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Planning and Team Shared Mental Models as Predictors of Team Collaborative Processes

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PLANNING AND TEAM SHARED MENTAL MODELS AS PREDICTORS OF TEAM COLLABORATIVE PROCESSES

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ABSTRACT

PLANNING AND TEAM SHARED MENTAL MODELS AS PREDICTORS OF TEAM COLLABORATIVE PROCESSES

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This study evaluates the role of team planning and the similarity of team shared mental models (TSMMs) as predictors of two types of collaborative behaviors that are known to contribute to team performance. A computer-based Networked Fire Chief (NFC) simulation task was used as a testing environment for emergent and dynamic situations. The relationships among team planning, similarity of task-focused team shared mental models (TASKTSMMs), similarity of team-focused team shared mental models (TEAMTSMMs), team backup behaviors, and implicit coordination were tested. This study provides evidence for the mediation effect of similarity of TASKTSMMs between team planning and team backup behaviors, and the mediation effect of team backup behaviors between similarity of TASKTSMMs and team performance. The results suggest that better team planning is more likely to encourage more backup behaviors and improved performance through teams having more similar task-focused mental models. Both the theoretical and practical implications were discussed and the limitations and future research were also addressed in the study.

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NOMENCLATURE

TSMMs	Team Shared Mental Models
STSMMs	Similarity of Team Shared Mental Models
ATSMMs	Accuracy of Team Shared Mental Models
TASKTSMMs	Task-Focused Team Shared Mental Models
TEAMTSMMs	Team-Focused Team Shared Mental Models
TMS	Transactive memory systems
TSA	Team situation awareness

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CHAPTER 1

INTRODUCTION

In today's organizations, work is often accomplished in a team setting. Teams are a critical instrument that organizations use for solving complex problems and achieving difficult goals (Stewart & Barrick, 2000). Many benefits have been attributed to the use of teams such as increased productivity, innovation, flexibility, as well as decreasing costs, absenteeism, turnover, etc. (Gable, 2009; Hauschildt & Kirchmann, 2001; Kyonne, 2008; Mendelsohn, 1998).

There are different classifications of teams. One such classification is to label teams as decision making teams, action teams, or project teams. Decision making teams are interdependent with respect to information, whereas action teams usually engage in more behaviorally interdependent activities, requiring team members to coordinate their actions in order to perform time-sensitive or physical tasks. On the other hand, project teams are involved in both informational – knowledge processing and behavioral actions in pursuing team goals (DeChurch & Mesmer-Magnus, 2010a). For instance, top management teams in organizations are examples of decision making teams, while various sports teams are examples of action teams. Complex engineering-intensive projects, such as software design and construction projects, are typically executed by project teams. In the field of engineering management, project teams play a more prominent role than purely decision making or action teams. This research utilized a simulation task to study project teams. The task involves both decision-making activities and interdependent actions among team members.

1.1 Research Background

1.1.1 Research Purpose

The purpose of this research is to study how teams operate under emergent and dynamic situations. In this study, the term "emergent" refers to the situations that arise suddenly and unexpectedly, whereas "dynamic" pertains to the changing conditions that call for quick judgment and prompt actions. Specifically, this study evaluates the relationships between team planning, team shared mental models (TSMMs), and team collaborative behaviors. This study also seeks to determine how these variables influence team performance.

1.1.2 The Importance of Team Cognition

Team cognition refers to the manner in which important knowledge of how the team functions is mentally organized, represented, and distributed within the team (Kozlowski & Ilgen, 2006). It is an emergent state describing conditions that dynamically enable and underlie effective teamwork that allows team members to anticipate and execute actions (Salas & Fiore, 2004). The term "emergent state" refers to novel and coherent structures, patterns, and properties that arise during the process of self-organization in complex systems. It is the product of a dynamic process when individuals interact as part of a team (Goldstein, 1999). Many researchers have emphasized the important effect of team cognition on team processes during the past decades. For instance, DeChurch and Mesmer-Magnus (2010a) conducted a meta-analysis on the relationship between team cognition and team processes, and they found that team cognition, generated through the course of interactions, usually served as a structure that guided team members' behaviors.

1.1.3 The Importance of TSMMs

Team cognition is a broad construct that includes variables such as team shared mental models (TSMMs), transactive memory systems (TMS), and team situation awareness (TSA). Each of the variables focuses on a different aspect of team cognition, and among those variables TSMMs have recently drawn much attention in team literature due to their role on team alignment and cooperation, especially for those teams that operate in emergent and dynamic situations (Bierhals, Schuster, Kohler, & Badke-Schaub, 2007; Carpenter et al., 2010; Mohammed, Ferzandi, & Hamilton, 2010; Ying & Erping, 2010).

TSMMs refer to the extent to which team members are “on the same page” and work in a coordinated fashion to cope with difficulties and achieve desired team performance. Prior studies suggested that TSMMs were positively related to collaborative processes such as backup behaviors, coordination, etc. (Fisher, Bell, Dierdorff, & Belohlav, 2012; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). However, the relationships between team planning, team shared mental models (TSMMs), and team performance are only partially understood.

1.1.4 Team Planning, Team Backup Behaviors and Implicit Coordination

Marks, Mathieu, and Zaccaro (2001) suggested that team processes might be classified into three different categories: transition processes (such as team planning, goal specification, and strategy formation), action processes (such as monitoring process towards goals, systems monitoring, backup behaviors, and coordination), and interpersonal processes (such as conflict management, motivation and confidence building, and affect management). They further pointed out that evaluating all the process variables in one study was often not practical and necessary. Instead, they recommended focusing on variables that were more relevant to the research context. This research focuses on processes that are critical to the project teams operating under emergent and dynamic situations. Specifically, team planning, team backup behaviors, and team implicit coordination are assessed.

Team planning, a transition process and one of the key drivers of team performance (Marks et al., 2001), occurs when team members conduct a series of preparation activities in order to attain certain goals and accomplish group tasks. In emergent and dynamic situations, the process of planning supports a critical element of task completion by focusing on scanning and assessing task requirements and constraints before the actual execution of the tasks. The process of planning also helps allocate responsibilities and roles to each team member in order to facilitate coordination and cooperation during task execution (Janicik & Bartel, 2003).

Team backup behaviors have been identified as a key action process contributing to team performance in emergent and dynamic situations (Marks et al., 2001). These behaviors reflect team members' willingness to devote their resources to support other team members under such conditions (Porter, Itir Gogus, & Yu, 2010).

Team implicit coordination, another important action process, refers to the team process that orchestrates the sequence and timing of interdependent actions within team dynamics (Marks et al., 2001). The role of implicit coordination is especially important to a team functioning under emergent and dynamic situations because in these contexts team members usually have limited time to formally coordinate and communicate with each other.

1.1.5 Contributions to Engineering Management

The field of engineering management is largely dominated by the use of project teams. Understanding how to enhance cognitive processes in teams and how those processes impact team performance is critical to advancing knowledge in this field.

On the other hand, the research on team cognition, or to be more specific, the research on TSMMs, is an important aspect of team research. TSMMs can help us better understand how to improve team alignment and coordination, making teamwork more effective. This research evaluates the effects of TSMMs within engineering project teams and is expected to contribute to both team research literature and the practice of engineering project teams. The advancement of both team research and the practice of engineering project teams would eventually be beneficial to the field of engineering management. Figure 1 shows the potential links between this research and the field of engineering management.

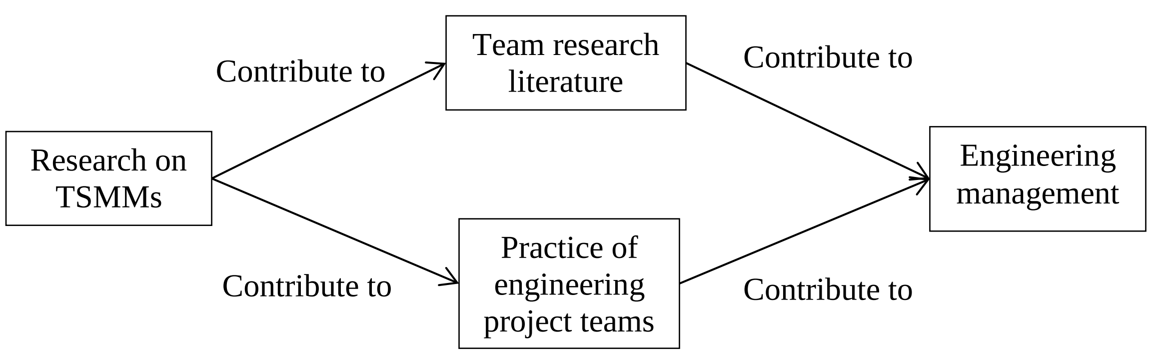


Figure 1: Contributions to Engineering Management

1.1.6 Potential Implications

The study has several potential implications: 1) theoretically, it is expected to contribute to the literature of team research by helping us understand how TSMMs influence collaborative processes and their conjunctive impact on team performance; 2) practically, the results of the study contribute to human resource management in the areas of planning, training, and leadership intervention by helping us understand how collaborative behaviors can be developed through planning and TSMMs; and 3) the employment of fire-fighting simulation as the research task may also be beneficial for the actual practice of engineering project teams that operate under emergent and dynamic situations since the task involves both decision making and action processes (though it is somewhat limited). Further discussion of these implications will be addressed in chapter 5.

1.2 Research Questions

1.2.1 Research Question One

Most of the previous research in TSMMs has focused on identifying the predictors of TSMMs and the outcomes that TSMMs would lead to. However, we still know little about how TSMMs support teams to translate their planning activities into successful collaborative processes. This study is designed to evaluate whether team planning and TSMMs are an inherent part of successful collaborative processes. The first research question is: “What is the role of TSMMs as a mediator between team planning and two collaborative processes, namely, team backup behaviors and team implicit coordination?”

1.2.2 Research Question Two

According to prior research, the construct of TSMMs can be evaluated through two different perspectives, one being task-focused and the other being team-focused. More details and background regarding these two elements are addressed in chapter 2. The second research question of this study is: "how are different elements of TSMMs affected by team planning, and how do they impact team backup behaviors and implicit coordination?"

1.2.3 Research Question Three

A major goal of team research is to find out what critical factors make teams more effective and what can be done to improve team performance through enhanced collaboration and coordination processes. Thus, the third research question is "how do TSMMs enhance team collaborative behaviors and therefore help teams perform better?"

1.3 Definition of Terms

1.3.1 Team Shared Mental Models (TSMMs)

Team shared mental models (TSMMs) is a representation of the common understanding and beliefs regarding task requirements, what can be done in advance, and who is responsible for each task within the team. TSMMs have been used to assess the extent to which teams are able to adapt quickly to an emergent and changing environment (Cannon-Bowers, Salas, & Converse, 1993).

1.3.2 Similarity of Team Shared Mental Models (STSMMs)

Similarity of Team Shared Mental Models (STSMMs) represents the extent to which team members have similar understandings or beliefs about task-focused and team-focused attributes or characteristics of the work they are tasked with doing. It is usually assessed based on the idea that team members' schema similarity could be described in terms of both task-focused and team-focused mental model characteristics (Rentsch & Hall, 1994).

1.3.3 Accuracy of Team Shared Mental Models (ATSMMs)

Accuracy of Team Shared Mental Models (ATSMMs) argues that similar TSMMs do not necessarily mean correct mental models that reflect reality. Team members may hold similar mental models but their mental models may still be erroneous, which may influence team performance, especially in situations where there is a set of proven strategies to accomplish the task (Edwards, Day, Arthur & Bell, 2006). Accuracy of team shared mental models will not be assessed in this study because it falls outside the scope of this research.

1.3.4 Task-focused Team Shared Mental Models (TASKTSMMs)

Task-focused team shared mental models (TASKTSMMs) assess the extent to which team members hold shared knowledge about task or job related characteristics in terms of task procedures, task strategies, likely contingencies, likely scenarios, environmental constraints and task component relationships (Cannon-Bowers et al., 1993).

1.3.5 Team-focused Team Shared Mental Models (TEAMTSMMs)

Team-focused team shared mental models (TEAMTSMMs) refer to the extent to which team members may have a shared understanding of how the team interacts in terms of roles and responsibilities, information sources, interaction patterns, communication channels, role interdependencies, information flow, etc. It is usually associated with the understanding of fellow teammates' knowledge, skills, attitude, preferences, tendencies, etc. (Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995).

1.3.6 Team Planning

Team planning is a process prior to a mission, during a mission, or both that is believed to contribute to the team performance. It includes activities such as setting goals, creating an open enviroment, sharing information related to task requirements, discussing relevant environment characteristics and constraints, prioritizing tasks, communicating and exchanging expectations, clarifying roles and responsibilities, distributing workloads, planning for unexpected events, etc. (Stout et al., 1999). It consists of a series of works that a group engages in to better coordinate their effort to attain their goals (DeChurch & Craig, 2008; Marks et al., 2001).

1.3.7 Team Backup Behaviors

Team backup behaviors reflect team members' willingness to devote their resources to support other team members in order to achieve better team performance (Porter et al., 2010).

1.3.8 Team Implicit Coordination

Team implicit coordination takes place when team members anticipate their colleagues' needs and adjust their own behaviors accordingly without having to communicate directly with each other or plan the activity (Rico, Sanchez-Manzanares, Gil, & Gibson, 2008).

CHAPTER 2

BACKGROUND OF THE STUDY

This chapter provides a review of prior empirical studies that are related to the team theoretical framework and the constructs of TSMMs, team planning, team backup behaviors, and team implicit coordination. It concludes with the proposed statistical model and associated hypotheses describing the relationships among those variables.

2.1 Literature Review

2.1.1 Team Theoretical Framework

Prior researchers have proposed different theoretical frameworks to assist team research, among which the input-process-outcome (IPO) framework is one of the most widely used (see figure 2) (Hackman, 1987; McGrath, 1984). In this framework, inputs include individual factors (such as personalities and abilities), team factors (such as team efficacy and team shared mental models), and organizational factors (such as organizational climate and culture). These various inputs combine to influence team processes, which describe team members' interactions towards task accomplishment. Outcomes refer to the results of the team activities, which include both team performance (such as performance behaviors and outcomes) and team members' affective outcomes (such as satisfaction and commitment).

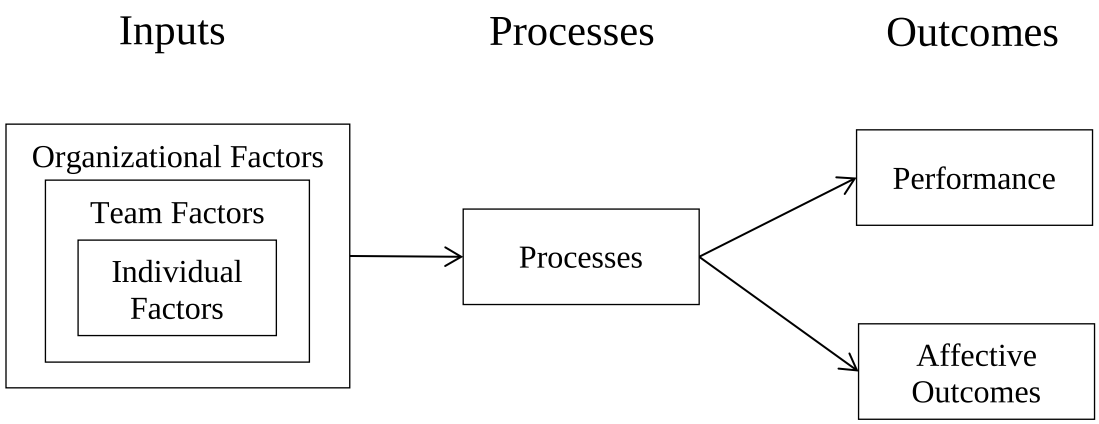


Figure 2: Input-Process-Outcomes Framework

However, this framework tends to overlook the variability of team processes over time and fails to consider the dynamic nature of teamwork. In response to this limitation, Marks et al. (2001) proposed a time-based framework of team processes that classified them into transition, action, and interpersonal processes (figure 2). During transition processes, teams focus on planning or task assessment, while during action processes teams conduct actual activities in order to achieve their team goals. On the other hand, interpersonal processes represent the "relationship management" among team members, which sets the basis for the effectiveness of other team processes. Based on this framework, the outputs of team transition processes become the inputs of team action processes. This study evaluates the role of team planning and team shared mental models (TSMMs) (transition processes) as predictors of two types of collaborative behaviors (action processes) that are known to contribute to team performance, which builds upon the model shown in figure 3.

