIS and to further understand this aspect of TDM, we conducted an exploratory laboratory-based study, utilizing student teams, aimed at understanding the development of TMMs during CIS.

METHODS

Participants

A total of forty undergraduate students were recruited from a large Northeastern university by email, classroom recruitment, and word of mouth. Participants were randomly formed into dyads and triads, resulting in a total of sixteen teams (eight dyads and eight triads).

Five of the sixteen teams were used in a pilot study. The other eleven teams were used in the main study (Table 1). This paper will discuss the results of the teams used in the main study. Both dyads and triads were utilized because they are defined as common team sizes (Salas et al., 1992).

Task

Three CIS tasks were given to the teams. The tasks were developed and adopted from previous work by Shah & González-Ibáñez (2010b), who utilized a CIS task within a laboratory setting. The tasks were created with the goal of being both familiar enough to participants that they would be able to complete them, but narrow enough that they would have to search for adequate information. The tasks are framed within a TDM context by requiring problem identification, planning, re-planning, and information seeking and retrieval. The first task is presented below.

"The National Cancer Institute has hired your team to identify the top 5 causes of pancreatic cancer. It will be up to your team to decide what those top 5 causes are. However, you must also provide some reasons (including substantial facts and evidence) why your team thinks these are the leading causes of pancreatic cancer. You may present your findings in whatever way you think is best, whether it is bullet points or a formal paper. You may utilize any website that you find useful as well as your individual knowledge of the subject."

The other two tasks, which we do not present because of space limitations, build upon the first task and deal with cancer-related issues.

Procedure

Participants were greeted upon arrival in the lab and asked to sign an informed consent form. Once signed, researchers explained the research study and process to participants. The researchers also provided background to the team on CIS and team cognition to help them understand the context of the study.

The researchers then explained that the team would be working in a co-located, face-to-face environment to complete a set of CIS tasks. Three laptops were positioned next to each other on a large table. Each participant sat in front of their particular laptop, but was not restricted from moving to view another team member's computer screen. They also could talk to each other.

Each CIS task had a time limit (first task – 15 minutes, second task – 5 minutes, third task – 10 minutes). The pilot teams indicated that they felt the tasks could adequately be completed within these time limits. All three CIS tasks were audio and video recorded for analysis. Once the team completed all three CIS tasks, participants then completed an individual cognitive interview, resulting in a total of 28 interviews being conducted. Participants were interviewed for 20-30 minutes about the CIS task and issues of team cognition. These were semi-structured cognitive interviews that used verbal probing techniques (Willis, 1999) and aspects of the critical decision-making method (Klein et al., 1989). Utilizing these methods, researchers asked participants to think retrospectively about the CIS task and explain their thoughts at different points in time. Through this method and specific interview questions, the researchers captured data regarding the development of team cognition, specifically TMMs, during CIS. During the interviews, the researchers spent extra time explaining and ensuring that the participants understood the concept of a TMM, allowing them to adequately discuss it. In addition to the cognitive interviews, individual declarative and team procedural concept maps were also collected. Due to length restrictions, we will not be addressing the concept map data in this paper. Upon completion of the study, each participant was paid $30.00 for participating. The entire study lasted 2 hours.

FINDINGS

The cognitive interviews were analyzed and coded using thematic analysis (Braun & Clarke, 2006). This process depends on the researchers becoming familiar with the data, systematically identifying codes and themes, and then defining and naming the common themes found across the data. Since this is team research, the analysis of the interviews had to go beyond only the individual. The analysis was completed at three different units of analysis: individual, individual teams, and all teams. The process of analyzing all three units is as follows: Each individual interview within the team was transcribed, coded, and thematically analyzed. The themes from each individual interview within that team were then analyzed to develop overall team themes based on the individual themes. The team themes from each team were then analyzed across all teams to develop overall study themes.

The observations recorded during the CIS task were also reviewed in relation to the thematic analysis of the cognitive interviews. Through analysis, a majority of teams described the development of a self-identified TMM specific to CIS. The following findings focus on the development of the CIS oriented TMM, taskwork and teamwork models within the overall CIS TMM, and attributes that positively affected the development of a CIS TMM.

