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Articulating and Understanding the Development of a Team Mental Model in a Distributed Medium

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Because teams are constantly evolving, we must continue to work towards understanding team cognition development. One particular example of this is the continued efforts towards understanding developmental differences in co-located and distributed mediums. Both of these settings are imperative and critical to teamwork. As individuals become more mobile and less physically connected, supporting teamwork in distributed settings is becoming more and more important. In this paper, we present a study focused on the development of a team mental model (TMM) of collaborative information seeking (CIS) in a distributed setting. The study's findings provide insights into how a TMM specific to CIS develops within a distributed medium, highlighting specific aspects that help and hurt development. Concluding thoughts are presented with the aim to further understand how TMMs develop differently within the contexts of co-located and distributed mediums.

INTRODUCTION

The importance of understanding the development of team cognition has been widely outlined over the years (Salas, Cooke, & Rosen, 2008). Because teams are constantly evolving, we must continue to work towards understanding team cognition development. One particular example of this is the continued effort towards understanding the developmental differences in co-located and distributed mediums. Both of these settings are imperative and critical to teamwork. As individuals become more mobile and less physically connected, supporting teamwork in distributed settings is becoming more and more important.

Human factors research has long attempted to understand the impact of physical distribution on team cognition development, leading to a variety of findings (Cummings & O'Leary, 2002). However, there are still *many* aspects of the relationship between distribution and team cognition that we do not understand. This has led to leaders within the team cognition community to call for more focused work describing the specific impact that distribution has on the development of team cognition (Salas, Cooke, & Rosen, 2008).

Due to the temporal, team configuration, and geographic complexities associated with distributed teams, the development of team cognition is complicated and often challenging (Cummings & O'Leary, 2002). Specifically, issues surrounding communication often arise within distributed teams, leading to significant team cognition difficulties. Having to communicate through a technological medium can lead to higher levels of ambiguity within the team. More specifically, the concept of team opacity is a challenge for distributed teams. Team opacity refers to the loss of team member (level) situational awareness through technology-mediated interaction (Fiore et al., 2003).

For a team to develop a team mental model (TMM), the team must reach a mental model convergence point. This is the point in time where individuals move from thinking only in terms of their individual mental model to thinking from the perspective of the TMM (convergence point) (McComb, 2007). McComb et al. (2010) found that it took distributed teams longer than face-to-face teams to reach this convergence point. The reasoning for this outcome was that the distributed teams focused only on the main points of the research task and not aspects of interpersonal teamwork. The second barrier that resulted in the distributed teams reaching the convergence point at a slower rate was that team members felt significant time pressure because they had to type and interact through a collaborative tool. In a separate study, Bolstad & Endsley (1999) examined the effects of physical proximity on team mental models and found that teams who interacted within a close physical proximity developed team mental models faster than teams who interacted in a distributed manner using a shared display.

This study builds on previous work that has focused on the impact of a distributed setting on the development of a TMM. Specifically, the development of a TMM of collaborative information seeking (CIS) within a distributed medium is studied. CIS is the process of seeking and retrieving information within a collaborative environment and is a critical aspect to team decision-making.

METHODS

Participants

A total of 20 student participants, who did not previously know each other, completed this study. The 20 participants were separated into 10 teams of dyads. Two dyad pilot teams completed the study and provided feedback. Most participants were 21 years old or older (58%) with more females (58%) than males participating. Participants also reported working on an average of 10 teams throughout their academic tenure with a 4.5 (5 point likert) average comfort level working within teams.

Task

A total of three CIS tasks were given to participants to complete. These are tasks derived from work by Shah & González-Ibáñez (2010a). The tasks are aimed at the participants finding specific information to answer a series of questions related to pancreatic cancer. As noted by McNeese,

Reddy, & Friedenberg (2014) these tasks encompass team decision-making by requiring problem identification, planning, re-planning, and information seeking and retrieval.