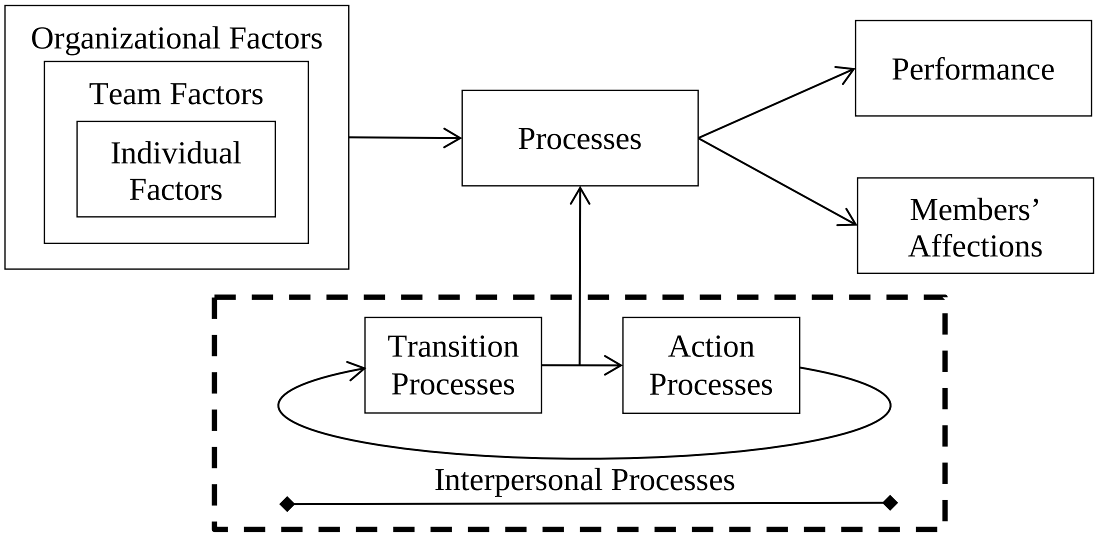


Figure 3: Time-Based Framework of Team Processes

2.1.2 Contents of TSMMs

TSMMs have been linked to improvements in team members' abilities to better predict others' needs in advance and to develop similar expectations for future events and improve coordination and cooperation amongst the team (Mathieu et al., 2000; Mohammed et al., 2010). There are different aspects of TSMMs that have been found to influence team processes including the technology/equipment used by the team, the type of job/task, team interaction, and knowledge of teammates (Klimoski & Mohammed, 1994).

Mathieu et al. (2000) proposed two measurements of TSMMs based on two main content domains: task-focused TSMMs (TASKTSMMs) and team-focused TSMMs (TEAMTSMMs). TASKTSMMs are associated with work goals and performance requirements (e.g., technology/equipment and job/task) and TEAMTSMMs include the interpersonal interaction requirements and skills of other team members (e.g., team interaction and knowledge of teammates). Figure 4 below shows two different content domains of TSMMs.

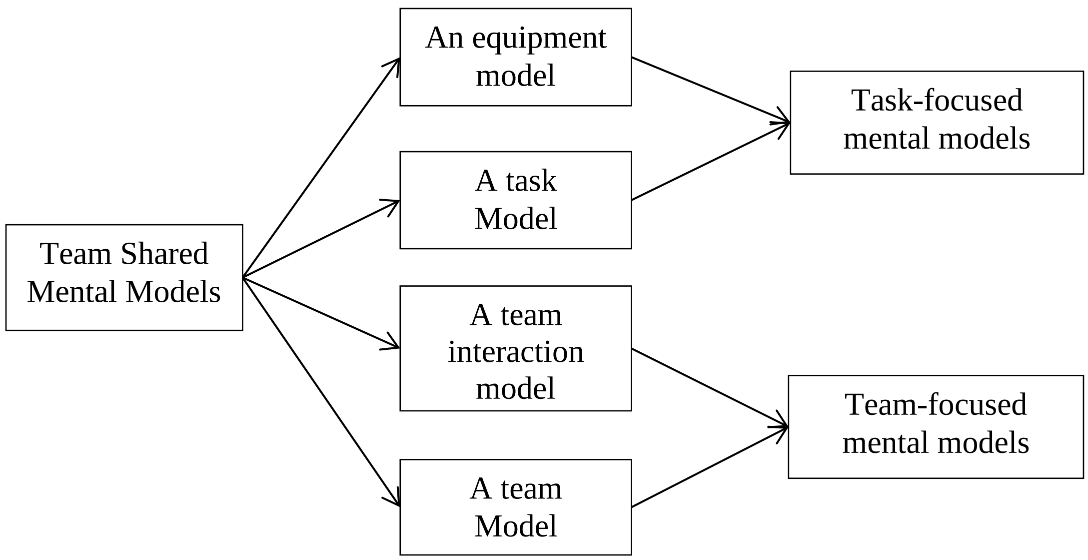


Figure 4: Contents of TSMMs

2.1.3 Properties of TSMMs

The core of team shared mental models is the word "shared," and it evaluates the extent to which team members' mental models are consistent or convergent within the team (Cannon-Bowers et al., 1993; Rentsch, Small, & Hanges, 2008). Various terms have been used to capture the "sharedness" of team members' mental models such as similarity, agreement, convergence, consistency, compatibility, consensus, etc. Among those different terms being used, "similarity" is the most commonly used one in previous literature (Rentsch & Hall, 1994).

Similarity of Team Shared Mental Models (STSMMs) represents the extent to which team members have similar understandings or beliefs about certain task-focused or team-focused attributes or characteristics (Rentsch & Hall, 1994). STSMMs are considered important predictors of team outcomes based on several studies (DeChurch & Mesmer-Magnus, 2010a; Edwards, Day, Arthur, & Bell, 2006; Ellis, 2006; Marks, Burke, Sabella, & Zaccaro, 2002), and a lack of shared mental models has been associated with poor team performance. The accuracy of TSMMs (ATSMMs) represents the "true state" or the quality of team shared mental models (Edwards et al., 2006; Fisher et al., 2012). Accuracy is a critical characteristic of TSMMs because similar mental models shared within the team do not necessarily mean correct mental models that reflect reality. Failure to measure the accuracy of TSMMs may also lead to overestimating the similarity of the TSMMs when evaluating the relationships between TSMMs and team outcomes (Smith-Jentsch, 2009). Figure 5 below shows two different properties of TSMMs.

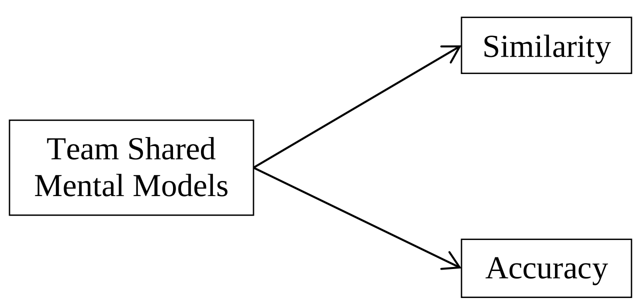


Figure 5: Properties of TSMMs

2.1.4 Compatible or Complementary TSMMs

Although TSMMs are often considered similar mental models shared within team members, the term "sharing" may have different meanings. Resnick (1991) argued that "sharing" could mean "having in common" (e.g., sharing equipment) or "dividing up" (e.g., sharing the workload).

Cooke, Salas, Cannon-Bowers, and Stout (2000) suggested that TSMMs might be divided into two different types: homogeneous (compatible) or heterogeneous (complementary). Homogeneous TSMMs refer to the extent that team members share similar or compatible knowledge, whereas heterogeneous TSMMs argue that team members hold distributed or complementary knowledge required for the task. However, most researchers identified TSMMs as the representation of knowledge which is held in common (compatible) rather than the knowledge distributed among team members (complementary) (Bierhals et al., 2007; Carpenter et al., 2010; Edwards et al., 2006; Lim & Klein, 2006; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005; Mathieu et al., 2000; Uitdewilligen, Waller, & Pitariu, 2013; Van den Bossche, Gijselaers, Segers, Woltjer, & Kirschner, 2011; Ying & Erping, 2010). Moreover, Cannon-Bowers et al. (1993, p. 236) asserted that *"the crucial implication of shared mental model theory was that team members hold compatible mental models that leaded to common expectations for the task and team"*. Therefore, TSMMs are defined as compatible (knowledge held in common) rather than complementary (knowledge distributed) mental models in this research.

2.1.5 Forms of TSMMs

The form of TSMMs is associated with how TSMMs are elicited and presented or how they are perceived and measured (DeChurch & Mesmer-Magnus, 2010a). In previous studies, TSMMs were evaluated from two different perspectives: perceptual or structured form (Rentsch et al., 2008). The perceptual perspective of TSMMs represents team members' beliefs, attitudes, values, perceptions, and expectations, whereas the structured perspective shows the structure or interpretive relations of team members' understanding about the task or the teamwork. In other words, the structured form of TSMMs emphasizes the knowledge arrangement or organized knowledge in team members' minds.

In essence, if TSMMs are evaluated through the perceptual form, researchers usually focus on eliciting team members' unstructured knowledge such as declarative knowledge (knowledge of what), procedural knowledge (knowledge of how), and strategic knowledge (knowledge of the context and application). On the other hand, if TSMMs are captured through the structured form, researchers would try to find team members' knowledge patterns (structured knowledge) to represent their mental models. Figure 6 below shows two different forms of TSMMs.

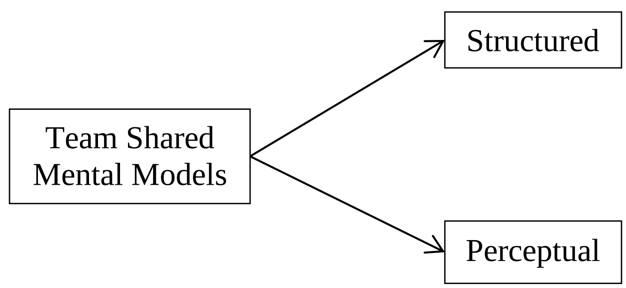


Figure 6: Forms of TSMMs

2.1.6 Measurement of Similarity of TSMMs (STSMMs)

The evaluation of STSMMs is usually operationalized in two ways: 1) elicit each individual's knowledge (mental model); and 2) measure the "sharedness" or similarity among team members' mental models. In the early stages of the research, there were debates about how to capture TSMMs. Some researchers suggested that TSMMs should be measured through the perceptual form which only elicits each team member's unstructured knowledge, while others argued that structured knowledge should be emphasized. In 2000, three important papers were published focusing on the measurement issues of STSMMs. According to Cooke et al. (2000), the measurement approaches for STSMMs can be characterized by three processes: 1) elicitation methods; 2) team metric; and 3) aggregation methods. The first process, elicitation methods, includes the methods of observations, interviews and surveys, process tracing, and conceptual methods. If we prefer to elicit each team member's unstructured knowledge, we may use the observation, interviews and surveys, or process tracing. On the other hand, if we want to capture individual's structured knowledge, conceptual methods, which usually take pairwise estimates of relatedness for a set of concepts and generate a spatial or graphical representation of those concepts, may be more appropriate. The second process, team metrics, is used to compare how similar or accurate team members' mental models are. Commonly used techniques for team metrics include Pathfinder, UCINET, Euclidean Distance, Multidimensional Scales, Pearson Correlations, etc. Since we only compare two team members' mental models at a time, we will need to aggregate the outcomes to the team level by using the aggregation methods, which is the third process in their approaches. Figure 7 shows the three processes discussed above for the evaluation of TSMMs.

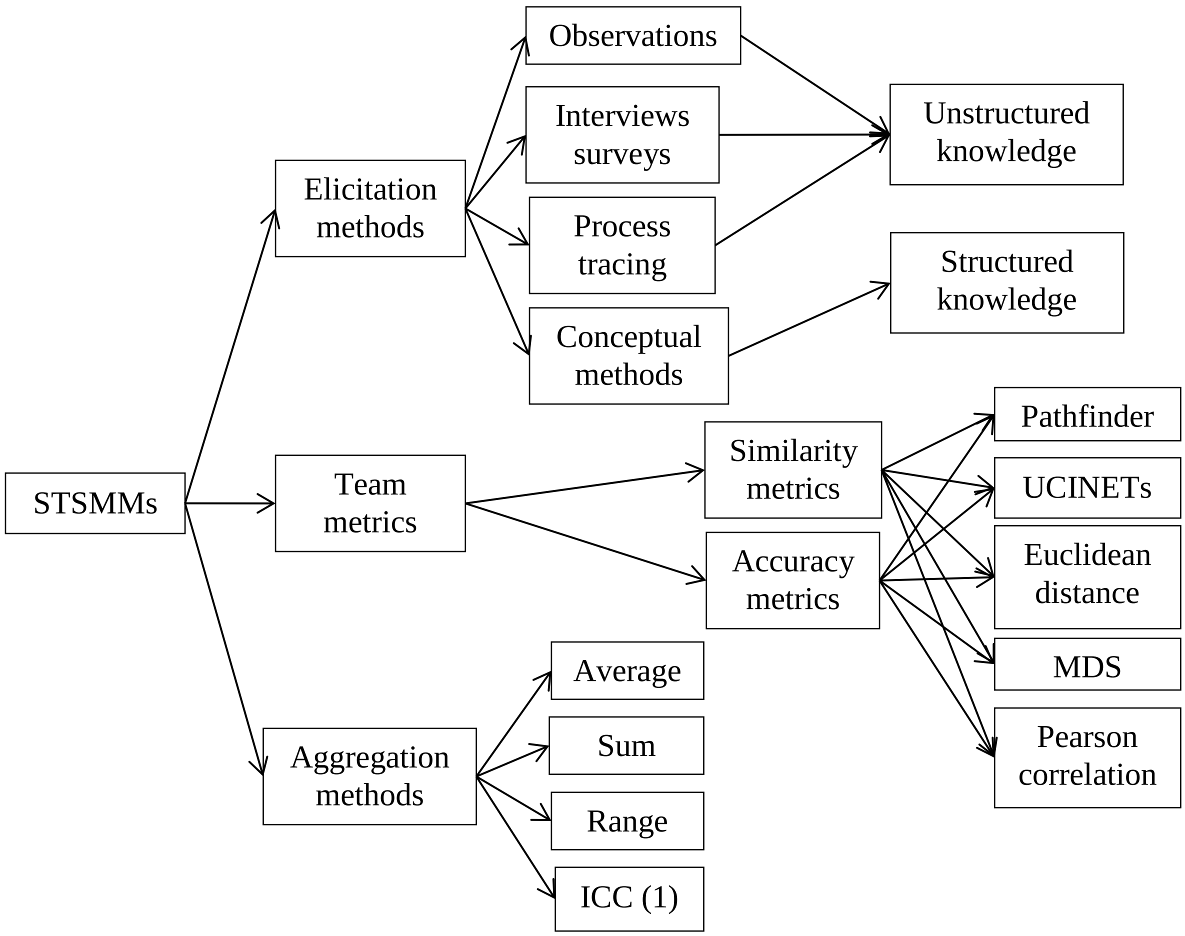


Figure 7: Three Processes to Measure STSMMs

2.1.7 Two-Steps Approach to Evaluate Similarity of TSMMs (STSMMs)

Besides the three processes suggested by Cooke et al. (2000), Mohammed, Klimoski, and Rentsch (2000) and Langan-Fox, Code, and Langfield-Smith (2000) proposed a two-step approach whose main idea was very similar to the three processes discussed above. In their paper, they divided the measurement of STSMMs into two phases: elicitation and representation. Elicitation is used to determine the components or content of a mental model, or to show each individual's unstructured or structured knowledge, whereas representation is utilized to reveal the structure of data or determine the relationships between elements in each individual's mind. The idea is to elicit unstructured or structured knowledge first and then find the relationships among those unstructured or structured knowledge. Figure 8 shows this two-step approach for the evaluation of STSMMs.

