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Investigating The Mechanisms That Drive Implicit Coordination In Teams

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INVESTIGATING THE MECHANISMS THAT DRIVE IMPLICIT COORDINATION IN TEAMS

By

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ABSTRACT

The purpose of this study was to empirically test the oft-noted hypothesis that shared mental models lead to implicit coordination. Specifically, this dissertation investigated the underlying mechanisms of implicit coordination and how different aspects of shared mental models affect the process. The research questions tested in this study were (a) how perceptions of sharedness affect the initiation of implicit coordination, (b) how actual levels of sharedness affect the process of implicit coordination, and (c) how quality of task mental models affects successful implicit coordination. Sixty same-gender, two-person teams engaged in a complex military reconnaissance planning task in which the team members were required to work together by exchanging information to plan routes for one unmanned aerial vehicle (UAV) and one unmanned ground vehicle (UGV). The results provided partial support for the influence of different facets of shared mental models on the process of implicit coordination. Specifically, individual mental model quality, not perceptions of sharedness or actual mental model sharedness, was the biggest predictor of the initiation of implicit coordination. Additionally, perceptions of sharedness and actual mental model sharedness interacted with one another, such that teams in mismatched conditions (high perceptions of sharedness but low actual sharedness [false consensus], or low perceptions of sharedness and high actual sharedness, [pluralistic ignorance]) tended to increase their communications. The implications and recommendations for future research on implicit coordination and shared mental models are discussed. Additionally, the implications for operators of unmanned vehicles are also discussed.

To my grandparents, Kenneth and Bernice

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CHAPTER ONE: INTRODUCTION

Statement of the Problem

Teams are fundamental to success in a variety of complex domains, ranging from potentially life-threatening environments (including the military, emergency response efforts, aviation and air traffic control, and medicine), to the business world, entertainment, and leisure activities (e.g., team sports). Success in these domains is often characterized by the skilled and coordinated performance of highly interdependent tasks, which require team members to interact with one another in order to accomplish team goals. Furthermore, teams are often required to perform complex tasks under conditions of extreme workload and great time pressure (as when emergency first responders and/or surgical teams are fighting to save lives or when air traffic controllers are trying to manage a large number of airplanes in a restricted space), heightened security concerns (such as when overt communication might be heard by opposing forces during military operations), and/or great social or organizational pressure (such as with business operations and sports teams that are looking to beat the competition).

In instances such as these, successful team performance requires team members to share information and task resources, have an understanding of the team goals, and coordinate their activities in order to achieve established goals. In high-pressure, high-workload domains, it is important for team members to be able to adjust their team coordination processes in order to maintain team performance in the presence of increasing task demands. For example, previous research has found that when high-performing teams experienced conditions of increased workload, they adaptively shifted from explicit forms of coordination to more implicit forms of coordination in order to maintain performance levels (Kleinman & Serfaty, 1989). Specifically, team members tended to volunteer more information or behaviors without specific requests to do so, thus facilitating team coordination in order to accomplish team goals. This beneficial adaptive strategy was named *implicit coordination*, which was thought to occur because the team members had shared mental models (SMMs) that allowed them to anticipate one another's needs (Kleinman & Serfaty).

Most prior investigations of implicit coordination have been conducted within the military domain. Yet, it certainly seems reasonable to assume that if implicit coordination is advantageous to teams in one complex domain, it may very well be useful in other complex domains as well. Currently, however, relatively little is known about implicit coordination and the conditions under which it can be invoked to enhance team coordination processes and performance. Because research in this area is limited and the related concepts are not fully understood, it is currently impossible to design team performance and team training situations that fully exploit the use of implicit coordination processes. However, gaining insight into the processes of implicit coordination and the conditions under which it can best be utilized could have tremendous potential for enhancing team processes, team performance, and team training scenarios in a variety of domains. If such information were available, it might be possible to develop new team training methods and scenarios so that future teams could be trained to be aware of and to use implicit coordination in order to maintain or enhance their own processes and performance.

Purpose of the Current Study

In a variety of modern operational domains, teams are required to perform complex tasks in time-sensitive, high-pressure environments. It is essential to ensure that these teams are equipped with the skills required for successful team performance. Harnessing the strengths of implicit coordination might be a strategy from which these teams could greatly benefit. While a number of studies have suggested that teams employ implicit coordination under some conditions (e.g., Entin & Serfaty, 1999; Urban, Weaver, Bowers, & Rhodenizer, 1996), little research has sought to examine the antecedent conditions and underlying mechanisms of implicit coordination. More specifically, it is currently not known what activates implicit coordination or what role SMMs play in this process. In order for implicit coordination to be utilized to its fullest potential, therefore, it is crucial to understand the mechanisms behind the process, the conditions that are necessary for implicit coordination, and the conditions under which implicit coordination is a beneficial strategy.

Thus, the purpose of the current investigation was to examine the factors that play a role in implicit coordination. This study was designed to investigate the process of implicit coordination, specifically focusing on the roles of (a) mental model sharedness, (b) mental model quality, and (c) team member perceptions of sharedness. The overarching goals were to determine which specific aspects of SMMs are relevant and necessary for the initiation of implicit coordination and for the successful maintenance or enhancement of team processes and performance. The current study was intended to provide a better understanding of implicit coordination. This, in turn, will make it possible for others to both develop and train teams that are characterized by factors conducive to implicit coordination. This could lead to improved team processes and performance in any number of domains that require team coordination to accomplish complex tasks.

CHAPTER TWO: LITERATURE REVIEW

Implicit Coordination

In 1989, Kleinman and Serfaty published the results of a study that investigated adaptive team coordination strategies. Using a resource allocation task, the authors required two-person teams to perform under varying levels of workload (manipulated by task tempo). Dependent measures were timeliness and accuracy in assigning resources, as well as the frequency of different types of communication. The results of the study showed that the workload manipulation had a significant impact on overall team performance and on the type of communications exhibited. Specifically, as task tempo increased, communication rates changed such that: under low and moderate tempos, explicit communication was more prevalent, while under high tempo, performance remained constant but communication rates decreased. The authors interpreted this decrease in resource requests and the concomitant increase in unsolicited resource transfers as a shift to what they termed *implicit coordination*. They further suggested that this strategy occurred because the team members had "mutual mental models to anticipate each other's resource needs and actions" (Kleinman & Serfaty, p. 25).

A few years later, Serfaty, Entin, and Volpe (1993) further explored the concept of implicit coordination by studying team adaptation to stress. The authors noted that implicit coordination "relies on anticipation of the information and resource needs of the other team members as obtained through the exercise of mental models of the other decision-makers, or via the exercise of a common mental image of the situation" (p. 1229). Further, they noted that implicit coordination requires both shared and accurate mental models. Serfaty et al. had manipulated three variables, uncertainty, time-pressure, and ambiguity, to ascertain how high-performing teams would adapt to stressful situations. The results showed that, under stressful conditions, the teams that were able to maintain performance levels and very low error rates were also characterized by changed communication patterns. Specifically, these team members significantly increased their unsolicited and anticipatory behaviors, which the authors interpreted as evidence that the teams were coordinating implicitly.

Potential Evidence of Implicit Coordination

Following this early research by Serfaty and others, a number of studies have found that teams seem to adopt an implicit coordination strategy under certain conditions. These studies have also served to identify the primary behaviors that have been associated with the occurrence of implicit coordination. The following review discusses the specific behaviors that have been observed and associated with implicit coordination in prior studies and the hypothesized linkage between implicit coordination and SMMs.

Reduction in Information and/or Resource Requests

One of the main findings that has been presented as evidence of implicit coordination is that higher-performing teams tend to reduce their communications related to requesting information and/or resources, as well as asking questions in general. For example, Kleinman and Serfaty (1989) found that, in higher-performing teams, communication requests for resources were dramatically reduced in the high-workload condition, as compared to both the low- and moderate-workload conditions. Similarly, in her study of crewmember decision making in the aircraft cockpit, Orasanu (1990) found that, during periods of high workload, good captains tended to reduce communications overall, including the amount of requested information. On the other hand, poorer-performing captains actually increased their overall communications, including their information requests. In addition, Urban, Bowers, Monday, and Morgan (1993) found that, under conditions of high workload, higher-performing teams asked more questions overall, but asked fewer questions about resources and responsibilities than lower-performing teams. In a follow-up study, Urban, Bowers, Monday, and Morgan (1995) found that, overall, higher-performing teams asked fewer questions and provided fewer answers that included requests. Finally, Waller, Gupta, and Giambatista (2004), in their study of nuclear power plant control crews, found that higher-performing teams engaged in significantly less information collection than lower-performing teams. Thus, it appears that under high workload conditions, higher-performing teams engage in fewer requests for information, regardless of whether their overall communication rates fluctuate. These occurrences of reduced communication have been identified as a component of implicit coordination.

Increase in Unsolicited/Voluntary Information and/or Resources

The other major finding that suggests the presence of implicit coordination has been an increase in the amount of information or resources that are provided without specific requests. Kleinman and Serfaty (1989) noted in their initial study that almost every single resource transfer was unsolicited in higher-performing teams under high workload. Stout, Cannon-Bowers, Salas, and Milanovich (1999) found that higher-performing teams were characterized by a higher rate of information provided in advance, specifically during conditions of high workload. Likewise, Volpe, Cannon-Bowers, Salas, and Spector (1996) found that higher-performing teams volunteered significantly more information, but this finding was not specific to conditions of high workload. Thus, it appears that implicit coordination occurs when team members provide information or resources voluntarily without explicit verbal request, making it possible for teams to reduce their requests for information without experiencing disruptions in team performance.

Anticipation Ratios

Because both a reduction in requests and an increase in unsolicited information and/or resources are representative of implicit coordination behaviors, some studies have looked at the ratio of requests to transfers as an indication of implicit coordination. Specifically, anticipation ratios, which are the number of transfers divided by the number of requests for each specific team member, have been used to investigate the presence or absence of implicit coordination. It is thought that higher anticipation ratios are indicative of information and/or resources being sent more often than they were requested (MacMillan, Entin, & Serfaty, 2004). For example, in Serfaty et al.'s (1993) study of team adaptation and coordination, it was found that the anticipation ratios for teams under high time pressure were significantly higher than under either low or moderate time pressure, although it was not specified whether these results were applicable overall or applied only to high-performing teams. Entin and Serfaty (1999) found similar results; namely, that higher-performing teams were characterized by higher anticipation ratios. However, these were overall results and not specific to high workload. Thus, the results of both studies suggested that better performing team members had increased their unsolicited resource transfers but decreased requests for those resources.

Before leaving this topic, a word of caution should be noted regarding the use of the anticipation ratio metric. While this is a convenient way to represent the number of transfers made per request given, examining data in terms of this single index alone can obscure the richness of the underlying team processes. Very different components of team coordination occur when requests are reduced as compared to when unsolicited behaviors are executed. These behaviors might occur in different team members, at different times, for different purposes, and with different consequences. Therefore, investigations of team processes should include assessments and analyses of both reduced requests and increased unsolicited behaviors. Failure to understand the relationship between these separate measures of team interaction could result in a limited understanding of the nature of team processes under different conditions. Consequently, the current study will focus on the sequence of behaviors that begins with an unsolicited behavior (and a lack of request) and leads to improved team processes.

Implicit Coordination and Shared Mental Models

Beginning with Kleinman and Serfaty's (1989) initial assertion that implicit coordination was associated with SMMs, many other authors have followed suit, suggesting that observed changes in communication could be attributed to SMMs. For example, Entin and Serfaty (1999) suggested that team members rely on mental models of each other's tasks to anticipate their resource needs and that the resulting higher anticipation ratios are at least "partial confirmation" (p. 322) of the existence of SMMs.

Urban, Bowers, Monday, and Morgan (1995), without explicitly stating that their study was evidence of implicit coordination, posited two possible explanations for their observed changes in communication patterns: (a) effective teams simply communicated more clearly, or, in line with implicit coordination, (b) team members of more effective teams were better able to anticipate the needs of their teammates. Moreover, Orasanu (1990) also suggested that team members of higher performing teams developed SMMs that enhanced their team performance, via improved communication processes, under conditions of high workload.

Two prior studies have actually used measurements of SMMs in an attempt to support the existence of implicit coordination. First, Stout et al. (1999) conducted a study of the relationship between planning, SMMs, and team coordination. The authors used the rate of communication provided in advance as their assessment of coordination between team members. As previously mentioned, these authors found that under conditions of high workload, team members in better performing teams provided higher rates of information in advance. However, Stout et al. found no significant relationship between SMMs and the rate of communication provided in advance. More recently, Waller et al. (2004) conducted a study of nuclear power plant crews, focusing on what they called SMM development. While they found that higher-performing teams engaged in less information collection, they also did not find a significant relationship between information collection and SMM development. Thus, neither study actually established a link between SMMs and the behaviors indicative of implicit coordination.

One likely explanation for these null findings is because none of the prior studies have measured or manipulated SMMs in ways that would allow the determination of whether SMMs were actually related to the communication pattern changes thought to be indicative of implicit coordination. Therefore, there are no available data to demonstrate that SMMs are decisively linked to the use of implicit coordination. Indeed, without having or providing empirical confirmation, these prior studies have assumed the existence of a relationship between SMMs and implicit coordination and have used the concept of SMMs as an explanation for the occurrence of implicit coordination.

Summary

The studies reviewed above indicate that implicit coordination is associated with a decrease in requests for information or resources and/or an increase in the voluntary, unsolicited provision of information or resources. Together, these may be measured in terms of the anticipation ratio. However, it should be noted that these studies all focused on communication analysis and that their findings were interpreted *post hoc* as demonstrating implicit coordination. That is, implicit coordination was defined *post hoc* as the pattern of team coordination behaviors that (a) often occurs under conditions of high workload and (b) is characterized by a reduction in certain aspects of communication. It should be further noted that the observance of implicit coordination in prior studies has been attributed to the presence of SMMs among the team members. However, to date, no empirical studies have conclusively and causatively linked SMMs to implicit coordination. What *is* known is that high-performing teams tend to exhibit different communication patterns than lower-performing teams, often under conditions of high workload. Whether or not this differential communication pattern is a function of, facilitated by, or limited by SMMs, however, has not been irrefutably shown. In order to examine these issues further, the following section provides a discussion of the definition and operationalization of implicit coordination.

A Working Definition of Implicit Coordination

Prior studies on implicit coordination have generally taken a macro or global approach to team coordination by analyzing patterns of behavior or ratios of behavior. While this approach was sufficient in uncovering the pattern of behaviors, it has not been particularly useful in determining whether implicit coordination is the result of a process or sequence of behaviors. In this study, a more micro level approach was taken, focusing on a specific sequence of behaviors. This approach is taken in an attempt to determine the specific steps involved in the process of implicit coordination and to determine whether, in fact, teams shift their behaviors in a standard way or in a haphazard way.

The American Heritage Dictionary (2000a) defines the term "implicit" as "implied or understood though not directly expressed." Communication is defined by the American Heritage Dictionary (2000b) as "the exchange of thoughts, messages, or information, as by speech, signals, writing, or behavior." Finally, to coordinate means to "harmonize in a common action or effort" (American Heritage Dictionary, 2000c). Combining these definitions, it appears that communication is a necessary but not sufficient condition for coordination, and thus implicit communication is encompassed in implicit coordination. In addition to implicit communication though, successful implicit coordination requires some action or follow through that brings a team closer to its goals.

Thus, the behaviors constitute "coordination" because multiple team members are actively interacting, and this coordination is "implicit" because the initiating behaviors are performed without explicit requests.

Beyond the above definitions, recent writers have described implicit coordination as "team members offering each other voluntarily the necessary information" (Rasker, Post, & Schraagen, 2000, p. 1169), "the ability of team members to act in concert without the need for overt communication" (MacMillan et al., 2004, p. 63), and the interactions of team members "without consciously trying to coordinate" (Espinosa, Lerch, & Kraut, 2004, p. 107). While each of these descriptions of implicit coordination is helpful, none fully operationalizes the construct. In addition, none of the definitions is specific enough to allow one to differentiate implicit coordination from similar constructs, such as anticipatory, supporting, or back-up behaviors (see Porter, Hollenbeck, Ilgen, Ellis, West, & Moon, 2003; Smith-Jentsch, Zeisig, Acton, & McPherson, 1998). Therefore, based on the above definitions and other related literature, the following discussion provides a first attempt to operationally define implicit coordination, specify what makes it different from similar constructs, and describe the types of behaviors that are encompassed in this term.

Definition

Successful implicit coordination is defined here as *the act of one team member voluntarily initiating team coordination behaviors that are recognized and exploited by another team member, and which should result in improved team processes.* For the purposes of this discussion, team performance is assumed to occur in situations that require team members to interactively share task-related information and performance resources, share an understanding of the performance requirements and team goals, and coordinate their activities dynamically in order to achieve the performance goals of the team. Furthermore, a period of team performance is assumed to include performance sequences in which one team member typically requests information or a task-related action from another team member at the appropriate time in the performance sequence. If the second team member responds in a timely manner by providing the requested information or action so that team performance occurs, team coordination has occurred; in this instance, the coordination is referred to as explicit coordination. However, according to the current definition, an occurrence of implicit coordination consists of a sequence of unified behaviors that exhibit the following three specific criteria: (a) the team member initiating the coordination must do so without an explicit request from another team member, (b) the team member on the receiving end must recognize the behaviors of his/her teammate and be able to exploit that behavior, which should lead to (c) an observable positive impact on team processes. In a specific team performance situation, teams that exhibit more of these behavioral sequences, as compared to behavioral sequences that are initiated by a request for information or resources (e.g., explicit coordination) are said to be implicitly coordinating.

It should be noted that the above definition expands previous definitions by placing more emphasis on the role of the second team member. This emphasis allows for a differentiation between implicit coordination and other behaviors, such as backup behaviors. Dimensions of backup behaviors include: (a) providing assistance to team members who need it, and (b) ensuring that the second team member recognizes that assistance was provided (Smith-Jentsch, Johnston, & Payne, 2000). The proposed definition of implicit coordination takes backup behaviors one step further, incorporating the second team member's actions directly into the definition. Specifically, if the behaviors by the first team member are neither recognized nor exploited by the second team member, then the attempt at implicit coordination has not been successful. Furthermore, if the behaviors are not useful to the second team member, then performance will not be improved and implicit coordination has not been successful. Thus, implicit coordination can only be successful if the three criteria of the definition have been met.

Figure 1 depicts the essential steps that define the proposed definition of successful implicit coordination. This depiction and the following descriptions of each step are presented here for the first time. They are not products of previous research, but are the proposed steps of implicit coordination that will be tested in this study.

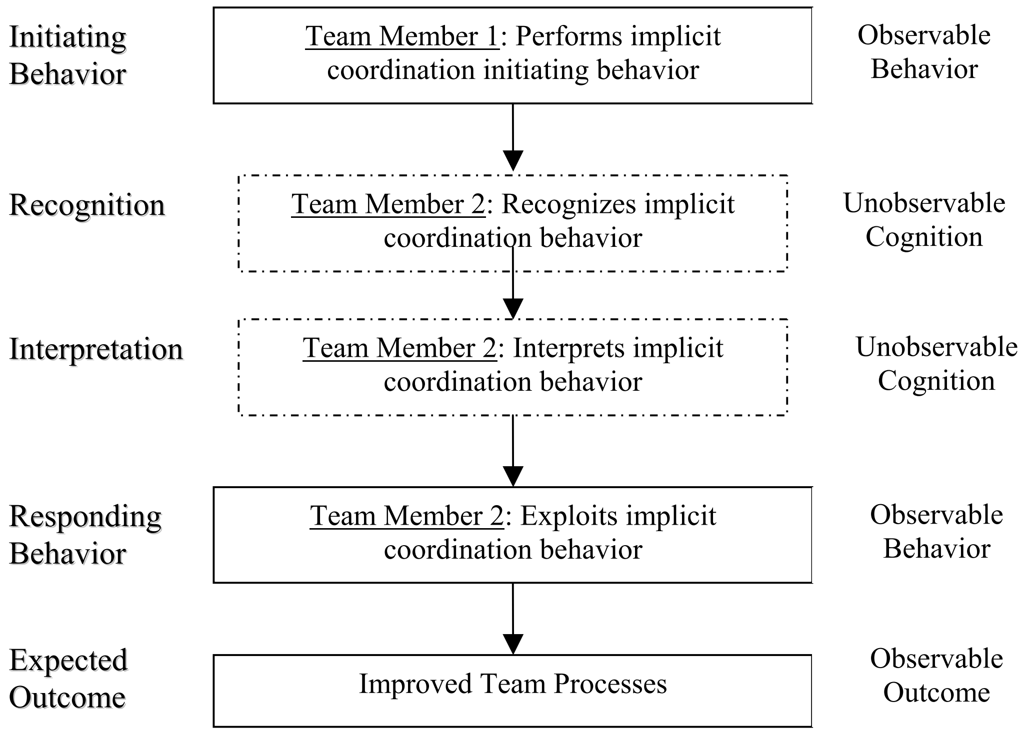

Figure 1. Graphical representation of the essential steps that define successful implicit coordination.

Initiating Behavior

Under the above definition, any coordinative behaviors, including explicit, verbal communications, can be encompassed in implicit coordination, as long as the defining criteria are present. When a team member initiates a behavioral sequence in the absence of a request to do so, and another team member can exploit the initiating behavior to improve team processes, then that behavioral sequence can fall under the rubric of implicit coordination. It should be noted that while some highly proceduralized, sequential tasks could also fall under the above definition of implicit coordination, these types of tasks are not the focus of the current study. For example, tasks that require teams to follow a detailed checklist, such as in the handling of hazardous materials, or in the firing of nuclear missiles, will not be the focus of this study. The reason for this is that transferring information or resources could simply be the next step in the procedure and thus would not be indicative of implicit coordination.

So, initiating behavior is the first step in the process of implicit coordination. In this step, the first team member initiates and carries out a team performance behavior, action, communication, procedure, etc. in an effort to coordinate with a second team member. By definition, an initiating behavior must be some observable, measurable behavior on the part of a team member who seeks to coordinate with another team member. Further, this behavior must serve to initiate a behavioral sequence that leads to a response on the part of another team member. In fact, this behavior could even be the absence of an action (for example, realizing a team member is overloaded and therefore not passing him or her additional work); however, because of the difficulties in observing and measuring an intentional lack of behavior this form of behavior has been excluded from the current definition and experimental study. As used here, the initiating behavior must simply be some observable behavior on the part of one team member to coordinate with another team member.

Recognition

It is important to emphasize that a second team member plays an active role in the process of implicit coordination. In order for successful implicit coordination to take place, the second team member must recognize that the first team member has initiated a relevant and useful behavior. If the second team member does not notice the first team member's initiating behaviors, then the behavioral sequence initiated by the initiating behavior will be broken and implicit coordination will not occur. Recognition of the initiating behavior and its significance is a necessary, but unobservable, part of implicit coordination. It is assumed to occur as a cognitive event that takes place in the second team member when he or she responds appropriately to an initiating behavior.

Interpretation

Next, the second team member must correctly interpret the initiating behavior. That is, after a second team member has recognized the occurrence of an initiating behavior, he or she must interpret the meaning and performance implications of the behavior and select an appropriate response. Interpretation is also considered to be an unobservable cognitive event. Its occurrence is assumed to have occurred when the team member makes an appropriate response to the initiating behavior.

It is hypothesized that SMMs become important during this step and the next one. The team members must have a shared understanding of what is happening and what needs to be done in the context of their team performance situation. If the team members do not have SMMs, then it is possible that either (a) the first team member will have performed some behavior that is actually not useful to the second team member, or (b) the second team member will not know how to exploit the behavior of the first team member. Either way, implicit coordination cannot result if <u>either</u> team member fails to understand and predict the other's actions.

Responding Behavior

This step in implicit coordination is critical because it is part of what distinguishes implicit coordination from other similar constructs, such as backup behavior. The occurrence of a responding behavior is the step in which the second team member actually uses the initiating behavior to the advantage of the team. For example, if information or a resource has been passed, it is at this point that the second team member uses that information or resource. Responding behaviors can include any behavior that directly exploits the initiating behavior in some way--hopefully to improve team processes--and that is observable and measurable. If the second team member recognizes the behavior and knows what is expected but does not follow through, then according to the current definition, implicit coordination has not resulted. Further, without the occurrence of the responding behavior, the prior occurrence of recognition and interpretation cannot be assumed. Again, it is recognized that in some highly proceduralized, sequential tasks, one team member might transfer a resource because he or she knows that his or her teammate will need it at some later point; however, these types of tasks are not the focus of this study. Implicit coordination necessitates that the second team member can exploit the actions of the first team member so that team processes are maintained or improved. The occurrence of the responding behavior makes it possible for the final step to occur in the team performance sequence that constitutes implicit coordination.

Expected Outcome

The expected outcome from successful implicit coordination is the observable maintenance or improvement of team processes. This outcome relies on both team members completing their respective steps in the process as defined above. Specifically, it requires that the first team member performs some observable initiating behavior. Furthermore, it requires that that the second team member (a) recognizes the initiating behavior, (b) correctly interprets the initiating behavior, and (c) exploits that behavior to result in improved team processes. All of these steps are thought to be mediated by SMMs that allow the second team member to correctly interpret the actions of the first team member.

Facilitating Factors of Implicit Coordination

While the above definition of implicit coordination helps to operationalize the construct of implicit coordination, there are other important factors that must be taken into account when discussing the underlying mechanisms of implicit coordination. These facilitating factors are important because they can serve to increase the likelihood that a team member will attempt implicit coordination. While implicit coordination can take place in the absence of these factors, the presence of these factors might greatly increase the likelihood that team members will engage in implicit coordination. Table 1 provides a list of these facilitating factors and a description of each.

Table 1

Factors that Facilitate Implicit Coordination

Facilitating Factor	Description
1. Motivation	The more motivated a team member is to improve team performance, the more likely is it that he or she will attempt implicit coordination
2. Belief that an initiating behavior exists	If a team member believes that there exists a behavior that can help improve team performance, the more likely it is that a team member will engage in implicit coordination attempts
3. Belief that initiating behavior will be interpreted correctly	If a team member believes that another team member will interpret the initiating behavior correctly, the more likely it is that he or she will attempt implicit coordination

Motivation

The first factor that should facilitate attempts of implicit coordination is the motivation on the part of a team member of wanting to engage in implicit coordination. As long as this motivation does not stem from an explicit request for help from another team member, it can facilitate the process of implicit coordination. This motivation can be based on the recognized critical nature of the situation, or an interpretation of a sign from another teammate, including obvious signs of frustration, such as yelling or swearing, and from less obvious events, such as a sudden increase or decrease in communication. The motivation could also be derived from a desire to maintain the current level of performance under increases in the perceived level of workload, or from the fact that a team member wants to improve performance on the given task.

Belief in the Efficacy of Initiating Behavior

Implicit coordination is also likely to be facilitated by a belief on the part of the first team member that he or she can do something that will improve the situation. This facilitation to the process is actually derived from two sources: (a) the first team member believes that there exists a behavior, communication, method, or procedure that, if executed, will improve the situation and (b) the first team member believes that he or she will be successful in carrying out this coordination behavior (i.e., the first team member has self-efficacy). If either of these conditions does not exist, then it is unlikely that an attempt at implicit coordination will even take place. If the first team member is unaware of a viable available behavior to perform, then there is nothing to attempt. On the other hand, if there is a viable option but the team member does not believe that he or she will be successful in completing that option, then it is also unlikely that implicit coordination will be attempted. Thus, implicit coordination attempts will be facilitated by both a belief that something can be done and that it can be done successfully.

Belief that the Initiating Behavior will be Interpreted Correctly

The third factor facilitating attempts of implicit coordination is the belief that the second team member will interpret the initiating behavior correctly, which is based on a belief that the two team members view things similarly (i.e., have SMMs). The minimal condition necessary for the first team member to attempt implicit coordination is that he or she believes he or she shares a correct mental model with the other team member (i.e., *a perception of sharedness)*. That is, the first team member must *believe* that the second team member has a similar understanding of the task and the team such that he or she will be able to successfully interpret and exploit the actions of the first team member. If the first team member does not *believe* that the second team member shares his or her views, then he or she will be unlikely to attempt to engage in implicit coordination. As will be discussed further below, these perceptions of sharedness may be completely separate from the actual level of sharedness between team member mental models.