Procedure

The study lasted approximately 70 minutes. When participants arrived in the laboratory, they were separated and each participant was taken by a researcher to a physically isolated computer terminal. Once seated, the researcher introduced the study and asked each participant to sign an informed consent form and complete a demographic survey. Next, the researcher brought the participants together and provided a high-level description of the study outlining each step. The researcher then explained the concepts of CIS and team mental models. Once the participants indicated that they understood the concepts, the researcher moved on to explaining the Coagmento system. Coagmento (Shah, 2010b) is a widely utilized CIS system in industry and academia that allows for multi-session and multi-user CIS related projects. In this study, participants could only use Coagmento to communicate and seek information with each other.

Participants gathered together and watched a video explaining the features of Coagmento and how to use the system. Once the video concluded, a researcher opened Coagmento on a computer and provided a real-time tutorial on how to use the system (lasting 5-10 minutes). After participants acknowledged that they understood how to use the system, the researchers advanced to the next part of the study. Participants were then given the three CIS tasks and worked through them using Coagmento in their physically isolated terminals. The amount of time given for each task was: task 1 (15 minutes), task 2 (5 minutes), and task 3 (10 minutes). These times were identified during the pilots and articulated as being appropriate for the requirements of each task.

After thirty minutes concluded and the participants finished the CIS tasks, they then participated in individual cognitive interviews. These interviews are a type of knowledge elicitation aimed at having participants revisit their thoughts about activities occurring at a specific point in time in order to gain a better understanding of their underlying cognition (Willis, 1999). Each interview lasted 25-30 minutes and explored multiple aspects of cognition with a particular focus on the development of team level cognition and whether a TMM specific to CIS developed in the distributed medium.

Once the participants finished their cognitive interviews, they were thanked for their time and paid a total of $20.00. After the participants left, the research team transferred the audio recordings of the cognitive interviews and logged the team's chat communication within Coagmento for further analysis.

Data Analysis

The cognitive interviews were analyzed at 3 different levels: individual, team, and across all teams. Specifically, the interviews were analyzed using thematic analysis ((Braun & Clarke, 2006). This is a widely used analytical process, requiring a complete review of the data, systematic coding, and the organization of codes to develop emerging themes. In addition, the chat logs from Coagmento were reviewed in accordance with the thematic analysis of the interviews.

FINDINGS

Through the data analysis, we gained insight into to the development of a distributed TMM of CIS. Furthermore, we have started to identify what helped and hurt TMM development in the distributed setting.

A Distributed Team Mental Model of CIS

A TMM developed in 9 of 10 teams. Traditionally, a TMM is composed of two different models: a *taskwork* model and a *teamwork* model (Mathieu et al., 2000). The TMMs that developed in the distributed setting were *taskwork* specific models. Often, team members mentioned that the TMM could have been stronger, but decreased communication (due to the distributed setting) limited its development. The lack of communication within the distributed medium is a significant reason why a strong teamwork model did not develop in *any* of the teams.

Scope and Content of a Team Mental Model of Distributed CIS

Participants often mentioned that they were *"on the same page"* and developed a shared understanding of the task itself, how to search for information, how to share information, and how to present information within the distributed medium. The model revolved around the concept of the task itself and how to conduct CIS to answer the tasks' questions. When directly asked whether a TMM developed in their team, participants always focused their answer on developing a shared understanding of the task, the method of answering the task, and understanding how to address the task within Coagmento. This focus subsequently resulted in the development of a taskwork specific model. Participants never mentioned developing a shared understanding of their team members' knowledge, skills, attitudes, or a shared understanding of team member roles – all characteristics specific to a teamwork model. A participant described the focus of their TMM:

"So I feel like our team mental model surrounded on the idea that both of us were… independently capable of bringing information to the table, and our team would then be able to synthesize really quickly because we're bringing information that's been prescreened basically, and then we're able to address and review it (for the completing the task)." (Team 1, #1)

As highlighted by the quote, the model focused on the task itself (finding relevant information), not necessarily understanding each team member at an interpersonal level. This participant noted the model developed through sharing information specific to the task. While there is teamwork occurring during the development of this TMM, the teamwork itself is oriented toward completing the task and finding information directly related to the task, and rather, not about understanding specifics about team members. The team members were focused on the task itself and not each other.