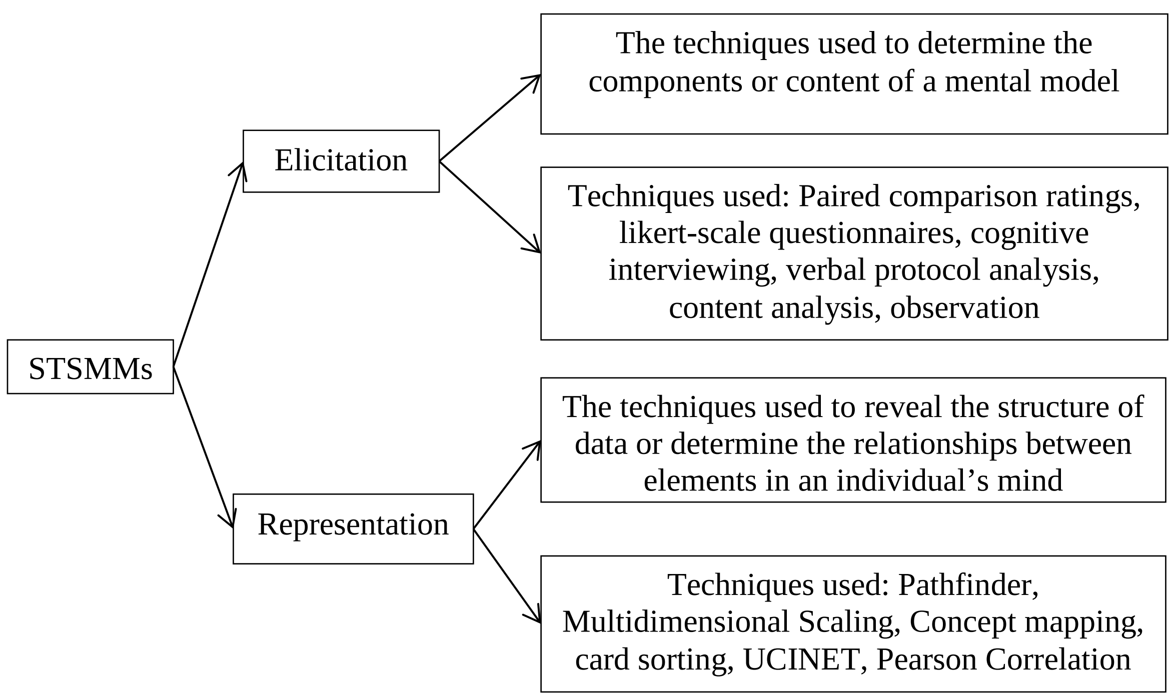


Figure 8: Two-Steps Approach to Evaluate STSMMs

2.1.8 Elicitation of TSMMs: Perceptual or Structured Form

The advantages of using the perceptual form (unstructured knowledge) to elicit team members' mental models are that: 1) it is easier for participants to perceive and make judgments; and 2) the questionnaires are tailored to the task which may be more directly related to the variables in research model. However, the disadvantages are that: 1) the perceptual form does not capture structured knowledge, especially after the year of 2000, TSMMs is usually defined as structured knowledge rather than unstructured knowledge shared within team members; and 2) many empirical studies have suggested that perceptual forms are less predictive of team processes than the structured form of TSMMs (DeChurch & Mesmer-Magnus, 2010b).

On the other hand, there have been strong theoretical foundations for use of the structured form (structured knowledge) to elicit team members' mental models: 1) TSMMs is usually defined as a cognitive structure or network of associations between concepts in each individual's mind (Ward & Reingen, 1990); 2) cognitive psychologists also suggest that knowledge of the interrelationships between the concepts in a domain is a critical variable that influences initial learning, subsequent retention, and later knowledge transfer (Langan-Fox et al., 2000); 3) researchers argued that team behavioral process and team performance reflect a pattern or organization of effort (DeChurch & Mesmer-Magnus, 2010a); and 4) meta-analysis shows that structured knowledge is more predictive of team process than unstructured knowledge, but both of them are predictive of team performance (DeChurch & Mesmer-Magnus, 2010b). However, there are still some disadvantages to using the structured form of TSMMs for the elicitation: 1) the individuals with same cognitive structure may not process information in the same manner (Mohammed et al., 2010), in other words, whether the structured knowledge shared among team members have direct impacts on team process or performance is questionable and it is highly dependent on how the information is processed; 2) it might be difficult for team members to make judgments about how their knowledge is inter-related or connected; 3) an individual's perceptions of how knowledge is structured and organized might change over time; and 4) a large number of relatedness judgments can significantly tax participants and lead to fatigue (Mohammed et al., 2010).

2.1.9 Technique Issues for the Representation of TSMMs

The techniques used to represent TSMMs include Pathfinder, UCINET, Euclidean Distance, Multidimensional Scales, Pearson Correlation, etc. Among these, Pathfinder and UCINET are the most widely applied methods in current studies. Pathfinder is *"a computerized networking technique which uses an algorithm to derive networks from proximity data based on the perceived relatedness among a list of concepts"* (Langan-Fox et al., 2000, p. 255). It transforms paired comparison ratings into a network structure in which the concepts are represented as nodes and the relatedness of concepts are represented as links between nodes. It is used to produce appropriate psychological scaling with respect to the underlying structure between knowledge concepts (Schvaneveldt, 1990). By using the Pathfinder, we may compare any two individuals' mental model matrices in order to get the value that represents the similarity of two individuals' mental models, or we may compare each individual's mental model matrix to the expert's mental model matrix to get the value that represents the accuracy of that individuals' mental model. Then by averaging those values at the dyad level, we could get a final value representing the whole team's task-focused or team-focused mental models, either similarity or accuracy. However, sometimes the use of Pathfinder is problematic because it only evaluates the consistency of two individuals' mental model matrices. Below is an example of how Pathfinder determines the similarity value of two individuals' mental models. For instance, we have person 1 and person 2, and their mental model matrices are shown in table 1, in which A, B, and C represent three critical knowledge concepts.

Person 1				Person 2			
	A	B	C		A	B	C
A	–	–	–	A	–	–	–
B	1	–	–	B	2	–	–
C	5	3	–	C	5	3	–

Table 1: Mental Model Matrices for Person 1 and Person 2

If we use the Pathfinder technique, we would have the following network structure for person 1 and person 2, which is shown in figure 9 below. The similarity value will be calculated by using the formula [X/(T-X)] where X is the number of common links between two networks and T is the total number of links in both networks. In this case, the similarity value between person 1 and person 2's mental models is 2/3.

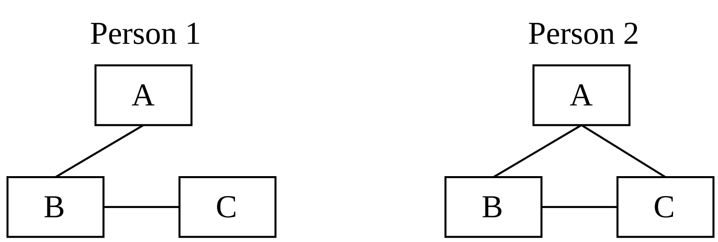


Figure 9: Network Structure for Person 1 and Person 2

Now suppose we have person 3, and his mental model matrix is shown in table 2 below.

Person 1				Person 3			
	A	B	C		A	B	C
A	–	–	–	A	–	–	–
B	1	–	–	B	2	–	–
C	5	3	–	C	2	2	–

Table 2: Mental Model Matrices for Person 1 and Peron 3

By applying the same Pathfinder technique, we get the same network structure for person 1 and person 3, which is shown in figure 10. If we calculate the similarity value between person 1 and person 3's mental models, we would get 2/3, which is the same as what we get from that of person 1 and person 2's. However, it is obvious that person 1's mental model is not similar to person 3's mental model according to their mental model matrices. The reason why it occurs is that Pathfinder only compares the similarity of the path structure for any two matrices rather than reflecting the actual similarity of two persons' mental models.

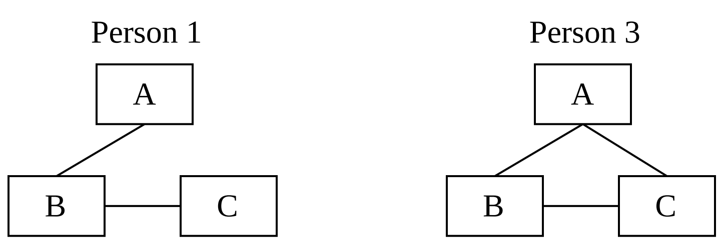


Figure 10: Network Structure for Person 1 and Person 3

On the other hand, the quadratic assignment proportion (QAP) correlations calculated by UCINET is another technique that is widely used for the measurement of similarity of TSMMs in current literature. As stated by Mathieu et al. (2005, p. 43), *"QAP correlations are equivalent to the Pearson correlations between the identical elements of two mental model matrices and therefore range from –1 (counter-sharedness) through 0 (no sharedness) to 1 (complete sharedness). In effect, they yield an index of sharedness that captures the extent to which team members' models exhibit similar patterns of relationships"*.

2.1.10 Team Planning

Team planning occurs when team members conduct a series of activities prior to a mission, during a mission, or both in order to attain certain goals and better accomplish group tasks (Marks et al., 2001), and it has drawn increased attention from researchers during the past few decades. The activities include setting goals, creating an open enviroment, sharing information related to task requirements, discussing relevant environment characteristics and constraints, prioritizing tasks, communicating and exchanging expectations, clarifying roles and responsibilities, distributing workloads, planning for unexpected events, etc. (Stout et al., 1999). It consists of a series of works that a group engages on in order to better coordinate their effort to attain their goals (DeChurch & Craig, 2008; Marks et al., 2001). Previous research suggests that team planning positively contributes to team performance (Janicik & Bartel, 2003; Locke, Durham, Poon, & Weldon, 1997).

2.1.11 Team Backup Behaviors

Team backup behaviors are aimed at assisting other members in performing their tasks so that the common collective goal can be achieved. Assistance may occur by 1) providing a teammate verbal feedback or coaching; 2) helping a teammate by completing specific actions; or 3) assuming and completing a task for a teammate (Dickinson & McIntyre, 1997). Prior studies suggest that when team members are not willing to support each other, the team performs poorly or even fails to achieve its collective goals due to lack of cooperation (Marks et al., 2001). Team backup behaviors have been suggested as a reflection of the team's commitment to a collective goal and have been linked to increased performance and continuous improvement (Kozlowski & Ilgen, 2006). Research has already found a positive link between backup behaviors and task performance in a number of empirical studies (Marks et al., 2002; Porter, 2005; Porter et al., 2003; Porter et al., 2010; Porter, Itir Gogus, & Yu, 2011).

2.1.12 Team Implicit Coordination

Team coordination refers to the process of orchestrating the sequence and timing of interdependent actions when a team executes a task (Marks et al., 2001). Rico et al. (2008) suggest that research has usually focused on explicit coordination, which typically occurs via planning or communication in order to manage the deadlines, plans, or schedules of the tasks. On the other hand, implicit coordination takes place when team members anticipate their colleagues' needs and adjust their own behavior accordingly without having to communicate directly with each other or plan the activity. Team implicit coordination is also suggested as a critical contributor to the team effectiveness in many studies (Fisher et al., 2012; Marks et al., 2002; Rico et al., 2008).

2.2 Development of the Hypotheses

This section discusses the rationale that supports the development of the hypotheses.

2.2.1 Team Planning and TSMMs

Stout et al. (1999, p. 61) found that *"effective team planning increased TSMMs among team members, allowed them to utilize efficient communication strategies during high-workload conditions, and resulted in improved coordinated team performance"*. However, in their research, Stout et al. (1999) only measured the relationship between team planning and the similarity of TASKTSMMs. Their argument was based on the idea that team planning for specific tasks might be more related to the similarity of TASKTSMMs, whereas interpersonal process (such as trust building) was more important to the similarity of TEAMTSMMs.

This study proposes that during transition processes (such as team planning, goal specification, and strategy formulation), team members work together to identify their overall goal, form their strategies and team plans, while they communicate and get to know each other. Thus, during planning team members engage in interpersonal processes as well as task preparation before the actual execution of the task. As a result, planning is expected to have a positive relationship to both TASKTSMMs and TEAMTSMMs. This study proposes that:

> *Hypothesis 1a: Team planning is positively related to the similarity of TASKTSMMs.*
>
> *Hypothesis 1b: Team planning is positively related to the similarity of TEAMTSMMs.*

2.2.2 TSMMs, Team Backup Behaviors, and Team Implicit Coordination

Empirical studies suggested that various TSMMs contents (task-focused or team-focused) and properties (similarity or accuracy) were positively related to team process variables such as team backup behaviors and implicit coordination (Fisher et al., 2012; Lim & Klein, 2006; Marks et al., 2002; Mathieu et al., 2000; Ying & Erping, 2010). However, to evaluate both contents and properties of TSMMs and their interactions in one study would be neither practical nor necessary. This study specifically focused on the role of TSMMs' similarity in terms of its two aspects (task-focused or team-focused). The evaluation of TSMMs' accuracy is outside the scope of this research.

Prior studies have investigated the relationship between TSMMs and team backup behaviors, or the relationship between TSMMs and implicit coordination in different research settings. For instance, Mathieu et al. (2000) found that both the similarity of TASKTSMMs and TEAMTSMMs would lead to improved team processes, thus, teams would perform better. Marks et al. (2002) suggested that higher similarity of TASKTSMMs would encourage more backup behaviors within the team while Fisher et al. (2012) argued that the similarity of TEAMTSMMs was more related to the implicit coordination rather than the explicit coordination. That is, team members who had similar TEAMTSMMs were better at predicting each other's needs and adapting their behaviors (characterized as implicit coordination) to facilitate teamwork. On the other hand, explicit coordination was usually captured through communication and interactions and did not rely much on tacit understanding (such as the similarity of TEAMTSMMs).

This research evaluates the relationships between different contents of TSMMs' similarity (task-focused and team focused) and team backup behaviors, and the relationships between different contents of TSMMs' similarity (task-focused and team focused) and team implicit coordination in two separate simulation scenarios (please refer to chapter 3 for details). In this study, I argue that both the similarity of TASKTSMMs and the similarity of TEAMTSMMs are positively related to team backup behaviors and implicit coordination, because team members with similar task-focused and team-focused mental models may be able to better assist their teammates and adjust their behaviors to their colleagues' actions. Based on the discussion above, I propose that:

Hypothesis 2a: The similarity of TASKTSMMs is positively related to team backup behaviors.

Hypothesis 2b: The similarity of TASKTSMMs is positively related to team implicit coordination.

Hypothesis 3a: The similarity of TEAMTSMMs is positively related to team backup behaviors.

Hypothesis 3b: The similarity of TEAMTSMMs is positively related to team implicit coordination.

2.2.3 Team Backup Behaviors, Team Implicit Coordination, and Team Performance

In team research, we are not only interested in how different variables associated with each other but also concerns about how they contribute to the final team performance. Previous studies suggested that both team backup behaviors (e.g. Porter et al., 2011) and team implicit coordination (e.g. Fisher et al., 2012) were positively linked to team performance. This study first tests the relationships among similarity of TASKTSMMs, similarity of TEAMTSMMs, team backup behaviors, and team implicit coordination, and then takes one more step to evaluate whether team backup behaviors and team implicit coordination still positively contribute to the performance of the team. Thus, I propose that:

Hypothesis 4a: Team backup behaviors are positively related to team performance.

Hypothesis 4b: Team implicit coordination is positively related to team performance.

2.2.4 Mediation Role of TSMMs

Janicik and Bartel (2003) conducted a study on the effect of team planning on time awareness norms and group coordination, and they found that time awareness norms mediated the effect of team planning on coordination. Time awareness norms are part of the group norms, which is believed to help regulate team members' behaviors (Bettenhausen & Murnighan, 1985). Group norms can be considered part of the similarity of TSMMs, because the similarity of TSMMs suggests that team members share similar knowledge in their mind and this knowledge typically includes group norms. In addition, effective team planning before the actual execution of the team task is expected not only enhance the understanding of task related knowledge among team members but also facilitate the interpersonal communication within the teams, which in turn leads to more adaptation (implicit coordination) and backup behaviors during the team action process. Therefore, I propose that:

Hypothesis 5a: The similarity of TASKTSMMs mediates the relationship between team planning and team backup behaviors.

Hypothesis 5b: The similarity of TASKTSMMs mediates the relationship between team planning and team implicit coordination.

Hypothesis 6a: The similarity of TEAMTSMMs mediates the relationship between team planning and team backup behaviors.

Hypothesis 6b: The similarity of TEAMTSMMs mediates the relationship between team planning and team implicit coordination.