Summary

Prior studies have demonstrated that high-performing teams can adapt their communication patterns during periods of high workload in order to compensate for increases in performance demands. While this finding provides potential evidence for implicit coordination, none of the studies reviewed here investigated the process whereby one team member voluntarily offers information or resources *and* another team member exploits those resources to maintain or enhance team processes and performance. In contrast, prior studies all focused on the reduction of requests and the increase in initiating behaviors. None of the prior studies mentioned the use of any measure of whether there was a responding behavior resulting from the initiating behavior. The results were for high-performing teams, so it is certainly possible that these teams were engaging in implicit coordination; however, it is also possible that the results of these studies can be explained in terms of backup behaviors that are the result of one team member's efforts. Thus, a more thorough investigation into the process of implicit coordination is needed in order to differentiate between these one-sided behaviors and team coordination.

Furthermore, while prior studies have presented some evidence for the presence of implicit coordination, the link between the shift to implicit coordination and SMMs is still a hypothesis that has yet to be fully investigated. This represents a potentially crucial oversight in the research to date regarding implicit coordination. While the notion that SMMs play a role in implicit coordination is logical, research is needed to assess the nature of the relationship between SMMs and implicit coordination behaviors. Before proposing specific ways to overcome this limitation in the previous literature, it will be necessary to discuss the construct of SMMs to determine what is currently known about them and to examine *how* SMMs might impact the use and efficiency of implicit coordination. This discussion is provided in the following section.

Mental Models

A number of researchers have suggested that the change from explicit to implicit coordination between team members can be attributed to mutual or shared mental models (SMMs) that allow team members to anticipate each other's needs (Cannon-Bowers, Salas & Converse, 1993; Entin & Serfaty, 1999; Espinosa, Kraut, Lerch, Slaughter, Herbsleb, & Mockus, 2001; Kleinman & Serfaty, 1989; MacMillan, Paley, Levchuk, Entin, Freeman, & Serfaty, 2001; Stout & Salas, 1993; Urban et al., 1996; Volpe et al., 1996; Weick & Roberts, 1993). In fact, even researchers not specifically referring to implicit coordination have suggested that SMMs should lead to improved team processes (Kraiger & Wenzel, 1997; Rentsch & Hall, 1994; Rouse, Cannon-Bowers, & Salas, 1992; Walsh, Henderson & Deighton, 1988) and team performance (Langan-Fox, Code, & Langfield-Smith, 2000; Porac & Thomas, 1990; Rentsch & Klimoski, 2001).

Mohammed and Dumville (2001) noted that the general consensus in the SMM literature was that increased sharedness should lead to improved team effectiveness.

In their review of the literature on this topic, Cannon-Bowers et al. (1993) asked whether too much sharedness can be detrimental to team performance. Specifically, might too much sharedness lead to a phenomenon similar to Janis' (1972) notion of *groupthink*, where a singular view might lead team members to make incorrect or poor decisions in order to preserve the group's cohesion? Cannon-Bowers et al. did not think so and instead concluded that teams that do not have SMMs are more likely to perform poorly or fail altogether, and, thus, "shared mental models [should] be fostered among team members as much as possible" (p. 237). Furthermore, Cannon-Bowers et al. offered two potential strategies to overcome possible negative effects of too much sharedness: (a) emphasize assertiveness skills to make team members more likely to challenge or question decisions, and/or (b) provide decision support systems that could suggest alternative options for the team to consider.

The following section describes those aspects of SMMs that are relevant to the current study. First, mental models and SMMs are defined. Next, the various types of mental models are differentiated and discussed in terms of their importance in this study. Finally, the section concludes with a discussion of the daunting nature of research on mental models and the difficulty involved in comparing results across studies.

Definitions of Mental Models

There is no single definition of a mental model that is universally accepted. What researchers do agree on is that a mental model is an internal representation of how something works or how things or concepts are connected with each other (cf. Eberts, 1994; Gentner & Stevens, 1983; Johnson-Laird, 1983; Norman, 1988; Rouse & Morris, 1986; Wilson & Rutherford, 1989). The definition that best suits the purposes of the current research was adopted from Wilson and Rutherford, who noted that:

> … a mental model is a representation formed by a user of a system and/or task, based on previous experience as well as current observation, which provides most (if not all) of their subsequent system understanding and consequently dictates the level of task performance. (p. 619)

Furthermore, within the team context, the concept of SMMs has arisen to explain how team members coordinate with one another and adapt to changing environments (see Cannon-Bowers et al., 1993). Cannon-Bowers et al. defined general SMMs as:

> Knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and, in turn, to coordinate their actions and adapt their behavior to demands of the task and other team members. (p. 228)

Both of the definitions above emphasize the fundamental role that mental models and SMMs play in how a person and/or team will perform on a given task. It is this key emphasis on the impact that SMMs have on team processes that makes these definitions essential for the current study. Because the current study focuses on the relationship between SMMs and implicit coordination, it is only logical to define these constructs in ways that emphasize their influence on team behaviors and performance. Although other terms have been used to describe knowledge structures (e.g., schemas, action scripts, expectations) and shared knowledge (e.g., shared cognition, shared understanding, transactive memory), the concepts of mental models and SMMs have always, at least in theory, been linked to implicit coordination. Thus, these concepts are the focus of the current study.

Types of Shared Mental Models

Cannon-Bowers et al. (1993) hypothesized that team members may have multiple mental models of their task and their team, including models that contribute to an understanding of (a) the equipment with which they need to interact (equipment model), (b) the task and the method of completion (task model), (c) team member roles and responsibilities (team interaction model), and (d) the knowledges, skills, and abilities (KSAs) of the other team members (team model). Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000) later reorganized the four types into two general categories: task-related (both equipment and task mental models) and team-related (both team interaction and team mental models).

For the purposes of the current study, Mathieu et al.'s distinction between task-related and team-related mental models will be used. The findings of the current study might suggest that future research should delve into the more specific categories. However, because the current goal is only to determine whether SMMs are related to implicit coordination, the simpler team vs. task delineation is appropriate and sufficient.

Difficulties in Conducting Mental Model Research

Similar to the previously addressed problem of variations in the definitions of implicit coordination, the construct of SMMs has had its fair share of ambiguity as well. Cannon-Bowers et al. (1993) hypothesized that different SMMs exist, yet there have been inconsistencies in how researchers have defined, labeled, and evaluated these SMMs

(Mohammed, Klimoski, & Rentsch, 2000). The following sub-sections will specifically address three aspects of SMMs that are relevant to the current study; namely, (a) mental model content, (b) mental model sharedness, and (c) mental model assessment. For an in-depth discussion of the various other problems that plague SMM research, please see Cannon-Bowers and Salas (2001), Klimoski and Mohammed (1994), or Mohammed et al. (2000).

Mental Model Content

While it has been suggested that there are different types of mental models, the specific content of these different mental models is still not clear. Granted, the team-related vs. task-related delineation put forth by Mathieu et al. (2000) seems fairly simple. However, the specific content of those mental models has changed from study to study based on the researchers' decisions about what was and was not important. Thus, even though there are different types of mental models, there are still no standards that define exactly what kind and specificity of information should be included in them. One of the consequences of this lack of standardization is that it becomes difficult to compare results across studies. While two different studies might purport to have assessed team SMMs, the content of those team SMMs may be completely different (Mohammed et al., 2000). This means that if one study found significant relationships between SMMs and other team variables, such as team performance, and the other study did not, the findings might have occurred because of the different content of the SMMs in the two studies. In order to overcome this limitation, future researchers should specify not only the type of SMMs they are measuring, but also specify the focus or emphasis of the content. This will allow for not only a better understanding of the SMM literature in general, but also will facilitate the process of comparing results across studies.

Mental Model Sharedness

A second aspect of SMMs that has varied across studies and made comparisons difficult has been the authors' understanding of what is defined as sharedness and how sharedness should be measured. There are at least three competing views on what "shared" actually means. For instance, shared could mean (a) overlapping between team members, (b) distributed across an entire team, or (c) compatible (cf. Cannon-Bowers & Salas, 1997, 2001; Cooke, Salas, Cannon-Bowers, & Stout, 2000). Overlapping refers to how similar two mental models are to one another. This is one of the most oft used definition of sharedness. Distributed across an entire team refers to the team having a complete mental model by combining pieces of each team member's individual model. Finally, compatible mental models should lead to *expectations* that are correct and/or similar, which lessen the importance of having identical models (Cannon-Bowers & Salas, 2001). Thus, when comparing the results of various studies, it is important to pay attention to how the authors have defined sharedness and how that sharedness was actually assessed. For the purposes of this study, the most common definition of sharedness, i.e., overlapping, will be used.

Mental Model Assessment

A third major aspect of SMM research that has differed from study to study and, therefore, affects the comparison of study results, is the assessment of the mental models, in terms of both measurement and analysis. In fact, the major hurdles in mental model research have been how to measure one's mental model and how to assess the sharedness between multiple models (Klimoski & Mohammed, 1994). A number of different techniques have been used in attempts to elicit and measure individuals' mental models. These have included, but have not been limited to: similarity (or pairwise) ratings (cf. Marks, Sabella, Burke, & Zaccaro, 2002), card sorting (cf. Evans, Hoeft, Jentsch, & Bowers, 2002; Hoeft, Evans, Jentsch, & Bowers, 2003; Smith-Jentsch, Campbell, Milanovich, & Reynolds, 2001), concept mapping (cf. Evans, Hoeft, Kochan, & Jentsch, 2005; Evans, Kochan, & Jentsch, 2003; Jonassen, Beissner, & Yacci, 1993), verbal protocols (cf. Ericsson & Simon, 1984), and textual analysis (cf. Carley, 1997).

Issues of reliability and validity have been raised with regard to each specific method of mental model assessment. For example, Hinsz (1995) emphasized that it is necessary to use more than one assessment method, especially because of reliability concerns. Since mental models are dynamic and may indeed be unreliable themselves, using one method to assess them simply does not assure any kind of consistency. Because of the complexity of mental models, especially at the team level, Mohammed et al. (2000) advised that multiple techniques should be used and that each choice should be justified for a given context. It should be noted, however, that Rouse and Morris (1986) believed that even an approach using multiple techniques to overcome the weaknesses of other techniques would still likely not capture an entire mental model.

Once a method or methods are chosen for analysis, the process of evaluating those mental models presents a whole new set of issues and concerns. Not only can different measurement techniques lead to different results, but different evaluation or assessment techniques can as well. For example, Smith-Jentsch, Mathieu, and Kraiger (2005) found different results when they evaluated SMMs using different ways to assess sharedness. Specifically, the authors measured both consistency (correlations between team members' mental models) and agreement (variance of mental models across a team) and found that the consistency measure was more strongly related to team performance. Therefore, authors who use the same measurement techniques might still find different results based on slightly varied scoring and/or comparison methods, once again contributing to the complexities in comparing results across studies.

Keeping in mind that there are difficulties in comparing the results of different SMM studies, the next section will review the studies that have investigated the relationship between SMMs and team processes and performance.

Mental Model Sharedness

The most widely studied attribute of mental models in teams is the degree of sharedness (similarity, overlap, convergence, agreement, etc.) between team members' individual mental models. The majority of research exploring the influence of SMMs has used the level of sharedness as the primary assessment of SMMs, with more similarity suggesting that team members have better SMMs. In general, the results have shown that more sharedness or overlap between mental models is associated with enhanced team coordination processes, which in turn have been found to be associated with better team performance (cf. Heffner, Mathieu, & Cannon-Bowers, 1998; Heffner, Mathieu, & Goodwin, 1998; Rentsch, 1993). However, it should be noted that none of these studies investigated the relationship between mental model sharedness and implicit coordination.

A number of the prior studies of SMMs in teams have shown direct or indirect linkages with multiple other team process and performance variables. Klimoski and Mohammed (1994) stated that SMMs set "up a chain of effects influencing multiple determinants of team effectiveness" (p. 425). Stout et al. (1999) showed that teams who planned better, also developed better SMMs and used more efficient communication strategies under conditions of high workload. However, similar to many other published studies in the past, Stout et al. did not specify which type of SMM was measured. Mathieu et al. (2000) have noted that, due to the results of recent studies on the unique effects of different mental models, "work on 'the' team model may be short-sighted at best, and confounded at worst" (p. 281). Furthermore, Mohammed and Dumville (2001) stated that "team mental models should not be referenced in the abstract without specifying whether the focus is on teamwork [or] taskwork" (p. 104). In attempts to overcome these problems, a number of studies have examined the impacts of the different types of SMMs on team processes and performance. These studies are described below.

Team-Related Mental Models

As stated earlier, team-related mental models are representations of the different team member roles, their KSAs, how they are supposed to coordinate with one another, etc. Various studies have found mixed results in terms of the relationships between team-related mental model sharedness and team processes, on the one hand, and team-related mental model sharedness and team performance, on the other. For a number of reasons, it seems reasonable to expect that sharedness among team-related mental models impacts team processes and performance. First, it makes sense that the more familiar team members are with each other and the more experience they have working together, the easier it should be to coordinate and accomplish team goals. Second, even a shared generic understanding of which team member is responsible for each sub-task should allow team members to predict more accurately the behaviors of their teammates, and also to have a better understanding of their own tasks. Third, a shared understanding of the teammates and their roles should also increase the accuracy with which team members could interpret the behaviors of the other team members. Each of these factors should lead to improved team processes, and in turn, enhanced team performance. The research results, however, have been somewhat mixed, which likely has been a result of the previously mentioned difficulties in conducting mental model research.

Relationship with Team Processes

Relatively few studies have directly investigated the relationship between team-related mental model sharedness and team processes. Of the available studies, some have failed to find any relationship (Marks, Zaccaro & Mathieu, 2000; Mathieu, Heffner, Goodwin, Cannon-Bowers & Salas, 2005; Sabella, 2000), while others report having found a significant relationship between the two variables. For example, Heffner (1997) found that the degree of sharedness between team mental models was a significant predictor of team processes, which were measured along six attributes: (a) leadership, (b) assertiveness, (c) decision making/mission analysis, (d) adaptability/flexibility, (e) situation awareness, and (f) communication. Mathieu et al. (2000) found similar results when looking at team processes in terms of three specific dimensions: (a) communication, (b) strategy formation and coordination, and (c) team cooperation.

Finally, Marks et al. (2002) found that sharedness of team interaction mental models was a significant and positive predictor of two team processes: (a) backup behaviors and (b) team coordination.

Relationship with Team Performance

Findings regarding the relationship between sharedness of team-related mental models and team performance have been equally mixed. Specifically, a number of studies have found no direct relationship between sharedness and team performance (Heffner, 1997; Mathieu et al., 2005; Sabella, 2000; Smith-Jentsch et al., 2005). Yet other studies have found direct relationships or mediated relationships between the two variables. Minionis (1995) found that sharedness was significantly and positively correlated with coordinated performance. Fleming, Wood, Ferro, Bader, and Zaccaro (2003) also found that shared team-interaction mental models were positively related to team performance. Marks et al. (2000) found a significant, positive relationship between team mental model sharedness and team performance that was partially mediated by team processes. Finally, both Mark et al. (2002) and Mathieu et al. (2000) found that the relationship between team-interaction mental model sharedness and team performance was fully mediated by team coordination variables.

Task-Related Mental Models

Task-related mental models include task-specific information about how to perform and complete the task, as well as the equipment needed to complete the task. In terms of the number of studies that investigated the influence of mental model sharedness on team processes and team performance, task mental models have received even less attention than team-related mental models. Nevertheless, there are reasons to expect task-related mental model sharedness to be related to team processes and performance. First, an overall shared understanding of the task should allow team members to appropriately distribute the responsibilities to ensure goal attainment. Second, a shared understanding of the task should facilitate team coordination because team members should be aware of what needs to be done and why. Third, a shared understanding of the task could even compensate for a lack of familiarity with teammates. As long as all of the team members understand the task, then they should be able to predict and interpret their teammates' behaviors. Similarly, these factors should all be associated with improved team processes, and in turn, team performance. The available studies in this regard are reviewed in the following two sections.

Relationship with Team Processes

No readily available studies were found that looked solely at the influence of task-related mental model sharedness on team processes and performance. However, a number of the studies that investigated team-related mental models also included an analysis of the relationship between task-related mental models and team processes or performance. The three studies that have evaluated the relationship between task mental model sharedness and team processes have all found a significant, positive relationship between the two (Heffner, 1997; Mathieu et al., 2000; Mathieu et al., 2005). While generalization from these three studies must be approached with caution, it can be safely noted that none of the available studies have found a non-significant relationship or a significant, conflicting (i.e., inverse) relationship between the two variables.

Relationship with Team Performance

Findings regarding the relationship between task-related mental model sharedness and team performance are similar to those regarding team-related mental model sharedness and team performance. That is, a number of different studies have provided evidence for differing relationships. At least one study found no relationship between task mental model sharedness and team performance (Smith-Jentsch et al., 2005). On the other hand, another study found the exact opposite relationship; that is, Fleming et al. (2003) found a significant positive relationship between the two variables. Alternately, Mathieu et al.'s (2000) results showed that task mental model sharedness had an indirect relationship with team performance, being mediated via team processes. Two other studies have found evidence of a partially mediated relationship between task mental model sharedness and team performance (Heffner, 1997; Mathieu et al., 2005). In both cases, the team processes were measured using the six dimensions of (a) leadership, (b) assertiveness, (c) decision making/mission analysis, (d) adaptability/flexibility, (e) situation awareness, and (f) communication. It should be noted that the one study that did not find a relationship between task mental model sharedness and team performance (Smith-Jentsch et al., 2005) was a post hoc study that did not have a team process measurement; therefore, the possibility of an indirect or mediated relationship cannot be ruled out from the results.

Summary

A general overview of the above-mentioned studies can be found in Table 2. The general pattern of results suggests that mental model sharedness appears to be related to team processes and team performance. Of the ten studies that assessed the relationship between SMMs and team processes, seven showed significant positive results. Of the 16 studies that assessed the relationship between SMMs and team performance, 13 found a significant and positive relationship. What is important to note here is that, even with all the confounding variables that affect comparisons between studies, the overwhelming evidence is that SMMs do have an impact on how teams coordinate and perform. Thus, the hypothesis that SMMs play a role in implicit coordination is a logical one and will be investigated further in the current study.

Table 2

Summary of Relationships found between Shared Mental Models and Team Processes and Team Performance Presented Chronologically

Study	Type of SMMs	Relationship with Team Processes	Relationship with Team Performance
Minionis (1995)	Team SMMs	Not noted	Significant positive relationship between Team SMMs and coordinated performance
Carley (1997)	Not specified	Not noted	Higher performing teams had more elaborate and different information in their mental models compared to lower performing teams
Heffner (1997)	Team SMMs	Team SMMs significant positive predictor of team processes	Team process significantly influenced team performance, no direct relationship with Team SMMs
	Task SMMs	Task SMMs significant positive predictor of team processes	Team process partially mediated the relationship between task SMMs and team performance
Stout, Cannon-Bowers, Salas, & Milanovich (1999)	Not Specified	No significant relationship between SMMs and information provided in advance	Indirect positive relationship between SMMs and performance via planning
Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers (2000)	Team SMMs	Significant positive relationship between Team SMMs and team processes	Relationship between Team SMMs and performance fully mediated by team process
	Task SMMs	Significant positive relationship between Task SMMs and team process	No direct relationship, indirect relationship via team process
Marks, Zaccaro, & Mathieu (2000)	Team Interaction SMMs	Team Interaction SMMs significant positive predictor of communication processes	Positive relationship between Team Interaction SMMs and team performance partially mediated by team process
Sabella (2000)	Team SMMs	Team SMMs not a significant predictor of coordination quality (backup behavior)	Team processes significantly predicted performance but no relationship between Team SMMs and performance

Study	Type of SMMs	Relationship with Team Processes	Relationship with Team Performance
Marks, Sabella, Burke, & Zaccaro (2002)	Team Interaction SMMs	Team Interaction SMMs significantly improved backup behaviors and significantly predicted team coordination	Positive relationship between Team Interaction SMMs and team performance completely mediated by coordination processes
Fleming, Wood, Ferro, Bader, & Zaccaro (2003)	Team Interaction SMMs	Not noted	Significant positive relationship between Team Interaction SMMs and team performance
	Task SMMS	Not noted	Significant positive relationship between Task SMMs and team performance
Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas (2005)	Team SMMs	No significant positive relationship between Team SMMs and team process	No significant relationship between Team SMMs and team performance
	Task SMMs	Task SMMs significant positive predictor of team processes	Positive relationship between Task SMMs and team performance partially mediated by team process
Smith-Jentsch, Mathieu, & Kraiger (2006)	Team Interaction SMMs	Not noted	Team Interaction SMMs not a significant predictor of team performance
	Task SMMs	Not noted	Task SMMs not a significant predictor of team performance
	Interaction between Team Interaction and Task SMMs	Not noted	Interaction significant positive predictor of team performance

Implicit Coordination and Mental Model Sharedness

While the studies that have assessed the relationship between both team and task mental model sharedness were reviewed in the previous section, the focus of the study proposed here was specifically on task mental models. This decision was made based two factors. First, the number of studies that have focused on task-related mental models are fewer than for team-related mental models. Consequently, much less is known about the influence of task-related mental models. Second, while being familiar with one's teammate and his/her roles is likely to enhance any type of coordination, it was a realistic assumption that having a shared understanding of the task will have a stronger overall effect on the process of implicit coordination. Team members might be able to compensate for a lack of task understanding if they have a great deal of experience with one another; however, this study utilized ad hoc teams brought together for the express purposes of participating in a research study. Thus, especially in this environment, task mental models are expected to be more appropriate.

It has already been noted that SMMs are hypothesized to be related to implicit coordination because SMMs allow team members to anticipate each other's needs. It makes sense that shared task mental models should facilitate team processes by allowing team members to coordinate more effectively with one another. However, in discussing the definition of successful implicit coordination earlier, it was noted that SMMs should be important in making it possible for the second team member to interpret and respond to initiating behaviors, but not as support for the first team member to attempt implicit coordination. In fact, one can go so far as to intentionally *not* include SMMs among the facilitating factors that increase the likelihood that a team member will engage in implicit coordination. It is reasonable to conclude that teams who have shared task mental models can be expected to be more efficient in their coordination, because team members will be more likely to attempt implicit coordination at the appropriate and necessary times and with the appropriate initiating behaviors. However, team members who do not have shared task mental models may be just as likely to attempt implicit coordination, which will likely be unsuccessful when they carry out an action that is inappropriate or do so at an inappropriate time, etc.

There are two reasons to believe that shared task mental models, even though they may not be predictive of attempts to coordinate implicitly, are essential for the correct interpretation and response behaviors in implicit coordination. First, if team members have a shared understanding of the task, then it is more likely that the initiating behavior was an appropriate behavior that the second team member can interpret easily. Second, the second team member should know what to do in response to the initiating behavior. Thus, shared task mental models should facilitate the process of implicit coordination. Furthermore, from the reviews on implicit coordination and on mental model sharedness, it would certainly not be a stretch to hypothesize that the two are related. Task mental model sharedness has been linked to both team processes and team performance; implicit coordination is an example of one type of team process. Thus, the likelihood that shared task mental models are related to the use of implicit coordination is high.

Therefore, for the current study, it was hypothesized that shared task mental models between team members would be positively related to the responding behaviors of the second team member. That is, shared task mental models would allow the second team member to correctly recognize, interpret, and react to the first team member's initiating behavior. This leads to the first experimental hypothesis for the current study:

> *Hypothesis 1*: The level of sharedness (i.e., overlap) between team members' task mental models will be a significant predictor of the use of implicit coordination, such that higher levels of sharedness will be associated with more responding behaviors.

Figure 2 presents a graphical depiction of the proposed process of implicit coordination and the hypothesized relationship between shared task mental models and responding behaviors.

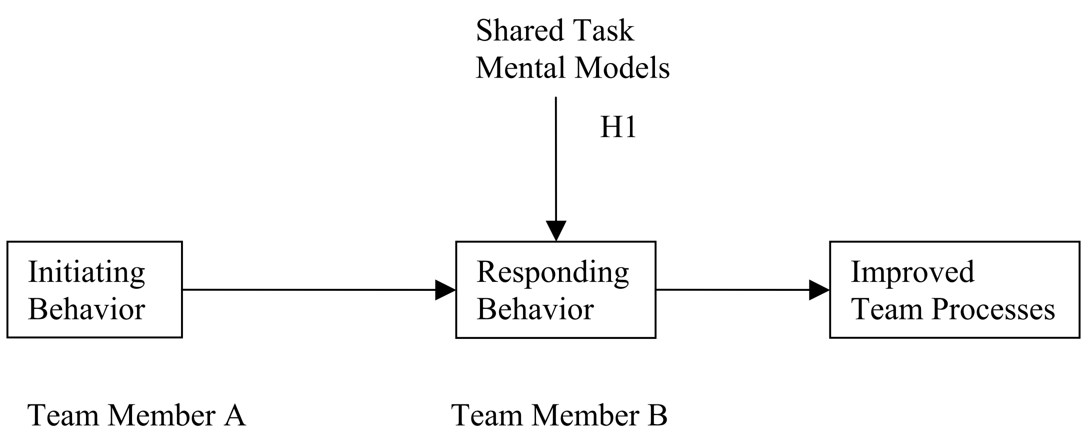

Figure 2. Proposed relationship between shared task mental models and implicit coordination.

Confirmation of this hypothesis would provide the first direct empirical evidence to support the much-referenced hypothesis that SMMs are related to implicit coordination. Specifically, it would show that shared task mental models play a role in implicit coordination by aiding the second team member to correctly recognize, interpret, and react to the first team member's initiating behavior.

Mental Model Accuracy and Quality

Whereas there is overwhelming evidence that the level of sharedness among team member mental models impacts team processes, issues related to the quality of those SMMs have received much less attention. As noted previously, it has been hypothesized that implicit coordination requires not only *shared* mental models, but *accurate* mental models as well (Serfaty et al., 1993). Other authors have also argued that the correctness of SMMs may be essential for effective teams (see Cannon-Bowers & Salas, 1990; Cooke et al., 2000; Druskat & Pescosolido, 2002; Ellis, 2005; Evans, Harper, & Jentsch, 2004; Hall, Volpe, & Cannon-Bowers, 1992; MacMillan et al., 2004; Rentsch & Hall, 1994; Rentsch, Heffner, & Duffy, 1994; Rouse et al., 1992; Smith-Jentsch, Campbell, Milanovich, & Reynolds, 2001; Smith-Jentsch, Kraiger, Cannon-Bowers, & Salas, 1998; Stout, 1994). There are a number of different terms that can be used to express how "good" a mental model actually is; the two most often used are accuracy and quality. In the past, accuracy has usually been assessed by comparing an individual's mental model with one correct, referent model. In contrast, quality has been assessed subjectively by an expert or by comparing an individual's mental model to any number of "correct" models. Although these terms are often used interchangeably, more detail is needed for the purposes of this study. The following discussion differentiates between studies that emphasized accuracy vs. quality.

Langan-Fox, Wirth, Code, Langfield-Smith, and Wirth (2001) posited that it is likely that team members must first develop an accurate mental model and then develop

SMMs. In fact, Converse, Cannon-Bowers, and Salas (1991) suggested that accuracy is a fundamental part of the SMM hypothesis. Further, Smith-Jentsch, Blickensderfer, Salas, and Cannon-Bowers (2000) suggested that having both shared and accurate team mental models should allow team members to (a) understand coordination breakdowns, (b) focus on specific goals, and (c) generalize lessons learned from previous experience. Table 3 presents the possible combinations between accuracy and sharedness among team member mental models.