Development of a Team Mental Model

Of the eleven teams that participated in the main study, nine teams stated that they developed a TMM specific to CIS. These teams were quick to state that a TMM developed, but many were unable to articulate how the TMM developed, often identifying that the model "*just kinda came out that way*" (Team 6, #1). However, some participants were able to provide insight into the development of the model. These participants explained that the overall TMM specific to CIS was a combination of each team member's own individual mental model. Specifically, even though each team member might have a different individual mental model, it was bounded within the overall goals of information seeking and sharing within the overall TMM. As one participant explained: "*The model was at least generally consistent among all 3 people. Because we had our ideas that we were sharing. So, I mean people may have had the different mental models, but the overall goal was still apparent in terms of the actual problem, solving the problem."* (Team 10, #1)

As team members worked together, they continued to share components of their individual mental models with each other. As they became more collaborative, individual mental

models changed to more closely match the overall team mental model. This change was prompted by individual team members learning about each other's mental models and then orienting their own particular model to better fit the overall TMM. A team member describes the process of sharing individual mental models to create a team model:
"*But the initial mental models were created independently, and then when we came back together and kind of generalized for an overall just broad, high level concept, we had a unified model, at least to continue to branch out and go okay how are we gonna address the problem."* (Team 8, #1)

Similarly, a different participant described the changing of individual mental models based on the influence of other team members' models to create the broader CIS TMM:
"Everyone has assumptions, and then when they do the research, their assumptions may change. So they have the initial mental model that just immediately when they're given the task, they would look at and go okay this is how I'm gonna address the problem, and how I'm gonna like look at the concepts. But when they start getting other influence from other members saying oh, well this is a huge causation because of this, well that may change their whole layout of the mental model." (Team 10, #1)

The CIS focused TMM was developed by individual team members sharing their mental models with each other. These individual models changed and were integrated with each other based on the CIS goals of the team and the influences of other team member's mental models. This process of development is very similar to McComb's (2007) conceptual framework that explains the process of mental model convergence during TDM.

Taskwork and Teamwork Models

Many researchers have found that a TMM consists of multiple models (Mathieu et al., 2000; Lim & Klein, 2006). For example, a TMM of CIS is only one of many context or activity specific TMMs that ultimately make up the "overall" team TMM. As highlighted in the introduction, TMMs generally consist of both a teamwork and taskwork model. Participants also referred to their CIS bounded TMM in terms of teamwork and taskwork models. All teams (9 of the 9 teams who identified a TMM) identified and discussed the TMM in terms of a taskwork model.

Team members explained that they developed a taskwork model that allowed them to find, keep track of, and share information. One team member explained how the taskwork model allowed the team to find information:
"*Once we had established some basic information, since we were pretty much clueless going into it, once we had some basic information, I think we were feeding off of each other's... using the document (to track) the information that we found, and we could kinda sense you know, alright, he's trying to form this link between these two things. I think there was definitely some feeling, some sensing where what each other was going with... with the information.*" (Team 10, #3)

Similarly, another participant explained that the team developed a common model of how to find information:
"We definitely got to the common state of seeking the common goal of whatever was written on the paper (the tasks), whether it be the... reasons why pancreatic cancer, or that sort a thing. And we all had a common mental model of how to go about doing that. You know, you just shout out what you found on some website. And through the mental model, we all knew kind of, you know, this was what was expected and how we were gonna continue going on." (Team 11, #2)

While the taskwork model developed in all of the teams who identified a TMM, the granularity of the task model varied throughout teams. It ranged from simply understanding which team member would write down what, to team members identifying systematic methods for the CIS process.