2.2.5 Mediation Role of Team Backup Behaviors and Team Implicit Coordination

Prior empirical studies have provided evidence that teams exhibiting a high degree of backup behaviors and implicit coordination are more likely to perform well (Fisher et al., 2012; Marks et al., 2002; Mathieu et al., 2000; Porter, 2005; Porter et al., 2010, 2011; Rico et al., 2008). In previous section 2.2.2, I propose that the similarity of TASKTSMMs and similarity of TEAMTSMMs are positively related to team backup behaviors, and the similarity of TASKTSMMs and similarity of TEAMTSMMs are positively related to team implicit coordination. In this section, I would go one further step to evaluate whether team backup behaviors and team implicit coordination play a mediation role between different contents of TSMMs' similarity (task-focused and team focused) and team performance. Thus, I propose that:

Hypothesis 7a: Team backup behaviors mediate the relationship between the similarity of TASKTSMMs and team performance.

Hypothesis 7b: Team backup behaviors mediate the relationship between the similarity of TEAMTSMMs and team performance.

Hypothesis 8a: Team implicit coordination mediates the relationship between the similarity of TASKTSMMs and team performance.

Hypothesis 8b: Team implicit coordination mediates the relationship between the similarity of TEAMTSMMs and team performance.

2.3 Research Model

Figure 11 shows the overall research model for this study including the hypotheses proposed in the prior sections.

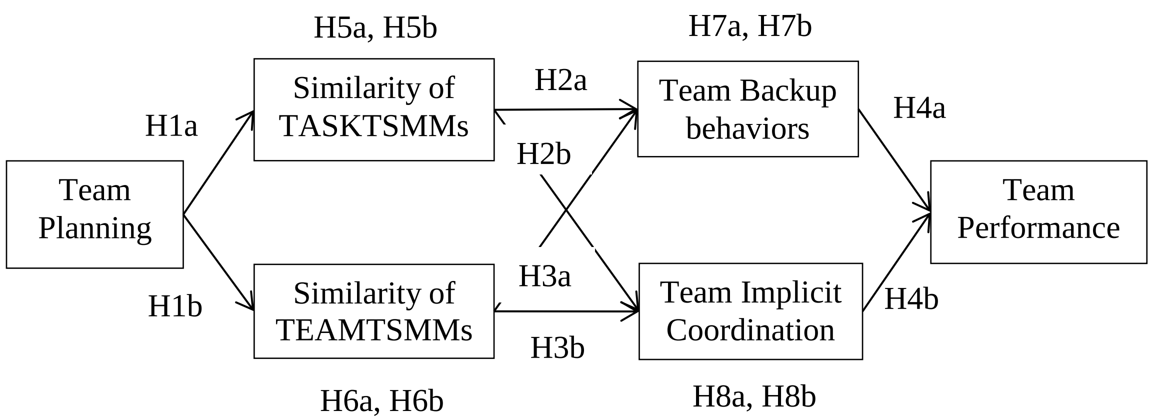


Figure 11: Research Model

CHAPTER 3

METHODOLOGY

This chapter outlines the methodology utilized in this study. In the first section, the description of the study sample and task is presented. The second section introduces the design of the experiment. The third section describes the variables, while the fourth section presents the statistical methods.

3.1 Description of the Study Sample and Task

3.1.1 Participants

The participants were undergraduate students from the Batten College of Engineering & Technology at Old Dominion University. A sample of 126 students was employed, and those students were randomly assigned to 42 teams, with three members on each team. All the teams were required to conduct a Networked Fire Chief (NFC) simulation task and the participants were given extra credits based upon the approval of the instructors in their classes. The study was submitted and approved by the Institutional Review Board for human subjects research at Old Dominion University.

3.1.2 Task

The Networked Fire Chief (NFC) simulation is a computer-supported simulation where the task consists of extinguishing fires. The task is a collaborative teamwork scenario in an emergent and dynamic environment that is considered well suited for a controlled experimental study of teams

(Uitdewilligen et al., 2013). The experimental setup includes three laptop computers connected to a common network. The goal of the simulation is to extinguish emerging fires with the use of resources including fire trucks and helicopters. The simulation task was adapted to fit the requirements of the experimental design.

3.1.3 Characteristics of the NFC simulation task

NFC is a microworld simulation which is rated as being high in dynamism (Gonzalez, Vanyukov, & Martin, 2005). This task has many ongoing changes and emergent situations that require a great deal of interactions among team members. The simulation task was selected based on the following considerations: 1) It reflects the dynamic nature of team processes; 2) It creates emergent situations that require team members to collaborate and address those situations in a short time period. In very dynamic contexts, early team planning (especially backup plans for unexpected events), TSMMs, and team collaborative behaviors (such as backup behaviors and implicit coordination) are considered critical factors that impact team performance. NFC simulation facilitates the customization of the context by creating a simulated environment that allows us to study those variables under controlled conditions.

The task may not reflect the full complexity of a fire, but it still has valuable implications for real life scenarios. Omodei, Fellows, Kerz, Knill, and McLeary (2006) conducted a survey on a number of experienced wild land fire fighters. The fire fighters indicated that the simulation provided a realistic scenario of how fires spread. They suggested that the NFC simulation task is a valuable tool to study teams working together in dynamic situations that involve scarce resources. In addition, this task measures dynamic decision making effort and performance, which can help fire agencies amend and develop processes and train their fire-fighters, particularly in areas of decision making under stress (Barber & Smit, 2014).

3.2 Experimental Design

3.2.1 Design and Procedure

Figure 12 shows the research protocol for the study. Each team was first given a 15 minute tutorial on how to use NFC simulation software with detailed instructions provided by the researcher. Then, each team participated in a 15 minute practice section that also provided them with opportunities to ask questions regarding the task. The goal of the practice scenario is to make sure that each participant gets familiar with the task requirements and software operation. Following the practice section, each team went through 10 minutes of pre-planning to come up with common strategies to complete the task. After this, participants filled out a survey measuring the similarity of TASKTSMMs and TEAMTSMMs. Finally, each team completed two consecutive fire-fighting simulation scenarios. The process was recorded for future evaluation.

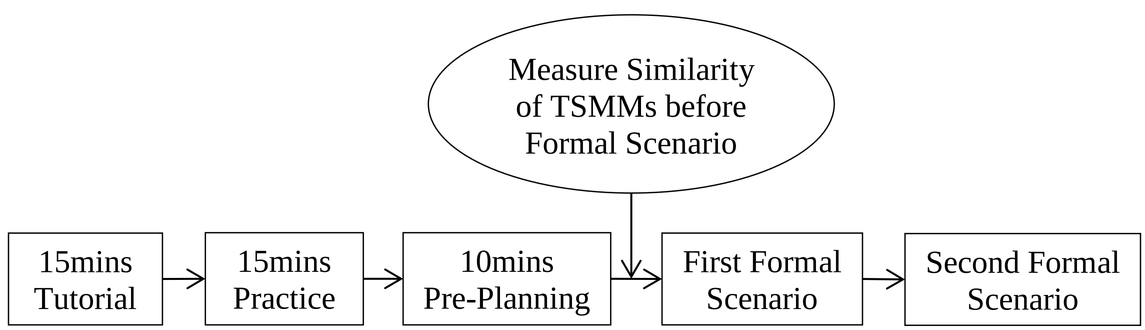


Figure 12: Research Protocol

3.2.2 Two Formal Scenarios

The protocol included two formal scenarios so that the proposed hypotheses could be tested. The first formal scenario was focused on exploring and assessing emerging backup behaviors. Team members were allowed to communicate during this scenario. The second formal scenario was focused on assessing team implicit coordination. Team implicit coordination took place when team members anticipated each other's needs and adjusted their own behavior accordingly without communicating directly. Consequently, during the second scenario, team members were not allowed to communicate with each other. Figures 13 and 14 show the conceptual models for two separate scenarios.

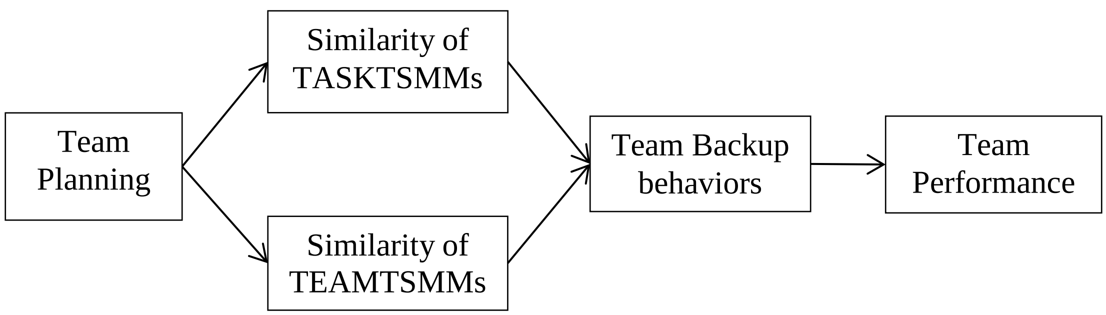


Figure 13: Experiment 1 – First Formal Scenario

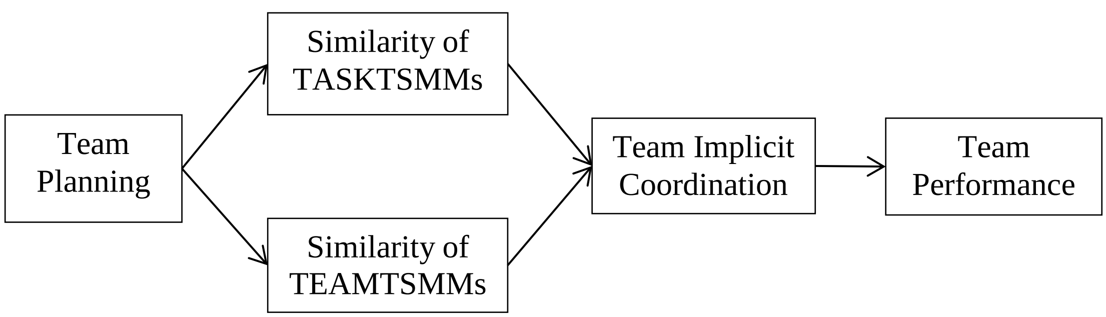


Figure 14: Experiment 2 – Second Formal Scenario

3.3 Measurements

3.3.1 Measurement of the Similarity of TSMMs

Based on the discussion in chapter 2, TSMMs may be elicited using different techniques such as paired comparison ratings, likert-scale questionnaires or cognitive interviewing. In this research, TSMMs are defined as organized knowledge concepts in each individual's mind. Paired comparison ratings were used to elicit the structured form of each individual's mental model. A set of pre-established knowledge concepts were first determined by the researchers, and then each individual was asked to make judgments on how these knowledge concepts were related to each other. This method requires the participants to relate the most critical factors or knowledge concepts that affect the task or team collaboration. The relationships between those critical factors or knowledge concepts become part of the task-focused or team-focused mental models. Typically, participants were asked to rate how those task-focused and team-focused knowledge concepts were inter-related to each other by using a 9-point Likert scales ranging from − 4 (negatively related, a high degree of one requires a low degree of the other) to 4 (positively related, a high degree of one requires a high degree of the other). After this step, a matrix was obtained to elicit each individual's structured form of mental model.

The critical task-focused knowledge concepts for this NFC simulation task have been already identified in previous research for the same simulation task (Uitdewilligen et al., 2013). They were: a) fire intensity; b) spreading of fire; c) direction of wind; d) speed of wind; e) burnt area; and f) difficulty of extinguishing fires. The critical team-focused knowledge concepts in this study were based on the six dimensions of teamwork adopted from Brannick, Prince, Prince, and Salas (1992) and Brannick, Roach, and Salas (1993). These six dimensions were: a) leadership;

b) assertiveness; c) decision making and mission analysis; d) adaptability and flexibility; e) situation awareness; and f) communication, which were also considered critical team-focused knowledge concepts by Mathieu et al. (2005). Brannick et al. (1992) suggested that these six dimensions were critical to team coordination behaviors. Since this study was designed to evaluate the relationships between TSMMs and team collaborative behaviors, it would be appropriate to adopt these six dimensions. The tables used for the elicitation of each individual's task-focused and team-focused mental model are attached in Appendix A.

Measurement of the similarity of TSMMs was divided into following steps: elicitation, representation, and aggregation. First, paired comparison ratings were used to elicit the structured form of each individual's mental model. Then quadratic assignment proportion correlations (QAP) calculated by UCINET were applied to represent the similarity values between any two individuals' mental model matrices, which was a continuous variable ranging from –1 (counter-sharedness) through 0 (no sharedness) to 1 (complete sharedness). Finally, each team had three QAP correlations since there were three pairs within a three-member team. A team's mental model similarity was calculated as the average of the three QAP paired correlations.

3.3.2 Measurement of Team Planning

Team planning refers to the preparation phase before the actual execution of the team task. It involves activities such as analyzing tasks, distributing workloads, sharing information, clarifying roles and responsibilities, getting familiar with each other, etc. (Janicik & Bartel, 2003; Stout et al., 1999). Prior research has measured team planning using different metrics

(DeChurch & Craig, 2008; Glick, Chermack, Luckel, & Gauck, 2012; Janicik & Bartel, 2003; Mathieu & Schulze, 2006; Mehta, Feild, Armenakis, & Mehta, 2009). Typically, the measurement of team planning is highly dependent on the type of team, research focus and experimental design.

In this research, team planning was operationalized through the observations of the recordings by two trained raters. The criteria for the evaluation of team planning were based on nine planning dimensions from the literature (Hackman, Brousseau, & Weiss, 1976; Hackman & Walton, 1986; Moore, 1978; Stout et al., 1999). Stout et al. (1999) used a 7-point Likert scale (1 = low, 7 = high) to rate each of the nine dimensions through the observation to assess quality of the planning from different perspectives. In order to fit the context of fire-fighting simulation task used in this study, the original dimensions proposed by Stout et al. (1999) were reduced to six. These six dimensions consist of: 1) creating an open environment; 2) exchanging preferences and expectations; 3) clarifying roles and responsibilities; 4) clarifying concerns of workload; 5) planning for unexpected events; and 6) addressing helping behaviors. Two trained raters used a 7-point Likert scale (1 = low, 7 = high) to evaluate the planning quality of each team with respect to each dimension listed above, and then provide a rating for the overall planning quality of each team. Finally, they came together to discuss their individual ratings and form a consensus rating for each planning dimension and also the overall planning quality of each team (Thorton & Byham, 1982). The reasons for adopting this measurement for assessing team planning are: 1) Prior research has successfully used this approach to assess planning in a similar context; and 2) These revised planning dimensions are more aligned with the team planning scenario in this research.

On the other hand, Stout et al. (1999) suggested that measurement errors in this type of observation protocol were common because individual raters brought in different perspectives or observations. To address potential issues with measurement errors when using the 1-7 scale, team planning was categorized into 3 groups: low level, moderate level, and high level. Teams with rating 1 and 2 were classified as low level of planning, teams with rating 3, 4, and 5 were classified as moderate level of planning, and teams with rating 6 and 7 were classified as high level of planning.

3.3.3 Measurement of Team Backup Behaviors

Team backup behaviors refer to the extent to which team members contribute their resources to help other team members in order to achieve better team performance (Porter et al., 2010). Backup behaviors usually result from a workload distribution problem (Porter et al., 2003). Therefore, if one team member's workload is much heavier than other team members', backup behaviors will be required. In the fire-fighting simulation task, each team member was in charge of a certain area and the fire started out in those three areas simultaneously. Then, the intensity of the fire in one area was manipulated to increase the workload of one team member. During the task execution, communication was allowed and the person who had heavier workload could verbally ask for help during the experimental scenario. If the other two team members did not help out, then it would significantly impair the final team performance. The operationalization of backup behavior was derived from the study by Porter et al. (2003), which measured backup behaviors in a similar setting. Specifically, backup behaviors were calculated as the total number of the fire units that had been cleared in the area with much heavier workload by the other two team members. The score of team backup behaviors in this first formal scenario varied from 0 to 100.

3.3.4 Measurement of Team Implicit Coordination

Team implicit coordination refers to the extent that team members consciously adapt their behaviors to their colleagues without direct communication (Rico et al., 2008). The operationalization of implicit coordination is similar to that of backup behaviors previously discussed. Instead of manipulating the fire intensity of one area, fires in the middle region was set to start out at different time points. No one was responsible for that area which created a need for the team to address the problem collaboratively. Since it was a team collaboration task, every team member was collectively responsible for extinguishing the fires in the middle region. No communication was allowed during this second formal scenario, and implicit coordination was calculated as the total number of the fire units that had been cleared in the middle area through the cooperation of the team members. The score of team implicit coordination in this scenario ranged from 0 to 200.