Table 3

Differing Combinations of Accuracy and Sharedness of Mental Models

	Low Accuracy	**High Accuracy**
Low Sharedness	Team members have neither accurate nor shared mental models	Team members have accurate mental models that are not similar to those of their teammates*
High Sharedness	Team members share inaccurate mental models	Team members have accurate mental models that are similar to those of their teammates

*Note: It is possible to have accurate mental models that are not shared in situations where the content of the mental models is different, the organization scheme or structure is different, or there are multiple "correct" methods or answers. In these instances, the mental models may still be of high quality, even though they aren't deemed "accurate" by some standard.

While it is expected that accurate *and* shared mental models typically form the most effective combination, little of the sharedness research has actually measured accuracy or quality in any way. One possible reason may be due to the increased difficulties in conducting research on the correctness of mental models and SMMs. For instance, can an average measure of accuracy across a team truly be useful in predicting team processes? A shared accuracy of 50% could mean more than one thing: two team members could both have 50% accuracy in their mental models; one team member could have 10% accuracy and the other 90% accuracy; etc. Should accuracy be measured and analyzed at the individual level rather than the team level? Which is more important, the relationship between some team accuracy score and overall team processes or the relationship between accuracy of one's own mental model and one's behaviors? These are questions that have yet to be answered. Furthermore, there is currently no research available that conclusively links the correctness of mental models with the use of implicit coordination. The few studies that have explored the relationship between mental model accuracy or quality and team processes and/or performance are described next.

Task-Related Mental Models

No studies that have focused on teams have looked at the accuracy or quality of task mental models without also taking into account the level of sharedness between team members. Only two studies (Heffner, 1997; Mathieu et al., 2005) have investigated the relationship between task-related mental model sharedness and quality and team processes and performance, and the findings on the relationship between task-related mental model quality and team processes and performance were both the same: no significant relationship was found. Task mental model quality alone has not been found to significantly predict team processes or team performance. Further, the interaction between task mental model sharedness and quality has not been found to significantly predict team processes or performance. The findings of two studies are obviously not conclusive in showing that no relationship exists; however, at this time, no published studies have reported that the quality of task-related mental models is related to any other team variables.

Summary

In light of the dearth of research examining the accuracy or quality of SMMs, it is clear that there is still much to learn about the interaction between the sharedness and quality of mental models. It appears that prior research has placed much more emphasis on the level of sharedness between mental models than on the quality of those SMMs. As no significant findings have been found regarding the quality of task-related mental models, it may be that task-related mental model quality does play a secondary role to mental model sharedness in terms of the impact on or relationship with team processes and team performance. Thus, while it seems logical to hypothesize that teams with accurate SMMs will outperform all other teams, this overview suggests that the quality might not be as important as the sharedness.

Implicit Coordination and Mental Model Quality

While "quality" and "accuracy" have often been used interchangeably, the term quality is preferred to accuracy and will be used here because it allows for the possibility of multiple correct interpretations of any given situation. Quality allows team members to organize their knowledge differently, focus on different constructs, focus on different levels, etc., while still having "correct" mental models. Thus, the current study investigated the relationship between mental model quality and implicit coordination.

The review of the mental model quality literature has shown: (a) there are only a small number of studies that have investigated the effects of mental model quality on team processes and (b) that the results of those few studies suggest that mental model sharedness may be more important that mental model quality. No studies have found a significant relationship between mental model quality and team processes or performance; yet, quality and sharedness may interact with one another.

Based upon the available literature, it was therefore hypothesized that the quality of mental models would be associated with improved team processes, the expected outcome of implicit coordination, but not with more attempts at implicit coordination or responding behaviors. It is likely that the quality of one's mental model will result in *more appropriate* initiating and responding behaviors, but not necessarily with more initiating and responding behaviors in general. The quality of one's mental model, though, should allow the second team member to correctly interpret the initiating behavior and follow through with the appropriate responding behavior, which should lead to the improved team processes. Thus, in order to examine this relationship between mental model quality and implicit coordination, the following hypothesis was posited:

> *Hypothesis 2*: The average quality of team members' task mental models will be a significant predictor of successful implicit coordination, such that higher quality task mental models will be associated with improved team processes.

Figure 3 presents a graphical depiction of the proposed process of implicit coordination and the hypothesized relationship between the quality of task mental models and the expected outcome of successful implicit coordination, improved team processes.

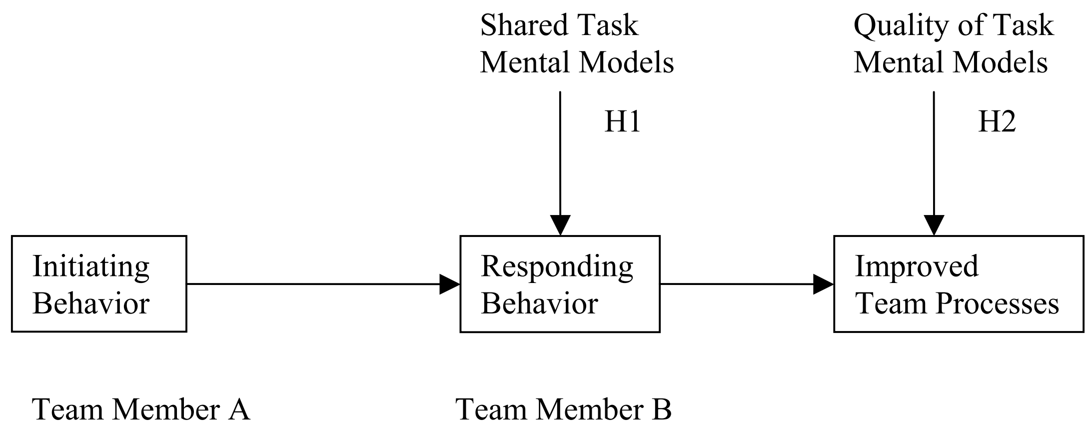

Figure 3. Proposed relationship between the quality of task mental models and implicit coordination.

Confirmation of this hypothesis would lend some support to the notion that accuracy or quality of mental models is important for successful team coordination. This study would be the first to establish a link between the quality of task mental models and the process of implicit coordination.

Additionally, an interaction between the sharedness and quality of task mental models was initially proposed, but upon further reflection, it was removed. Specifically, if task mental models sharedness is related to the number of responding behaviors, then the quality of those task mental models will play a more important role when team members have high sharedness simply because the base rate of responding behaviors will be higher. In other words, when team members do not have SMMs, then it is hypothesized that they will engage in less responding behaviors and therefore have fewer opportunities to reach successful implicit coordination. However, this relationship is dependent on the baseline rates for low and high levels of sharedness. As can be seen in Figure 4, the overall base rate for low sharedness should be significantly lower than for high sharedness, and the difference between high and low quality is therefore more pronounced under conditions of high sharedness. Yet there is no reason to believe that the proportion of successful implicit coordination behaviors will be any different for low vs. high sharedness. Thus, while it is expected that the quality of task mental models will appear to have a stronger influence under conditions of high sharedness, this relationship is expected to be proportional and therefore not necessarily an interaction.

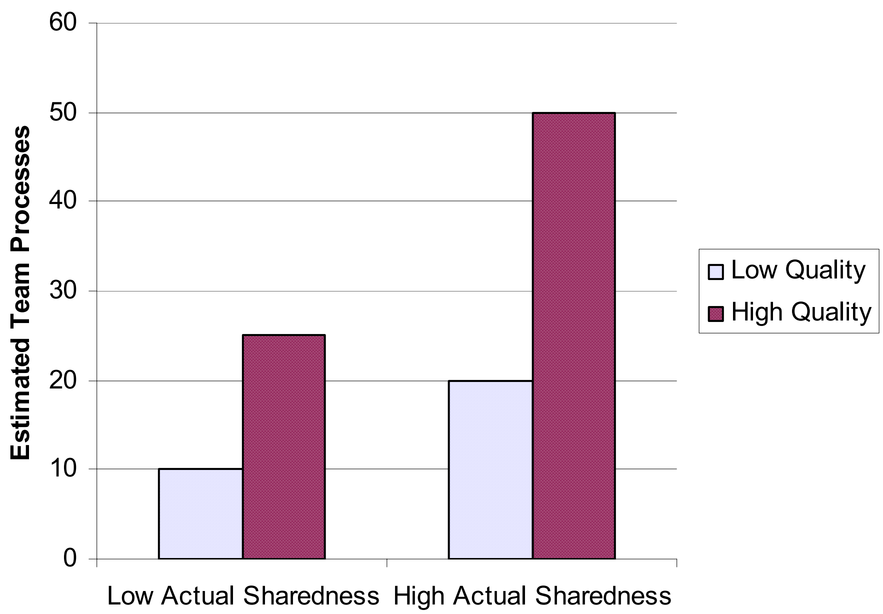

Figure 4. Expected proportional relationship between sharedness and quality of task mental models.

Perceptions of Sharedness

While actual SMMs in teams may facilitate team performance through implicit coordination, one question that has not fully been explored is the influence of *perceptions* of SMMs. Specifically, must team members be aware that they share mental models in order to use them? Klimoski and Mohammed (1994), in their discussion of what it means to share a mental model, suggested that an awareness of that sharedness may also be contained in the notion of sharedness. Specifically, It was suggested that there must be some awareness among team members regarding how their teammates think and behave in order for the team to hold SMMs. Thus, Klimoski and Mohammed argued that mental models are only shared *if team members believe they are*. In fact, Klimoski and Mohammed stated that "similarity is a necessary but not sufficient condition for saying that a shared mental model exists….we feel that *some* level of awareness is necessary" (p. 422). Furthermore, Fiore and Salas (2004) noted in the conclusion to their book on team cognition that the two overarching themes in the book were (a) communication and (b) awareness. Thus, the impact of team member awareness or perceptions of sharedness is certainly a topic that deserves more attention than it has received.

This notion of shared understanding or awareness is similar to other constructs, such as transactive memory (Wegner, 1986) and perceptual accuracy (Scheff, 1967). *Transactive memory* has been defined as a memory system that is composed of (a) the different knowledges possessed by the team members and (b) an awareness or understanding of who knows what. In essence, the concept of transactive memory is similar to team-related mental models, as both focus on knowledge of another teammate and more sharedness between mental models would suggest that team members are aware of their teammate's roles, responsibilities, and possibly the knowledge their teammates must possess in order to fulfill their duties. However, transactive memory differs from SMMs in that team members are not expected to have shared or overlapping knowledges per se, but to simply have an understanding of how knowledge is distributed throughout the team. Thus, a team member should know who to turn to in the event that help or expertise on a subject is required. Moreland (1999) suggested that accuracy of team members' perceptions of what the other team members know is an important component of the transactive memory framework and will impact team processes.

On the other hand, *perceptual accuracy* describes the extent to which one person can correctly predict another team member's perceptions (as the same or different from one's own). This concept was introduced under the theory of co-orientation by Scheff (1967). Co-orientation is the study of the knowledge and assumptions required for social interaction. It is based on the merging of agreement between member's beliefs and attitudes and the accuracy of one's perceptions about another's beliefs and attitudes. According to Scheff, there are four specific types of co-orientation: consensus (high agreement and high accuracy), dissensus (low agreement and high accuracy), pluralistic ignorance (high agreement and low accuracy), and false consensus (low agreement and low accuracy). Scheff suggested that the type of co-orientation required was dependent on how members were required to coordinate with one another.

The concept of co-orientation was expanded upon and extended to the field of organizational climate by Poole and McPhee (1983). Rentsch and Hall (1994) then further expanded the theory to describe "schemas about schemas" (p. 237), which is a comparable notion to Klimoski and Mohammed's (1994) description of team members' awareness of SMMs. Specifically, Rentsch and Hall discussed the similarity between two team members, as opposed to Scheff's (1967) original discussion of the similarity between one person and the majority.

Expanding this notion to SMMs, co-orientation can be used to assess perceptions of sharedness between team member mental models. Table 4 describes each of the four types of co-orientation in terms of SMMs. *Reality* refers to whether or not there actually is sharedness between team member mental models, while *perceptions of sharedness* refers to whether team members believe there is sharedness. As can be seen from Table 4, it is quite possible that inaccurate perceptions of sharedness could have detrimental effects on team performance. For instance, if team members incorrectly believe they do not have SMMs, they may be less likely to attempt actions they feel their teammates will not understand. Conversely, if team members incorrectly believe that they do have SMMs, they may be constantly attempting to coordinate unsuccessfully. Yet, correct perceptions of sharedness may improve team processes even under conditions of low agreement by (a) forcing the team members to try to better understand each other's perceptions, or (b) reducing the number of unsuccessful attempts to coordinate.

Table 4

Co-orientation Applied to Shared Mental Models

	Perceptions of Low Sharedness	**Perceptions of High Sharedness**
Reality: Low Sharedness	Dissensus: team members correctly believe that they do not have shared mental models	False Consensus: team members incorrectly believe that they have shared mental models
Reality: High Sharedness	Pluralistic Ignorance: team members incorrectly believe that they do not have shared mental models	Consensus: team members correctly believe that they have shared mental models

Development of Perceptions of Shared Mental Models

So, how do team members develop their perceptions or beliefs of what others know and how closely it relates to their own knowledge base? Nickerson (1999) suggested that people use "one's own knowledge as the primary basis for developing a model of what specific others know" (p. 737) and thus "other things being equal, one is likely to overestimate the extent to which a random other person's knowledge corresponds to one's own" (p. 740). This awareness or perception is then altered based on interactions that either confirm or dispute the default model, and that model is updated accordingly. Furthermore, Nickerson noted that "one's best guess as to how another person will react in a specific context is one's awareness, or belief, of how one would react in that context" (p. 746). Thus, following the logic of Nickerson's argument, team members are likely to believe they have SMMs from the onset and would try to predict their team members' behaviors based on what they themselves would do under the same circumstances.

In terms of Table 4 then, Nickerson's (1999) hypothesis would suggest that team members enter a new scenario believing that they have SMMs with their teammates; which could result in either a state of consensus (correct perception) or false consensus (incorrect perception/overestimation). If the team is in a state of consensus, then team coordination should be facilitated because the team members know they have SMMs and can act accordingly. However, if the team is in a state of false consensus, then team coordination should be hindered because behaviors will be based on inaccurate assumptions.

Empirical Evidence of Perceptual Influences

To my knowledge, there have been no studies that have analyzed the *perceptions* of SMMs as opposed to the actual SMMs. Nor has co-orientation been applied to SMMs in the previous literature. However, there have been a number of studies that have investigated team member perceptions of other team members from various other perspectives. In fact, Nickerson (1999) noted that there is plenty of evidence to suggest that a person's behavior is influenced by his/her perceptions of what other people know.

A number of studies have found that more accuracy in regard to transactive memory is related to improved performance in groups (Austin, 2003; Libby, Trotman, & Zimmer, 1987; Littlepage & Silbiger, 1992). Additionally, Austin found that consensus (i.e., team members agree in their perceptions of who knows what) was significantly, and positively, related to overall performance as well. Thus, when team members shared accurate perceptions about their team members' knowledge, the team was able to coordinate effectively and attain its performance goals. In contrast, teams that were characterized by shared, yet inaccurate perceptions were less likely to coordinate and perform effectively.

Woehr and Rentsch (2003) discussed perceptions related to team members' schemas. Wilson and Rutherford (1989) noted schemas/schemata differ from mental models in that they are considered to be stored in memory and activated at necessary times, while mental models are thought to arise from schemata and to be dynamically reconstructed as they are used. Woehr and Rentsch discussed team member schema similarity in terms of the Social Relations Model (Kenny, 1994), which breaks interpersonal communication down into the perceiver and the perceived. Extrapolating to teams, Woehr and Rentsch noted a number of dimensions along which team member schema similarity and the Social Relations Model coincide. Sample dimensions of relevance are listed in Table 5. While these dimension descriptions are more geared toward social phenomena rather than cognitive phenomena, such as SMMs, there are obvious similarities that can be extracted. For example, consensus has already been described as team members having an accurate understanding of their SMMs. In turn, each of the dimensions listed in Table 5 could be applied to the mental model construct. In order to gain a thorough understanding of the team members' perceptions of one another, it might be useful to look at a number of these dimensions when determining how team members view each other and the team as a whole.

Table 5

Social Relations Model Applied to Team Member Shared Perceptions

Dimension	General Question	Description
Consensus	Is Team Member 1 viewed similarly by others?	The degree of congruence among team members' views of each individual member.
Reciprocity	Do Team Member 1 and Team Member 2 view each other similarly?	The degree of congruence among team members in their tendencies to view each other similarly.
Assumed Reciprocity	Does Team Member 1 think others perceive him/her as s/he perceives them?	The degree of congruence in team members' beliefs that their teammates perceive them as they perceive their teammates.
Meta-Accuracy	Does Team Member 1 know how s/he is perceived?	The degree of congruence among team members' accuracy in understanding how their teammates view them.
Assumed Similarity	Does Team Member 1 perceive others as s/he perceives him/herself?	The degree of congruence among team members' perceptions that their teammates perceive them as they view themselves.

Note: Adapted from Woehr & Rentsch (2003)

In terms of empirical data, Woehr and Rentsch (2003) investigated team members' perceptions of themselves and each of their teammates across an entire semester. The results showed that perceiver effects (as opposed to partner or relationship effects) had the biggest impact on rating variance. The authors interpreted this finding as "individuals tend not to differentiate among teammates and thus performance appears to be 'in the eye of the beholder'" (Woehr & Rentsch, p. 4). Furthermore, the results also showed that for three of the six performance dimensions evaluated, individuals rated their teammates as similar to themselves, which reiterated Nickerson's (1999) hypothesis discussed earlier. The implications of this finding demonstrate the strength and importance of individual perceptions and clearly support the notion that those perceptions influence how team members will interact with one another.

Finally, taking a different perspective, Mitchell (1986) looked at measures of knowledge of other team member behaviors by investigating internal frames of reference. Mitchell's study was based on Culbert and McDonough's (1980) theory of alignment, which Mitchell described as an internal frame of reference that "create[s] an individual 'lens' through which one views and interprets….[and] affect[s] significantly how people perceive events and assign meaning, and how they interact with one another" (p. 17). Mitchell provided training to participants on each other's internal frames of reference, had participants answer questions regarding each person's relationship with each other person, and calculated a relationship index between each pair of individuals. The results clearly showed that those who received alignment training demonstrated significant improvements in their knowledge about other individuals' knowledge. Mitchell noted that the alignment training allowed participants to share information about themselves that allowed the others to predict and explain their behavior more accurately afterwards. Again, this would suggest that team member perceptions will influence how they coordinate with one another.

Summary

The research on SMMs continues to evolve. The question of how individual perceptions of sharedness and/or others' mental models affect behaviors and team coordination has received some speculation, but very little direct research. A number of researchers have posited that some type of awareness is necessary in order to achieve sharedness. Studies from a number of different approaches have emphasized the importance of individual perceptions on team processes. Further exploration into how perceptions of sharedness affect team processes, specifically team coordination, as well as how perceptions of SMMs interact with actual SMMs is warranted.

Implicit Coordination and Perceptions of Sharedness

There is evidence to suggest that team member perceptions of other team members' knowledges can significantly influence how team members interact and coordinate with one another. Researchers have consistently suggested that SMMs are related to implicit coordination and that without SMMs, implicit coordination would not be possible. This is a logical argument that is being tested in the first set of hypotheses of the current study. But how do perceptions of SMMs fit into the puzzle? What if team members have SMMs but do not believe that they do, such as in pluralistic ignorance? Will they not even attempt implicit coordination strategies? In contrast, what if team members believe they have SMMs when they do not, such as in false consensus? Will team members attempt to engage in implicit coordination unsuccessfully if their behaviors are guided by false beliefs? The various approaches to understanding individual perceptions suggest that these perceptions are strong indicators of how team members are likely to interact with one another. In fact, it is possible that these perceptions may be even more influential in whether team members will engage in implicit coordination than the actual sharedness of their mental models.

As previously mentioned, the belief that the initiating behavior will be interpreted correctly is considered to be a facilitating factor that should increase the likelihood of a team member attempting to engage in implicit coordination. This belief is encompassed in the more global perceptions of sharedness, i.e., that the team members have a shared understanding and should therefore interpret behaviors in a similar fashion. Thus, one could hypothesize that it is these perceptions of sharedness, rather than the actual level of sharedness between mental models, that will increase the likelihood that a team member will begin the process of implicit coordination. Specifically, it is anticipated that team members with perceptions of sharedness will engage in more implicit coordination attempts than team members who do not believe they have SMMs. This leads to the final hypothesis that asserted that the perceptions of sharedness would be positively related to implicit coordination attempts:

> *Hypothesis 3*: The perceptions of sharedness regarding task mental models on the part of the first team member will be a significant predictor of implicit coordination attempts by that team member, specifically initiating behaviors. In other words, perceptions of more sharedness will be associated with more initiating behaviors.

Figure 5 presents a graphical depiction of the proposed process of implicit coordination and the hypothesized relationship between perceptions of sharedness and initiating behaviors.

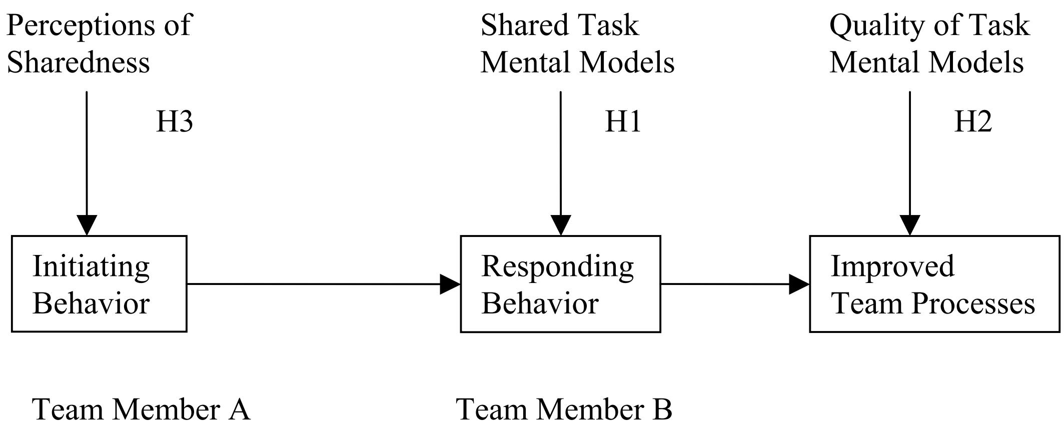

Figure 5. Proposed relationship between perceptions of sharedness and implicit coordination.

Confirmation of this hypothesis would have strong theoretical implications for the team literature. Previous research on SMMs and team processes and performance has always focused solely on the actual level of sharedness between mental models and has not addressed whether team members know they have SMMs. Providing evidence that perceptions of sharedness also drive team behaviors could support the notion that we have been missing a key ingredient in team performance research.

Finally, having suggested that it is the perceptions of sharedness, rather than the actual sharedness that drive implicit coordination attempts, it is necessary to also examine the relationship between perceptions and actual sharedness. Similar to the case regarding the interaction between sharedness and quality, upon reflection, I decided that the difference would be proportional and, therefore, not necessarily an interaction. Specifically, if perceptions of sharedness are related to the number of initiating behaviors, then the actual sharedness between those task mental models will seem to play a more important role when team members have perceptions of high sharedness simply because the base rate of initiating behaviors will be higher. In other words, when team members do not have perceptions of sharedness, then it is hypothesized that they will engage in less initiating behaviors. A graphical depiction of this is presented in Figure 6. Since it is hypothesized that implicit coordination will be more likely attempted when team members believe that they have SMMs, then the base rate of initiating behaviors will be higher and the chance for responding behaviors will also be higher. Again, there is no reason why these proportions should not be similar.

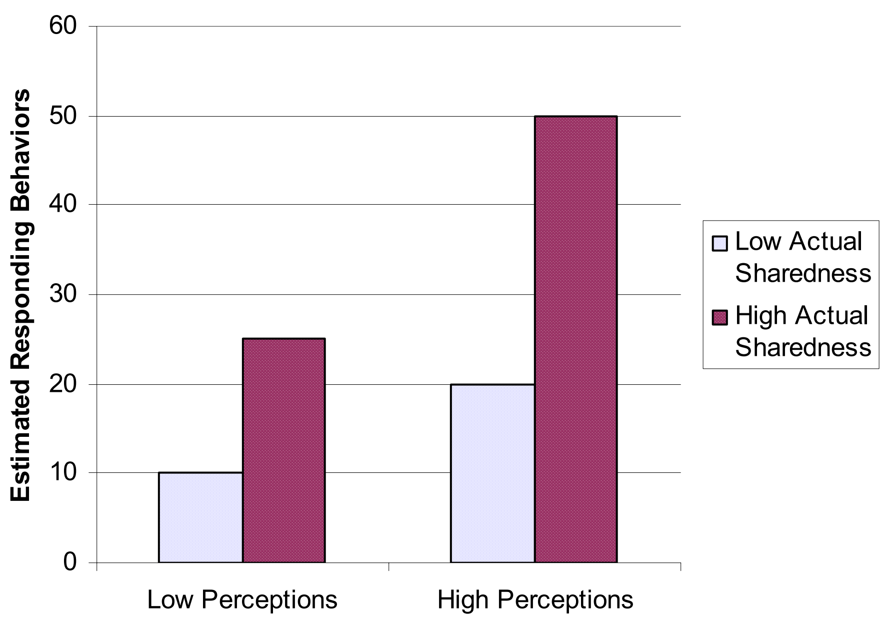

Figure 6. Expected proportional relationship between perceptions of sharedness and actual sharedness of task mental models.

All of the previous research on SMMs has focused on obtaining some actual measure of a person's mental model and then comparing individual models against one another. To my knowledge, no studies have investigated how perceptions of SMMs influence team member behaviors and coordination. The above hypothesis sought to determine whether overlooking perceptions of SMMs has been a shortcoming of previous research in the area and sought to analyze whether or not perceptions of SMMs are necessary for efficient team coordination. If this hypothesis were confirmed, it would provide evidence that team members need to be aware of their SMMs in order to use them most effectively and that merely measuring SMMs without taking into account perceptions of SMMs may be short sighted. Significant findings here could help to interpret previous findings that did not find a significant relationship between SMMs and other team factors, such as team processes; perhaps the teams simply did not know they had SMMs and thus were not able to successfully utilize them.

It should be noted here that this study was mainly concerned with how implicit coordination in initiated and which factors are associated with that process (i.e., SMMs and/or perceptions of sharedness). It is understood that the relationship between implicit coordination and team performance is likely affected by SMMs as well; however, it is not the goal of the current study to investigate which conditions lead to the best team performance. Before we can learn the most appropriate ways to use implicit coordination, a firm understanding of the underlying mechanisms is required.

Overall Summary

The hypotheses presented in this study were put forth in order to investigate the underlying mechanisms of implicit coordination and what role SMMs play in relation to implicit coordination. It has previously been suggested that SMMs are related to implicit coordination. This study furthered that line of research in two specific ways. First, three different aspects of SMMs were addressed: (a) sharedness or overlap, (b) quality, and (c) perceptions of sharedness. Second, implicit coordination was broken down into discrete stages that could be analyzed separately and together. By breaking down both SMMs and implicit coordination, the relationship between SMMs and implicit coordination could be more thoroughly analyzed. The hypotheses can be divided into three specific categories with respect to team coordination processes: those related to initiating behaviors, those related to responding behaviors, and those related to successful coordination. The design of the study was based on the hypotheses that (a) the perception of sharedness is the main aspect of SMMs that is related to initiating behaviors, and (b) the actual sharedness of mental models is related to responding behaviors, and (c) the quality of mental models is related to improved team processes or successful coordination.