In addition to the taskwork model, a more complicated teamwork model developed in some teams (3 of the 9 teams who identified a TMM). The teamwork model was only present in teams that possessed the ability to assume, predict, and expect each other's understanding. The teamwork model required more time to develop then the taskwork model. A majority of teams never advanced to the point of having a teamwork model because they were never able to work seamlessly together and anticipate what each other was doing. The taskwork model was simpler to develop because it was easier to explicitly communicate how the team was going to search for information. These tasks then became systematic and predictable over time. The teamwork model required that the teammates "understand" each other, a much more difficult process. Some teams did reach this level of understanding within the TMM. As one participant explained, her team reached the level of anticipating what each other would say:
"*The way we worked together. And then we kind of, were anticipating what the other one was saying. We were on the same page the whole time, and stuff like that, so."* (Team 14, #2)

Another team member explained that his team reached such a level of understanding amongst each other that minimal communication was needed to accomplish the task:
"It kinda became like second nature. Once we got the second task, we all started doing our research and, we didn't really need to talk about the task." (Team 9, #2) The participants' comments reflect and highlight the level of sophistication that is required to establish a level of team understanding that allows for prediction and anticipation.

Attributes Supporting CIS TMM Development

While participants indicated many different attributes helped to contribute to developing a TMM of CIS, a few were repeatedly mentioned. These attributes were leadership, previous team experience, and understanding the team's goal.

Leadership.

Most participants described leadership within the team as an attribute necessary to develop an effective TMM. Yet, they were also adamant that it must be the correct type of leadership. Many participants identified that a leader must promote equal responsibility and delegation and not be "power hungry". Effective leadership helped to develop the TMM in multiple ways. One participant highlighted how a leader can initiate teamwork from the beginning of the process:

"*I think having a leader is something that causes you to step back, and instead of you know, diving right into doing the project, you know, getting a mental model, you know, getting used to working together would be the first step I think. A leader would make sure that that would happen. Versus all the individuals trying to dive right into their task and then, there's not a specific person that everybody's looking for in order to get this common understanding and process of how to do what they're doing."* (Team 11, #2)

Similarly, another participant explained that a leader helps to develop common ground within the team:

"*I think it helped (leadership in regard to the team mental model). If one person kind of takes a leadership role in the very beginning, and establishes, alright, let's do this; this is our common goal, this is how we can work to achieve it, this is what we have to do, then, everything is laid out, everyone's on the same page, you don't really, like you don't waste any time, it's more efficient, but then I feel like you should... divide up the responsibility, or it can... hurt the model."* (Team 14, #2)

In addition, participants also described how leaders can helped mediate conflict within the team:

"*The team leader is able to facilitate ideas evenly. If 2 people are conflicting within a group, the team leader can act as like a mediator, and is able to make sure everyone's ideas get, get like passed along. And... I think that helps with getting everyone on the same page, which helps build the team mental model."* (Team 10, #3)

Previous Team Experience.

When asked specifically if previous team experience helped to develop a TMM during the CIS task, almost all of the participants strongly indicated that it did. Participants explained that the more previous experience they had working in teams led them to better understand the expectations of teamwork and how to better work in teams. One team member explained that experience helps working in teams, and subsequently developing a TMM:

"Oh sure. I'm all about the more you experience something, the more you practice something, the better you get at it. And the more experience I had with teams is, helped me, you know, kinda read people better, and... you know, see what works and doesn't works, and, work in terms of working together, getting other people to work together. So, I think it definitely helped; my prior experience (in regards to developing a TMM)." (Team 10, #3)

Another participant pointed out that team experience led to the development of team expectations:

"100% (in response to if experience helps develop a team mental model). It's just like any other thing, the more experience and practice that you have with it, the better you are at it, the better you can become, the more things you can learn from it. I think someone that, for instance, myself, already having previous knowledge, you kinda know what to expect and... kinda know what to get out of things." (Team 12, #1)

In this study, experience allowed team members to make assumptions, anticipate, and develop expectations in regard to the team's information seeking process. Similar team expectations laid the basis for the TMM development. A team composed of individuals with previous team experience allowed them to start with a general shared understanding of what to expect during CIS, which allowed quicker development of a TMM.

Common Understanding of Goal(s).