3.3.5 Measurement for Team Performance

Team performance is defined as how well team members accomplished their assigned task (Hackman, 1987). In this research, team performance was assessed through the final simulation scores generated by the simulation software, ranging from 0 (worst performance) to 100 (best performance).

3.3.6 Control Variables

Three control variables were originally included in this research: average game experience, familiarity with teammates, and fire-fighting experience. These variables were used to account for incoming game experience (Wilson et al., 2009) and team outcomes (Huckman, Staats, & Upton, 2009). Average game experience was measured with a single questionnaire item (Uitdewilligen et al., 2013): "Please indicate how often you played computer or mobile games on average during the last year (in hours per week)?" Familiarity with teammates was evaluated by one survey item (Ying & Erping, 2010) ranging from 1 (not at all) to 7 (very familiar): "Overall, how well did you know your team members before this simulation?" Fire-fighting experience was also measure by one survey item: "Do you have any fire-fighting experience in real environment before (yes or no; if yes, please indicate how many years)?"

3.4 Analysis

3.4.1 Hypotheses

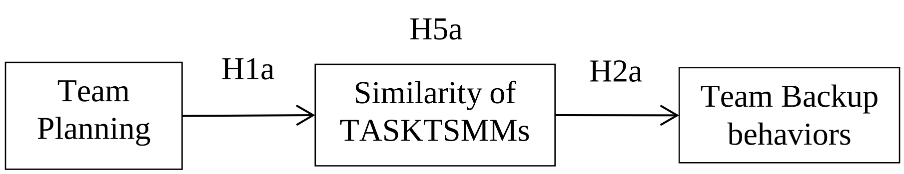
As discussed in chapter 2, there are 16 hypotheses in this study, with hypotheses 1a to 4b testing the positive relationships between two variables and hypotheses 5a to 8b testing the mediation effect of the similarity of TASKTSMMs, the similarity of TEAMTSMMs, team backup behaviors, and team implicit coordination. A complete list of the hypotheses is shown in the table below.

Table 3. List of the hypotheses

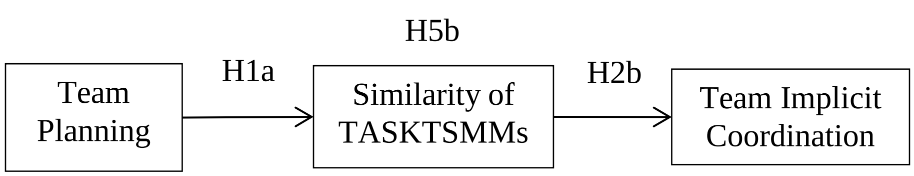
H1a: Team planning is positively related to similarity of TASKTSMMs
H1b: Team planning is positively related to similarity of TEAMTSMMs
H2a: Similarity of TASKTSMMs is positively related to team backup behaviors.
H2b: Similarity of TASKTSMMs is positively related to team implicit coordination.
H3a: Similarity of TEAMTSMMs is positively related to team backup behaviors.
H3b: Similarity of TEAMTSMMs is positively related to team implicit coordination.
H4a: Team backup behaviors are positively related to team performance.
H4b: Team implicit coordination is positively related to team performance.
H5a: Similarity of TASKTSMMs mediates the relationship between team planning and team backup behaviors.
H5b: Similarity of TASKTSMMs mediates the relationship between team planning and team implicit coordination.
H6a: Similarity of TEAMTSMMs mediates the relationship between team planning and team backup behaviors.
H6b: Similarity of TEAMTSMMs mediates the relationship between team planning and team implicit coordination.
H7a: Team backup behaviors mediate the relationship between similarity of TASKTSMMs and team performance.
H7b: Team backup behaviors mediate the relationship between similarity of TEAMTSMMs and team performance.
H8a: Team implicit coordination mediates the relationship between similarity of TASKTSMMs and team performance.
H8b: Team implicit coordination mediates the relationship between similarity of TEAMTSMMs and team performance.

3.4.2 Statistical Analysis

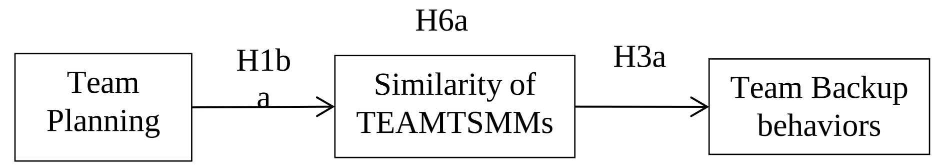
In this research, hypotheses 1a to 4b were tested through multiple regression. Hypotheses 5a to 8b were tested through a biased-correct bootstrapping approach proposed by Preacher and Hayes (2008), which estimated indirect effect and its corresponding confidence intervals. Simple mediation was used to test the hypotheses based on the reasoning that multiple mediators might complement or compete with each other within the same model. The intercorrelation between multiple mediators might lead to multicollinearity problems and thus increase the width of confidence interval. In essence, we might have a smaller chance of detecting a small mediation effect using multiple mediator models compared to use of the simple mediation model (Hayes, 2013). Therefore, the hypotheses were tested using 8 simple mediation models to evaluate both direct and indirect effect (mediation) of the variables in this study. As such, 16 hypotheses were tested separately in 8 models shown below (figure 15).



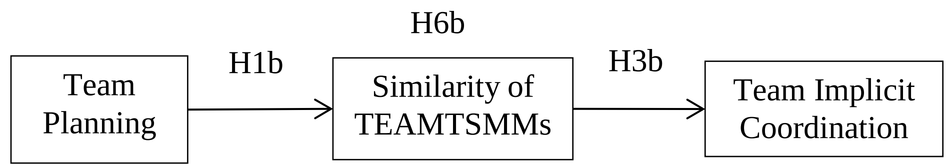
Simple Mediation Model 1



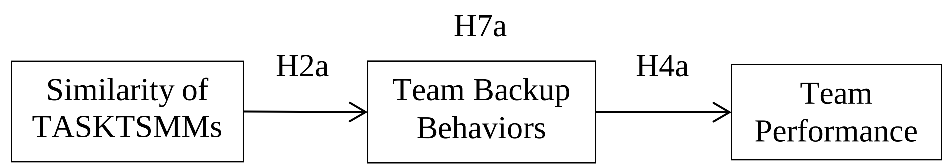
Simple Mediation Model 2



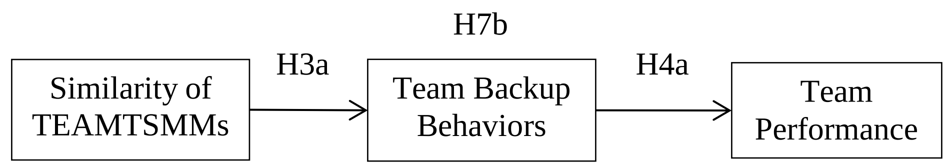
Simple Mediation Model 3



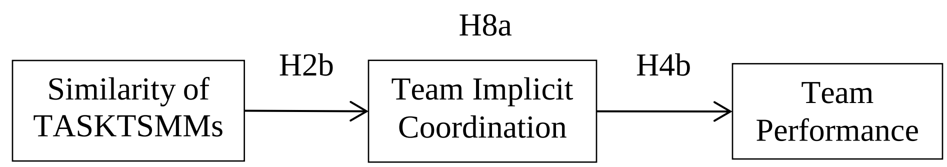
Simple Mediation Model 4



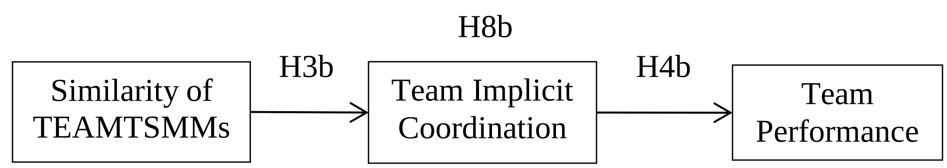
Simple Mediation Model 5



Simple Mediation Model 6



Simple Mediation Model 7



Simple Mediation Model 8

Figure 15. Simple Mediation Models

3.4.3 Precondition of Mediation Test

Historically, one must establish the association between X and Y before any mediation test has been undertaken. However, recent studies have suggested that the evidence of simple association between X and Y should not be imposed as a precondition for the mediation analysis (Hayes, 2013, p. 88). This rationale is based on the reasoning that "lack of correlation does not disprove causation and correlation is neither a necessary nor a sufficient condition of causality" (Bollen, 1989).

3.4.4 Aggregations

Team planning, team backup behavior, team implicit coordination, and team performance were evaluated at the team level. Similarity of TASKTSMMs and TEAMTSMMs was measured at the dyad level using the QAP correlations and then aggregated at the team level using average values within teams. However, since the ultimate goal is to evaluate whether or not team members share similar mental models, there is no need to validate the aggregation by looking at the r_{wg}, ICC(1) and ICC(2), which are the indices of within-group agreement, inter-rater reliability and inter-rater agreement (James, Demaree, & Wolf, 1984; LeBreton & Senter, 2008).

3.4.5 Sample Size

Sample size is usually dependent upon the statistical methods we use. In this research, the method of biased-correct bootstrapping was applied to evaluate the mediation effect of the variables of interest. Efron and Tibshirani (1994) suggested that 20 to 80 samples would be needed to apply a bootstrapping approach. In this study, a sample of 42 teams were collected.

CHAPTER 4

RESULTS

This chapter presents the results and findings of the statistical analysis. The first section of this chapter shows the descriptive statistics including sample demographical data and zero-order correlation matrix. In the second section, results of the hypothesis testing are presented. The third section summarizes the findings.

4.1 Descriptive Statistics

Table 4 presents the demographic data in this study. Overall, 126 students from the College of Engineering and Technology at Old Dominion University participated, 84% male and 16% female, respectively. With regards to ethnicity, the sample includes 60% white, 16% black, 8% Hispanic, 11% Asian, and 5% others. The majority of the students, 110 out of 126, are below the age of 30, while 14 are above 30 years, and the other 2 did not indicate age. In terms of major, the sample includes Civil Engineering (26%), Electrical Engineering (18%), Mechanical Engineering (34%), and others (22%).

4.1.1 Demographic Data

Table 4. Sample details

No	Item		Sample Size	Percentage
1	Gender	Male	106	84%
		Female	20	16%
2	Ethnicity	White	75	60%
		Black or African American	20	16%
		Hispanic or Latino	10	8%
		Asian	14	11%
		Other	7	5%
3	Age	18 – 24	95	75%
		25 – 30	15	12%
		Above 30	14	11%
		Not indicated	2	2%
4	Major	Civil Engineering	33	26%
		Electrical Engineering	22	18%
		Computer Engineering	5	4%
		Mechanical Engineering	43	34%
		Modeling & Simulation	7	6%
		Engineering Management	3	2%
		Engineering	5	4%
		Other	8	6%

4.1.2 Correlation and Descriptive Statistics

The correlation and descriptive statistics are presented in table 5. The table shows the means, standard deviations, and the correlations between variables from both experiments 1 and 2. As revealed by table 5, none of the three control variables (game experience, familiarity, and firefighting experience) was significantly correlated to team planning, similarity of TASKTSMMs, similarity of TEAMTSMMs, team backup behaviors, team implicit coordination, or team performance, indicating that control variables did not have significant impact on this simulation task and thus can be excluded from the analysis.

The first half of the table suggested that both similarity of TASKTSMMs ($r = .38$, $p < .05$) and backup behaviors ($r = .43$, $p < .01$) were significantly related to team performance in experiment 1, suggesting that teams with more backup behaviors and similar task-focused mental models are more likely to perform well. This is consistent with previous empirical studies on this subject (e.g. Marks et al., 2002). However, team planning and similarity of TEAMTSMMs were not significantly related to team performance, indicating that teams with better planning or more similar team-focused mental models might not necessarily perform well.

The correlation matrices from experiment 2 were shown in the second half of the table. There were not any significant correlations found between the variables interested in this study. Especially, neither similarity of TASKTSMMs nor team implicit coordination were significantly correlated with team performance in experiment 2.

Table 5. Correlation and Descriptive Statistics

Variable	Mean	SD	1	2	3	4	5	6	7
Experiment 1									
1. Game Experience	10.59	10.12							
2. Familiarity	3.19	2.40	.24						
3. Firefighting Experience	.38	1.10	-.03	-.32*					
4. Team Planning	.93	.64	.06	.03	-.20				
5. Similarity of TASKTSMMs	.27	.21	.21	-.12	-.26	.30			
6. Similarity of TEAMTSMMs	.17	.22	-.14	-.09	-.26	.11	.17		
7. Backup Behaviors	57.57	17.10	.22	-.27	.22	.12	.30	-.09	
8. Team Performance	84.56	6.36	.22	-.08	.18	.07	.38*	.04	.43**
Experiment 2									
1. Game Experience	10.59	10.12							
2. Familiarity	3.19	2.40	.24						
3. Firefighting Experience	.38	1.10	-.03	-.32*					
4. Team Planning	.93	.64	.06	.03	-.20				
5. Similarity of TASKTSMMs	.27	.21	.21	-.12	-.26	.30			
6. Similarity of TEAMTSMMs	.17	.22	-.14	-.09	-.26	.11	.17		
7. Implicit Coordination	125.07	23.59	.27	-.02	.16	-.01	-.02	-.21	
8. Team Performance	87.26	6.15	.17	.14	.10	.00	.21	-.14	.14

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

4.2 Hypothesis Testing

4.2.1 Simple Mediation Model 1 Based on Data from Experiment 1

As shown in figure 16, Hayes' method (Hayes, 2013) was used to test the mediation effect of similarity of TASKTSMMs between team planning and team backup behaviors. The results from simple mediation model 1 suggested that the direct effect of team planning on team backup behaviors was not significant ($\beta = .03, p = .86 > .05$). However, the indirect effect of team planning on team backup behaviors through the similarity of TASKTSMMs models was marginally significant at .05 confidence level ($\beta = .30, p = .05 \leq .05; \beta = .30, p = .07 > .05$). More importantly, the bias-corrected bootstrapping results showed that the confidence interval $(.131, 7.988)$ for the mediation effect of similarity of TASKTSMMs did not contain 0, indicating that there was evidence to support the mediation effect of similarity of TASKTSMMs between team planning and team backup behaviors at .05 confidence level.

In summary, hypotheses 1a, 2a, and 5a were supported by the data from experiment 1, suggesting that team planning positively affected team backup behaviors indirectly through the mediation effect of similarity of TASKTSMMs.

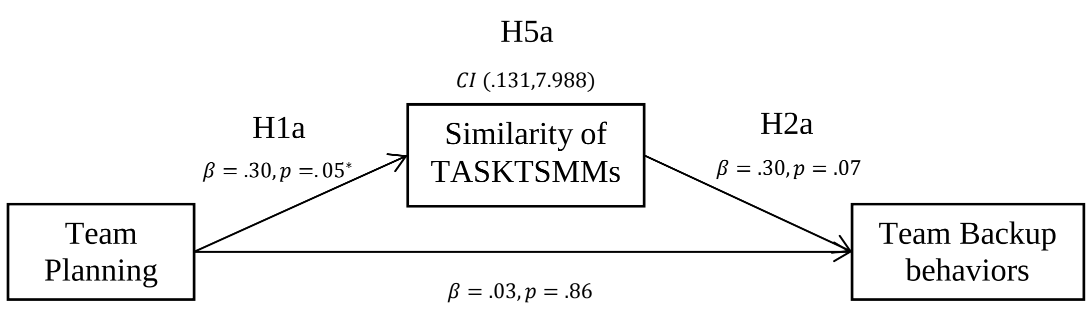


Figure 16. Simple Mediation Model 1 Based on Data from Experiment 1

4.2.2 Simple Mediation Model 2 Based on Data from Experiment 2

Simple mediation model 2 tested the mediation effect of similarity of TASKTSMMs between team planning and team implicit coordination. The results showed that the direct effect of team planning on team implicit coordination was not significant ($\beta = -.01, p = .96 > .05$). The indirect effect of team planning on the similarity of TASKTSMMs was significant ($\beta = .30, p = .05 \leq .05$) but the indirect effect of similarity of TASKTSMMs on team implicit coordination was not significant ($\beta = -.02, p = .91 > .05$). The bias-corrected bootstrapping results showed that the confidence interval $(-5.365, 3.990)$ for the mediation effect of similarity of TASKTSMMs contained 0, indicating that there was not enough evidence to support the mediation effect of similarity of TASKTSMMs between team planning and team implicit coordination at .05 confidence level (figure 17).