CHAPTER THREE: METHOD

Participants

Participants were 138 students from the University of Central Florida (UCF), forming 69 teams of two. The data for four teams (IDs 11, 14, 31, and 34) were discarded because they did not finish the entire session. Additionally, data from two teams (IDs 20 and 36) were discarded because the team members did not chat with one another at all during the session. Team 3's data were discarded because one of the teammates made a comment that contaminated one of the manipulations. Data from one team (ID 51) was discarded because one of the teammates was a non-native English speaker and had difficulty completing the tasks. Finally, the data from Team 32 was discarded because it was obvious that one of the teammates did not take the task seriously or respond appropriately. After removal of the aforementioned nine teams, data from 120 participants, comprising 60 teams, were used for analysis. All further descriptive and inferential statistics reported below, including participant demographics, are based only on these 120 participants.

The students included 72 males and 48 females, with a mean age of 20.53 years (range 18 to 41). Participants completed the study in same-gender teams of two. Thirty-eight (63.3%) of those teams were comprised of participants who did not know each other prior to the session, while the other 22 teams (36.7%) were comprised of friends or siblings. Approximately half (48.3%) of the participants were freshmen, and only 9 participants (7.5%) had any military experience. They were all recruited via the Psychology and Digital Media Departments at UCF and received extra credit for their participation. All participants were treated ethically according to the guidelines of the

American Psychological Association (APA) and the UCF Institutional Review Board (IRB; see Appendix A for IRB Approval Form).

Experimental Design

The study employed a 2 (high vs. low actual sharedness) x 2 (high vs. low perceptions of sharedness) between-subjects design. The third variable, quality, was a quasi-experimental variable that was measured, but not manipulated. While this variable was of interest, perceptions of and actual mental model sharedness were the main foci of this study. Table 6 presents the experimental design of the study.

Table 6

Experimental Design

	Low Perceptions (LP) of Sharedness	**High Perceptions (HP) of Sharedness**
Low Actual (LA) Sharedness	LA-LP (Dissensus)	LA-HP (False Consensus)
High Actual (HA) Sharedness	HA-LP (Pluralistic Ignorance)	HA-HP (Consensus)

Experimental Task

Recognizing the complexities of the military environment, Urban et al. (1995) stated that "operational military environments provide ideal settings for the development of team performance" (p. 123). Within the military environment, one particular area in need of research is the performance of reconnaissance and surveillance (R&S) missions. A strong correlation has been found between the success of an R&S mission and subsequent operational or battlefield success (Goldsmith & Hodges, 1987). However, it is common knowledge that the Army is not extremely efficient in conducting R&S missions (McCarthy, 1995), and the inclusion of robotic assets, such as unmanned ground vehicles (UGVs) and unmanned aerial vehicles (UAVs), is only adding to the complexity of these missions.

R&S is essential to the success of any military mission, and therefore, the planning of R&S is recognized as "singularly the most significant event that takes place in the lifecycle of a tactical mission" (White, 1997, ¶ 1). Because the planning of R&S missions using robotic assets represents a complex domain in which team members are required to interact with each other to complete team goals, this task provided an idea vehicle for investigating the current hypotheses. The task chosen for this study required teams to draw the most appropriate and efficient routes for their robotic assets onto a map provided to them. The task was only complete when both teammates agreed on the route(s) they had selected. Precedent for focusing on mission planning comes from several previous studies of team coordination that emphasized the planning stages of various mission scenarios (cf. Larson, Christensen, Abbott, & Franz, 1996; Jeffrey, 1999; Pai, 2006; Stout et al., 1999).

Equipment

Computers

The study utilized two workstations and one experimenter station. The two workstations where the participants completed the study were nearly identical. Both workstations used standard personal computers with ViewSonic E771 17-inch Monitors. A standard 3 button mouse was used to draw the routes at each workstation for each asset. Both participants wore generic headphones for the duration of the study.

Headphones were used to dampen any outside noise. The workstations were separated from each other by a partition so that the participants could not see each other during the study. Both the headphones and partition were used to help isolate participants and discourage verbal communication. These controls were effective in preventing all teams from verbally communicating during the experiment.

Software

The study used Microsoft® Office PowerPoint® 2003 for the training portion and Marratech 5.1 virtual meeting software for the performance portion. Marratech was downloaded free from www.marratech.com. The Marratech software allowed multiple computers to network through a direct cable connection. The software allowed remote computers to share the same desktop, view the same screen, and exchange information through electronic chat, voice, or video. This study took advantage of the Marratech Whiteboard and Chat functions. The Whiteboard worked similar to common paint programs. An image could be imported onto the Whiteboard and then participants could draw lines and arrows, manipulate objects, and point to specific locations on the Whiteboard. All actions of one participant could be seen by the other and vice versa. The Chat window worked similar to common instant message programs; participants could type a message to their teammate and that message would appear on both computers, with the name of the sender and a time stamp. A sample screen shot is shown in Figure 7.

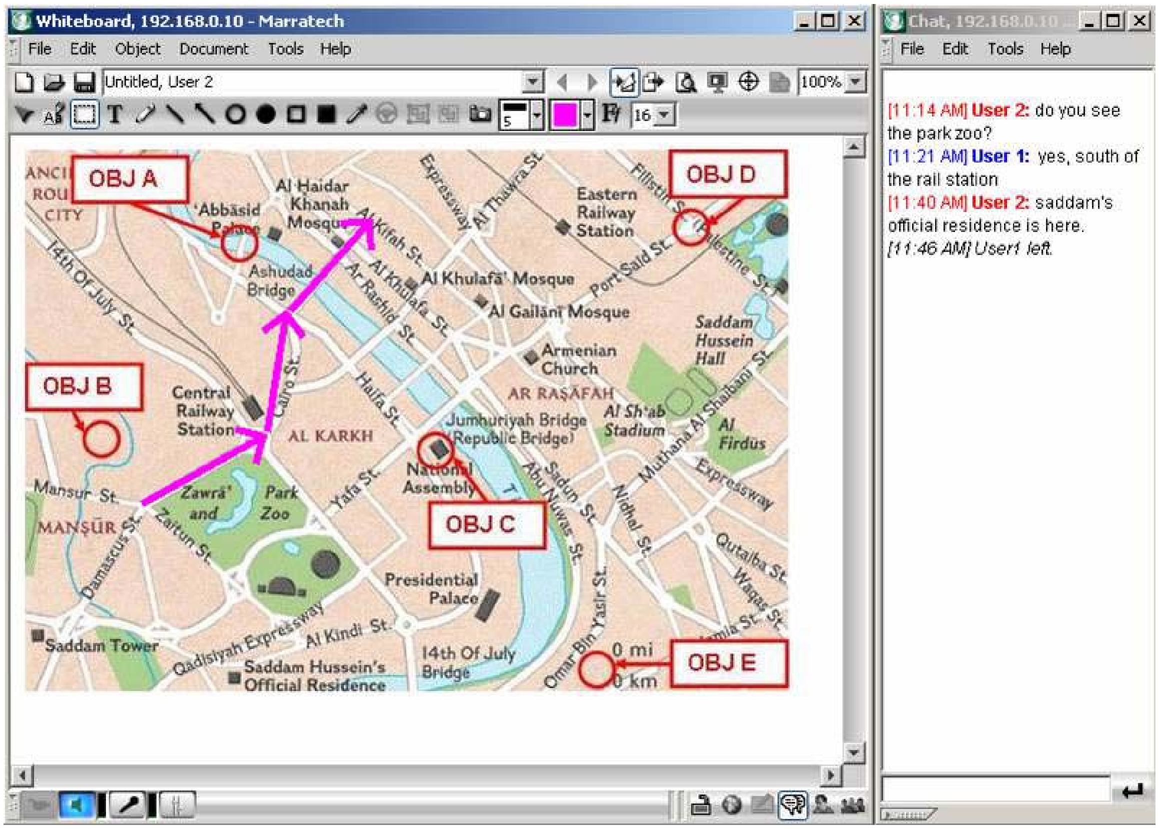

Figure 7. Screen shot from Marratech 5.1 software.

Recording Equipment

All actions performed on the computers at Workstation A were recorded onto DVD-Rs. As both computers displayed all of the same information, it was not necessary to record both computers. An ATI All-in-Wonder X800 XL 256 MB GDDR3 PCI Express Graphics Card was installed on Computer A. This allowed for the display to be sent to the monitor, and to the CyberHome DVR 1600 DVD Recorder. The sessions were monitored at the experimenter station on an Insignia 13-inch television via an S-Video cable.

Materials

All experimental paperwork can be found in the Appendices. These include: an informed consent form (Appendix B), a biographical data form (Appendix C), a self-monitoring measure (adapted from Snyder & Gangestad, 1986; Appendix D), an extraversion measure (adapted from Costa & McCrae, 1996); Appendix E), a reconnaissance planning quiz (Appendix F), a task mental model measure (derived from Smith-Jentsch et al.'s [2005] Cue-Strategy Associations Measure; Appendix G), a perceptions of sharedness pre-measure (Appendix H), an appropriateness of implicit coordination measure (Appendix I), a perceptions of sharedness post-measure (Appendix J), the NASA-TLX instructions and forms (Hart & Staveland [1988]; Appendix K), and a debriefing form (Appendix L).

Training Materials

The training materials consisted of PowerPoint slideshow presentations that presented the participants with the essential information they needed to complete their tasks. Two different training programs were used to instill high or low sharedness between the teammates. In order to achieve high sharedness, both team members received the same training program, specifically, (a) Training Module 1 and Training Module 1 or (b) Training Module 2 and Training Module 2. In contrast, to achieve low sharedness, team members received different training programs, specifically, Training Module 1 and Training Module 2.

The training materials provided the participants with general information about military reconnaissance tasks, the importance of environmental factors, how to strategically utilize UGVs and UAVs, and other information essential to planning a military reconnaissance mission. The modules differed in their emphasis on certain strategies of using the UGV and UAV in conjunction, the importance of different factors, the importance of utilizing all available assets, and the importance of making quick decisions. The modules also provided the participants with a description of the Marratech software and the basic functions that they would be using. Appendix N presents the differences between the two training modules.

Scenario Materials

Three different scenarios were developed and used in this study: the Training Scenario, the Samarra Scenario, and the al Kufah Scenario. Each scenario consisted of a map that was imported onto the Marratech Whiteboard and two packets of information. Packet A was always given to the participant at Computer A, and Packet B was always given to the participant at Computer B. Packet A always provided information about the UAV and the weather, while Packet B always included information about the UGV and the terrain. Additional information about obstacles and mission specifics were included in both packets. Some of the information was identical, while the majority of the information was different. Appendix O presents the materials for all three scenarios.

Procedure

Participants signed up for the study in same-gender teams of two. The teams were matched for gender and then randomly placed in one of six assigned conditions. Table 7 shows the six assignments. There were two assignments each for Consensus and Pluralistic Ignorance because there were two possible combinations for High Actual Sharedness (i.e., where both teammates received Training Module 1, or both teammates received Training Module 2).

Table 7

Experimental Assignments

Assignment		N	Training Module Computer A	Training Module Computer B	Perceptions
1	Dissensus	32	HQ1	HQ2	Low
2	False Consensus	32	HQ1	HQ2	High
3	Pluralistic Ignorance	10	HQ1	HQ1	Low
4	Consensus	12	HQ1	HQ1	High
5	Pluralistic Ignorance	18	HQ2	HQ2	Low
6	Consensus	16	HQ2	HQ2	High

Note: Divide N by 2 to get number of teams. Assignments 3 and 5 and Assignments 4 and 6 are collapsed during analysis to create the 4 experimental conditions.

Upon entering the experimental environment, participants were asked to take a seat at either of the two workstations and turn off their cell phones. They were then asked to read and sign the Informed Consent Form (Appendix B) and to complete the Biographical Data Form (Appendix C). Next, the participants were read an explanation of the study. This explanation differed between the High and Low Perceptions conditions. If participants were in a High Perceptions condition, they were told that both team members were receiving the same training as “Reconnaissance Equipment Operators.” If the participants were in a Low Perceptions condition, they were told that they would be receiving two different types of training: the participant at Computer A would be trained as a “Reconnaissance Equipment Operator”, while the participant at Computer B would be trained as a “Surveillance Systems Specialist”. Appendix M provides the dual explanations that were read throughout the experiment, with the specific differences highlighted.

Next, participants were asked to put on headphones so that they would be discouraged from talking to one another during the remainder of the study. They then began their training. Depending on the condition they were in, the participants received either Training Module 1 or Training Module 2. Both modules consisted of 78 slides that took approximately 15-20 minutes to read through. After both participants completed the training, they were asked to fill out the Reconnaissance Planning Quiz (Appendix F) that was designed to reemphasize the key points of the Training Modules. Next, they were asked to complete two personality measures, the Self-Monitoring Measure (Appendix D) and the Extraversion Measure (Appendix E). While the participants were filling out the personality measures, the experimenter graded the Reconnaissance Planning Quizzes. There were two answer keys, one for each Training Module. Appendix F shows the correct answers for each Training Module. After completing the personality measures, the participants were given feedback on their quiz performance.

The participants were then read an explanation of their practice session and given 15 minutes to engage in a Training Scenario (Appendix O). Throughout all scenarios, the participant on Computer A was responsible for planning a route for the UAV, while the participant on Computer B was responsible for planning a route for the UGV. The Training Scenario was identical to the actual performance scenarios, except that the participants could not chat with each other and could not see what their teammate was doing. The purpose of the Training Scenario was to allow the participants to become familiar with the Marratech software and the types of information they would be receiving with each subsequent performance scenario.

After the Training Scenario, the participants were asked to complete the Mental Model Measure (Appendix G), the Perceptions of Sharedness Pre-Measure (Appendix H), and the Appropriateness Measure (Appendix I). All teams then completed the two performance scenarios (Appendix O), which were counterbalanced across teams. Before each scenario, they were read a brief description about their task. The scenarios took approximately 15-20 minutes each to complete. After the first scenario, the participants were given the NASA-TLX instructions and blank forms to fill out (Appendix K). They then completed the second scenario and filled out the NASA-TLX a second time. Next, the participants were administered the Mental Model Measure (Appendix G) for a second time and a Perceptions of Sharedness Post-Measure (Appendix J).

The participants were then debriefed on the study, with emphasis on the deception used (Appendix L). They were provided with the opportunity to ask any questions or discuss their feeling about the study. Copies of the Debriefing Form and the Psychology Department's Research Experience form were presented to each participant. Finally, the participants were thanked for their participation and asked not to discuss the study with potential participants to avoid contamination of the experimental manipulations.

Data Coding

Mental Model Quality

In order to assess the quality of each team member's mental model, unique scoring sheets were created for the two different training modules. As previously discussed, the two modules provided opposing information about the types of strategies that should be used. For example, Training Module 1 told participants to always consider using both assets first, while Training Module 2 told participants to always consider using only one asset first. Thus, scoring sheets were developed that took into account these differences. Participants received points for following the strategies that were emphasized in their respective training modules. The possible points ranged from 0 to 13 for each of the four scenarios within the mental model measures, resulting in an overall total range of 0 to 52 points. Overall, the average quality score was 33.91 (SD = 7.171).

To obtain an overall team quality score, the two team members' scores were averaged together. These team averages were then used to split the teams into a high and a low group, based on the median score (35.50). This resulted in 26 teams with average low quality mental models with an average team quality score of 30.42 (SD = 6.146). Of the 26 teams with low quality mental models, 46% (12) were composed of team members who both had low quality mental models, while the other 54% (14) were composed of one team member with a lower quality mental model and one with a higher quality mental model. In contrast, there were 34 teams with average high quality mental models (M = 36.18, SD = 5.823). Of the 34 teams with average high quality mental models, only 32% (11) were composed of team members who both had high quality mental models, while the other 68% were composed of one team member with a lower quality mental model and one with a higher quality mental model. Thus, only 38% of the teams were completely high quality or low quality, while the remaining 62% were actually mixed-quality prior to taking the team average.

Initiating Behaviors

Communications between teammates were analyzed by reviewing the chat file transcripts for each scenario. First, the overall number of messages and words from each scenario were tallied. Next, a list of all possible pieces of information that could be passed from one team member to the other was created. In the al Kufah Scenario, there were 41 possible pieces of information that Team Member A could have discussed with Team Member B and 42 possible pieces of information that Team Member B could have discussed with Team Member A. Of those, approximately 39% were the same pieces of information. In the Samarra Scenario, there were 38 possible pieces of information that Team Member A could have discussed with Team Member B and 36 possible pieces of information that Team Member B could have discussed with Team Member A. Of those, approximately 32% were the same pieces of information.

Three independent raters viewed each chat file and coded four types of information exchanges: (a) the information that was requested by Team Member A, (b) the information provided to Team Member A without a request, (c) the information that was requested by Team Member B, and (d) the information provided to Team Member B without a request. A total tally for each type of information exchange was calculated for each scenario. The total tallies from each of the independent raters were then correlated to determine inter-rater reliability. The results showed the correlations between the three raters were $r_{12} = .914$, $r_{13} = .871$, and $r_{23} = .848$, which were all significant at the .01 level.

As one of the goals of this study was to look at specific sequences of events, it was necessary to create one standard list of the information exchanges in order to then investigate the next step in the chain of events. Thus, first, to determine where there were major differences between raters, standard deviations were calculated. Any specific case that had a standard deviation of 2.00 or above was then reevaluated until a consensus was reached about the appropriate rating for the specific case. There were 19 specific cases that required re-evaluation. Seven of these were requests, so they were set aside. For the remaining 12 cases, each file was reviewed and a final decision was reached. For all the other cases whose standard deviations were less than 2.00, the maximum tally of the three raters was used. This was done to optimize the number of opportunities for the sequence of implicit coordination to occur. For ties, the items were checked for reliability across raters. In the end, the correlations between the three raters were r_{12} = .927, r_{13} = .907, and r_{23} = .894, which were all significant at the .01 level.

Thus, the information exchanges where information was provided without a request became the initiating behaviors. A total was taken for each team member within each scenario so that a total could be calculated for each individual and for the overall team.

Figure 8 is a screen shot that shows some representative initiating behaviors. Specifically, Team Member B, who was in charge of the UGV, provided Team Member A, who was in charge of the UAV, with three critical pieces of information: (a) Initiating Behavior 1 (IB 1) – "You have to go to Neck", (b) Initiating Behavior 2 (IB2) – "Torso is a place that I cannot go", and (c) Initiating Behavior 3 (IB 3) – "Hand just needs a quick check to see if there are any vehicles there so that means it would be better for you to go there and just check it out real quick". These three behaviors are highlighted in the Chat File in yellow. These were typical information exchanges that were counted as initiating behaviors. As can be seen from the Chat File, no request for any of this information was made on the part of Team Member A.

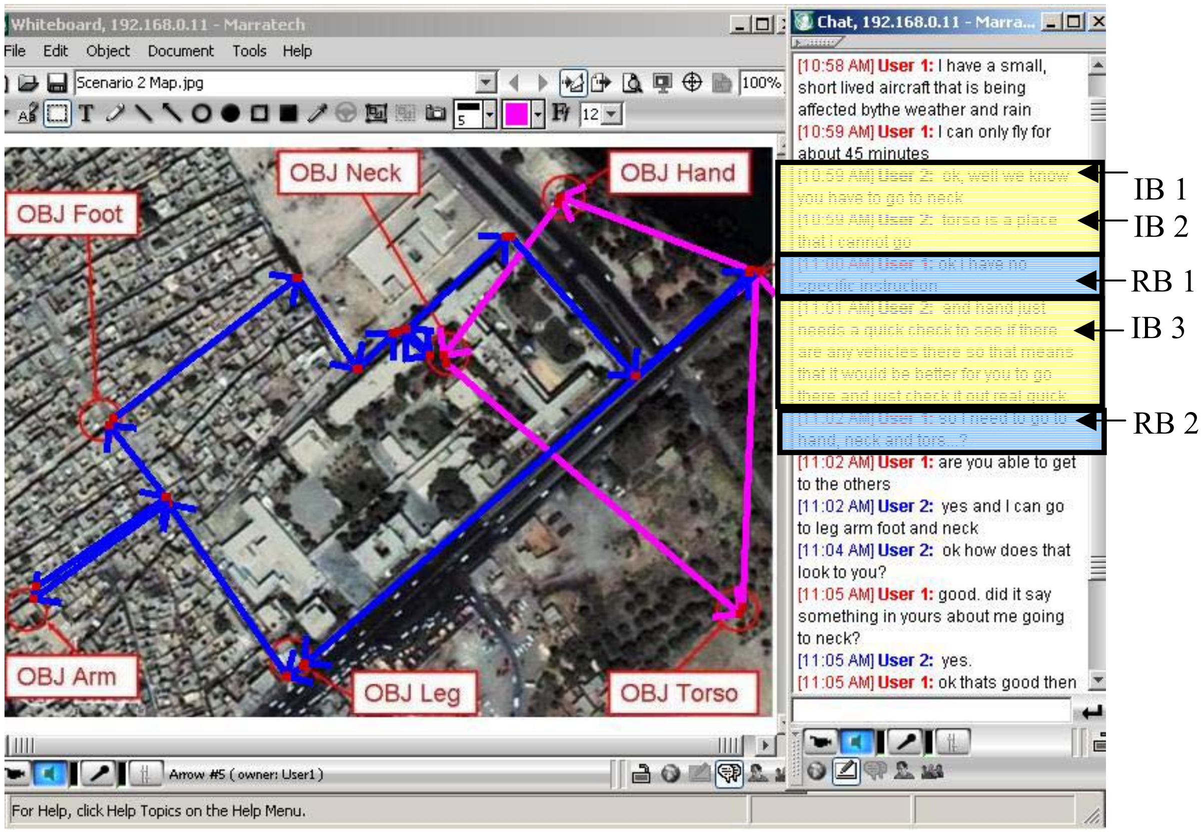

Figure 8. Sample screen shot from Team 15, al Kufah Scenario.

Note: The Chat shows three initiating behaviors by Team Member B and their corresponding verbal responding behaviors by Team Member A. RB 1 is a verbal Acknowledgment Responding Behavior. RB 2 is a Synthesis Responding Behavior. The Map shows Team Member A's route drawn in magenta to Hand, Neck, and Torso in response to Team Member A's initiating behaviors. RB 3, RB 4, and RB 5 are all Action Responding Behaviors that were given a 5 rating.

Responding Behaviors

After the standard set of initiating behaviors was agreed upon, the chat files and video recordings for each team were reviewed to look for responding behaviors. Responding behaviors fell into three categories: (a) an acknowledgement, such as "O.K." or, "I did not have that info", (b) synthesis, in which the second team member integrated the information with the information he or she had already been given, and (c) action, in which the route planning decisions reflected an application of the information provided in the initiating behavior.

First, two raters independently rated the chat file transcipts for each team for instances of acknowledgement and synthesis responding behaviors. The two raters then watched the DVDs for each team together and coded whether or not the corresponding actions were present for those behavioral sequences. The possible action responding behaviors included: (a) drawing an arrow, (b) deleting an arrow, (c) pointing to a location, (d) changing the size or direction of an arrow, and/or (e) moving an arrow. Each action responding behavior was rated on a 1-5 scale to indicate the degree of confidence the action was indeed associated with the initiating behavior. Prior to rating the action responding behaviors, the raters discussed that confidence was represented by several factors including: (a) amount of time passed between initiating behavior and given action, (b) content of conversation between the initiating behavior and given action, and (c) other possible reasons for the given action. These factors were not individually analyzed because it was deemed that they could not be uniquely separated from the core construct.

This overall process resulted in a measure of each type of responding behavior for each team in each scenario. The following types of responding behaviors were identified: (a) frequency of acknowledgements, (b) frequency of synthesis communications, (c) overall verbal responses (total acknowledgements plus synthesis), (d) frequency of all actions, (e) frequency of all actions rated 3 or higher, (f) frequency of all actions rated 4 or higher, and (g) frequency of all responding behaviors (total verbal plus all actions).

Referring back to Figure 8, the three different types of responding behaviors are also exhibited. Specifically, after Team Member B provided Team Member A with IB 1 and IB 2, Team Member B responded with an Acknowledgement Responding Behavior (RB 1) – "OK I have no specific instruction." After IB 3, Team Member B responded with a Synthesis Responding Behavior (RB 2) – "So I need to go to Hand, Neck, and Torso?" These responding behaviors are highlighted in the Chat File in blue. These were typical information exchanges that were counted as verbal responding behaviors. Additionally, there are three action responding behaviors visible in the figure. Based on the three initiating behaviors, Team Member A drew a route to Hand (RB 3), Neck (RB 4), and Torso (RB 5). The route was drawn within 5 minutes of the information exchange, and no other significant information was exchanged in between the initiating behaviors and the actions. Thus, each of the three actions was given a rating of 5 because it was evident to the reviewers that the actions were a direct result of Team Member B's initiating behaviors. These were representative of the types of actions that were observed throughout the coding process.

Team Processes

Finally, team process measures were created in order to determine overall team process scores. To reiterate, there were 74 possible pieces of information that could have been discussed in the Samarra Scenario and 83 possible pieces of information that could have been discussed in the al Kufah Scenario. Each of these pieces of information was rated on a 1-3 scale of how important the information was in terms of planning the routes. Specifically, those pieces of information that were crucial to route planning were given a 3 and those that should have no effect on route planning were given a 1. In the Samarra

Scenario, the distribution of information was: twenty-four (28.9%) pieces of information were given the highest rating of 3, twenty-one (25.3%) pieces of information were given the middle rating of 2, and twenty-nine (34.9%) pieces of information were given the lowest rating of 1. In the al Kufah Scenario, the distribution of information was: twenty-five (44.6%) pieces of information were given the highest rating of 3, thirty-three (25.3%) pieces of information were given the middle rating of 2, and twenty-five (33.8%) pieces of information were given the lowest rating of 1. To derive a team process score, the ratings for all pieces of information discussed, both requested information and initiating behaviors, were totaled. Thus, the team process score was an overall score of the relevancy of information that was discussed throughout each scenario. In the al Kufah Scenario, these ratings ranged from 7 to 56 (M = 26.68, SD = 11.454). In the Samarra Scenario, these ratings ranged from 0 to 48 (M = 23.73, SD = 10.186).

CHAPTER FOUR: RESULTS

Organization

This section provides a general overview of the organization of the results section. All analyses were conducted on SPSS 11.5 for Windows statistical software. Unless otherwise noted, an alpha level of .05 was used. First, a comparison of the two scenarios was conducted to determine whether there were any significant differences between them with respect to workload and instances of implicit coordination. Next, two sub-sections are presented that provide information on (a) data cleaning and (b) random assignment and manipulation checks.

After these general analyses, tests of hypotheses are described. The tests of the three hypotheses are presented in the order of the proposed steps of implicit coordination (initiating behaviors → responding behaviors → improved team processes). Thus, first the analysis related to initiating behaviors and the impact of perceptions of sharedness (Hypothesis 3) is presented. Next, the analyses related to responding behaviors and the impact of actual mental model sharedness (Hypothesis 1) are presented. Finally, the analysis related to team processes and the impact of mental model quality (Hypothesis 2) is presented. Additionally, supplemental analyses investigated the effect of all independent variables on all dependent variables to assess the expected proportional relationships (as seen in Figures 4 and 6). To begin, Table 8 presents the means, standard deviations, and inter-correlations between the study variables.