In addition to leadership and team experience, participants often indicated that the development of a TMM was dependent on the entire team having a common understanding of their CIS goals. Teams had to not only decide what their goal was, but also develop a common understanding of that goal. A participant explained the importance of a common understanding of the goal and its relation to finding information:

"I think just having that common understanding of what the, what the goal was (helped develop the team mental model). Not only what the goal was, but, once we had the, the information, once we had the means to get to that goal. We were all on the same page, since we all had the, had similar information, and we were starting to sense patterns with the information, I think that definitely helped." (Team 8, #3)

Once a common understanding of the goal was reached among all team members, they were then able to start collaborating and searching for information. Most teams directly identified their goal at the beginning of the task, leading some participants to indicate that the first step in developing a TMM is reaching a common understanding of the goal. One team member articulates this first step:

"*If you don't know what you're trying to do, you're not going to have a common understanding. I think that's definitely the first thing that you need to do in order to create a mental model is to understand, you know, how you're gonna get, or what you're gonna do and how."* (Team 11, #3)

Understanding the common goal at the onset of teamwork allowed for the quicker development of shared understanding, leading to TMM development.

DISCUSSION AND CONCLUSION

CIS is an important aspect of TDM that begins early and continues throughout the process. Examining CIS from a team cognitive perspective highlights not only how a TMM specific to CIS develops, but also how CIS is interwoven into the broader TDM process. Without effective collaboration during information seeking activities, teams may struggle through the TDM process (Lipshitz, et al., 2001). Our participant teams often highlighted the importance of CIS to their overall TDM process. Although CIS clearly impacts the TDM process, this study raises avenues for future research on CIS's impact on TDM. For instance, how much impact does successful/unsuccessful CIS activities have on the TDM process? In this particular study, we were focused on describing the development of the CIS TMM. In future work, we will focus on trying to evaluate the impact of CIS activities on the TDM process.

This study also highlights an important issue that is often under-examined – the relationship between cognition and interaction. Cognition and interaction share a close relationship (Van den Bossche, 2006), so much so that they

directly affect each other (Ybarra et al., 2008). Team cognition and interaction are in fact very closely related. In recent work by Cooke et al. (2013), an argument is made that interaction is the foundation of team cognition. In prior CIS research, much of the focus has been on how team members collaboratively interact with each other (Reddy & Spence, 2008). In this paper, we have focused on the cognitive issues of CIS. However, we are also interested in further understanding the relationships between cognition and interaction and have used methodology that allows us to capture both interaction (observations) and cognition (cognitive interviews). Although we do not report those results here, the development of a CIS TMM also had implications for the types of interactions amongst team members during CIS.

We are also interested in understanding the content of a CIS specific TMM. As described in the procedure section, we have also collected both individual declarative and team procedural concept maps. Through the analysis of these maps, we will try to understand the content of CIS specific TMMs in individual teams and across teams.

The findings presented here highlight that the process of TMM development during CIS is similar to what has been found in TMM development research conducted in other studies and domains (mental model convergence- McComb, 2007; taskwork and teamwork models- Lim & Klein, 2006; leadership- Dionne et al., 2010). However, to the best of our knowledge, this is the first study to attempt to understand the role of team cognition in CIS and describe the development of a TMM specific to CIS. Furthermore, most TMM development research, to date, has been focused on the conceptual development of the model. This has led to call for researchers to capture the developmental process through empirical data collection (Kennedy & McComb, 2010). We have started to do that through this work.

The Human Factors community has long examined team cognition and TDM, yet little research has focused on the CIS process. CIS is not just a single step during TDM, but is continually re-occurring throughout the process. Planning and re-planning happen routinely during TDM, leading to new goals. In order to understand and meet these goals, teams must constantly adapt to find new information throughout the process. We believe that a detailed understanding of CIS will help improve TDM.

ACKNOWLEDGEMENTS

The authors are grateful to the reviewers for their thoughtful comments. We would also like to thank our participants for their time. This work is supported by the U.S. National Science Foundation under grant IIS-0844947.

REFERENCES

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101.