In summary, hypothesis 1a was supported, but hypotheses 2b and 5b were not supported by the data from experiment 2, suggesting that team planning neither directly nor indirectly affected team implicit coordination through the mediation effect of similarity of TASKTSMMs. However, it suggested that team planning was positively associated with similarity of TASKTSMMs.

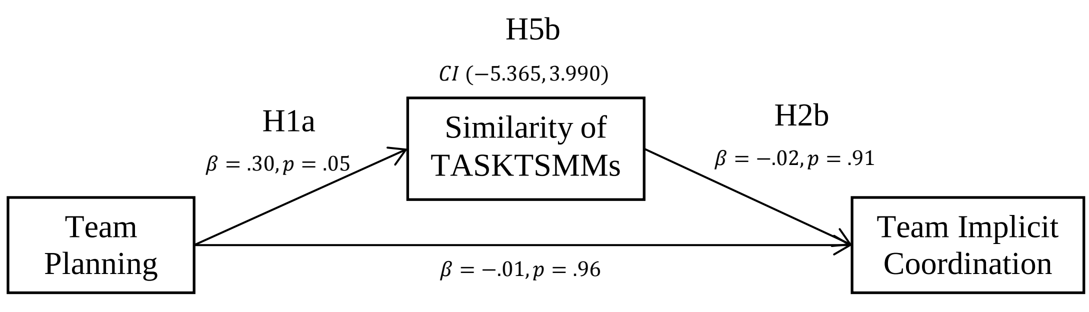


Figure 17. Simple Mediation Model 2 Based on Data from Experiment 2

4.2.3 Simple Mediation Model 3 Based on Data from Experiment 1

Figure 18 shows the model for the mediation effect of similarity of TEAMTSMMs between team planning and team backup behaviors from experiment 1. The results suggested that the direct effect of team planning on team backup behaviors was not significant ($\beta = .13, p = .42 > .05$). The indirect effect of team planning on team backup behaviors through similarity of TEAMTSMMs was also not significant at .05 confidence level ($\beta = .11, p = .48 > .05; \beta = -.11, p = .51 > .05$). The bias-corrected bootstrapping results showed that the confidence interval ($-3.051, .450$) for the mediation effect of similarity of TEAMTSMMs contained 0, indicating that there was not enough evidence to support the mediation effect of similarity of TEAMTSMMs between team planning and team backup behaviors at .05 confidence level.

In summary, hypotheses 1b, 3a, and 6b were not supported by the data from experiment 1, suggesting that team planning neither directly nor indirectly affected team backup behaviors through the mediation effect of similarity of TEAMTSMMs.

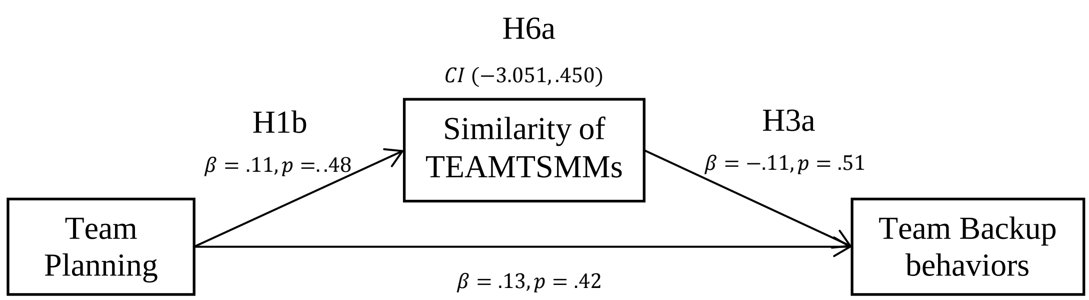


Figure 18. Simple Mediation Model 3 Based on Data from Experiment 1

4.2.4 Simple Mediation Model 4 Based on Data from Experiment 2

The mediation effect of similarity of TEAMTSMMs between team planning and team implicit coordination was tested in experiment 2. The results shown in figure 19 suggested that the direct effect of team planning on team implicit coordination was not significant ($\beta = .01, p = .95 > .05$). The indirect effect of team planning on team implicit coordination through similarity of TEAMTSMMs was also not significant at .05 confidence level ($\beta = .11, p = .48 > .05; \beta = -.21, p = .19 > .05$). The bias-corrected bootstrapping results showed that the confidence interval $(-6.733, .751)$ for the mediation effect of similarity of TEAMTSMMs contained 0, indicating that there was not enough evidence to support the mediation effect of similarity of TEAMTSMMs between team planning and team implicit coordination at .05 confidence level.

In summary, hypotheses 1b, 3b, and 6b were not supported by the data from experiment 2, suggesting that team planning neither directly nor indirectly affected team implicit coordination through the mediation effect of similarity of TEAMTSMMs.

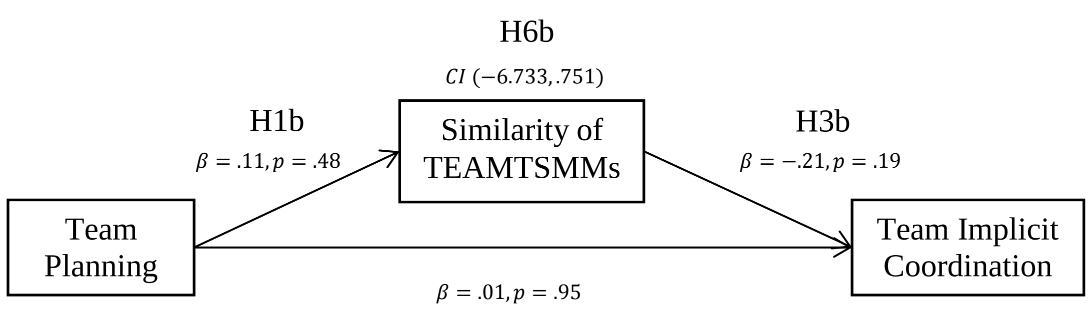


Figure 19. Simple Mediation Model 4 Based on Data from Experiment 2

4.2.5 Simple Mediation Model 5 Based on Data from Experiment 1

The mediation effect of team backup behaviors between similarity of TASKTSMMs and team performance was assessed using the same method from Hayes (2013). Results showed that the direct effect of similarity of TASKTSMMs on team performance was marginally significant ($\beta = .27, p = .07 > .05$). The indirect effect of similarity of TASKTSMMs on team performance through team backup behaviors was statistically significant at .05 confidence level ($\beta = .30, p = .05 \leq .05; \beta = .35, p = .02 < .05$). The bias-corrected bootstrapping results suggested that the confidence interval $(.209, 11.553)$ for the mediation effect of team backup behaviors did not contain 0, indicating that there was evidence to support the mediation effect of team backup behaviors between similarity of TASKTSMMs and team performance at .05 confidence level (figure 20).

In summary, hypotheses 2a, 4a, and 7a were supported by the data from experiment 1, suggesting that similarity of TASKTSMMs directly affected team performance while it also indirectly impacted team performance through the mediation effect of team backup behaviors.

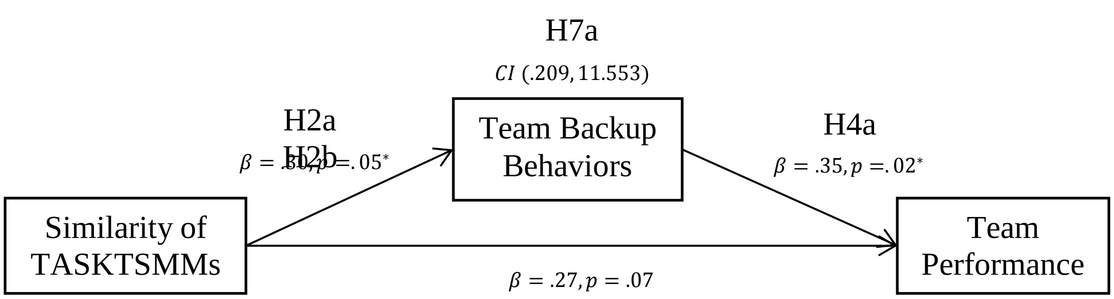


Figure 20. Simple Mediation Model 5 Based on Data from Experiment 1

4.2.6 Simple Mediation Model 6 Based on Data from Experiment 1

The mediation effect of team backup behaviors between similarity of TEAMTSMMs and team performance was also tested. As shown in figure 21, the direct effect of similarity of TEAMTSMMs on team performance was not statistically significant ($\beta = .08, p = .57 > .05$) and the indirect effect of similarity of TEAMTSMMs on team backup behaviors was also not significant ($\beta = -.09, p = .57 > .05$). However, the indirect effect of team backup behaviors on team performance was significant at .05 confidence level significant ($\beta = .44, p = .00 < .05$). The bias-corrected bootstrapping results suggested that the confidence interval $(-5.753, 1.826)$ for the mediation effect of team backup behaviors contained 0, indicating that there was not enough evidence to support the mediation effect of team backup behaviors between similarity of TEAMTSMMs and team performance at .05 confidence level.

In summary, hypothesis 4a was supported, but hypotheses 3a and 7b were not supported by the data from experiment 1, suggesting that similarity of TEAMTSMMs neither directly nor indirectly affected team performance through the mediation effect of team backup behaviors. However, team backup behaviors were positively associated with performance.

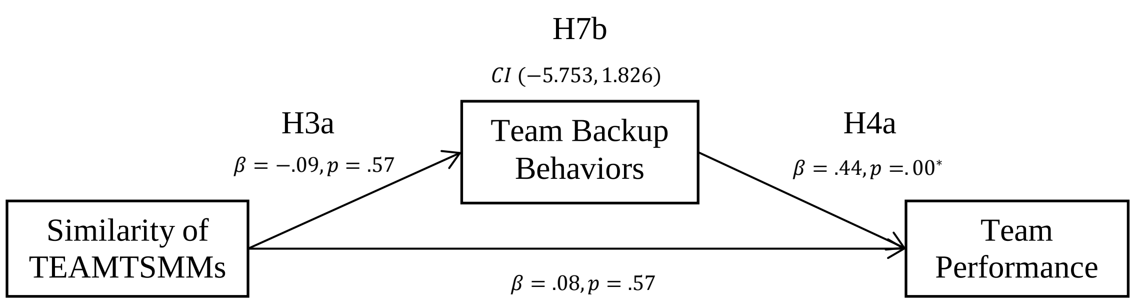


Figure 21.Simple Mediation Model 6 Based on Data from Experiment 1

4.2.7 Simple Mediation Model 7 Based on Data from Experiment 2

Figure 22 shows the model for the mediation effect of team implicit coordination between similarity of TASKTSMMs and team performance in experiment 2. The results suggested that the direct effect of similarity of TASKTSMMs on team performance was not significant ($\beta = .22, p = .17 > .05$). The indirect effect of similarity of TASKTSMMs on team performance through team implicit coordination was also not significant at .05 confidence level ($\beta = -.02, p = .89 > .05; \beta = .15, p = .34 > .05$). The bias-corrected bootstrapping results showed that the confidence interval $(-2.604, 1.532)$ for the mediation effect of team implicit coordination contained 0, indicating that there was not enough evidence to support the mediation effect of team implicit coordination between similarity of TASKTSMMs and team performance at .05 confidence level.

In summary, hypotheses 2b, 4b, and 8a were not supported by the data from experiment 2, suggesting that similarity of TASKTSMMs neither directly nor indirectly affected team performance through the mediation effect of team implicit coordination.

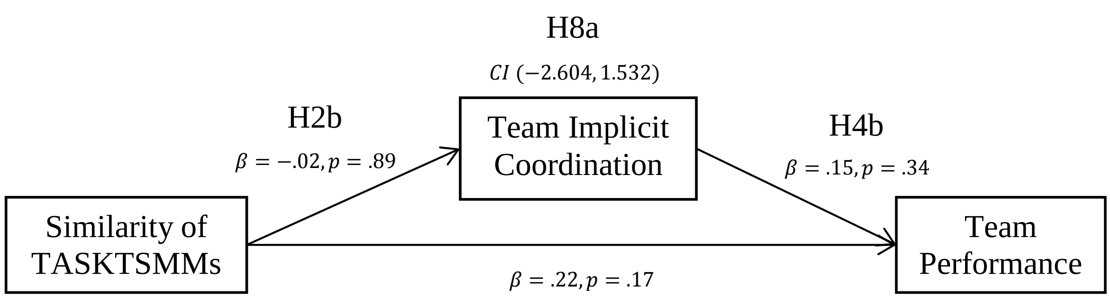


Figure 22. Simple Mediation Model 7 Based on Data from Experiment 2

4.2.8 Simple Mediation Model 8 Based on Data from Experiment 2

The mediation effect of team implicit coordination between similarity of TEAMSMMs and team performance has been tested and shown in figure 23. The results suggested that the direct effect of similarity of TEAMTSMMs on team performance was not significant ($\beta = -.11, p = .49 > .05$). The indirect effect of similarity of TEAMTSMMs on team performance through team implicit coordination was also not significant at .05 confidence level ($\beta = -.21, p = .19 > .05; \beta = .12, p = .46 > .05$). The bias-corrected bootstrapping results showed that the confidence interval $(-4.593, .960)$ for the mediation effect of team implicit coordination contained 0, indicating that there was not enough evidence to support the mediation effect of team implicit coordination between similarity of TEAMTSMMs and team performance at .05 confidence level.

In summary, hypotheses 3b, 4b, and 8b were not supported by the data from experiment 2, suggesting that similarity of TEAMTSMMs neither directly nor indirectly affected team performance through the mediation effect of team implicit coordination.

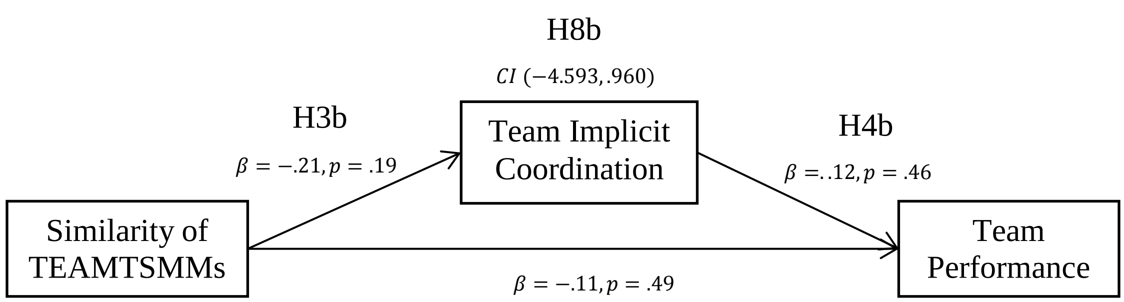


Figure 23. Simple Mediation Model 8 Based on Data from Experiment 2

4.2.9 The Effect Size for the Mediation Effect

Preacher and Kelley (2011) introduced an effect size measure, known as ‘kappa-squared’ (k^2), which was defined as the ratio of the indirect effect relative to its maximum possible value in the data. It is a widely accepted measure for the effect size of simple mediation analysis in the current literature. In this study, I applied this measure to evaluate the effect size of the mediation. Based on the results stated in previous sections, two significant mediation effects were detected: 1) the mediation effect of similarity of TASKTSMMs between team planning and team backup behaviors; and 2) the mediation effect of team backup behaviors between similarity of TASKTSMMs and team performance. The kappa-squared (k^2) calculated for these two significant mediation effect were .09 and .11, respectively, meaning that the indirect effect of team planning on team backup behaviors through the similarity of TASKTSMMs was about 9% of its maximum possible value and the indirect effect of similarity of TASKTSMMs on team performance through team backup behaviors was about 11% of its maximum possible value.

4.3 Summary of Findings

Table 6 summarizes the results from the hypothesis testing. Regarding regression testing, hypotheses 1a, 2a, and 4a were supported by the data from both experiment 1 and 2, indicating that: 1) team planning was positively related to the similarity of TASKTSMMs; 2) the similarity of TASKTSMMs was positively related to team backup behaviors; and 3) team backup behaviors was positively related to team performance.

With respect to mediation testing, hypotheses 5a and 7a were supported, suggesting that: 1) similarity of TASKTSMMs mediates the relationship between team planning and team backup behaviors; and 2) team backup behaviors mediate the relationship between similarity of TASKTSMMs and team performance. Apart from that, no other mediation effects were detected in this study.