By developing a taskwork model specific to CIS, team members were able to assume and predict how to complete the tasks over time, which affected how they worked together. As a participant describes below:

"The first question we had, had a lot of communication because we like were just diving into it. And I feel like we were like,—what do we wanna do, how, like, do we wanna have an

introduction, all this just different, like formatting, stuff like that. And then by the second one, it was still pretty, I mean we still talked about it (formatting and organization), before we made that with the second one. But like, there was still, I mean I guess not as much in the second one, but definitely by the third one, I don't even think we, I think we messaged each other like, a few times toward the end. And, I feel like it, it was just like a general understanding of what we had to do, and like I didn't have any questions for her. And, but we didn't even really need to like… make sure like she was on the same page 'cause we both knew I guess." (Team 8, #2)

This quote highlights how the taskwork oriented TMM helps develop a structure for the team to follow during the tasks. This limits the need for communication because the team establishes a shared understanding of the task and how to complete it.

Aspects Positively Impacting Team Mental Model Development in A Distributed Setting

In this study, the development of the TMM was based on the sharing of individual mental models among the team members. The TMM grew and developed over time as aspects of individual team members' mental models were shared with each other. A participant explained the development of the TMM:

"Yeah, so like I feel like it's built upon, built —on the basis of individual… like… individual learning models and mental models. And then… combining that to like team mental model. So, like that's how we're able to collaborate, we're able to work, to work on it together, able to do it together. But at the same time still maintaining my own perception of how to get things done." (Team 2, #1)

In addition to the development of the TMM being dependent on team members' individual mental models, participants were able to identify other aspects that helped them develop the TMM in the distributed setting. Ultimately, the interaction of these aspects with each other built team cognition and the TMM. In Table 1, we highlight all the aspects identified by participants as helping in the development of a TMM but because of space limitations, we will only discuss two in-depth – Awareness, and Trust & Assumptions.

Aspect Helping to Develop TMM	Description
Team experience within the distributed setting	Team members noted that increased experience working in a distributed setting made it easier to overcome the limitations of setting. Consequently, this helped to better develop a TMM.
Communication & Sharing Information	Team members noted that communicating within the distributed medium was critical to developing the TMM. Specifically, because the TMM was task oriented, sharing information relevant to the task was of increased importance. While many participants noted that communication was limited in the distributed medium, they were still able to communicate through Coagmento. However, because there was a lack of face-to-face communication, it made the development of the TMM more difficult.
Learning how to work with each other over time	Participants explained that working with each other over an extended time period led to a shared understanding of the associated taskwork, allowing for the TMM to grow.
Awareness	Will be discussed below
Trust & Assumptions	Will be discussed below
Leadership or lack of leadership	Participants pointed to leadership or a lack of leadership as both helping to develop the TMM. Team members noted that a leader could help to organize the team and subsequently help focus the development of the TMM. Additionally, some team members also mentioned that a lack of leadership was a positive for the development of the TMM. These participants indicated that a leader could potentially force their individual mental model on the team, resulting in the TMM not being actually representative of the entire team. Without leadership, team members explained that all team members' individual models could better contribute to the overall TMM.
Structure and repetition of distributed CIS	Many participants explained that the nature of distributed CIS led them to develop a shared understanding of how to complete the task. Communication in the distributed setting was predicated on a structure of one person communicating then another replying and this pattern repeating. This repetition allowed for team members to understand how to communicate and share information in this setting, aiding in the development of the TMM.

Table 1: Aspects Benefiting Team Mental Model Development in a Distributed Setting

Awareness

Awareness helped teams to not only complete the CIS task but also develop their TMM. A participant explained the overall need for awareness during CIS: *"You really gotta look out for what everyone else is doing, and not just focus on your own research. Kinda gotta look at where they're going with it, and… go from there. And make sure you're not stepping on each other's toes."* (Team 1, #2). Awareness developed through two different types of activities: (1) team members actively informing each other what they were doing through chat, or (2) the team members monitoring each other's actions via features in Coagmento (bookmarking webpages, sending information, search history, and a shared document).