Table 8

Means, Standard Deviations, and Inter-correlations between Study Variables

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
1. Gender	-	-	-											
2. Friends	-	-	.01	-										
3. Military Exp	0.08	0.26	-.17	-.15	-									
4. RPGVS Exp	3.48	1.42	-.46**	-.03	.15	-								
5. RPAVS Exp[t]	0.40	0.11	.37**	-.11	-.21*	-.39**	-							
6. Video Game Exp[t]	1.53	0.47	.56**	.08	-.10	-.41**	.30**	-						
7. PC Exp[t]	0.19	0.21	.13	.15	-.05	-.34**	.11	.45**	-					
8. Chat / IM Exp[t]	0.14	0.20	.03	-.02	-.09	-.16	.12	.36**	.55**	-				
9. Extraversion	62.87	9.88	-.21*	-.06	.08	-.04	-.13	-.26**	-.02	-.11	-			
10. Self-monitoring[t]	3.58	0.98	-.27**	.15	.10	.14	-.13	-.09	-.06	.16	-.20*	-		
11. Perceptions Manip	-	-	.07	.00	.03	-.09	.05	.13	.01	-.03	-.11	.05	-	
12. Actual Manip	-	-	-.05	.09	.01	.13	-.11	-.01	-.01	-.08	-.04	.06	.00	-
13. Perceptions Pre-test[t]	3.65	0.84	.10	-.21*	.14	-.08	.19*	.15	.12	.20*	-.02	.08	-.14	.02
14. Actual Sharedness	43.63	10.71	.03	.06	-.08	-.04	.06	.10	.08	-.01	-.10	-.08	.08	.58**
15. Quality	33.91	7.17	.02	-.12	-.11	.21*	.07	-.14	-.18	-.12	.00	-.20*	-.09	.09
16. Workload	56.17	16.35	.01	.18*	-.13	.10	.10	.17	.07	-.06	-.21*	.10	-.04	.08
17. # Messages	28	16.36	-.11	.34**	-.02	.06	-.12	.03	.03	-.08	-.03	.10	-.01	.10
18. # Words	201	116	-.08	.09	.02	-.06	-.13	.00	-.07	-.10	.01	.06	.00	.10
19. Initiating Behaviors[t]	0.70	0.21	-.03	-.05	.17	.01	-.10	-.06	-.05	-.01	-.01	.03	-.03	-.01
20. Acknowledge RBs[t]	0.19	0.20	.14	.02	.01	-.04	.10	.13	-.10	-.07	-.02	-.06	.08	.20*
21. Synthesis RBs [t]	1.12	0.65	-.11	-.02	.02	.04	-.07	-.06	-.03	.01	.04	.15	.00	.02
22. All Actions[t]	0.71	0.75	-.08	.06	-.05	.03	.02	.03	-.03	-.02	-.13	.02	.04	.02
23. Team Quality	34.29	4.72	.06	-.15	-.09	.14	.06	-.14	-.19	-.15	.09	-.15	-.16	.12
24. Team Processes	26.68	11.45	-.02	-.14	.07	.02	.03	.03	.11	.32*	-.25	.10	-.06	-.02

	M	SD	13	14	15	16	17	18	19	20	21	22	23	24
13. Perception Pre-test^t	3.65	0.84	(.90)											
14. Actual Sharedness	43.63	10.71	.00	(.85)										
15. Quality	33.91	7.17	.01	.09	-									
16. Workload	56.17	16.35	-.01	.24**	.06	-								
17. Messages	27.90	16.36	.10	.07	.08	.27**	-							
18. Words	200.8	116	.17	.04	.08	.20*	.79**	-						
19. Initiating Behaviors^t	0.70	0.21	.10	-.09	.16	.12	.42**	.50**	-					
20. Acknowledge RB^t	0.19	0.20	.08	.04	.10	.09	.15	.11	.32**	-				
21. Synthesis RB^t	1.12	0.65	.05	-.03	.07	.15	.35**	.40**	.64**	.10	-			
22. All Actions^t	0.71	0.75	-.04	-.01	.02	.03	-.03	-.06	-.18*	-.11	-.32**	-		
23. Team Quality	34.29	4.72	.01	.08	.59**	.17	.19	.28*	.39**	.15	.22	.10	-	
24. Team Processes	26.68	11.45	.19	-.10	.32*	.05	.47**	.57**	.74**	.22	.60**	.11	.29*	-

Note: * = significant at $p < .05$, ** = significant at $p < .01$. ^{t} = transformed variables used. N = 120 for all variables except team level variables (N = 60). RB = responding behavior. All variables were measured on the individual level unless specified otherwise. Actual Sharedness is based on absolute difference scores and therefore a higher score means less sharedness.

Scenario Comparison

Prior to hypothesis testing, analyses of the behaviors in and the perceptions of the Samarra Scenario and the al Kufah Scenario were conducted. First, a 2 (scenario order) x 2 (scenario) x 7 (NASA-TLX subscales) mixed-model analysis of variance (ANOVA) was performed to determine whether there were significant differences in perceived workload between the two scenarios and whether there were any order effects. The between-subjects factor was order of scenarios, while the within-subjects factors were the actual scenario and the NASA-TLX subscales. The results showed that the test for between-subjects effects was not significant, F (1,118) = 0.613, p = .435, but there was a significant within-subjects main effect for the scenario (F [1,118] = 67.559, p < .0001, partial η^2 = .364). Specifically, participants perceived the al Kufah Scenario to be characterized by significantly higher workload than the Samarra Scenario ($M_{al\ Kufah}$ = 49.76, $SD_{al\ Kufah}$ = 1.356, $M_{Samarra}$ = 38.899, $SD_{Samarra}$ = 1.328), regardless of the order of scenarios.

In addition, a paired-samples t-test showed that there were significantly more initiating behaviors in the al Kufah Scenario than the Samarra Scenario, t(119) = -3.042, p = .003 ($M_{al\ Kufah}$ = 4.53, $SD_{al\ Kufah}$ = 2.660, $M_{Samarra}$ = 3.72, $SD_{Samarra}$ = 2.464). Team members also sent significantly more messages, t(119) = -6.285, p < .0001 ($M_{al\ Kufah}$ = 27.90, $SD_{al\ Kufah}$ = 16.360, $M_{Samarra}$ = 19.87, $SD_{Samarra}$ = 13.005), with more words, t(119) = -6.067, p < .0001 ($M_{al\ Kufah}$ = 200.81, $SD_{al\ Kufah}$ = 115.868, $M_{Samarra}$ = 138.99, $SD_{Samarra}$ = 88.496) in the al Kufah Scenario than in Samarra Scenario.

Thus, participants not only found the al Kufah Scenario to be more difficult, but they also communicated more and had more instances of initiating behaviors. Even after considering the total number of available pieces of information (i.e., 83 in the al Kufah Scenario and 74 in the Samarra Scenario), the former was characterized by a greater proportion of implicit coordination (5.5% vs. 5.0%). This, in itself, supported the notion that teams used more implicit coordination when workload was higher.

In order to maximize the possible effect sizes for the hypothesized relationships, the al Kufah Scenario was selected as the focus for analysis. Because the Samarra Scenario had significantly less communications and perceived workload, I posited that its inclusion might water down the results and detract from the findings. Therefore, for the remainder of the results section, unless otherwise specified, all analysis will focus on behaviors in al Kufah Scenario.

Data Cleaning

First, the data were screened for normality. There were a number of variables that were significantly skewed and transformations were made based on the recommendations by Tabachnick and Fidell (2001). If data analysis results did not differ between the raw data and the transformed data, then the raw data were used.

Biographical Data

Two of the biographical data variables, experience with video games and the Self-Monitoring Measure, were moderately negatively skewed and were transformed using the square root (reflected). Two of the biographical data variables, experience with PCs and chat/instant messaging programs, were substantially negatively skewed and were transformed using the logarithm (reflected). Finally, experience with radio or remote-controlled air vehicles was severely positively skewed and was transformed using the inverse. After transformation, these variables were no longer significantly deviating from normality.

Study Variables

The measured perceptions of sharedness variable (Perceptions Pre-Measure Total Score) was moderately negatively skewed and was transformed using the square root (reflected). Finally, a number of the dependent variables were positively skewed. Specifically, number of initiating behaviors, number of acknowledgement responding behaviors, and total verbal responding behaviors were all substantially positively skewed and transformed using the logarithm. The number of synthesis responding behaviors, total action responding behaviors, total 4+ rated action responding behaviors, and total 3+ action responding behaviors were all moderately positively skewed and were transformed using the square root. After transformation, these variables were no longer significantly deviating from normality.

Random Assignment and Manipulation Checks

To confirm the random assignment of teams to the different experimental conditions, a random assignment check was performed by running a one-way (assigned experimental condition: dissensus, false consensus, pluralistic ignorance, consensus), between-subjects multivariate analysis of variance (MANOVA) on individual difference data that should not have been influenced by that assignment. These individual difference variables were (a) age, (b) Self-Monitoring score, (c) Extraversion score, (d) experience with video games, and (e) experience with instant messaging chat programs. The results showed that the random assignment of teams to the different experimental conditions was successful in that there were no significant effects on any of the individual difference variables. Table 9 presents the means and standard deviations of the random assignment check.

Table 9

Means and Standard Deviations for Individual Difference Variables by Assigned Condition

Variables	Overall (N = 122)	High Perceptions of Sharedness: Same Training (Consensus)	High Perceptions of Sharedness: Different Training (False Consensus)	Low Perceptions of Sharedness: Same Training (Pluralistic Ignorance)	Low Perceptions of Sharedness: Different Training (Dissensus)	MANOVA Results	
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*F* (3, 116)	*p*
Age (years)	20.53 (3.737)	19.96 (1.732)	20.78 (4.917)	20.64 (4.130)	20.66 (3.404)	0.278	.841
Self-Monitoring Score[t]	42.23 (6.999)	43.00 (7.092)	40.66 (8.253)	42.36 (6.372)	43.00 (6.085)	0.591	.622
Extraversion Score	62.87 (9.878)	63.75 (11.131)	60.03 (11.125)	62.75 (8.329)	65.03 (8.283)	1.485	.222
Experience with video games[t]	4.44 (1.494)	4.36 (1.521)	4.19 (1.424)	4.50 (1.552)	4.72 (1.508)	0.874	.457
Experience with chat or instant messaging programs[t]	5.43 (0.886)	5.39 (0.832)	5.50 (0.950)	5.32 (1.090)	5.50 (0.672)	0.288	.834

Note: [t] = transformed scores used. No significant differences found.

Psychometric Properties of Manipulation Check Measures

Perceptions of Sharedness

The perceptions of sharedness were manipulated by explaining to teams that they were receiving similar or different training. A Perceptions of Sharedness Pre-Measure was used to assess the team members' actual perceptions of sharedness *prior* to performance, and a Perceptions of Sharedness Post-Measure was used to assess the team members' actual perceptions of sharedness *after* performance. Table 10 presents the descriptive statistics of the Perceptions of Sharedness Pre-Measure items. As can be seen from Table 10, participants tended to lean toward the higher end of the scale more than the lower end. Specifically, the Mode was never lower than 4, and for four of the seven items, none of the participants selected the lowest rating of 1.

Table 10

Descriptive Statistics for Perceptions of Sharedness Pre-Measure Items

	M	*SD*	*Mode*	*Min*	*Max*
1. You and your teammate have a shared understanding of the task.	4.53	1.092	5	1	6
2. Your teammate will be able to anticipate your behaviors.	3.48	1.174	4	1	6
3. You will be able to anticipate your teammate's behaviors.	3.52	1.223	4	1	6
4. Your teammate has a good understanding of your role in the team.	4.41	1.104	5	2	6
5. You have a good understanding of your teammate's role in the team.	4.52	1.108	5	2	6
6. Your teammate will understand what you are doing.	4.15	.993	4	2	6
7. You will understand what your teammate is doing.	4.16	.935	4	2	6
Overall pre-teamwork total	28.98	6.133	33	11	42

Note: Items 1-7 rated on a scale of 1= Not at All to 6 = Completely. Overall pre-teamwork total is simply the sum of the first seven items for each person.

Even though the Perceptions of Sharedness Pre-Measure showed that teams were already leaning toward higher perceptions of sharedness, a comparison of the Pre- and Post-Measures was conducted to determine if those perceptions shifted in a systematic way during performance. A 4 (assigned experimental condition: dissensus, false consensus, pluralistic ignorance, consensus) x 2 (administration: pre-measure, post-measure) x 7 (individual items on Perceptions of Sharedness Pre-Measure) mixed-model ANOVA was conducted with assigned experimental condition as the between-subjects variable and administration and questions as the within-subjects variables. There was no significant effect for condition, $F(1, 116) = 0.668$, $p = .574$. There were, however, significant main effects for both administration ($F[1, 116] = 157.726$, $p < .0001$, partial $\eta^2 = .576$) and question (Greenhouse-Geisser $F[3.287, 381.330] = 70.824$, $p < .0001$, partial $\eta^2 = .379$), and a significant interaction between the two (Greenhouse-Geisser $F[4.038, 468.448] = 3.944$, $p = .004$, partial $\eta^2 = .033$). Figure 9 presents a graphical depiction of the two-way interaction. As can be seen in Figure 9, participants reported higher scores on all seven of the Perceptions Post-Measure items as opposed to the Perceptions Pre-Measure.

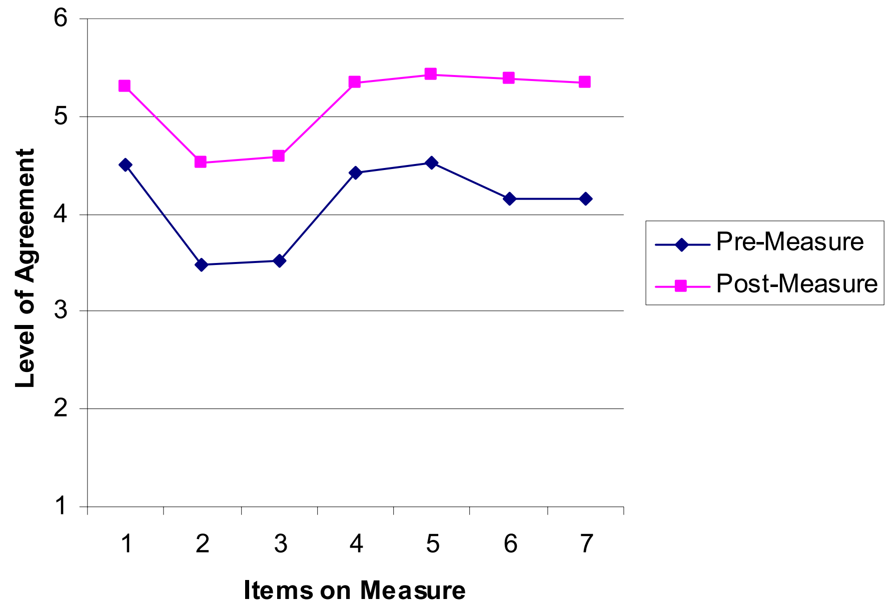

Figure 9. Two-way interaction between administration and question on perceptions of sharedness measures.

Actual Mental Model Sharedness

Similar to the perceptions of sharedness manipulation, while the actual mental model sharedness was manipulated by giving teammates the same or different training, a Mental Model Pre-Measure was used to assess the team members' actual sharedness *prior* to performance and a Mental Model Post-Measure was used to assess the team members' actual sharedness *after* performance. A comparison of the Pre- and Post-Measures was conducted to determine if actual sharedness among team members' mental models shifted during performance. A 4 (assigned experimental condition: dissensus, false consensus, pluralistic ignorance, consensus) x 2 (administration: pretest, posttest) x 4 (scenario) x 6 (strategy) mixed-model ANOVA was conducted with assigned experimental condition as the between-subjects variable and administration, scenario, and strategy as the within-subjects variables. There was no significant effect for condition, $F(1, 116) = 1.106$, $p = .350$. There was also no significant effect for administration, $F(1, 116) = 0.294$, $p = .589$, suggesting that participants' mental models about the most effective strategies to use did not shift during performance.

Although the main focus of this manipulation was the difference between team members, it was first necessary to assess whether the two training modules produced different mental models. A 2 (training) x 4 (scenario) x 6 (strategy) mixed-model ANOVA was conducted with training module as the between-subjects variable and scenario and strategy as the within-subjects variables. The results showed that the test for between-subjects effects was significant, $F (1, 118) = 202.363$, $p < .0001$, partial $\eta 2 = .632$. Thus, it appears that the mental model measure was indeed sensitive enough to capture differences in mental models.

Mental Model Quality

Although mental model quality was a quasi-independent variable because it was only measured and not manipulated, it was still important to determine whether there were differences in quality between participants who received Training Module 1 and participants who received Training Module 2. An independent samples t-test showed that there were no significant differences in quality based on the training module received, $t(118) = .994$, $p = .347$. Thus, there was no evidence that either training module produced superior mental models.

Manipulation Checks

Perceptions of Sharedness

Prior to testing the hypotheses, a manipulation check was performed on the perceptions of sharedness manipulation. A one-way (manipulated perceptions: low, high) between-subjects analysis of covariance (ANCOVA) was performed on the (square root) Perceptions Pre-Measure Total using friends/not friends and experience with video games as a covariate. The friends/not friends variable was used because it was expected that those teams who had knowledge of each other prior to the study would have higher perceptions of sharedness. The experience with video games variable was used because participants completed the Perceptions of Sharedness Pre-Measure immediately after they completed their training session in which they interacted with the Marratech 5.1 software.

After adjustment by the covariates, the perceptions of sharedness manipulation had a significant effect on the (square root) Perceptions Pre-Measure Total, $t(116) = 1.846$, $p = .034$ (one-tailed), partial $\eta 2 = .029$. This effect was in the expected direction, with the higher perceptions group scoring lower on the transformed Perceptions Pre-Measure Total, which are a reflection of the raw data. Thus, the instructions about whether teammates received the same or different training significantly influenced participants' measured perceptions of sharedness when the effects of friends/not friends and video game experience were controlled for.

Actual Mental Model Sharedness

Prior to testing the hypotheses, a manipulation check was also performed on the actual sharedness manipulation. As it was not expected that any other factors would influence this manipulation, no covariates were used. An independent samples t-test investigated the impact of the manipulated level of sharedness (high vs. low) on the absolute difference scores between teammates on the Mental Model Pre-Measure. The results were significant, $t(58) = -5.446$, $p < .0001$ (one-tailed), partial $\eta^2 = .338$. The results were in the expected direction, with teams who received the same training (i.e., higher actual sharedness) exhibiting lower difference scores ($M = 37.00$, $SD = 8.990$) than those who received different training ($M = 49.44$, $SD = 8.680$). Thus, receiving the same or different training significantly influenced participants' actual mental model sharedness.

Tests of Hypotheses

Analysis for Hypothesis 3

To recap, Hypothesis 3 stated that perceptions of higher sharedness would lead to more initiating behaviors. To test this hypothesis, a one-way (manipulated perceptions: low, high) between-subjects univariate ANCOVA was performed on the (log) initiating behaviors using role in team (assigned computer) as a covariate. After adjustment by the covariate, the manipulated perceptions of sharedness did not significantly impact the (log) initiating behaviors, $t(117) = 0.312$, $p = .38$ (one-tailed). These results did not support Hypothesis 3. No evidence was found that perceptions of sharedness led to more initiating behaviors.

Analysis for Hypothesis 1

Verbal Responding Behaviors

Hypothesis 1 stated that higher levels of actual mental model sharedness would lead to more responding behaviors. First, the effect of team members' actual mental model sharedness on verbal responding behaviors was evaluated. A one-way (manipulated actual mental model sharedness: low, high) between-subjects multivariate analysis of covariance (MANCOVA) was performed on the transformed verbal responding behaviors (log acknowledgement responding behaviors, square root synthesis responding behaviors, and log total verbal responding behaviors), using (log) initiating behaviors as a covariate. After adjustment by the covariate, the manipulated mental model sharedness did not significantly impact (square root) synthesis responding behaviors ($t[117] = -0.420$, $p = .34$ [one-tailed]); however, manipulated mental model sharedness did significantly influence (log) acknowledgement responding behaviors ($t[117] = -2.316$, $p = .011$ [one-tailed], partial $\eta^2 = .044$), albeit in the opposite direction than hypothesized. These results did not support Hypothesis 1. No evidence was found that higher actual mental model sharedness led to more verbal responding behaviors.

Action Responding Behaviors

Next, the effect of team members' actual mental model sharedness on action responding behaviors was evaluated. A one-way (manipulated actual mental model sharedness: low, high) between-subjects MANCOVA was performed on the transformed action responding behaviors (square root of actions rated 4 or more, square root of actions rated 3 or more, and square root of all rated actions), using (log) initiating behaviors as a covariate. The results are presented in Table 11. After adjustment by the covariate, the manipulated mental model sharedness did not significantly impact any of the action responding behaviors. These results failed to provide support for Hypothesis 1. No evidence was found that higher actual mental model sharedness led to more action responding behaviors.

Table 10

MANCOVA Table for Between-Subjects Effects of Actual Mental Model Sharedness for Action Responding Behaviors

Factor	**SS**	**df**	**Mean Square**	***F***	***p***
Square root of 4+ Rated Action Responding Behaviors	0.074	1	0.065	0.188	.666
Error	46.091	117	0.394		
Square root of 3+ Rated Action Responding Behaviors	0.245	1	0.224	0.510	.476
Error	56.062	117	0.479		
Square root of All Rated Action Responding Behaviors	0.020	1	0.020	0.037	.849
Error	64.658	117	0.553		

Analysis for Hypothesis 2

Hypothesis 2 stated that the quality of team's mental models would be a significant predictor of weighted team processes, which are the outcome of successful implicit coordination. This analysis was conducted at team level because team processes are a team level variable and an individual analysis would not be logical. An independent samples t-test showed that average team quality significantly affected the team processes, $t(58) = -2.779$, $p = .004$ (one-tailed), partial $\eta^2 = .118$. The effect was in the predicted direction, with teams with, on average, higher quality mental models exhibiting better team processes ($M = 30.09$, $SD = 11.427$) than teams with lower quality mental models ($M = 22.23$, $SD = 10.045$). These results supported Hypothesis 2 which had stated that higher quality mental models lead to better team processes.

Summary of Hypothesis Testing

Table 11 presents a summary of the hypothesis testing, including the types of analysis used and the findings from each analysis.

Table 11

Summary of Hypothesis Testing

$H_{\#}$	**H_1**	**Test of Hypothesis**	**Dependent Variable(s)**	**Finding**	**Result**
3	$M_{HP} > M_{LP}$	ANCOVA, covariate: role in team	Logarithm of initiating behaviors	$t(117) = 0.312$, $p = .38$ (one-tailed)	Not Supported
1	$M_{HA} > M_{LA}$	MANCOVA, covariate: initiating behaviors	Logarithm of acknowledgement responding behaviors;	$t(117) = -2.316$, $p = .011$ (one-tailed)**;	Not supported
			Square root of synthesis responding behaviors;	$t(117) = -0.420$, $p = .34$ (one-tailed);	
			Square root of all action responding behaviors	$F(1, 117) = 0.037$, $p = .848$	
2*	$M_{HQ} > M_{LQ}$	Independent samples t-test	Weighted team processes	$t(57) = -2.779$, $p = .004$ (one-tailed), partial $\eta^2 = .118$	Supported

Note: *Hypothesis 2 is analyzed on the team level. ** Effect in opposite direction than predicted.

Supplemental Analyses

The expected proportional relationships between perceptions of sharedness and actual sharedness, and actual sharedness and mental model quality, were investigated via a series of 2 (perceptions) x 2 (actual sharedness) x 2 (quality) analyses on each of the stages of implicit coordination. Continuing with the same organization scheme, these results are presented in the order of the proposed implicit coordination stages.

Initiating Behaviors

Although the hypothesis that perceptions of sharedness facilitated the process of implicit coordination was not supported, additional analyses were conducted to determine whether actual mental model sharedness or quality of mental models affected initiating behaviors. A 2 (manipulated perceptions: low, high) x 2 (manipulated actual sharedness: low, high) x 2 (measured quality: low, high) between-subjects ANCOVA was performed on the (log) initiating behaviors using role in team (assigned computer) as a covariate. After adjusting for the covariate, only individual mental model quality had a significant effect on (log) initiating behaviors, $F(1, 111) = 4.551$, $p = .035$, partial $\eta^2 = .039$. Individuals with higher quality mental models had significantly more (log) initiating behaviors than individuals with lower quality mental models ($M_{High} = .7283$, $SD_{High} = .19258$, $M_{Low} = .6617$, $SD_{Low} = .21954$).

Responding Behaviors

Although the hypothesis that actual mental model sharedness would drive responding behaviors was not supported, additional analyses were conducted to determine whether manipulated perceptions of sharedness or quality of mental models affected responding behaviors. A 2 (manipulated perceptions: low, high) x 2 (manipulated actual sharedness: low, high) x 2 (measured quality: low, high) between-subjects MANCOVA was performed on the transformed verbal responding behaviors using (log) initiating behaviors as covariates. The results showed that there were no significant main effects for perceptions of sharedness or mental model quality; however, there was a significant two-way interaction between perceptions of sharedness and actual mental model sharedness, $F(1, 110) = 8.943$, $p = .003$, partial $\eta^2 = .075$. As can be seen from Figure 10, participants provided more synthesis responding behaviors when they were in a manipulated mismatched condition, that is participants who received the same training but were told they got different (pluralistic ignorance) or participants who received different training but were told they got the same training (false consensus). In other words, participants whose perceptions did not match their reality tended to "think aloud", discuss their options with their teammates, or obtain permission from their teammates, as opposed to simply taking the information and applying it directly to their route planning. This was not the expected proportional relationship that was displayed in Figure 6, in which participants with both high perceptions and high actual sharedness (consensus) were expected to have the highest number of responding behaviors, while participants with both low perceptions and low actual sharedness (dissensus) were expected to have the lowest number of responding behaviors.

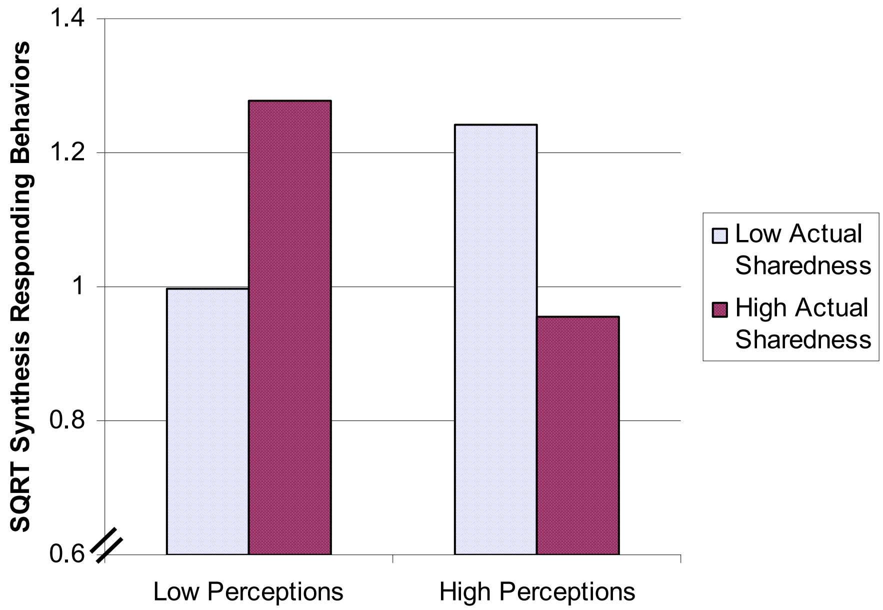

Figure 10. Two-way interaction between manipulated perceptions of sharedness and manipulated actual mental model sharedness on (square root) synthesis responding behaviors.

Additional analyses showed no evidence of the impact of perceptions of sharedness, actual mental model sharedness, or mental model quality on any action responding behaviors.

Team Processes

Finally, analyses were conducted to determine whether manipulated perceptions of sharedness or manipulated actual mental sharedness affected responding behaviors. A 2 (manipulated perceptions: low, high) x 2 (manipulated actual sharedness: low, high) x 2 (measured average quality: low, high) between-subjects ANOVA was performed on the weighted team processes. The results showed that there were no significant main effects for perceptions of sharedness or actual mental model sharedness; however, there was a significant two-way interaction between the two, $F(1, 52) = 4.044$, $p = .050$, partial $\eta^2 = .072$. This effect exhibited almost the same pattern as was found for the synthesis responding behaviors. As can be seen from Figure 11, teams had higher weighted team process scores when they were in a manipulated mismatched condition, that is participants who received the same training but were told they got different (pluralistic ignorance) or participants who received different training but were told they got the same training (false consensus). In other words, teams whose perceptions did not match their reality tended to exchange more information, and/or more *important* pieces of information than teams whose perceptions matched their realities. This interaction was not the expected proportional relationship shown in Figure 4. It was expected that actual sharedness and *mental model quality* would affect team processes, not actual sharedness and perceptions of sharedness.