Table 6. Summarization of the hypothesis testing

Hypothesis	Result
H1a: Team planning is positively related to similarity of TASKTSMMs	Supported
H1b: Team planning is positively related to similarity of TEAMTSMMs	Not supported
H2a: Similarity of TASKTSMMs is positively related to team backup behaviors.	Supported
H2b: Similarity of TASKTSMMs is positively related to team implicit coordination.	Not supported
H3a: Similarity of TEAMTSMMs is positively related to team backup behaviors.	Not supported
H3b: Similarity of TEAMTSMMs is positively related to team implicit coordination.	Not supported
H4a: Team backup behaviors is positively related to team performance.	Supported
H4b: Team implicit coordination is positively related to team performance.	Not supported
H5a: Similarity of TASKTSMMs mediates the relationship between team planning and team backup behaviors.	Supported
H5b: Similarity of TASKTSMMs mediates the relationship between team planning and team implicit coordination.	Not supported
H6a: Similarity of TEAMTSMMs mediates the relationship between team planning and team backup behaviors.	Not supported
H6b: Similarity of TEAMTSMMs mediates the relationship between team planning and team implicit coordination.	Not supported
H7a: Team backup behaviors mediates the relationship between similarity of TASKTSMMs and team performance.	Supported
H7b: Team backup behaviors mediates the relationship between similarity of TEAMTSMMs and team performance.	Not supported
H8a: Team implicit coordination mediates the relationship between similarity of TASKTSMMs and team performance.	Not supported
H8b: Team implicit coordination mediates the relationship between similarity of TEAMTSMMs and team performance.	Not supported

CHAPTER 5

DISCUSSION AND CONCLUSION

This chapter discusses the findings of the study. In the first two sections, both the theoretical and practical implications are presented. The limitations of the study are stated in the third section, and the recommendation for the future research is discussed in the fourth section. Finally, the conclusion is addressed in the last section.

5.1 Theoretical Implications

5.1.1 Team Planning, Similarity of TASKTSMMs, and Similarity of TEAMTSMMs

Hypothesis 1a tested the relationship between team planning and similarity of TASKTSMMs. The result from the data analysis supported the positive link between these two variables, which was consistent with the findings from the study of Stout et al. (1999). Thus, the first important theoretical implication from this study is that in highly dynamic contexts, teams with better planning are more likely to form similar task-focused mental models among team members.

On the other hand, hypothesis 1b was rejected by the data analysis, indicating that team planning was not significantly related to the similarity of TEAMTSMMs. Similarity of TEAMTSMMs refers to the extent to which team members may have a shared understanding about team-focused knowledge concepts such as a) leadership; b) assertiveness; c) decision making and mission analysis; d) adaptability and flexibility; e) situation awareness; and f) communication (Mathieu et al., 2005). In this study, the task assigned to the teams required team members to work with each other for a short time period. During the planning scenario, team members generally focused on discussing the task-focused knowledge concepts such as fire intensity, spreading of fire, and direction of wind, but they did not fully engage in discussing teamwork related concepts such as leadership, assertiveness, adaptability, and flexibility. In this scenario, it was observed that better team planning was conducive to similarity of TASKTSMMs among team members but not to similarity of TEAMTSMMs. This result might differ if teams are working on long-term and highly complex projects. For instance, if team members need to meet with each other and plan together more frequently, better team planning might help the teams to form similar mental models regarding their approach to collaborate.

5.1.2 Similarity of TASKTSMMs, Backup Behaviors, and Implicit Coordination

Hypothesis 2a was supported by the results indicating that the similarity of TASKTSMMs was positively related to team backup behaviors. That is, teams with more similar task-focused mental models shared among members were more likely to help each other during the task execution. This is another important theoretical implication from the study, because it suggests that backup behaviors can be enhanced when there is similarity of TASKTSMMs among team members.

Hypothesis 2b was not supported, suggesting that similarity of TASKTSMMs was not significantly related to team implicit coordination. This result is similar to the findings from a previous study on this subject, in which Marks et al. (2002) found that TASKTSMMs accounted for significant variability in team backup quantity ($\beta = .30, p < .05$), backup quality ($\beta = .29, p < .05$), and team performance ($\beta = .34, p < .05$), but not for team coordination ($\beta =$

$.24, p > .05$). The result from this study provided further support to the findings of Marks et al. (2002), suggesting that the development of similarity of TASKTSMMs would not facilitate more coordination within the teams.

5.1.3 Similarity of TEAMTSMMs, Team Backup Behaviors, and Implicit Coordination

Neither hypothesis 3a nor hypothesis 3b were supported by the results, indicating that similarity of TEAMTSMMs was not significantly related to team backup behaviors and team implicit coordination. This finding differs from a previous study, in which Fisher et al. (2012) found a positive association between the similarity of TEAMTSMMs and team implicit coordination ($\beta = .34, p < .05$). The inconsistency of the results from these two studies is possibly due to the nature of the task used. As explained previously, the fire-fighting simulation did not lead to extensive discussion within the teams about team-focused knowledge concepts such as leadership, assertiveness, adaptability, and flexibility. As a result, identifying relationships between the similarity of TEAMTSMMs and collaborative behaviors such as backup behaviors and implicit coordination is unlikely. Fisher et al. (2012) applied a business simulation as team task in their study and the teams were asked to act as top management teams and make strategic decisions with respect to the activities of the organization. The team task used in their research was a capstone based long-term project, in which team members met with each other many times during the semester to conduct the discussions and make their decisions. This study revealed that the type and nature of the task can have a large effect on the development of similarity of TEAMTSMMs.

5.1.4 Team Backup Behaviors, Team Implicit Coordination, and Team Performance

With respect to hypotheses 4a and 4b, the results suggested that team backup behaviors were positively related to team performance but team implicit coordination was not associated with team performance. The significant relationship between team backup behaviors and team performance has been documented before (e.g. Marks et al., 2002; Porter, 2005; Porter et al., 2010). This study has built upon prior works by evaluating the effects of team backup behaviors on team performance for teams operating under pressure and time limits.

On the other hand, no relationship was found between team implicit coordination and team performance, unlike a prior study conducted by Fisher et al. (2012). From my observation in this study, team members usually had their own workload during the fire-fighting simulation, but they were also required to contribute to the collective task. Team members who focused more on collective work sometimes overlooked their individual tasks and thus negatively impacted overall team performance, especially when teams worked under pressure or tight timelines.

5.1.5 The Mediation Effect of Similarity of TASKTSMMs

Hypotheses 5 to 8 tested the mediation effect, which was a key element of this study. Hypothesis 5a suggested that the similarity of TASKTSMMs mediated the relationship between team planning and team backup behaviors and it was supported by the data analysis. The results suggested that there was evidence to state that better team planning would be more likely to encourage more backup behaviors among team members through the effect of similar task-focused mental models. If we take a further step and look at the data results, we find that the direct effect of team planning on team backup behaviors was insignificant ($\beta = .76, p = .86 >$

.05), meaning that team planning did not affect team backup behaviors directly but rather indirectly through more aligned task-focused mental models among team members.

Hayes (2013, p. 173) stated that the mediation models are about more than establishing that X affects M and Y, but rather claiming M causes Y. In order to make this potential causal inference from the mediation analysis, we generally incorporate the covariates in the mediation models to eliminate the confounding or epiphenomenal association. However, none of the three control variables in this study (game experience, familiarity, and firefighting experience) was significantly correlated to team planning, similarity of TASKTSMMs, similarity of TEAMTSMMs, team backup behaviors, team implicit coordination, or team performance, indicating that control variables did not have significant impact on this simulation task and we might be able to study the variables interested without considering the effect of those control variables.

Additionally, hypothesis 5b was rejected providing no evidence to support the mediation effect of similarity of TASKTSMMs between team planning and team implicit coordination. Given the fact that team implicit coordination was insignificantly related to any other variables in this study, it is understandable that this hypothesis was not supported by the mediation analysis.

5.1.6 The Mediation Effect of Similarity of TEAMTSMMs

Hypotheses 6a and 6b were both rejected by the mediation testing, indicating that there was not enough evidence to support the mediation effect of similarity of TEAMTSMMs, either between team planning and team backup behaviors, or between team planning and team implicit coordination. As discussed previously, the task used in this study was a short-term project (fire-fighting simulation game), which did not provide enough time for team members to discuss team-focused knowledge concepts such as leadership, assertiveness, adaptability, and flexibility. Thus, the similarity of TEAMTSMMs did not play an important role in this study and that was probably the reason why the mediation effect of similarity of TEAMTSMMs had not been detected from the analysis.

5.1.7 The Mediation Effect of Team Backup Behaviors

Hypothesis 7a suggested that team backup behaviors mediated the relationship between the similarity of TASKTSMMs and team performance. Based on the results, the direct effect of similarity of TASKTSMMs on team performance was marginally significant ($\beta = 8.04, p = .07 > .05$) and the indirect effect through team backup behaviors was also significant ($\beta = 24.47, p = .05 \leq .05; \beta = .13, p = .02 < .05$), indicating that similarity of TASKTSMMs can directly affect team performance but also indirectly impact team performance through the mediation effect of team backup behaviors.

On the other hand, hypothesis 7b was rejected, indicating no support for the mediation effect of team backup behaviors between similarity of TEAMTSMMs and team performance. Given the fact that the similarity of TEAMTSMMs was not significantly correlated with either team backup behavior or team performance, it is understandable that this hypothesis was not supported by the mediation analysis.

5.1.8 The Mediation Effect of Team Implicit Coordination

Hypotheses 8a and 8b were not supported. There was not enough evidence to support the mediation effect of team implicit coordination, either between the similarity of TASKTSMMs and team performance, or between the similarity of TEAMTSMMs and team performance. As explained previously, teams might still perform poorly even when lots of implicit coordination was observed. This was because some team members might focus too much on the collective works but overlook their personal workload, which was not beneficial to the overall team performance. Collective works might distract some team members from working effectively on their personal workload and it was especially true when both personal workload and collective works contributed equally to the final team performance, and when teams needed to finish the work under tensions and within the time limit. In this case, team implicit coordination might not positively contribute to team performance and the mediation effect of team implicit coordination would not be supported.

5.2 Practical Implications and Limitations

5.2.1 Teams Operating under Emergent and Dynamic Situations

One of the major focuses for the design of this study is to observe how teams behave under emergent and dynamic situations. This is especially important for engineering teams that are required to solve the problems under constraints, pressure, and with strict time limits. For instance, when some emergent issues occur during the construction process, construction teams need to figure out the solutions within a short time limit. Another example would be the maintenance teams, who are usually required to fix the glitches under constraints and tensions when the machines are not working properly. Therefore, understanding how engineering teams operating under emergent and dynamic situations can help us further improve the performance of such teams in the future. In the following sections, I will discuss the practical indications for each of the variables evaluated in this study.

5.2.2 Team Planning

Team planning has always been considered an important predictor of team performance in the team literature (e.g. Janicik & Bartel, 2003; Locke et al., 1997; Marks et al., 2001). However, how does it affect teams operating under emergent and dynamic situations and how does it affect team shared cognition? How can we facilitate the planning quality and efficiency? This study has provided some of the answers to these questions. From the results, we know that team planning does not directly affect performance; instead, it facilitates the formation of similar task-focused mental models among team members. Team planning can help team members develop more aligned mental models about task execution and, in turn, positively affect backup behaviors and team performance. By better analyzing the tasks and communicate the task related information more efficiently (such as having a list of guidelines on critical issues that needed to be considered during project execution or developing a shared understanding about how to tackle the task), teams can have more productive collaboration.

On the other hand, the results suggest that team planning does not contribute to the similarity of TEAMTSMMs. Based on the researcher's observation, team-focused knowledge concepts were not generally discussed during the planning phase. From the literature (Fisher et al., 2012), we know that the similarity of TEAMTSMMs is still an important aspect of team collaboration, but the nature of the team or task does not emerge during the teamwork. Therefore, for those engineering teams operating under constraints and tight timelines, team members should be well trained and educated on the teamwork related concepts or skills prior to the teamwork.

5.2.3 Similarity of TASKTSMMs

Another key focus of this study is to evaluate the effect of team shared mental models (TSMMs) on team collaborative behaviors and performance. TSMMs has been widely addressed as an important factor to team performance in the literature (e.g. Carpenter et al., 2010; Lim & Klein, 2006; Van den Bossche et al., 2011) and the results of this study help expand previous studies by evaluating the effect of similarity of TSMMs in both contents (task-focused and team-focused) for teams operating under emergent and dynamic situations.

Specifically, results suggested that similarity of TASKTSMMs positively affect the performance of the teams operating under emergent and dynamic situations. Thus, from the practical perspective, improving the similarity of TASKTSMMs should be beneficial to teams. Empirical studies have explored antecedents of TSMMs, including team member characteristics (such as gender, age, educational similarity, experience), team interventions (such as planning, leadership, and training), and contextual factors (such as stress, workload, and environment) (Mohammed et al., 2010). Based on these findings, we should pay more attention to personnel selection since personal characteristics are believed to be linked to the similarity of TASKTSMMs. In addition, collaborative processes may be enhanced through interventions that facilitate the similarity of TASKTSMMs, such as training, team building activities, or deliberate planning. Finally, manipulating contextual factors, such as unevenly distributed stress and workload, can also enhance the collaborative processes.

5.2.4 Team Backup Behaviors and Implicit Coordination

Team backup behaviors were associated with team performance whereas team implicit coordination was not significantly related to performance or any other variables. When team backup behaviors or implicit coordination was addressed in the literature, researchers usually focused on its positive impact on team performance. However, collaborative behaviors may not always be beneficial to team performance (Barnes et al., 2008). This study provided some further insight on the relationship between team backup behaviors and team performance, or between team implicit coordination and team performance in rapidly changing and time constrained contexts. In this study, team members were required to work in an emergent and dynamic environment and they needed to accomplish the work within a limited time. Team members had their own workload but also some extra time to backup or coordinate with others. Based on researcher's observation during the experiment, some team members devoted their resources to help others but overlooking their own responsibilities. This approach can be detrimental for teams working under highly changing conditions and time pressure. Thus, one practical implication is that team backup behaviors and implicit coordination should not always be a priority. Any backup or coordination behaviors may be encouraged when everyone effectively finishes his or her personal workload.

5.2.5 Counter-Effect of TSMMs

With respect to the potential counter-effect of TSMMs, some studies suggested that team shared mental models may hinder the diversity of thoughts in the team and thereby adversely affect performance in highly cognitive tasks (Santos, Passos, & Uitdewilligen, 2016). This study focused on how team members react and collaborate under emergent and dynamic situations. In essence, team members need to make quick decisions and take instantaneous action in response to what happens during the task execution. In such conditions, diversity of thoughts from team members did not play an important role in team collaboration and team performance.

5.2.6 Limitations

First, the goal of this study is to evaluate team collaborative behaviors under emergent and dynamic situations. A computer based fire-fighting simulation scenario was used as the team task with groups of undergraduate students at Old Dominion University. Real engineering teams operating under emergent and dynamic situations might encounter more complex tasks and contextual factors. However, this study provides a controlled setting to understand how planning and collaborative behaviors can influence performance. Exploring these variables and relationships in a field setting can strengthen the findings from this study.

Second, due to the nature of the task and teams employed, the results of the study may not be generalized to other environments such as teams working on highly complex and long-term projects. The results are more likely to be applicable to teams that need to make quick decisions and take immediate action under pressure or resource constraints (emergent and dynamic situations). In addition, the sample consisted of undergraduate students from Old Dominion

University. Participants did not work together prior to this research task. Thus, the results may only be applicable to newly formed teams rather ongoing teams.

Third, this study is limited due to the relatively small sample size (42 teams). A simple mediation model was used to test the mediation effect for the variables of interest. Other statistical methods such as structure equation modeling (Kline, 2015) and multiple mediator models (Hayes, 2013) may also be used to test the overall effect of the model in this study when a larger sample size is available. As stated by Hayes (2013), the strength of using the simple mediation model is that we may be able to detect the small mediation effect for the variable interested compared to the use of multiple mediator models, but the simple mediation model does not allow us to compare the effects of different mediators and evaluate the overall fit of the model.