By keeping aware of each other's search actions, they gained insight into how their partner was approaching the task and the type of work he or she was doing. This helped team members to direct their individual model to better align with other team members' models, consequently developing the TMM. Awareness was *extremely* important in the distributed medium because team members did not have access to many of the co-located aspects of teamwork (non-verbal communication, face-to-face synchronous communication). These limitations impacted overall awareness, resulting in increased teamwork difficulties. Yet, through the two aforementioned practices (actively informing each other, monitoring through Coagmento), team members created awareness in all of the distributed teams. As a participant described, using awareness within the distributed medium helped create the TMM:

"*It (awareness) definitely helped the development of the team mental model, because… you can see that one person's doing their part of the project, and not just sitting there playing with their fingers or something. Like you know, you know*

they're being productive, and then you can trust that their part will be okay and you can just do your part without worrying about it. And then it, it's the kind a thing with like the basketball like the blind pass like, alright you do number 1 and 2 and I'm just gonna assume you're gonna do it the right way 'cause I'll do 3 and 4 the right way. (Team 10, #2).

Along with highlighting the importance of awareness to the TMM, this quote also details how awareness helped the team member make assumptions and develop trust in their team. Trust and assumptions were two aspects of CIS teamwork that were often noted as being important to developing a TMM in the distributed medium. In the next section, this aspect will be described in greater detail.

Trust & Assumptions

Team members often described the need for trust and the ability to make assumptions as instrumental to developing a TMM in the distributed setting. Team members had to make assumptions about each other's CIS activities because the distributed setting did not allow team members to physically *view* what their teammates were doing during these activities. A participant explained the barriers of the distributed medium and the need for assumptions:

"And in this, you know, you're a little bit, you know blinded, by, by you know the, the digital interface, right. So you don't know exactly what she's doing, but like at the same time you know, you, you kinda have to establish, you kinda make the assumption that you know the other person is doing work, or you kinda make that prediction." (Team 3, #1)

Team members had to actively work to develop this awareness through communicating with each other or processing relevant awareness information from Coagmento. The need to actively work to develop awareness within the distributed medium created a problem- team members could not work on the information seeking task and simultaneously monitor everything that their team member was doing. For this reason, they made assumptions about what each other was doing. Participants noted numerous times that they had to assume that their team member was appropriately working on some aspect of the task. One team member described the type of assumptions that were made during distributed CIS work:

"*We just kind of, I think we had a lot of assumptions that the other person knew what they were doing, and that they knew how to find reasonable data that wasn't stuff that you had to change or it wasn't… I can't think of the word. It was—like it was good information, for lack of a better term."* (Team 9, #1)

In addition to needing to make assumptions in the distributed medium, team members also mentioned trust as being critical during distributed CIS. A participant explained the role of trust:

"*I think not being together, there was less discussion, I guess like over the chat. So it was more of a trusting like they were just gonna… they were gonna be doing it too, but if I was together with someone I think I would… have more discussion like okay, let's do this, okay let's do this; okay, let's do this."* (Team 7, #1)

When asked about TMM development, team members often brought up the importance and need for trust. Specifically, team members indicated that they must not only assume but trust that their teammates were appropriately carrying out their CIS tasks. As highlighted above, increased awareness of team members' actions significantly helped to develop trust. Consequently, the trust that was built among team members allowed for better development of a TMM. A participant articulated the role that trust played in the team mental model:

"I mean I, I assumed he was doing work, but… it's kind of a working relationship where you just trust that your team members and your coworkers are doing what they're supposed to be doing, and that when push comes to shove they'll be ready to execute and deliver. It wasn't a case of micromanaging or me asking hey, what are you doing now, it was more a case of… both of us… having a similar enough mental model that we could trust each other to just do work and just stay productive for as much of the time as possible." (Team 1, #2)

Interestingly, when team members discussed trust, they did not explain it as developing over time. Rather, participants noted that due to the limitations of the distributed medium, they were forced to trust their team member from the onset of collaboration.