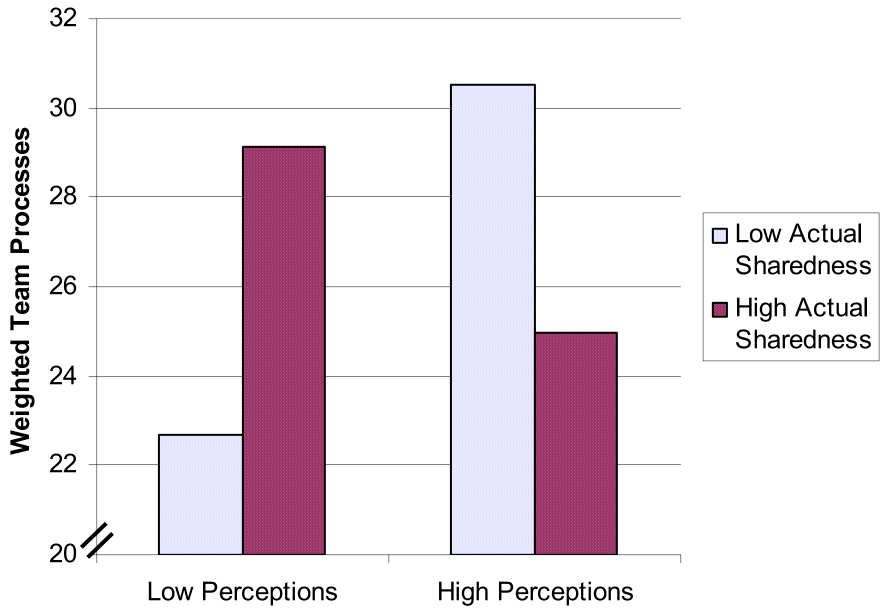

Figure 11. Two-way interaction between manipulated perceptions of sharedness and manipulated actual mental model sharedness on weighted team processes.
Note: Higher score means better team processes.

CHAPTER FIVE: DISCUSSION

The research reported here investigated the process of implicit coordination, and the effects of perceptions of sharedness, actual mental model sharedness, and quality of mental models on the different proposed stages of that process. Specifically, it was hypothesized that (a) perceptions of sharedness would facilitate initiating behaviors, (b) actual mental model sharedness would drive the corresponding responding behaviors, and (c) mental model quality would influence team processes. The results of this study provided only partial support for the impact of mental models on the process of implicit coordination in teams. The specific findings are discussed in the following sections.

Evidence for Implicit Coordination

First, this study did provide additional support for the existence of implicit coordination. To reiterate, implicit coordination has been found to occur when teams are experiencing higher levels of workload (Kleinman & Serfaty, 1989). In this study, participants reported significantly higher levels of workload for the al Kufah Scenario, regardless of the order of scenarios. A comparison of the frequency of initiating behaviors showed that there were significantly more initiating behaviors in the al Kufah Scenario than in the Samarra Scenario. Thus, teams were engaging in more attempts at implicit coordination under conditions of greater perceived workload. This supports the underlying notion that high perceived workload facilitates implicit coordination. At the same time, given the range of possible workload scores, there are definitely tasks that could result in higher workload scores. Hence, even higher workload could results in more evidence for implicit coordination.

Perceptions of Sharedness

Many of the researchers who previously referred to or found evidence for implicit coordination have suggested that the phenomenon is driven by team members having SMMs. This dissertation sought to determine whether team members must *have* SMMs or simply *believe* that they do. In this study, perceptions of sharedness were manipulated by telling teammates that they would receive the same or different training. It was expected that those who were told they were receiving the same training would have perceptions of higher sharedness than those who were told they would be receiving different training. Although this was found, participants tended to have high perceptions of sharedness even if they were in the condition in which they were told they received different training. As the participants had minimal interaction with one another prior to filling out the Perceptions of Sharedness Pre-Measure, this might have been a manifestation of Nickerson's (1999) hypothesis that, when people have limited information about another person, they tend to use themselves as default models for their teammates and, consequently, overestimate the extent to which they have SMMs.

Additionally, it was found that whether or not the teammates were friends, and their individual reported experience with video games, also affected the reported perceptions of sharedness. Although the effect of prior knowledge of each other was a predictable relationship, the effect of video game experience was not. While participants reported their video game experience at the beginning of the study, they filled out the Perceptions of Sharedness Pre-Measure directly after completing the 15-minute Training Scenario. Thus, it may have been that when participants filled out the Perceptions of Sharedness Pre-Measure, they were focused more on their own self-efficacy in terms of video games than on the instructions that they received the same or different training. This suggests that teammates may have focused on the “Assumed Similarity” dimension of the Social Relations Model (Kenny, 1994), in which team members perceived their teammates as they perceived themselves, rather than vice versa. This also falls in line with Woehr and Rentsch’s (2003) findings that perceiver effects had a bigger effect than partner effects. In other words, perceptions about oneself had more of an impact than perceptions about one’s teammate. In the end, however, the manipulation did significantly impact measured perceptions of sharedness, when the effects of these two covariates were adjusted for.

I hypothesized that higher perceptions of sharedness would be associated with more initiating behaviors, or attempts at implicit coordination, because participants who believed they had a shared understanding would believe their teammates would know what to do with the information they were providing. The results of this study found no evidence to support the predicted relationship. Due to the significantly negatively skewed distribution of the measured perceptions of sharedness, it might have been that perceptions were simply not low enough for the low group to show differences from the high group. Indeed, it is possible that the effect of perceptions of sharedness on implicit coordination is only evident when people have very low perceptions of sharedness. In other words, there might have been a range restriction in terms of the participants’ actual perceptions of sharedness.

The above findings might also have been a manifestation of the amount of time in which teams completed the task. That is, while there was no time limit, teams normally only took approximately fifteen minutes per scenario. This likely led to the significantly positively skewed distribution of the number of initiating behaviors. The average number of initiating behaviors per person per scenario was less than five. The question of whether longer interactions with one another would result in a more pronounced effect of perceptions of sharedness is at best questionable. As perceptions are molded with interaction, it is likely that the participants would have simply had even higher perceptions of sharedness by the completion of the task.

Actual Mental Model Sharedness

In addition to assessing the perceptions of sharedness, it was also important to determine the impact that the actual level of sharedness had on coordination between team members. The manipulation check for actual mental model sharedness was highly significant. Those participants who received different training had different mental models in terms of the appropriate strategies to use to complete the task under varying conditions. Additionally, those teammates who received different training had significantly more differences between their mental models than those teammates who received the same training. Further, as a function of the positively skewed distribution of initiating behaviors, the distribution of responding behaviors was also positively skewed. There were an average of less than 3 verbal responding behaviors and less than 2 action responding behaviors per scenario. To test Hypothesis 2, that more sharedness would be associated with more responding behaviors, two separate analyses were run for verbal and action responding behaviors.

Verbal Responding Behaviors

For verbal responding behaviors, only verbal acknowledgements were significantly affected by actual mental model sharedness; however, this effect was contrary to the predicted direction. Specifically, it was lower actual mental model sharedness that led to more acknowledgement responding behaviors than higher sharedness. One possible reason for these at first contradictory findings may have been that acknowledgement responding behaviors may not actually be an indication that the information is being used, or used effectively. An "O.K." signifies that someone has received the message, but does not indicate that the person understands the information, believes the information is relevant, or plans on using the information. Acknowledgement responding behaviors are the lowest form of observable responding behaviors, and they may in fact be the nice person's non-response. Thus, the finding that less actual sharedness led to more acknowledgements was not terribly surprising. Additionally, it should be noted that the effect size for this relationship was only 1%, suggesting that there are certainly other factors that played a role in how teammates coordinated with and responded to each other.

On the other hand, there was no significant effect for actual mental model sharedness on synthesis responding behaviors. Thus, in contrast to what was expected, high actual sharedness was not associated with more synthesis responding behaviors. One possible reason for this finding was the significantly positively skewed distribution of recorded synthesis responding behaviors. As has already been noted, there were less than 3 verbal responding behaviors per person per scenario. Of these, there were more acknowledgements than synthesis responding behaviors. Therefore, the lack of an effect here might again have been due to range restriction in that there was simply not enough variability in synthesis responding behaviors to uncover its true relationship with actual mental model sharedness.

Another possible reason is that rather than verbally use the information, teammates might have been processing the information in their minds in order to use later. Obviously, only *observable* responding behaviors could be analyzed. The possibility that the information was received and processed without any further discussion cannot be overlooked. Indeed, participants might have used the information in subsequent actions without any verbal indication whatsoever. Therefore, it was necessary to examine the effects of actual mental model sharedness on action responding behaviors as well.

Action Responding Behaviors

Similar to the findings for synthesis responding behaviors, no significant findings supported the hypothesis that actual mental model sharedness made an impact on action responding behaviors either. So, even if participants were not discussing the information but simply using it later, there was still no evidence of an effect of actual mental model sharedness on responses to initiating behaviors. Action responding behaviors also suffered from the range restriction issues of the verbal responding behaviors; however, they had an added complication. As has already been noted, the average number of observable action behaviors was less than 2 per person. Coding action responding behaviors was a difficult task because, while verbal responses always immediately followed the initiating behaviors, actions did not. It is entirely possible that there were action behaviors that could have been included in the overall count, but the participant made no indication that the action was associated in any way with the information initially provided. Either way, there was no evidence that supported Hypothesis 1.

Supplemental Findings on Initiating Behaviors

Though not significant, one interesting finding related to actual mental model sharedness was the lack of an effect on initiating behaviors, or the beginning step in implicit coordination. While this study hypothesized that perceptions of sharedness would facilitate implicit coordination, numerous others (cf., Kleinman & Serfaty, 1989; Serfaty, Entin, & Volpe, 1993) have posited that it is the actual sharedness between team members' mental models that facilitates implicit coordination. However, to date, no published evidence has supported the notion that actual mental model sharedness is the driving force. The two previous studies that measured SMMs and behaviors indicative of implicit coordination did not find a link between SMMs and implicit coordination (Stout et al., 1999; Waller et al., 2004). This study did not find a direct link between actual mental model sharedness and the initiation of implicit coordination either.

Mental Model Quality

In addition to studying how perceptions of sharedness and actual mental model sharedness affected implicit coordination, the effect of mental model quality on implicit coordination was also assessed. Mental model quality was measured by comparing individual's mental models against expert mental models for the target task. Even with half of the teams composed of mixed quality mental models, the average team mental model quality score still significantly affected team processes, in the predicted direction. Teams with high quality mental models exhibited significantly better team processes than those with low quality mental models. Thus, Hypothesis 2 was supported. It should be noted, however, that the effect size for this relationship was only 11%, again suggesting that there are certainly other factors affecting this process.

Even so, this finding is important for a number of reasons. First, the analysis was conducted at the team level; and, therefore, only average quality scores were used. An investigation into how an individual's mental model quality affects his/her actions would likely lead to even greater effect sizes. Yet, even those averaged scores still impacted team processes. Furthermore, it should be noted that half of the teams actually consisted of team members who had received different training and, consequently, had different mental models. That means that even team members who had high quality, but different mental models had better team processes than team members who both had low quality mental models. This finding is contrary to Mathieu et al.'s (2005) findings that those teams with high quality but different mental models had the lowest team process scores. These discrepant findings may be a function of how team processes were measured. In the current study, team processes were only assessed at the communication level. Mathieu et al. also included five other dimensions of teamwork: leadership, assertiveness, decision making, adaptability, and situation awareness. It would be interesting to further investigate the differential effects of mental model quality and SMMs on the various aspects of team processes to determine which specific aspects are hindered or helped by the different combinations.

Moreover, as noted in the literature review, very little previous research has assessed the relationship between mental model quality and team processes, and none found a significant relationship between the two without factoring in mental model sharedness (Heffner, 1997; Mathieu et al., 2005). Two recently published articles, however, both found a direct relationship between mental model accuracy and team *performance*, without the inclusion of sharedness (Edwards, Day, Arthur, & Bell, 2006;

Lim & Klein, 2006). In fact, Edwards et al. found that mental model accuracy was a stronger predictor of team performance when the focus was solely on task mental models, as in this study. Thus, the results of this study fall in line with the most currently published findings on SMMs and mental model accuracy.

Additionally, the findings of this study certainly support the authors who have argued that correctness of mental models is important for team processes (cf. Rouse et al., 1992; Smith-Jentsch, Kraiger, Cannon-Bowers, & Salas, 1998). These results also support the notion that, for tasks or situations in which it is possible to accomplish goals in more than one manner, it is important to consider multiple correct or ideal mental models. Using one correct or expert model and assessing "accuracy" may be short-sighted and might result in unintentionally overlooking true relationships between variables. Using only one expert model also eliminates the ability to consider unique and interactive effects of sharedness and quality, which can be "conceptually and empirically separable" (Mathieu et al., 2005, p. 52). Therefore, future researchers should be wary of not including some quality index in their analyses of mental models or SMMs.

Supplemental Findings on Initiating Behaviors

Additional analyses also found an unexpected relationship between mental model quality and initiating behaviors. While neither perceptions of sharedness nor actual mental model sharedness significantly impacted the frequency of initiating behaviors, mental model quality did. Specifically, those individuals with higher quality mental models voluntarily gave significantly more information to the teammates than those with lower quality mental models. This finding is interesting because (a) it is part of a small, but growing, number of studies that have found that quality or accuracy is important for team processes and/or performance (Edwards et al., 2006; Lim & Klein, 2006), and (b) it is actually contrary to the prior assumption that SMMs lead to implicit coordination. In this study, having a good understanding of the task was the prompting factor for implicit coordination, *not* having a shared understanding of the task.

Interactive Effects of Perceptions and Actual Sharedness

Perhaps the most interesting finding of this study was the interactive effect of perceptions of sharedness and actual mental model sharedness that emerged during data analysis. A similar pattern was found for all three stages of implicit coordination (though not significant for initiating behaviors). Specifically, in this study, teams who were in mismatched conditions (pluralistic ignorance: teammates were told they received the same training but in reality got different training; false consensus: teammates were told they received different training but in reality got the same training) had significantly more synthesis responding behaviors and significantly higher team process scores than those teams whose perceptions matched their realities. As previously mentioned, this means that participants whose perceptions did not match their reality tended to discuss their intentions and actions much more than participants whose perceptions matched their realities. Additionally, teams whose perceptions did not match their realities tended to exchange more information overall. These findings were in contrast to the expected proportional relationships presented in Figures 4 and 6. Not only were the relationships different, but for team processes, it was expected that actual mental model sharedness would interact with quality, not perceptions.

One plausible explanation for this relationship is that teammates realized there was some disconnect in their understanding of their partner and/or the task and that they increased information exchanges in an attempt to overcome or understand that disconnect. In terms of those with low perceptions and high actual sharedness, this might have been a snowball effect. In other words, teams might have realized they had one thing in common and then just continued passing information to see what else they had in common. For those with high perceptions and low actual sharedness, the increase in information exchanges might have stemmed from the discovery of knowledge gaps and an effort to fill those in. As previous research has found that lower performing teams engage in more communication than higher performing teams (cf., Orasanu, 1990; Urban et al., 1995), it would be interesting to determine if those effects were due to perceptions and reality being incompatible.

Limitations and Directions for Future Research

Communications

One of the main limitations of this study was the way in which the behaviors encompassed in the implicit coordination process were conceptualized and operationalized. Specifically, as already mentioned, the number of expected target behaviors was small, resulting in possible range restriction issues. While the core task in this study was based on communications between the teammates, only those exchanges of critical pieces of information were considered part of the implicit coordination process. Therefore, even though teams engaged in approximately fifteen-minute-long chat sessions, the coded initiating and responding behaviors were constrained to only specific pieces of information. This could be rectified in the future by using tasks that require more time and more interaction between teammates.

Perhaps more importantly, this study focused on information that could be verbally (or textually) transmitted from one team member to another. In this study, the only type of resource that was passed between team members was information itself. That is, all instances of implicit coordination were coded by looking at verbal communications. At first, this may seem counter-intuitive. People often associate implicit coordination with a reduction in communications; therefore, measuring implicit coordination with communications may not fall in line with others' understanding of the phenomenon. However, as noted in the introduction, the construct of implicit coordination has previously been ill-defined, and for the purposes of this study, verbal communications in the absence of explicit requests were included in the definition of implicit coordination. Implicit coordination is thought to occur when information and/or resources are passed without explicit requests. Thus, verbal information exchanges do fall under the rubric of implicit coordination, at least until a more formal definition is adopted by the community.

The results of this study suggest it is possible that either (a) verbal communications may not be included in the implicit coordination process, or (b) implicit coordination may not be a useful strategy when information exchange is part of the primary task. Indeed, if verbal information exchanges are *not* truly part of implicit coordination, then the findings of this study may, in fact, be in line with previous assumptions about implicit coordination. That is, it would not necessarily be expected that SMMs are directly related to explicit coordination sequences. In order to gain more insight into the process of implicit coordination, and to augment the findings of this study, future research should analyze the process of implicit coordination when team members can physically pass resources to one another to determine if the same relationships still hold true. Additionally, future work should consider situations in which information exchange is not a primary task.

Workload

A second limitation to this study was that the task might have not been difficult enough to elicit the levels of perceived workload that facilitate the process of implicit coordination. While the al Kufah Scenario was characterized by more reported workload, the average overall workload was less than 60 (out of 100). Previous researchers have suggested that implicit coordination only occurs under extremely high levels of workload. The workload scores in this study would not be considered extremely high; and therefore the process of implicit coordination may not have occurred in this study as it might for tasks characterized by higher perceived workload.

One possible way to overcome this limitation and the previously discussed limitation on communications at the same time is to select a dual-task environment for future research. First, dual-task environments are known to produce higher levels of workload and are also often more representative of real-world tasks. In dual-task environments, team members often have their own primary tasks and then share a secondary task. Second, because the joint task is the secondary task, then communication between the teammates cannot be the core task. Thus, the dual-task environment should elicit high enough levels of workload and lessen the reliance on information exchanges as the only behavior available for analysis.

Moreover, it would also be interesting to investigate the impact of brief periods of high workload on implicit coordination in order to observe systematic changes over time.

As implicit coordination is thought to be an adaptive strategy that is beneficial under conditions of high workload, a greater understanding of the phenomenon could be gained by research focusing on (a) when/if teams shift to implicit coordination and (b) when/if teams shift back to explicit coordination.

Performance

A third limitation of this study was that the focus was on the process of implicit coordination and the accompanying team processes, not on the resulting team performance. For the purposes of investigating the process of implicit coordination, a team performance score was not necessary because the sequence of behaviors should have been the same whether or not the process was effective. However, the idea that this strategy is only beneficial under conditions of high workload and for high performing teams should not be overlooked. If it is true that the process is most pronounced and most useful for high performing teams in high workload situations, then it may be that there are indeed relationships that would be found when factoring in team performance scores. However, if SMMs are associated with team performance, then focusing only on high performing teams in high workload situations may result in having many more teams with high sharedness than low sharedness, leading to difficulty in disentangling the relationships between the three variables. Future researchers in this area should be cognizant of the possible relationship between implicit coordination and team performance, even if the focus is on the specific sequence of behaviors encompassed in implicit coordination.

Implications and Conclusions

Although this study found only partial support for the hypotheses that perceptions of sharedness, actual mental model sharedness, and mental model quality affect implicit coordination, there are still a number of implications that can be derived from the findings.

Operationalization of Implicit Coordination

First and foremost, this study sheds light on the difficulties of operationalizing the construct of implicit coordination. In this study, I attempted to more fully operationalize the construct by reviewing previous definitions and research and then combining the findings to create a definition of successful implicit coordination and to identify the sequence of behaviors that make up this process. The definition in this study focused on behaviors that were not preceded by a request, which included explicit communications not preceded by a request. Other researchers may oppose this idea and disregard explicit communications altogether, whether they were previously requested (explicit) or not (implicit). If explicit communications are not included, then researchers need to more clearly define implicit coordination as coordination behaviors that are (a) not preceded by a request and (b) not composed of any explicit communications. As there have been few previous attempts to operationalize this construct, even with the findings of the current study, there is still work needed to determine which behaviors are included in the process and which are not.

In addition to specifying which behaviors may be included in implicit coordination, it is also necessary to further assess the sequence of behaviors. In this study, the initiation of implicit coordination was the transfer of information from one team member to another. However, as I laid out in the Introduction, possible facilitating factors of implicit coordination included (a) motivation, (b), perceptions of a useful course of action, and (c) perceptions of sharedness. Perhaps it is the case that the initiation happens before the proposed stages presented in this study. In fact, it is possible that the initiating behaviors coded here were actually responding behaviors to some other behavior that prompted the exchange of information. It may very well be that the relationship between SMMs and implicit coordination would be unmasked if the beginning stage of implicit coordination actually preceded the exchange of information. Thus, this study demonstrates the complexity of the construct implicit coordination and highlights the need for future researchers to more clearly define what they include as implicit coordination behaviors.

Importance of Mental Model Quality

This study was the first study designed specifically to investigate the relationship between SMMs and implicit coordination. Surprisingly, the results of this study suggested that an individual's mental model quality was more important for facilitating implicit coordination than the level of sharedness between team members, at least in tasks where team performance relies solely on the transfer of information. In fact, this study does not support the position that implicit coordination is the result of SMMs that allow teammates to anticipate each other's behaviors. Conversely, the findings suggest that the behaviors are driven by an individual's understanding of the task and the appropriate strategies to complete said task. In that sense, while it takes more than one person to complete the proposed stages of implicit coordination, the actual driving force might be at the individual level. In this study, individual mental model quality predicted initiating behaviors and average team mental model quality predicted team processes. Thus, this study provided evidence for the importance of mental model quality, and future research is needed to further explore its effects on team coordination.

Perceptions vs. Actual Sharedness

This study also provides partial support for the hypothesis that for team members to have SMMs, they must be aware of their sharedness (Klimoski & Mohammed, 1994). Specifically, the findings suggest that awareness or perceptions of sharedness significantly interacted with actual levels of sharedness. The results of this study showed that teams whose perceptions did not match reality in terms of sharedness exhibited different behavioral patterns than those teams whose perceptions matched their reality. Specifically, teams in the mismatched conditions seemed to communicate more, possibly because they recognized the mismatch and were attempting to compensate or uncover their discrepancies. These results, therefore, highlight the importance of team members' perceptions about themselves and their teammates, and future studies on SMMs should not overlook the possible interactive effects of perceptions and actual sharedness.

Successful vs. Unsuccessful Implicit Coordination

This study has also provided evidence for multiple stages of implicit coordination and for the existence of *unsuccessful attempts* at implicit coordination. First, I was able to successfully analyze the unique steps in the sequence of behaviors involved in implicit coordination. For each sequence of behaviors, therefore, it was possible to observe the beginning and ending behaviors. Consequently, the results of this study showed that not every initiating behavior was followed by a responding behavior or an improvement in team processes. This is important because it suggests that one cannot assume that the increase in unsolicited transfers (initiating behaviors) is always successful, i.e., a good and/or useful. If one team member is simply doing a data dump, or passing as much information as possible, it is likely that this would not be a beneficial strategy. Furthermore, if there is a decrease in requests from a team member, it may simply be that that team member does not need additional information. So, while implicit coordination has always been touted as a good thing, the presence of initiating behaviors without responding behaviors suggests that additional research is necessary to determine the factors that influence successful vs. unsuccessful implicit coordination.

Application to Unmanned Vehicles

Finally, this study also has implications for UAV and UGV operators working together in complex military environments. Quality, and not sharedness, was found to be a significant predictor of initiating behaviors and team processes. This finding suggests that UAV and UGV operators, who have a firm grasp of their own tasks, including their own capabilities and limitations, should be able to work together efficiently, even if they have never operated the other type of unmanned vehicle. Furthermore, the findings on the interaction between perceptions of sharedness and actual mental model sharedness suggest that those teams whose perceptions match their realities will not need to communicate as much, which can be extremely important in time-sensitive missions with heightened security issues. Therefore, if teammates are briefed on each others' capabilities beforehand, in terms of their experience with operating UGVs, UAVs, and in mixed-vehicle teams, the likelihood that they will be in a mismatched condition will be greatly reduced. As technological advances are made, teams of UAV and UGV operators will become much more prevalent. Keeping in mind that there are multiple aspects of mental models that play a role in team coordination can help in training these teams to perform at optimal levels.

APPENDIX A

IRB APPROVAL FORMS

University of Central Florida

Office of Research & Commercialization

October 26, 2005

Raegan Hoeft, Doctoral student
University of Central Florida
Team Performance Laboratory
PVL 408
Orlando, FL 32816-1390

Dear Ms. Hoeft:

With reference to your protocol #05-2978 entitled, **"Team Coordination during a Military Reconnaissance Planning Task,"** I am enclosing for your records the approved, expedited document of the UCFIRB Form you had submitted to our office. **This study was approved on 10/23/05 and the expiration date will be 10/22/06.** Should there be a need to extend this study, a Continuing Review form must be submitted to the IRB Office for review by the Chairman or full IRB at least one month prior to the expiration date. This is the responsibility of the investigator. **Please notify the IRB office when you have completed this research study.**

Please be advised that this approval is given for one year. Should there be any addendums or administrative changes to the already approved protocol, they must also be submitted to the Board through use of the Addendum/Modification Request form. Changes should not be initiated until written IRB approval is received. Adverse events should be reported to the IRB as they occur.

Should you have any questions, please do not hesitate to call me at 407-823-2901.

Please accept our best wishes for the success of your endeavors.

Cordially,

Barbara Ward

Barbara Ward, CIM
UCF IRB Coordinator
(FWA00000351, IRB00001138)

Copies: IRB File
Florian Jentsch, Ph.D.

BW:jm

12443 Research Parkway • Suite 302 • Orlando, FL 32826-3252 • 407-823-3778 • Fax 407-823-3299

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THE UNIVERSITY OF CENTRAL FLORIDA
INSTITUTIONAL REVIEW BOARD (IRB)

IRB Committee Approval Form

PRINCIPAL INVESTIGATOR(S): Raegan Hoeft **IRB #: 05-2978**
(Supervisor: Florian Jentsch, Ph.D.)
PROJECT TITLE: Team Coordination during a Military Reconnaissance PlanningTask

[X] New project submission [ ] Resubmission of lapsed project #
[ ] Continuing review of lapsed project #_____ [ ] Continuing review of #
[ ] Study expires: [ ] Initial submission was approved by expedited review
[ ] Initial submission was approved by full board review but continuing review can be expedited
[ ] Suspension of enrollment email sent to PI, entered on spreadsheet, administration notified _____

Chair
[x] Expedited Approval

Dated: 23 OCT 2005
Cite how qualifies for expedited review:
minimal risk and #6, #7

[ ] Exempt

Dated: ________
Cite how qualifies for exempt status:
minimal risk and ________

[X] Expiration
Date: 10/22/2006

IRB Reviewers:

Signed: [signature]
Dr. Sophia Dziegielewski, Vice-Chair

Signed: ____________________
Dr. Jacqueline Byers, Chair

Signed: ____________________
Dr. Tracy Dietz, Designated Reviewer

Complete reverse side of expedited or exempt form
[ ] Waiver of documentation of consent approved
[ ] Waiver of consent approved
[ ] Waiver of HIPAA Authorization approved

NOTES FROM IRB CHAIR (IF APPLICABLE): Approved first Review, Deception is used, PI should consider using a debriefing form when-ever deception is used. This study appears to use minimal deception so approved as written.

APPENDIX B

INFORMED CONSENT FORM

Student Informed Consent Form

Name: ____ PID No.:________ _____

I am 18 years of age or older and agree to participate in the study "Military Reconnaissance Mission Planning," conducted by principal investigator; Raegan Hoeft, under the guidance of Florian Jentsch.