In this study, both the effects of similarity of TASKTSMMs and the similarity of TEAMTSMMs have been evaluated. However, according to the literature reviews, recent studies suggested that TSMMs not only included two different contents (task-focused and team-focused), but had two important properties (similarity and accuracy) as well. The accuracy of TSMMs refers to the degree to which team members' mental models are consistent with experts' mental models and it may have great impact on team performance because it indicates the actual quality of TSMMs among team members (Mohammed et al., 2010). Due to the scope of this study, the researcher only focused on the similarity of TSMMs in both contents (task-focused and team-focused) but not the accuracy of TSMMs, which is the third limitation of this study.

Finally, recent studies have suggested that TSMMs change and evolve over time (e.g. Uitdewilligen et al., 2013), so team members may not share the similar or accurate mental models at the beginning, but they may become more similar or accurate towards the end. This study collected the data at a given point in time but did not assess changes in TSMMs.

5.3 Future Research

Real engineering teams typically operate under emergent and dynamic situations that cannot be fully reflected in a controlled experimental design such as the one in this study. The results from this study can be further strengthened by future research in the field. Data can be collected from civil engineering teams, manufacturing teams, or software engineering teams to better understand the relationships between planning, collaborative behaviors, and team performance. This study focused on the similarity of TSMMs. However, as discussed in the previous section, accuracy is also a key property of TSMMs that can be further explored in future studies.

Another potential area for future studies is to incorporate the effect of time into the study of TSMMs. Both the similarity of TASKTSMMs and the similarity of TEAMTSMMs change over time, especially when team interventions such as team training and team planning are imposed. Thus, it would be beneficial to evaluate the evolving effect of TSMMs by measuring it at different time points such as measuring the similarity of TASKTSMMs and the similarity of TEAMTSMMs before team planning and after team planning in this study. We may also evaluate the similarity of TASKTSMMs and the similarity of TEAMTSMMs at the end of the experiment to see if the team collaboration process would further foster a more similar or accurate mental model among team members.

Individual differences greatly impact how the mental model emerges and how team members behave (Mohammed et al., 2010). Future studies may address the individual differences in terms of team member characteristics such as gender, age, cognitive ability, and prior teamwork experience. These factors may be incorporated as control variables or considered as additional variables to the existing model in this study.

Finally, the results of this study may be relevant to the practice of agile teams in the future. An agile team usually consists of a small group of dedicated individuals who are empowered, self-organizing, self-managing and have the skills to work together in order to achieve the team goals in a short time period (Cohn, 2010). The concept of agile teams has drawn increased attention in recent years (Hoda, Noble, & Marshall, 2012). This study focused on the teams that operate under emergent and dynamic situations, which reflects some elements in the context of agile teams. In future research, we may investigate the variables interested in this research (such as team planning, TSMMs, and team collaborative behaviors) in real agile teams and evaluate how they contribute and affect the performance of those teams.

5.4 Conclusion

This study evaluates the role of team planning and the similarity of team shared mental models (TSMMs) as predictors of two types of collaborative behaviors that are known to contribute to team performance. A computer-based Networked Fire Chief (NFC) simulation task was used to imitate the process of engineering teams operating under emergent and dynamic situations. The relationships among team planning, similarity of TASKTSMMS, similarity of TEAMTSMMs, team backup behaviors, and implicit coordination were tested. This study provides evidence for the mediation effect of similarity of TASKTSMMs between team planning and team backup behaviors, and the mediation effect of team backup behaviors between similarity of TASKTSMMs and team performance. The results suggest that better team planning is more likely to encourage more backup behaviors and improved performance through teams having more similar task-focused mental models.

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Appendix A

Survey

Team ID __________
Fire Station ID __________
Experiment Date and Time __________

Please answer the following questions:

1. Please specify your gender: _____Male _____Female

2. Please specify your ethnicity: _____White _____Black or African American

   _____Native American or American Indian _____Hispanic or Latino _____Asian

3. In what year were you born? _________________

4. What is your major? ___________________________

5. Please indicate how often you played computer or mobile games on average during the last year (in hours per week)?

6. Overall, how well did you know your team members before this simulation using the rating scale from 1 (not at all) to 7 (very familiar)?

7. Do you have any fire-fighting experience in real environment before (yes or no; if yes, please indicate how many years)?

Please rate the relatedness between any of two concepts in the table.

Rating Criteria:

4: negatively related, a high degree of one requires a low degree of the other

0: not related

4: positively related, a high degree of one requires a high degree of the other

	fire intensity	spreading of fire	landscape flammability	direction of wind	speed of wind	burnt area	difficulty of extinguishing fires
fire intensity	—						
spreading of fire	—	—					
landscape flammability	—	—	—				
direction of wind	—	—	—	—			
speed of wind	—	—	—	—	—		
burnt area	—	—	—	—	—	—	
difficulty of extinguishing fires	—	—	—	—	—	—	—

Definitions of some of the terminologies:

Flammability: is how easily something will burn or ignite, causing fire or combustion.

Rating Criteria:

4: negatively related, a high degree of one requires a low degree of the other
0: not related
4: positively related, a high degree of one requires a high degree of the other

	leadership	assertiveness	mission analysis and decision making	Adaptability and flexibility	situation awareness	communica tion
leadership	—					
assertiveness	—	—				
mission analysis and decision making	—	—	—			
Adaptability and flexibility	—	—	—	—		
situation awareness	—	—	—	—	—	
communication	—	—	—	—	—	—

Definitions of some of the terminologies:

Leadership: a process of social influence in which one person can enlist the aid and support of others in the accomplishment of a common task.

Assertiveness: is the quality of being self-assured and confident without being aggressive.

Situation awareness: being aware of what is happening in the vicinity, in order to understand how information, events, and one's own actions will impact goals and objectives, both immediately and in the near future.

Adaptability/flexibility: an ability to change something or oneself to fit to occurring changes.

Appendix B

Research Experiment Script

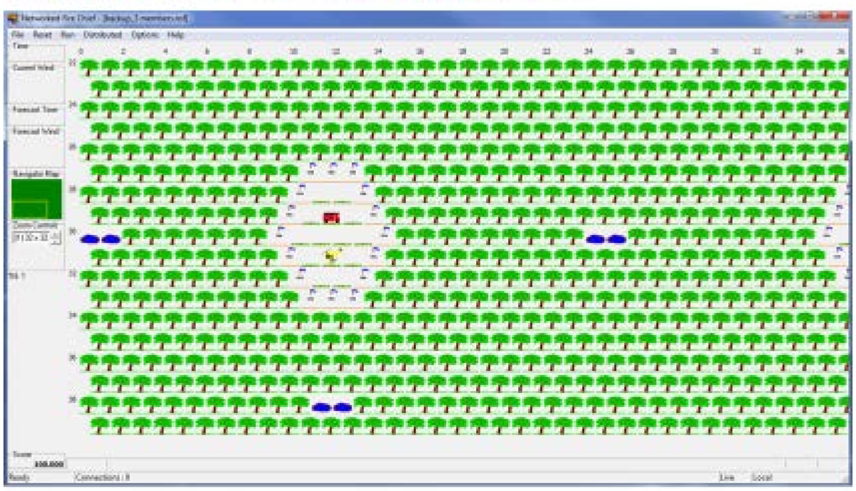
First Part:
Introduction to Networked Fire Chief

— A Firefighting Simulation Game

OLD DOMINION UNIVERSITY

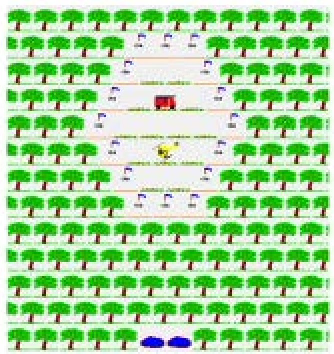
1

Interface of NFC Simulation



2

Icons of NFC Simulation



Fire Station

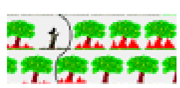
Fire Truck

Helicopter

Forest

Dam

Icons of NFC Simulation

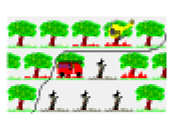


Fire intensity is signaled by flame size. As flame appears larger, intensity is greater. Note that more intensive fire will spread out much faster.

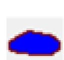
Fire Truck

Helicopter

Fire trucks are used to extinguish light fire while ***helicopters*** are used to extinguish intensive fire.
Helicopters need to be refilled every time it is used, while ***fire trucks*** have enough water to extinguish fire for 10 times.



Left click on the appliance and ***drag to*** the desired cell. ***Treat the cell*** by left clicking the appliance in the desired cell.



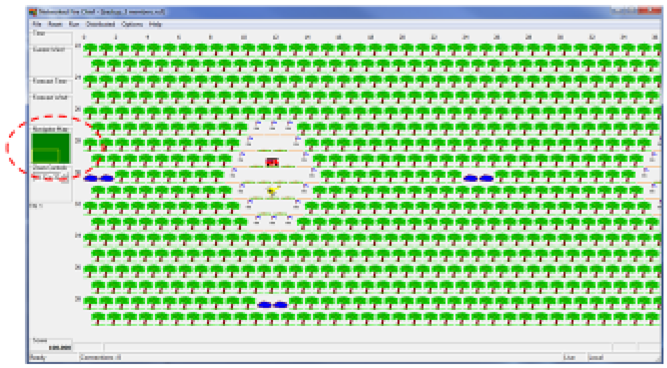
Full Water

No Water

Refill water by moving fire trucks and helicopters to dams. It appears blue when there is water in dam and turns to completely brown when there is no water.

Map Navigating

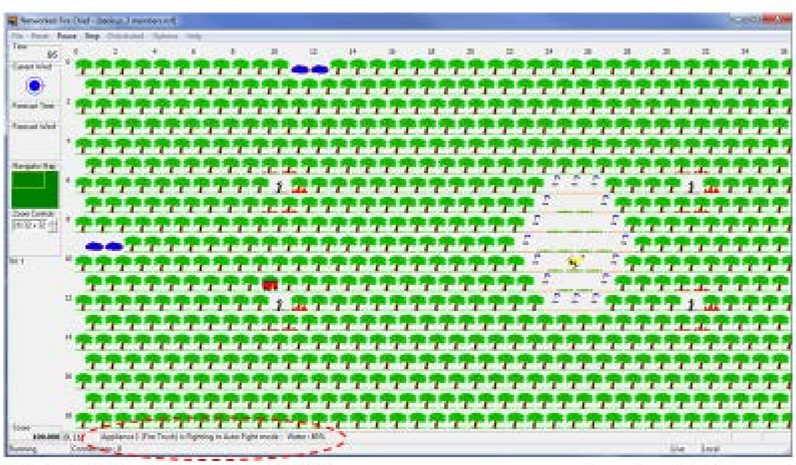
- Navigate map using green "Navigator Map" on left side of the screen.
- Click and hold down left mouse button while dragging yellow rectangle to desired location. The yellow rectangle encompasses the area that is currently visible.



5

Information about Appliance

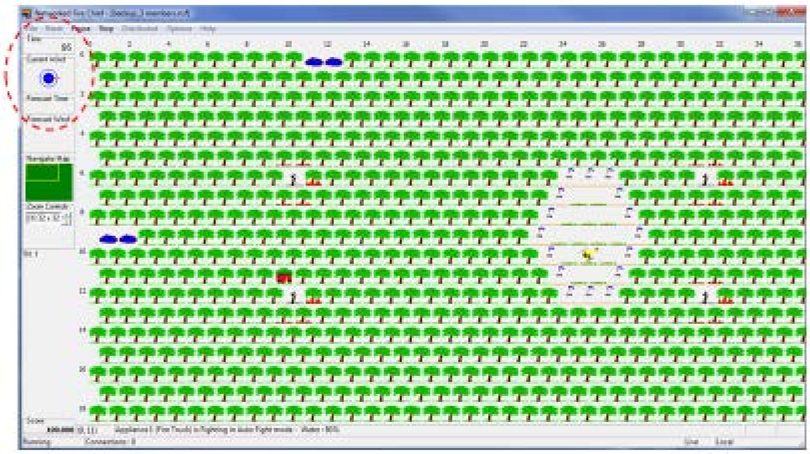
- Displayed at the bottom of the screen: water level and status of the appliance.



6

Time and Wind

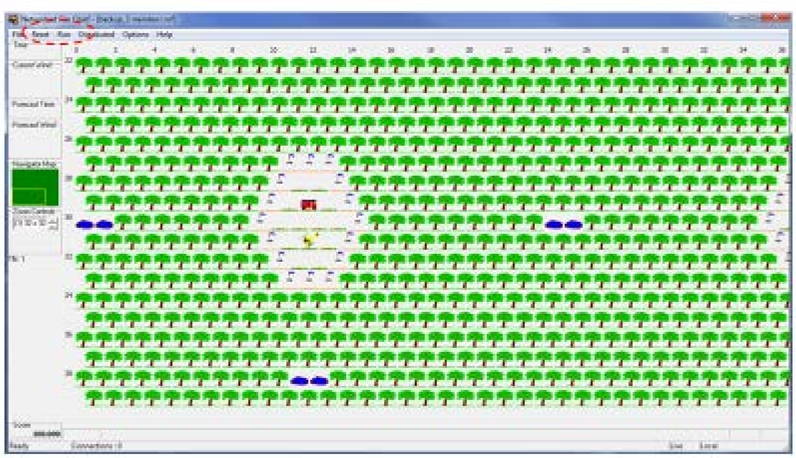
- Displayed on the left top of the screen.



7

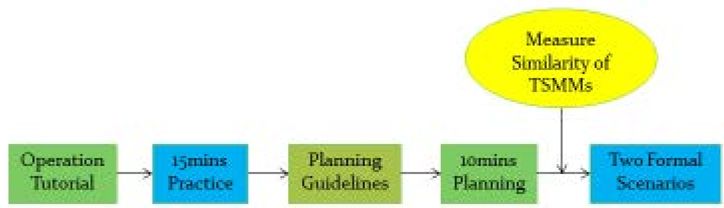
Run or Reset the Simulation

- Click on the "Run" or "Reset" from the drop-down menu.



8

General Procedure



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Goal of the Experiment

- To control or extinguish fires as much as possible by using the fire truck and helicopters.
- To test the effectiveness of teamwork through a networked fire-fighting simulation.

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Lets do the practice

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Second Part:
Guidelines for Team Planning

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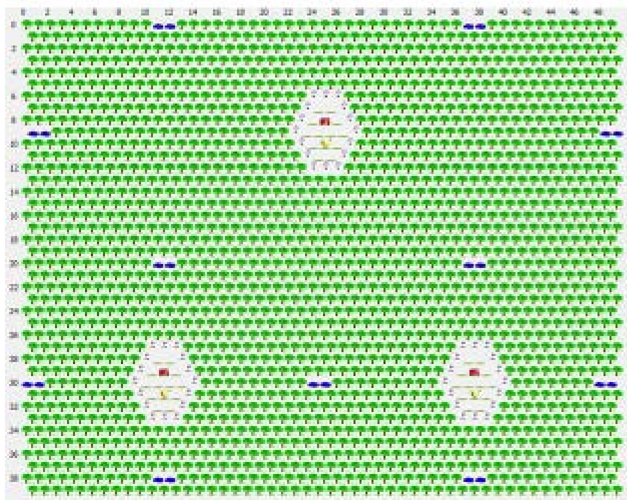
Introduction of Formal Scenarios



Two Formal Scenarios

- Each team member will be in charge of the appliance in one fire station.
- Each fire station will have 1 fire truck and 1 helicopter.
- The fire will start out at some certain time and certain places.
- You may communicate in the first scenario but not the second scenario.

Guidelines for Team Planning

- Get familiar with each other.
- Talk about your experience of the game.
- Exchange your preferences and expectations.
- Make plans for unexpected events.
- Clarify your roles and responsibilities.
- Distribute the potential workloads.
- Discuss the possible timing and sequencing issue.

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VITA

Zikai Zhou was born in Shanghai, China, on February 21, 1983. He received his undergraduate degree in Construction Engineering on June, 2005 from Tongji University, Shanghai, China. After his undergraduate study, he worked in a large construction company in Shanghai, China for about 4 years and his responsibilities for the job were to manage the project plan, material, and cost during the construction process.

In the year of 2010, he came to the United States to seek for the advanced education. After two years' work, he obtained his master degree in Engineering Management and System Engineering at Old Dominion University, Norfolk, VA, on December, 2011 and continued his Ph.D. study in the same department afterwards. He will accomplish his Ph.D. study in Engineering Management and System Engineering at Old Dominion University, Norfolk, VA, on May, 2017. His main areas of research interest are organization analysis, team analysis, and research methodologies.