Difficulties Associated With The Distributed Environment in Developing a Team Mental Model

Participants also indicated that difficulties associated with carrying out CIS activities in the distributed setting complicated their ability to develop a TMM of CIS. In some cases, the communication limitations of the distributed setting negatively impacted the development of the TMM. One specific limitation concerned the inability to actually talk with team members in real time. In Coagmento, participants were limited to synchronous chat. Many participants found that this slowed down their overall communication. Consequently, the slower communication limited the overall amount of communication that took place. One participant explained the inability to speak with each other and its negative impact on CIS and the TMM:

"It's, it does, it, it did hurt it a little bit (TMM development in distributed medium). I felt like… like having face to face conversation, like let's say if we were just next to each other and, didn't have a divider, and we can actually say hey, you know. It's ease—it's easier to communicate verbally than it is to just, you know. And it'd also be easy to just look over and say hey, you know, I'm looking at the same thing. So, I guess it would be, communication would be easier." (Team 6, #2)

Many participants specifically noted problems associated with having to type everything in order to communicate, resulting in slower communication:

"I think it hurt (TMM development in distributed medium). Because… it's tough to tell… with the way we were, without being able to talk to each other. Like… just the thoughts, and I mean, I mean there's only so much you can put into words in typing. So I think it was, I think it hurt. " (Team 4, #2)

Although it was limited, communication still did occur in the distributed setting, which allowed for the development of the TMM. However, because the distributed communication occurred at a slower pace than face-to-face interaction, the development of the TMM took longer. Multiple team members explained the affect that the distributed setting had on how long the TMM took to develop:

"Uh… yeah. I mean I think being distributed did slow the development of our mental model for, it was definitely slower than if we had not been distributed. Yeah, 'cause definitely it took a few minutes to kind of… figure out how this was gonna go. But then by the end of the first task, I kinda figured it was gonna be like, me suggesting things and him agreeing." (Team 4, #1)

Because the distributed synchronous communication occurred slower than face-to-face, the TMM developed at a slower rate. In addition, participants also mentioned having to focus on multiple aspects of CIS within the distributed condition, such as communication, information sharing, and awareness. This could overload their cognitive abilities and have a negative affect on the TMM.

DISCUSSION AND CONCLUSION

The development of a TMM in a distributed medium is complicated, as highlighted by this study. The findings describe how a TMM can be developed within this medium through the benefits of multiple variables (awareness, trust, experience). However, the scope of the TMM is limited to a taskwork model because of multiple communication issues. These findings align with previous work conducted by McComb & colleagues (2010) who found that distributed TMM development occurred slowly because decreased communication led to the primary focus being on the task itself.

Furthermore, the design of this study and McNeese and colleagues' (2014) study are similar and when compared, reveal some interesting insights about the development of TMMs in co-located and distributed mediums. While teamwork models were rare in both studies, a few (3 out of 10) teams did develop teamwork specific models in the co-located medium (McNeese, Reddy, & Friedenberg, 2014). On the other hand, no teamwork models developed in the distributed setting. This raises an interesting question as to why there was a higher prevalence of teamwork models in the co-located medium than the distributed medium? Analysis between the studies shows that the limited communication in the distributed environment coupled with other previously discussed issues prevented the in-depth discussions needed to develop teamwork models. Since communication takes longer in the distributed setting, participants were only able to focus on the task itself and not on understanding their partner.

Yet, surprisingly, although the TMMs are different in scope (teamwork vs taskwork) in the two settings, they often developed in similar ways. In both studies, the developmental process involved individual team members sharing their ideas. Over time, team members learn about each other's cognition and then revise their individual cognition to orient with the team's goals. Depending on the type of TMM (taskwork or teamwork) this process may only be focused on task oriented cognition/procedures, or it may also include a deeper level of understanding that encompasses the team members' knowledge and skills. One might not expect the development of the TMM to follow this pattern within the distributed setting due to the communication limitations that have previously been discussed. However, team members were still able to share enough of their individual cognition within the distributed setting to meet the threshold needed for an emerging team level cognition.

In conclusion, as individuals become more mobile, the importance of understanding the development of team cognition in a distributed manner becomes more critical. Through this study, we have added to the literature in this area.

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