In this research, I will participate in a study targeted at measuring coordination and communication during a military reconnaissance planning task. The experiment will consist of one session with two parts. Since communication will be measured, I understand, and consent, that I will be video and/or audio taped during the study. **The first part will consist of paperwork including biographical data and some teamwork surveys. The second part will focus on training and two trials planning a military reconnaissance task for about 30 minutes each with a workload and team coordination survey following the trials, which should take approximately 5 minutes. Performance on these tasks will remain completely confidential (see below). Including training, performance during the sessions, paperwork, and debriefing, this experiment will last approximately 2 hours. Upon completion of the study, credit for participation in an experiment will be given in accordance with the procedures established within the Department of Psychology.**

Risks and Benefits

Participation in the current study includes minimal risks commonly associated with the use of computer display terminals. All performance and personal data will be kept confidential.

If you believe you have been injured during participation in this research project, you may file a claim with UCF Environmental Health & Safety, Risk and Insurance Office, P.O. Box 163500, Orlando, FL 32816-3500 (407) 823-6300. The University of Central Florida is an agency of the State of Florida for purposes of sovereign immunity and the university's and the state's liability for personal injury or property damage is extremely limited under Florida law. Accordingly, the university's and the state's ability to compensate you for any personal injury or property damage suffered during this research project is very limited.
Information regarding your rights as a research volunteer may be obtained from:

UCFIRB Office
University of Central Florida (UCF) Office of Research
Orlando Tech Center
12443 Research Parkway, Suite 302
Orlando, Florida 32826
Telephone: (407) 823-2901

Confidentiality of Personal Data:

All data I will contribute to this study will be held in strict confidentiality by the researchers. That is, my individual data will not be revealed to anyone other than the researchers and their immediate assistants.

To insure confidentiality, the following steps will be taken: (a) only researchers will have access to the data in paper or electronic form. Data will be stored in locked facilities; (b) the actual forms will not contain names or other personal information. Instead, a number assigned by and only known to the experimenters will match the forms to each participant; (c) only group means scores and standard deviations, but not individual scores, will be published or reported.

MY PARTICIPATION IN THIS RESEARCH IS COMPLETELY VOLUNTARY. I CAN WITHDRAW MY PARTICIPATION AT ANY TIME WITHOUT PENALTY - THIS INCLUDES REMOVAL/DELETION OF ANY DATA I MAY HAVE CONTRIBUTED. SHOULD I DECIDE

NOT TO COMPLETE THE STUDY, HOWEVER, I WILL BE ELIGIBLE ONLY FOR THE COURSE CREDIT FOR THAT PART OF THE STUDY WHICH I HAVE COMPLETED.

This research is conducted by Raegan Hoeft, the principal investigator. I have been given the opportunity to ask the research assistants any questions I may have. For further questions regarding this research, contact Raegan Hoeft:

Raegan Hoeft
Team Performance Lab
University of Central Florida

Orlando, FL 32816-1390

Phone: (407) 921-3554

Signature:____ Date: __________

APPENDIX C

BIOGRAPHICAL DATA FORM

Biographical Data Form

Please complete the following questions. Any information you provide is voluntary and will be kept strictly confidential. A participant number will be assigned to your responses and in no way will your name be associated with the data. The information you provide will be used only for the purposes of this study. If you have any questions, please ask.

1. Age: ____
2. Gender: ____ M ____ F
3. Handedness: ____ Right-handed ____ Left-handed ___ Ambidextrous
4. Year in school: ____ Freshman ____ Sophomore ____ Junior ____ Senior ____ Graduate
5. Major: ______________________
6. Military experience (including ROTC), area and length of time:____________
   Active duty _______ National Guard _______ Reserve _______
7. Native language (if not English): _________________
8. Do you wear prescription glasses or corrective contact lenses? ___ Yes ___ No
   If yes, are you wearing them now? ___ Yes ___ No
9. Do you have any previous flying or sailing experience? ___ Yes ___ No
10. Using the scale below, please indicate how you would rate your experience with seeing or working with any type of radio or remote controlled ground vehicles (cars, trucks, toys, etc.):

1	2	3	4	5	6
NOT AT ALL FAMILIAR					VERY FAMILIAR

11. Using the scale below, please indicate how you would rate your experience with seeing or working with any type of radio or remote controlled air vehicles (airplanes, helicopters, blimps, etc.):

1	2	3	4	5	6
NOT AT ALL FAMILIAR					VERY FAMILIAR

12. Using the scale below, please indicate how you would rate your experience with seeing or working with any type of video games:

1	2	3	4	5	6
NOT AT ALL FAMILIAR					VERY FAMILIAR

13. Using the scale below, please indicate how you would rate your experience with seeing or working with any type of personal computers (PCs):

1	2	3	4	5	6
NOT AT ALL FAMILIAR					VERY FAMILIAR

14. Using the scale below, please indicate how you would rate your experience with seeing or working with any type of instant messenger or chat program:

1	2	3	4	5	6
NOT AT ALL FAMILIAR					VERY FAMILIAR

APPENDIX D

SELF MONITORING MEASURE

Personality Measure 1

Please complete the following questions by circling your answer. Any information you provide is voluntary and will be kept strictly confidential. A participant number will be assigned to your responses and in no way will your name be associated with the data. The information you provide will be used only for the purposes of this study. If you have any questions, please ask.

Using the scales below, please circle your answer:

1. I find it hard to imitate the behavior of others.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

2. At parties and social gatherings, I do not attempt to do or say things that others will like.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

3. I can only argue for ideas that I already believe.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

4. I can make impromptu speeches even on topics about which I have almost no information.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

5. I guess I put on a show to impress or entertain others.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

6. I would probably make a good actor.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

7. In a group of people, I am rarely the center of attention.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

8. In different situations and with different people, I often act like a very different person.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

9. I am not particularly good at making other people like me.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

10. I am not always the person I appear to be.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

11. I would not change my opinions (or the way I do things) in order to please someone or win their favor.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

12. I have considered being an entertainer.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

13. I have never been good at games like charades or improvisational acting.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

14. I have trouble changing my behavior to suit different people and different situations.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

15. At a party, I let others keep the jokes and stories going.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

16. I feel a bit awkward in public and do not show up quite as well as I should.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

17. I can look anyone in the eye and tell a lie with a straight face (if for the right end).

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

18. I may deceive people by being friendly even when I really dislike them.

1	2	3	4	5	6
STRONGLY DISAGREE					STRONGLY AGREE

APPENDIX E

EXTRAVERSION MEASURE

Personality Measure 2

Please complete the following questions by circling your answer. Any information you provide is voluntary and will be kept strictly confidential. A participant number will be assigned to your responses and in no way will your name be associated with the data. The information you provide will be used only for the purposes of this study. If you have any questions, please ask.

Using the scales below, please circle your response:

1. I like to have a lot of people around me.

1 STRONGLY DISAGREE	2	3	4	5 STRONGLY AGREE

2. I laugh easily.

1 STRONGLY DISAGREE	2	3	4	5 STRONGLY AGREE

3. I don't consider myself especially "light-hearted".

1 STRONGLY DISAGREE	2	3	4	5 STRONGLY AGREE

4. I really enjoy talking to people.

1 STRONGLY DISAGREE	2	3	4	5 STRONGLY AGREE

5. I like to be where the action is.

1 STRONGLY DISAGREE	2	3	4	5 STRONGLY AGREE

6. I usually prefer to do things alone.

1 STRONGLY DISAGREE	2	3	4	5 STRONGLY AGREE

7. I often feel as if I am bursting with energy.

1 STRONGLY DISAGREE	2	3	4	5 STRONGLY AGREE

8. I am a cheerful, high-spirited person.

1	2	3	4	5
STRONGLY DISAGREE				STRONGLY AGREE

9. I am not a cheerful optimist.

1	2	3	4	5
STRONGLY DISAGREE				STRONGLY AGREE

10. My life is fast-paced.

1	2	3	4	5
STRONGLY DISAGREE				STRONGLY AGREE

11. I am a very active person.

1	2	3	4	5
STRONGLY DISAGREE				STRONGLY AGREE

12. I often enjoy playing with theories or abstract ideas.

1	2	3	4	5
STRONGLY DISAGREE				STRONGLY AGREE

APPENDIX F

RECONNAISSANCE PLANNING QUIZ

Reconnaissance Planning Quiz

1. Is it more important to be quick or accurate?
    a. Quick *(Correct for Training Module 1)*
    b. Accurate *(Correct for Training Module 2)*

2. Should you try to protect your assets or use all your available assets?
    a. Protect your assets *(Correct for Training Module 2)*
    b. Use all available assets *(Correct for Training Module 1)*

3. Is it more appropriate to attempt an Augmenting Strategy or a Cueing Strategy first?
    a. Augmenting Strategy *(Correct for Training Module 1)*
    b. Cueing Strategy *(Correct for Training Module 2)*

4. Is it more appropriate to attempt a One Asset Only Strategy or a Redundancy Strategy first?
    a. One Asset Only Strategy *(Correct for Training Module 2)*
    b. Redundancy Strategy *(Correct for Training Module 1)*

5. Which is more likely to affect your assets?
    a. Terrain *(Correct for Training Module 2)*
    b. Weather *(Correct for Training Module 1)*

6. Should you contact your superiors if you are missing information or have questions?
    a. No *(Correct for Training Module 1)*
    b. Yes *(Correct for Training Module 2)*

7. Are your assets cheap and easy to replace or expensive and difficult to replace?
    a. Cheap and easy to replace *(Correct for Training Module 1)*
    b. Expensive and difficult to replace *(Correct for Training Module 2)*

APPENDIX G

MENTAL MODEL MEASURE

Cue-Strategy Association Measure

Rate the appropriateness of the following strategies in planning for the following situation.

Scenario 1:		
	Intent:	Find a safe route for command to send a relief truck through
	Time:	No immediate time pressure
	Enemy:	Mildly hostile
	Weather:	Clear, sunny day
	Terrain:	No discernable obstacles
	Information:	Complete and up to date

1. Using an augmenting strategy where the UAV and UGV are sent along different routes

1 Not at All Appropriate	2	3	4	5	6 Completely Appropriate

2. Contact command for further orders before deciding how to proceed

1 Not at All Appropriate	2	3	4	5	6 Completely Appropriate

3. Use a redundancy strategy where both the UAV and UGV are sent along the same routes

1 Not at All Appropriate	2	3	4	5	6 Completely Appropriate

4. Send only a UAV

1 Not at All Appropriate	2	3	4	5	6 Completely Appropriate

5. Send only a UGV

1 Not at All Appropriate	2	3	4	5	6 Completely Appropriate

6. Use a cueing strategy where the UAV goes to the Objective and reports back whether the UGV is needed

1 Not at All Appropriate	2	3	4	5	6 Completely Appropriate

Rate the appropriateness of the following strategies in planning for the following situation.

<u>Scenario 2</u>:	Intent:	Find out where the enemy is and what the threat level is
	Time:	No immediate time pressure
	Enemy:	Unknown threat level, specific Objectives unknown
	Weather:	Stormy night, rainy with strong winds
	Terrain:	Jungle with thick vegetation
	Information:	Incomplete and outdated information

1. Using an augmenting strategy where the UAV and UGV are sent along different routes

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

2. Contact command for further orders before deciding how to proceed

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

3. Use a redundancy strategy where both the UAV and UGV are sent along the same routes

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

4. Send only a UAV

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

5. Send only a UGV

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

6. Use a cueing strategy where the UAV goes to the Objective and reports back whether the UGV is needed

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

Rate the appropriateness of the following strategies in planning for the following situation.

<u>Scenario 3</u>:	Intent:	Find out where exactly where enemy is within confined area
	Time:	1 hour window to get in and out, must plan quickly
	Enemy:	Hostile enemy, Objectives unknown
	Weather:	75% chance of sandstorm in next two hours
	Terrain:	Desert filled with landmines
	Information:	As up to date as possible

1. Using an augmenting strategy where the UAV and UGV are sent along different routes

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

2. Contact command for further orders before deciding how to proceed

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

3. Use a redundancy strategy where both the UAV and UGV are sent along the same routes

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

4. Send only a UAV

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

5. Send only a UGV

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

6. Use a cueing strategy where the UAV goes to the Objective and reports back whether the UGV is needed

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

Rate the appropriateness of the following strategies in planning for the following situation.

Scenario 4:		
	Intent:	Unclear whether need specific or generic enemy location info
	Time:	No immediate time pressure
	Enemy:	Hostile enemy spread out over a large area
	Weather:	No significant information available
	Terrain:	No significant information available
	Information:	Incomplete

1. Using an augmenting strategy where the UAV and UGV are sent along different routes

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

2. Contact command for further orders before deciding how to proceed

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

3. Use a redundancy strategy where both the UAV and UGV are sent along the same routes

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

4. Send only a UAV

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

5. Send only a UGV

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

6. Use a cueing strategy where the UAV goes to the Objective and reports back whether the UGV is needed

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

APPENDIX H

PERCEPTIONS OF SHAREDNESS PRE-MEASURE

Pre- Teamwork Measure

Please complete the following questions by circling your answer. Any information you provide is voluntary and will be kept strictly confidential. A participant number will be assigned to your responses and in no way will your name be associated with the data. The information you provide will be used only for the purposes of this study. If you have any questions, please ask.

Using the scales below, please indicate *the extent to which you believe*:

1. that you and your teammate have a shared understanding of your task:

1	2	3	4	5	6
NOT AT ALL SHARED					COMPLETELY SHARED

2. your teammate will be able to anticipate your behaviors:

1	2	3	4	5	6
NOT AT ALL ANTICIPATE					COMPLETELY ANTICIPATE

3. you will be able to anticipate your teammate's behaviors:

1	2	3	4	5	6
NOT AT ALL ANTICIPATE					COMPLETELY ANTICIPATE

4. *your teammate* has a good understanding of *your role* in the team:

1	2	3	4	5	6
NOT AT ALL UNDERSTAND					COMPLETELY UNDERSTAND

5. *you* have a good understanding of *your teammate's role* in the team:

1	2	3	4	5	6
NOT AT ALL UNDERSTAND					COMPLETELY UNDERSTAND

6. *your teammate* will understand what *you* are doing:

1	2	3	4	5	6
NEVER UNDERSTAND					ALWAYS UNDERSTAND

7. *you* will understand what *your teammate* is doing:

1	2	3	4	5	6
NEVER UNDERSTAND					ALWAYS UNDERSTAND

APPENDIX I

APPROPRIATENESS MEASURE

Appropriateness Measure

Rate the appropriateness of the following strategies in planning for the following situation.

Scenario #1

You and your teammate have been planning R&S missions together for a long time; you were both trained at the same facility and have been in the same unit ever since. You believe you both have a firm grasp on what the appropriate way to plan is. You are faced with a time critical situation in which you need to plan a mission as quickly as possible so that the commander can be updated on the current status of the enemy. You find that you are the one who has been given the information regarding the commander's intent. REMEMBER – time is of the essence!

1. Immediately share the commander's intent information with your teammate

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

2. Tell your teammate that you have the information, but only share the specifics if asked

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

3. Remember that you have the information, but relay it only if your teammate asks for it

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

4. Make a decision about the commander's intent based on the information given to you

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

5. Ask your teammate if he or she has any other information about the commander's intent

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

6. Verify your interpretation with your teammate before reaching a conclusion

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

Rate the appropriateness of the following strategies in planning for the following situation.

Scenario #2

You and your teammate have just been given your first R&S missions to plan. Your teammate has just been transferred from another unit; however you know that he or she was trained at the same facility as you were. You are faced with a time critical situation in which you need to plan a mission as quickly as possible so that the commander can be updated on the current status of the enemy. You find that you are the one who has been given the information on the probable characteristics of the enemy units. REMEMBER – time is of the essence!

Rate the appropriateness of the following strategies in planning for this situation.

1. Immediately share the information about the enemy with your teammate

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

2. Tell your teammate that you have the information, but only share the specifics if asked

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

3. Remember that you have the information, but relay it only if your teammate asks for it

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

4. Make a decision about the enemy's threat level based on the information given to you

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

5. Ask your teammate if he or she has any other information about the enemy

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

6. Verify your interpretation with your teammate before reaching a conclusion

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

Rate the appropriateness of the following strategies in planning for the following situation.

Scenario #3

You and your teammate have just been given your first R&S missions to plan; your teammate has just been transferred from another unit and received training from a different facility than you did. You are faced with a time critical situation in which you need to plan a mission as quickly as possible so that the commander can be updated on the current status of the enemy. You find that you are the one who has been given the information about the capabilities of your assets. REMEMBER – time is of the essence!

Rate the appropriateness of the following strategies in planning for this situation.

1. Immediately share the information about your assets with your teammate

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

2. Tell your teammate that you have the information, but only share the specifics if asked

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

3. Remember that you have the information, but relay it only if your teammate asks for it

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

4. Make a decision about which assets to use based on the information given to you

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

5. Ask your teammate if he or she has any other information about the asset capabilities

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

6. Verify your interpretation with your teammate before reaching a conclusion

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

Rate the appropriateness of the following strategies in planning for the following situation.

Scenario #4

You and your teammate have worked together planning R&S missions numerous times; your teammate has received a different type of training than you, and you believe you have a better understanding of the task than he or she does. You are faced with a time critical situation in which you need to plan a mission as quickly as possible so that the commander can be updated on the current status of the enemy. You find that you are the one who has been given the information about each Objective. REMEMBER – time is of the essence!

Rate the appropriateness of the following strategies in planning for this situation.

1. Immediately share the information about the Objective with your teammate

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

2. Tell your teammate that you have the information, but only share the specifics if asked

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

3. Remember that you have the information, but relay it only if your teammate asks for it

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

4. Make a decision about how to gather information about each Objective based on the information given to you

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

5. Ask your teammate if he or she has any other information about the Objective

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

6. Verify your interpretation with you teammate before reaching a conclusion

1	2	3	4	5	6
Not at All Appropriate					Completely Appropriate

APPENDIX J

PERCEPTIONS OF SHAREDNESS POST-MEASURE

Post-Teamwork Measure

Please complete the following questions by circling your answer. Any information you provide is voluntary and will be kept strictly confidential. A participant number will be assigned to your responses and in no way will your name be associated with the data. The information you provide will be used only for the purposes of this study. If you have any questions, please ask.

Using the scales below, please indicate *the extent to which you believe*:

1. that you and your teammate had a shared understanding of your task:

1	2	3	4	5	6
NOT AT ALL SHARED					COMPLETELY SHARED

2. your teammate anticipated your behaviors:

1	2	3	4	5	6
NOT AT ALL ANTICIPATED					COMPLETELY ANTICIPATED

3. you anticipated your teammate's behaviors:

1	2	3	4	5	6
NOT AT ALL ANTICIPATED					COMPLETELY ANTICIPATED

4. *your teammate* had a good understanding of *your role* in the team:

1	2	3	4	5	6
NOT AT ALL UNDERSTOOD					COMPLETELY UNDERSTOOD

5. *you* had a good understanding of *your teammate's role* in the team:

1	2	3	4	5	6
NOT AT ALL UNDERSTOOD					COMPLETELY UNDERSTOOD

6. *your teammate* understood what *you* were doing:

1	2	3	4	5	6
NEVER UNDERSTOOD					ALWAYS UNDERSTOOD

7. *you* understood what *your teammate* was doing:

1	2	3	4	5	6
NEVER UNDERSTOOD					ALWAYS UNDERSTOOD

APPENDIX K

NASA-TLX INSTRUCTIONS AND FORMS

NASA-TLX Instructions

Part I

Rating Scales. We are not only interested in assessing your performance but also the experiences you had during the experiment. In the most general sense, we are examining the "workload" you experienced. Workload is a difficult concept to define precisely but a simple one to understand generally. The factors that influence your experience of workload may come from the task itself, your feelings about your own performance, how much effort you put into it, or the stress and frustration you felt. In addition, the workload contributed by different task elements may change as you become more familiar with the task. Physical components of workload are relatively easy to conceptualize and evaluate. However, the mental components of workload may be more difficult to assess.

Since workload is something that is experienced individually by each person, there are no set "rulers" that can be used to estimate the workload associated with different activities. One way to find out about workload is to ask people to describe the feelings they experienced while performing a task. Because workload may be caused by different factors, we would like you to evaluate several of them individually rather than by lumping them into a single, global evaluation of overall workload. This set of six rating scales was developed for you to use in evaluating your experiences during this task. Please read the descriptions of the scales carefully. If you have any questions about any of the scales in the table, please ask me about them. It is extremely important that they be clear to you. You may keep the descriptions with you for reference while completing the scales.

For each of the six scales, you will evaluate the task by marking an X in a multiple of 5 that can range from 0 to 100 to reflect the point that matches your experience. Pay close attention to each scale's endpoint description when making your assessments. Note that when the rating scale for PERFORMANCE appears, the scale will go from "good" on the *left* to "bad" on the *right*. This means that a *low* number will represent good performance, while a *high* number will signify poor performance. This order has been confusing for some people. Read the description for each scale carefully before making your rating.

NASA-TLX Instructions

Part II

Pairwise Comparisons. Rating scales of this sort are extremely useful, but their utility is diminished by the tendency people have to interpret them in different ways. For example, some people feel that mental or temporal demands are the greatest contributors to workload regardless of the effort they expended in performing a given task or the level of performance they achieved. Others feel that if they performed well the workload must have been low; and if they performed poorly, then it must have been high. Still others believe that effort or feelings of frustration are the most important determinants of their experiences of workload. Previous studies using this scale have found several different patterns of results. In addition, the factors that determine workload differ depending on the task. For instance, some tasks might be difficult because they must be completed very quickly. Other tasks may seem easy or hard because the degree of mental or physical effort required. Some task may seem difficult because they cannot be performed well no matter how much effort is expended.

The next step in your evaluation is to assess the relative importance of the six factors in determining how much workload you experienced. You will be presented with pairs of rating scale titles (e.g. EFFORT vs. MENTAL DEMAND) and asked to choose which of the two items was more important to your experience of workload in the task that you just performed. Each pair of scale titles will appear together and you will be asked to circle the more important one. After indicating your response to a pair of scale titles, please go on to the next pair until you have selected a response for all pairs.

Please consider your choices carefully and try to make them consistent with your scale ratings. Refer back to the rating scale definitions if you need to as you proceed. There is no correct pattern of responses. We are only interested in your opinions.

RATING SCALE DEFINITIONS

Title	Endpoints	Descriptions
MENTAL DEMAND	LOW/HIGH	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	LOW/HIGH	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	LOW/HIGH	How much time pressure did you feel due to the rate or pace at which the task or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
PERFORMANCE	GOOD/POOR	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
EFFORT	LOW/HIGH	How hard did you have to work (mentally and physically) to accomplish your level of performance?
FRUSTRATION LEVEL	LOW/HIGH	How insecure, discouraged, irritated, stressed, and annoyed versus gratified, content, relaxed, and complacent did you feel during the task?

Scoring Form 1

1. Mental Demand - Individual

Low High

2. Physical Demand - Individual

Low High

3. Temporal Demand - Individual

Low High

4. Performance - Individual

Good Bad

5. Effort - Individual

Low High

6. Frustration - Individual

Low High

Scoring Form 2

For each of the pairs (e.g., mental demand vs. effort) choose which one of the two items was more important to *your experience of workload* (Circle).

Circle one of each pair:

Sources of Workload Comparisons

Effort or Performance	Temporal Demand or Frustration
Temporal Demand or Effort	Physical Demand or Frustration
Performance or Frustration	Physical Demand or Temporal Demand
Physical Demand or Performance	Temporal Demand or Mental Demand
Frustration or Effort	Performance or Mental Demand
Performance or Temporal Demand	Mental Demand or Effort
Mental Demand or Physical Demand	Effort or Physical Demand
Frustration or Mental Demand	

APPENDIX L

DEBRIEFING FORM

Debriefing Form

This experiment was designed to examine team communication and performance in planning reconnaissance missions with unmanned ground and aerial vehicles. More specifically, we were interested in looking at how and when you engaged in implicit coordination, which is giving information or resources to your teammate without being asked for them. We manipulated whether or not you received the same training as your teammate and then also manipulated whether or not you believed you received the same training. Therefore, some of you were in a condition in which we deceived you into believing your teammate received the same or different training than you when that was untrue. This deception was necessary to determine whether your perceptions influenced your actual performance. If you have any questions about the study or would like to discuss your experience regarding this deception, please feel free to ask them now. We want you to know that we could not do our work without your help, so your participation is greatly appreciated. If you would like to learn more about the findings of this study, please feel free to contact Raegan Hoeft at 407-921-3554 or hoeft2@hotmail.com.

Thank you for your participation**.**

APPENDIX M

PERCEPTIONS OF SHAREDNESS MANIPULATION MATERIALS

The following materials were read to participants at specified times during the scenarios. The highlighted portions are the differences between the Low and High Perceptions conditions.

Military Reconnaissance Planning Study Explanation – Low Perceptions

Thank you for your participation in our study. Today you will be working together as a team to plan military reconnaissance missions using robotic assets, specifically unmanned aerial and unmanned ground vehicles. Each of you will be in charge of one specific asset. We are interested in how teams of operators plan these missions, the types of information they find important, the strategies they use, etc. First you will be given training on how to plan reconnaissance missions and how you will complete today's tasks. You will receive two different types of training. One of you will be the "Reconnaissance Equipment Operator" and the other will be the "Surveillance Systems Operator". You will be given a notepad and pen should you want to take notes during the training. The training will be given via Microsoft PowerPoint. To move forward to the next slide you can either click on the mouse button or use the space bar. Once you complete the training, you will be asked to complete some paperwork and then plan a number of reconnaissance missions. The entire session should last approximately 2 hours. Again, you will be given different training for Reconnaissance Equipment Operator and Surveillance Systems Operator. Do you have any questions?

Military Reconnaissance Planning Study Explanation – High Perceptions

Thank you for your participation in our study. Today you will be working together as a team to plan military reconnaissance missions using robotic assets, specifically unmanned aerial and unmanned ground vehicles. Each of you will be in charge of one specific asset. We are interested in how teams of operators plan these missions, the types of information they find important, the strategies they use, etc. First you will be given training on how to plan reconnaissance missions and how you will complete today's tasks. You will both receive the same training as "Reconnaissance Equipment Operators". You will be given a notepad and pen should you want to take notes during the training. The training will be given via Microsoft PowerPoint. To move forward to the next slide you can either click on the mouse button or use the space bar. Once you complete the training, you will be asked to complete some paperwork and then plan a number of reconnaissance missions. The entire session should last approximately 2 hours. Again, you will both be given the same training for Reconnaissance Equipment Operators. Please let me know when you have completed the training. Do you have any questions?

Practice Session Explanation – Low Perceptions

Now that you have completed your individual training as Reconnaissance Equipment Operator and Surveillance Systems Operator, you will be given a 15 minute practice session before the actual performance portion of this study. This practice session is to allow you to become familiar with how to use the software and with the type of information that you will be provided with during each scenario. You have received different training, and during the remainder of the study, you will be in charge of drawing the route for only one robotic asset. The Reconnaissance Equipment Operator at Computer A (*point to the person at computer A*) will be in charge of the UAV while the Reconnaissance Equipment Operator at Computer B (*point to the person at computer B*) will be in charge of the UGV. During the practice session, you will not communicate with one another, you will simply take the time to get used to the software and to practice planning a route for your asset. You will receive a packet of information that will help you in your planning. Feel free to write on the paperwork if it will help you. You can highlight or underline important pieces of information, or you can make notes for yourself, whatever will help you plan the mission. On the map, there is a red arrow pointing down from the top edge. This is where your routes should begin and end. Do you see the red arrow? Do you have any questions? Please put your headphones on now. You may begin.

Practice Session Explanation – High Perceptions

Now that you have both completed your training as Reconnaissance Equipment Operators, you will be given a 15 minute practice session before the actual performance portion of this study. This practice session is to allow you to become familiar with how to use the software and with the type of information that you will be provided with during each scenario. You have both received the same training; however, during the remainder of the study, you will be in charge of actually drawing the route for only one robotic asset. The Reconnaissance Equipment Operator at Computer A (*point to the person at computer A*) will be in charge of the UAV while the Reconnaissance Equipment Operator at Computer B (*point to the person at computer B*) will be in charge of the UGV. During the practice session, you will not communicate with one another, you will simply take the time to get used to the software and to practice planning a route for your asset. You will receive a packet of information that will help you in your planning. Feel free to write on the paperwork if it will help you. You can highlight or underline important pieces of information, or you can make notes for yourself, whatever will help you plan the mission. On the map, there is a red arrow pointing down from the top edge. This is where your routes should begin and end. Do you see the red arrow? Do you have any questions? Please put your headphones on now. You may begin.