Cannon-Bowers, J. A., Salas, E., & Converse, S. A. (1990). Cognitive psychology and team training: Training shared mental models and complex systems. *Human Factors Society Bulletin*, *33*(12), 1-4.

Cooke, N. J., Kiekel, P. A., Salas, E., Stout, R., Bowers, C., & Cannon-Bowers, J. (2003). Measuring team knowledge: A window to the cognitive underpinnings of team performance. *Group Dynamics: Theory, Research, and Practice*, *7*(3), 179.

Cooke, N. J., Gorman, J., Myers, C., Duran, J. (2013) Interactive Team Cognition. *Cognitive Science*, *37* (2), 255-285.

Dionne, S. D., Sayama, H., Hao, C., & Bush, B. J. (2010). The role of leadership in shared mental model convergence and team performance improvement: An agent-based computational model. *The Leadership Quarterly*, *21*(6), 1035-1049.

Foster, J. (2006). Collaborative information seeking and retrieval. *Annual Review of Information Science and Technology*, *40*(1), 329-356. doi:10.1002/aris.1440400115

Kennedy, D. M., & McComb, S. A. (2010). Merging internal and external processes: examining the mental model convergence process through team communication. *Theoretical Issues in Ergonomics Science*, *11*(4), 340-358.

Klein, G. A., Calderwood, R., & Macgregor, D. (1989). Critical decision method for eliciting knowledge. *Systems, Man and Cybernetics, IEEE Transactions on*, *19*(3), 462-472.

Klimoski, R., & Mohammed, S. (1994). Team mental model: Construct or metaphor? *Journal of Management*, *20*(2), 403-437.

Lim, B. C., & Klein, K. J. (2006). Team mental models and team performance: A field study of the effects of team mental model similarity and accuracy. *Journal of Organizational Behavior*, *27*(4), 403-418.

Lipshitz, R., Klein, G., Orasanu, J., & Salas, E. (2001) Taking Stock of Naturalistic Decision Making. *Journal of Behavioral Decision Making, 14,* 331-352.

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team process and performance. *Journal of Applied Psychology*, *85*(2), 273.

McComb, S. A. (2007). Mental model convergence: The shift from being an individual to being a team member. *Multi-level Issues in Organizations and Time*, *6*, 83-147.

Mohammed, S., Ferzandi, L., & Hamilton, K. (2010). Metaphor no more: A 15-year review of the team mental model construct. *Journal of Management*, *36*(4), 876-910.

Reddy, M. C., & Jansen, B. J. (2008). A model for understanding collaborative information behavior in context: A study of two healthcare teams. *Information Processing & Management*, *44*(1), 256-273.

Reddy, M. C., & Spence, P. R. (2008). Collaborative information seeking: A field study of a multidisciplinary patient care team. *Information Processing Management*, *44*(1), 242 - 255.

Rouse, W. B., Cannon-Bowers, J. A., & Salas, E. (1992). The role of mental models in team performance in complex systems. *Systems, Man and Cybernetics, IEEE Transactions on*, *22*(6), 1296-1308.

Salas, E., Dickinson, T. L., Converse, S. A., & Tannenbaum, S. I. (1992). Toward an understanding of team performance and training.

Shah, C. (2010a). Collaborative information seeking: A literature review. *Advances in Librarianship*, *32*, 3-33.

Shah, C., & González-Ibáñez, R. (2010b). Exploring information seeking processes in collaborative search tasks. *Proceedings of the American Society for Information Science and Technology*, *47*(1), 1-7.

Van den Bossche, P. (2006). Social and cognitive factors driving teamwork in collaborative learning environments: Team learning beliefs and behaviors. *Small Group Research*, *37*(5), 490-521.

Willis, G. B. (1999). Cognitive interviewing: A "how to" guide. *Research Triangle Park, NC: Research Triangle Institute.*

Ybarra, O., Burnstein, E., Winkielman, P., Keller, M. C., Manis, M., Chan, E., & Rodriguez, J.(2008). Mental exercising through simple socializing: Social interaction promotes general cognitive functioning. *Personality and Social Psychology Bulletin*, *34*(2), 248-259.