First Scenario Explanation – Low Perceptions

We are now ready to begin the performance part of the experiment. You are now going to plan your first mission together as a team. You will each be given a packet of papers to help you plan the mission. It is up to you to determine what information is important and what isn't, what you want to share with your teammate and what you don't. You will not necessarily have all of the same information as your teammate. You will not be allowed to talk to one another during the planning; you must communicate with each other via the Chat Window on the right hand side of the screen. While you will each be planning the routes for separate vehicles, you must ultimately agree on those routes before you are finished. Remember, you were trained as a Reconnaissance Equipment Operator and you will be responsible for the UAV route. You were trained as a Surveillance Systems Operator and you will be responsible for the UGV route. Your computers are already set to the appropriate colors for each route. As with the training, you can highlight or underline important pieces of information, or you can make notes to yourself in your packet of information.

For Scenario 1: On the map, there is a red arrow pointing up from the bottom edge.
For Scenario 2: On the map, there is a red arrow pointing in from the right edge.

This is where your routes should begin and end. Do you see the red arrow? Do you have any questions? You may begin.

First Scenario Explanation – High Perceptions

We are now ready to begin the performance part of the experiment. You are now going to plan your first mission together as a team. You will each be given a packet of papers to help you plan the mission. It is up to you to determine what information is important and what isn't, what you want to share with your teammate and what you don't. You will not necessarily have all of the same information as your teammate. You will not be allowed to talk to one another during the planning; you must communicate with each other via the Chat Window on the right hand side of the screen. While you will each be planning the routes for separate vehicles, you must ultimately agree on those routes before you are finished. Again, although both of you were trained as Reconnaissance Equipment Operators, Computer A will still be responsible for the UAV route and Computer B will still be responsible for the UGV route. Your computers are already set to the appropriate colors for each route. As with the training, you can highlight or underline important pieces of information, or you can make notes to yourself in your packet of information.

For Scenario 1: On the map, there is a red arrow pointing up from the bottom edge.
For Scenario 2: On the map, there is a red arrow pointing in from the right edge

This is where your routes should begin and end. Do you see the red arrow? Do you have any questions? You may begin.

Second Scenario Explanation – Low Perceptions

You are now going to plan your second mission together as a team. Again, you will each be given a packet of papers to help you plan the mission. It is up to you to determine what information is important and what isn't, what you want to share with your teammate and what you don't. You will not necessarily have all of the same information as your teammate. You will not be allowed to talk to one another during the planning; you must communicate with each other via the Chat Window on the right hand side of the screen. While you will each be planning the routes for separate vehicles, you must ultimately agree on those routes before you are finished. Again, you were trained as a Reconnaissance Equipment Operator and you will be responsible for the UAV route. You were trained as a Surveillance Systems Operator and you will be responsible for the UGV route. Your computers are already set to the appropriate colors for each route. As with the first mission, you can highlight or underline important pieces of information, or you can make notes to yourself in your packet of information.

For Scenario 1: On the map, there is a red arrow pointing up from the bottom edge.
For Scenario 2: On the map, there is a red arrow pointing in from the right edge.

This is where your routes should begin and end. Do you see the red arrow? Do you have any questions? You may begin.

Second Scenario Explanation – High Perceptions

You are now going to plan your second mission together as a team. Again, you will each be given a packet of papers to help you plan the mission. It is up to you to determine what information is important and what isn't, what you want to share with your teammate and what you don't. You will not necessarily have all of the same information as your teammate. You will not be allowed to talk to one another during the planning; you must communicate with each other via the Chat Window on the right hand side of the screen. While you will each be planning the routes for separate vehicles, you must ultimately agree on those routes before you are finished. Again, although both of you were trained as Reconnaissance Equipment Operators, Computer A will still be responsible for the UAV route and Computer B will still be responsible for the UGV route. Your computers are already set to the appropriate colors for each route. As with the first mission, you can highlight or underline important pieces of information, or you can make notes to yourself in your packet of information.

For Scenario 1: On the map, there is a red arrow pointing up from the bottom edge.
For Scenario 2: On the map, there is a red arrow pointing in from the right edge.

This is where your routes should begin and end. Do you see the red arrow? Do you have any questions? You may begin.

APPENDIX N

DIFFERENCES BETWEEN TRAINING MODULES

Differences between Training Modules

Emphasis on Speed (Module 1) vs. Accuracy (Module 2)

Module 1

Developing R&S Plan

- R&S planning is *extremely time-critical*
  - Requests for immediate R&S missions are common
  - Quick decision-making is key
    - You must immediately begin planning the mission as soon as the request is received
    - You must be able to make quick decisions so that the mission can commence as soon as possible
    - You must be able to make quick decisions – use all of the information that is available and relevant

Developing R&S Plan

- R&S planning is *extremely time-critical*
  - Continued…
    - If you are missing information, you must make your best educated guess and plan accordingly
    - You are discouraged from requesting additional information from your superiors because there is no guarantee that they have that information or can get it to you in time
    - Keep this time-critical factor in mind as you learn about the different types of information you may or may not have available
  - Do not sacrifice quickness for accuracy! It is better to be fast than perfect.

Summary

1. Planning is time-critical
2. Do not ask superiors for help
3. Use all your assets
4. UAVs can travel great distances quickly, but they are strongly impacted by weather conditions and can only provide an overview rather than specific details
5. Always consider using an Augmenting or Redundancy strategy before a strategy that does not utilize all assets

Module 2

Developing R&S Plan

- R&S planning must be *as accurate as possible*
  - Requests are usually placed 24 hours in advance
  - Accurate decision-making is key
    - You must familiarize yourself with all available information first in order to have a complete understanding of the task
    - You must be able to make accurate decisions so that the mission can be as successful as possible
    - You must be able to make well-informed decisions – use only the information that is accurate and up-to-date

Developing R&S Plan

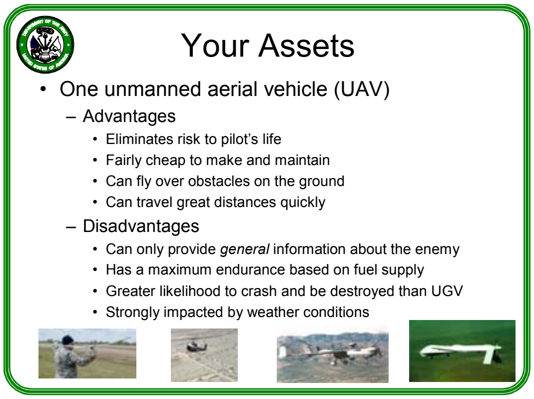
- R&S planning must be *as accurate as possible*
  - Continued…
    - If you are missing information, you should never guess what that information might be
    - You are encouraged to request additional information from your superiors in order to make sure your information is up-to-date
    - Keep this accuracy factor in mind as you learn about the different types of information you may or may not have available
  - Do not sacrifice accuracy for quickness!! It is better to be correct than fast.

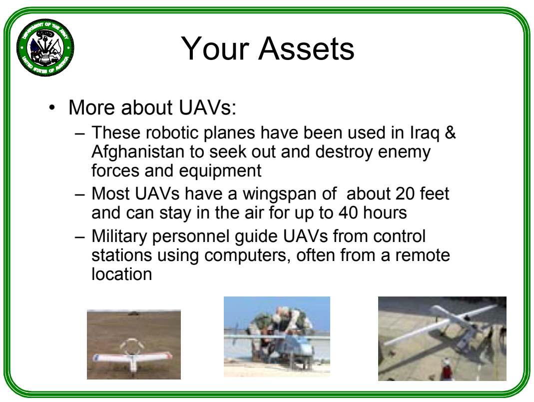
Summary

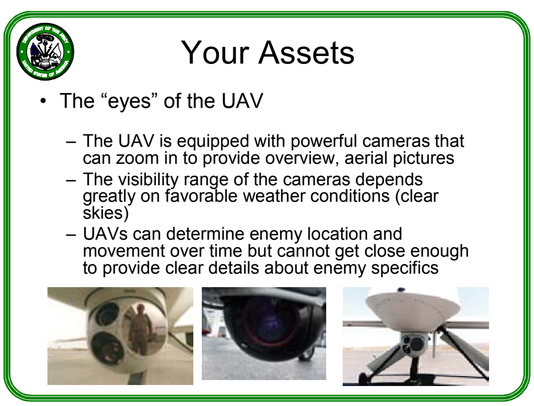
1. Planning must be accurate
2. Ask superiors for help if you are missing information
3. Protect your assets as much as possible
4. UGVs can get very close to the enemy to provide specific details, but they are strongly impacted by terrain conditions and take longer to travel from one place to another
5. Always consider using a Cueing strategy or one asset only strategy before a strategy that uses all assets

Emphasis on UAV (Module 1) vs. UGV (Module 2)

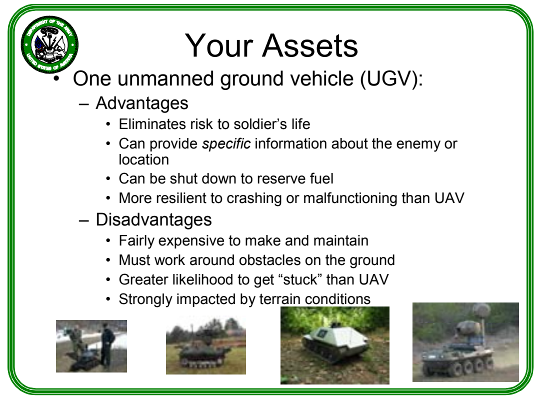
Module 1

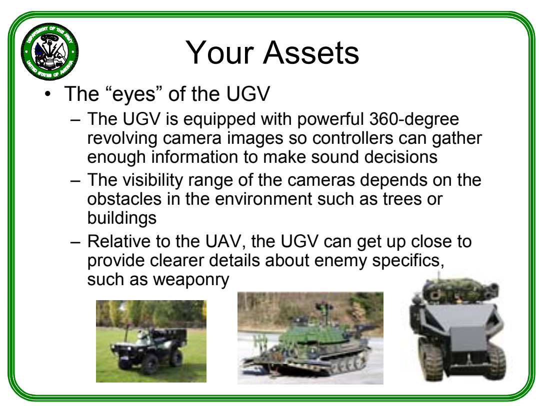






Module 2





Emphasis on UAV (Module 1) vs. UGV (Module 2) - continued

Module 1

Your Assets

- Here are some sample views from UAVs




Summary

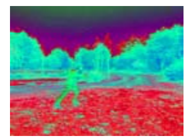
1. Planning is time-critical
2. Do not ask superiors for help
3. Use all your assets
4. UAVs can travel great distances quickly, but they are strongly impacted by weather conditions and can only provide an overview rather than specific details
5. Always consider using an Augmenting or Redundancy strategy before a strategy that does not utilize all assets

Module 2

Your Assets

- Here are some sample views from UGVs






Summary

1. Planning must be accurate
2. Ask superiors for help if you are missing information
3. Protect your assets as much as possible
4. UGVs can get very close to the enemy to provide specific details, but they are strongly impacted by terrain conditions and take longer to travel from one place to another
5. Always consider using a Cueing strategy or one asset only strategy before a strategy that uses all assets

Emphasis on Using All Assets (Module 1) vs. Protecting Assets (Module 2)

Module 1

Your Assets

- It is important that you utilize all assets that are available
  - Robotic assets, such as UGVs and UAVs, should be used as much as possible
    - Military rules state that you must use of all available assets
    - Robots are fairly inexpensive and easy to replace if lost
    - Using one asset to complete a task that two assets can do more efficiently can lead a waste of time and other resources
  - It is inefficient and a waste of money to not use assets that are at your disposal

Your Assets

- There are a number of different strategies for using your assets
  - Use both assets
    - Augmenting strategy – sending out both the UGV and the UAV along separate routes to cover more area in less time
    - Redundancy strategy – sending both the UGV and UAV along the same routes to the same locations to have two views in case one asset is lost
    - Cueing strategy – sending out the UAV first to determine whether the UGV is needed at all
  - Use only one asset (only UGV or only UAV)

Your Assets

- As previously noted, it is important that you try to take advantage of all your assets
  - This decision will be based on an assessment of all available information, including time pressures and environmental conditions (i.e., When does the commander need the information? Is there enough time to send out both assets along the same route or will separate routes be more efficient? What are the weather conditions? Can both assets even be used?)
    - *Augmenting or redundancy strategy should be considered first*
    - Cueing strategy should be considered second
    - Using only one asset should be a last resort

Module 2

Your Assets

- It is important that you protect your assets as much as possible
  - Robotic assets, such as UGVs and UAVs, should not be overused
    - Military rules state that you must protect and preserve your assets
    - Robots are very expensive and difficult to replace if lost
    - Using numerous assets to complete a task that one asset can do can lead to an unnecessary loss of assets
  - It is inefficient and a waste of money to use all assets that are at your disposal when one asset can successfully complete the task

Your Assets

- There are a number of different strategies for using your assets
  - Use only one asset (only UGV or only UAV)
  - Use both assets
    - Cueing strategy – sending out the UAV first to determine whether the UGV is needed at all
    - Augmenting strategy – sending out both the UGV and the UAV along separate routes to cover more area in less time
    - Redundancy strategy – sending both the UGV and UAV along the same routes to the same locations to have two views in case one asset is lost

Your Assets

- As previously noted, it is important that you protect your assets as much as possible
  - This decision will be based on an assessment of all available information, including time pressures and environmental conditions (i.e., When does the commander need the information? Should both assets be used or will one be sufficient? What are the terrain conditions? Which one could be sent out alone?)
    - *Using only one asset should be considered first*
    - Cueing strategy should be considered second
    - Augmenting or redundancy strategy should be a last resort

Emphasis on Using All Assets (Module 1) vs. Protecting Assets (Module 2) - continued

Module 1

Summary

1. Planning is time-critical
2. Do not ask superiors for help
3. Use all your assets
4. UAVs can travel great distances quickly, but they are strongly impacted by weather conditions and can only provide an overview rather than specific details
5. Always consider using an Augmenting or Redundancy strategy before a strategy that does not utilize all assets

Module 2

Summary

1. Planning must be accurate
2. Ask superiors for help if you are missing information
3. Protect your assets as much as possible
4. UGVs can get very close to the enemy to provide specific details, but they are strongly impacted by terrain conditions and take longer to travel from one place to another
5. Always consider using a Cueing strategy or one asset only strategy before a strategy that uses all assets

Emphasis on Augmenting or Redundancy Strategies (Module 1) vs. One Asset or Cueing Strategies (Module 2)

Module 1

Your Assets

- Using both the UAV and UGV
  - There may be occasions where using both assets is more effective than using only one asset
  - For example, environmental conditions may make the UGV or UAV partially inoperable or inefficient requiring backup or support from the other asset
  - You may not have enough time to send out only one asset to collect all of the information
  - It will be your job to determine whether using both assets is the best solution given the available information and resources

Your Assets

- Augmenting Strategy
  - Using numerous assets at the same time to support the R&S plan
  - Sending those assets along different routes; the UAV can go to certain Objectives while the UGV can go to other Objectives
  - This allows for the collection of the most amount of information in the shortest amount of time
  - Augmenting call also be a useful strategy when environmental factors are influencing the usefulness of one or more assets

Augmenting Strategy

You can see that by sending the UAV and UGV on different

You can see also see that the UAV does not have to abide by the roads or paths available, while the UGV does.

Module 2

Your Assets

- Using either the UAV or UGV solely
  - There may be occasions where using only one asset is more effective than using both assets
  - For example, environmental conditions may make the UGV or UAV inoperable or inefficient
  - You may simply be more familiar and more comfortable with one asset as opposed to the other
  - It will be your job to determine whether using one asset is the best solution given the available information and resources

Your Assets

- UGV Only Strategy
  - Using only the UGV to collect all of the necessary information from the various Objectives
  - With this strategy only one route is necessary
  - There must be enough time for the UGV to navigate along its route to collect all the information
  - This strategy may be best when extremely specific information is needed and the asset must get close to the enemy
  - This strategy many also be useful when the terrain conditions make the UAV inefficient, such as in dense urban environments or jungle environments

UGV Only Strategy

Note that city environments can be especially treacherous for UGVs, as there will likely be obstacles and/or unsafe routes which could lead to the loss of the UGV.

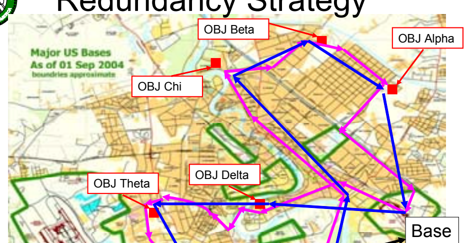
Emphasis on Augmenting or Redundancy Strategies (Module 1) vs. One Asset or Cueing Strategies (Module 2) - continued

Module 1

Your Assets

- Redundancy Strategy
  - Using numerous assets at the same time to support the R&S plan
  - Sending those assets along the same route; the UAV and the UGV both go to all Objectives
  - This strategy ensures continuous coverage and multiple viewpoints of all Objectives
  - Augmenting call also be a useful strategy when environmental factors are influencing the usefulness of one or more assets

Redundancy Strategy



Note that even though the UAV can get to the next Objective more quickly, it must wait for the UGV to arrive before moving on. This means that the amount of fuel the UAV has will be important in determining whether to use this strategy.

Your Assets

- As previously noted, it is important that you try to take advantage of all your assets
  - This decision will be based on an assessment of all available information, including time pressures and environmental conditions (i.e., When does the commander need the information? Is there enough time to send out both assets along the same route or will separate routes be more efficient? What are the weather conditions? Can both assets even be used? Which one could be sent out alone?)
    - *Augmenting or redundancy strategy should be considered first*
    - Cueing strategy should be considered second
    - Using only one asset should be a last resort

Module 2

Your Assets

- UAV Only Strategy
  - Using only the UAV to collect all of the necessary information from the various Objectives
  - With this strategy only one route is necessary
  - This strategy may be useful when there is a limited amount of time to collect the information because the UAV can travel quickly
  - This strategy may be best when only general information is needed and the asset does not need to get close to the enemy
  - This strategy many also be useful when the terrain conditions make the UGV inefficient, such as with rivers without bridges, mountainous regions, or roadblocks

UAV Only Strategy

Note that city environments can be treacherous for UAVs because there are numerous buildings, power lines, etc. that can interfere with the communication between the UAV and the command, which could lead to complete loss of signal, and consequently, the UAV.

Your Assets

- As previously noted, it is important that you protect your assets as much as possible
  - This decision will be based on an assessment of all available information, including time pressures and environmental conditions (i.e., When does the commander need the information? Should both assets be used or will one be sufficient? What are the terrain conditions? Which one could be sent out alone?)
    - *Using only one asset should be considered first*
    - Cueing strategy should be considered second
    - Augmenting or redundancy strategy should be a last resort

Emphasis on Augmenting or Redundancy Strategies (Module 1) vs. One Asset or Cueing Strategies (Module 2) - continued

Module 1

Summary

1. Planning is time-critical
2. Do not ask superiors for help
3. Use all your assets
4. UAVs can travel great distances quickly, but they are strongly impacted by weather conditions and can only provide an overview rather than specific details
5. Always consider using an Augmenting or Redundancy strategy before a strategy that does not utilize all assets

Module 2

Summary

1. Planning must be accurate
2. Ask superiors for help if you are missing information
3. Protect your assets as much as possible
4. UGVs can get very close to the enemy to provide specific details, but they are strongly impacted by terrain conditions and take longer to travel from one place to another
5. Always consider using a Cueing strategy or one asset only strategy before a strategy that uses all assets

Emphasis on Weather (Module 1) vs. Terrain (Module 2)

Module 1

Effects of Weather

- You must have a working knowledge of weather in order to prepare for possible adverse conditions
- Weather factors that can affect R&S planning
  - Reduced visibility
  - Surface winds
  - Precipitation
  - Cloud Coverage
  - Temperature
  - Humidity

Effects of Weather

- Reduced visibility
  - Can be beneficial because conceals positions and can aid in achieving surprise
  - Can also hinder the effectiveness of R&S when cannot see where the enemy is
- Surface winds
  - Strong winds limit airborne and aviation operations
  - Can damage material and structures, create false radar returns, cause personal injury, add to reduced visibility

Effects of Weather

- Precipitation
  - Affects mobility of forces and tracked or wheeled equipment or vehicles
  - Can reduce visibility
  - Heavy rains can make some unpaved, low-lying, and off-road areas impassable
  - Can drastically reduce personnel effectiveness by causing discomfort, increasing fatigue, and creating other physical and psychological problems

Module 2

Effects of Terrain

- You must have a working knowledge of terrain in order to prepare for possible adverse conditions
- Terrain factors that can affect R&S planning
  - City
    - Buildings and roads
  - Desert
    - Sand and lack of established paths
  - Jungle
    - Thick vegetation

Effects of Terrain

- City environment
  - Buildings can be used for observation posts and to conceal position from enemies but may also obstruct views of the enemy and hide snipers
  - Buildings and electrical power lines can interfere with radio communications
  - Roads and alleyways are already established routes to navigate through the city but can also expose forces to enemy observation and possible fire

Effects of Terrain

- Desert
  - Wide open spaces provide little concealment for friendly or enemy forces
  - Obstacles including quicksand, wet sand, and sand dunes can make travel difficult
  - Lack of established roads and the presence of landmines can also make travel difficult
  - Radio communications and signals should be clear unless weather conditions are adverse

Emphasis on Weather (Module 1) vs. Terrain (Module 2) - continued

Module 1

Effects of Weather

- Cloud coverage
  - Can influence aviation operations
  - Affects ground operations by reducing illumination and visibility or by enhancing effects of artificial light
- Temperature and Humidity
  - High temps can lead to heat-related injuries and engine wear that leads to equipment failures
  - Low temps can lead to cold weather injuries and cause damage to vehicle cooling systems and engines

Effects of Weather

- Any of these aspects of weather can significantly impact which assets to use
  - Will a UAV be able to successfully fly to its assigned location, collect the appropriate information, and then communicate that information back?
  - Will the weather significantly impact the terrain to impede the ability of the UGV to navigate to its assigned location, collect the appropriate information, and then communicate that information back?

Summary

1. Planning is time-critical
2. Do not ask superiors for help
3. Use all your assets
4. UAVs can travel great distances quickly, but they are strongly impacted by weather conditions and can only provide an overview rather than specific details
5. Always consider using an Augmenting or Redundancy strategy before a strategy that does not utilize all assets

Module 2

Effects of Terrain

- Jungle
  - Thick vegetation, rivers, swampy areas, and sharp ridges can all slow movement and reduce radio communications
  - Tree-top canopies can reduce illumination from below and limit visibility from aerial vehicles above
  - Wildlife can also affect mobility as well as attention

Effects of Terrain

- Any of these aspects of terrain can significantly impact which assets to use
  - Will a UGV be able to successfully navigate to its assigned location, collect the appropriate information, and then communicate that information back?
  - Will the terrain significantly impact the UAV's ability to view its assigned location, collect the appropriate information, and then communicate that information back?

Summary

1. Planning must be accurate
2. Ask superiors for help if you are missing information
3. Protect your assets as much as possible
4. UGVs can get very close to the enemy to provide specific details, but they are strongly impacted by terrain conditions and take longer to travel from one place to another
5. Always consider using a Cueing strategy or one asset only strategy before a strategy that uses all assets

Emphasis on Not asking for Help (Module 1) vs. Asking for Help (Module 2)

Module 1

Developing R&S Plan

- R&S planning is *extremely time-critical*
  - Continued…
    - If you are missing information, you must make your best educated guess and plan accordingly
    - You are discouraged from requesting additional information from your superiors because there is no guarantee that they have that information or can get it to you in time
    - Keep this time-critical factor in mind as you learn about the different types of information you may or may not have available
  - Do not sacrifice quickness for accuracy! It is better to be fast than perfect.

Summary

1. Planning is time-critical
2. Do not ask superiors for help
3. Use all your assets
4. UAVs can travel great distances quickly, but they are strongly impacted by weather conditions and can only provide an overview rather than specific details
5. Always consider using an Augmenting or Redundancy strategy before a strategy that does not utilize all assets

Module 2

Developing R&S Plan

- R&S planning must be *as accurate as possible*
  - Continued…
    - If you are missing information, you should never guess what that information might be
    - You are encouraged to request additional information from your superiors in order to make sure your information is up-to-date
    - Keep this accuracy factor in mind as you learn about the different types of information you may or may not have available
  - Do not sacrifice accuracy for quickness!! It is better to be correct than fast.

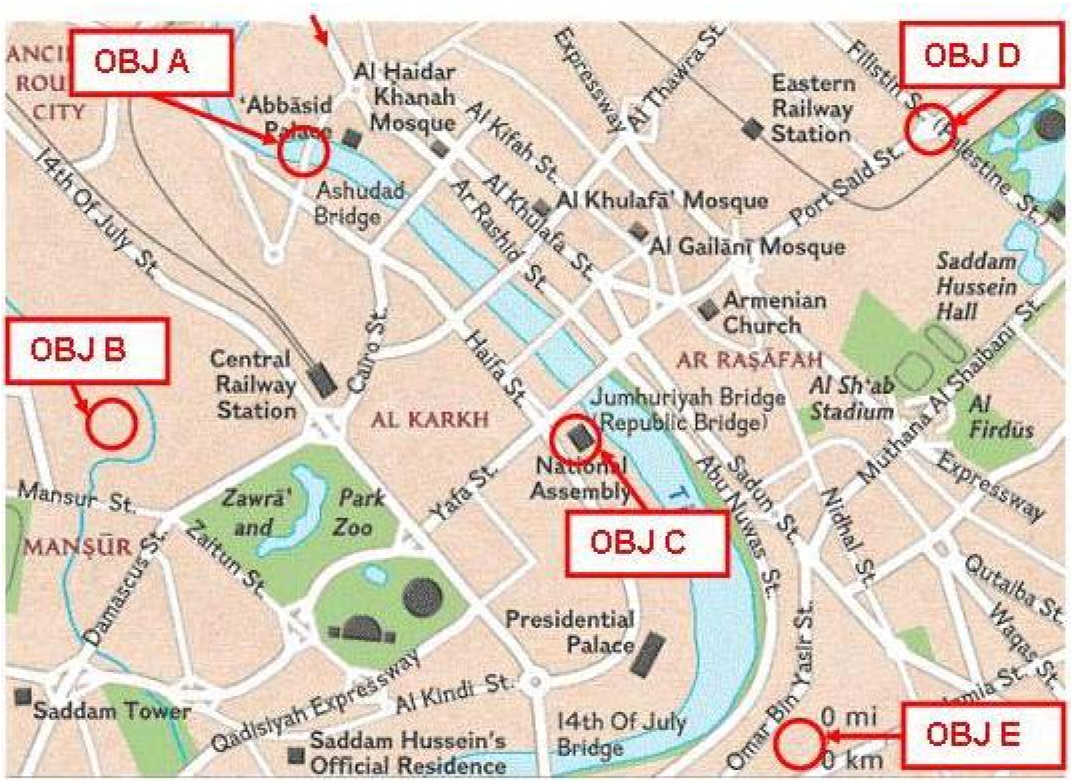
Summary

1. Planning must be accurate
2. Ask superiors for help if you are missing information
3. Protect your assets as much as possible
4. UGVs can get very close to the enemy to provide specific details, but they are strongly impacted by terrain conditions and take longer to travel from one place to another
5. Always consider using a Cueing strategy or one asset only strategy before a strategy that uses all assets

APPENDIX O

SCENARIO MATERIALS

Training Scenario Materials



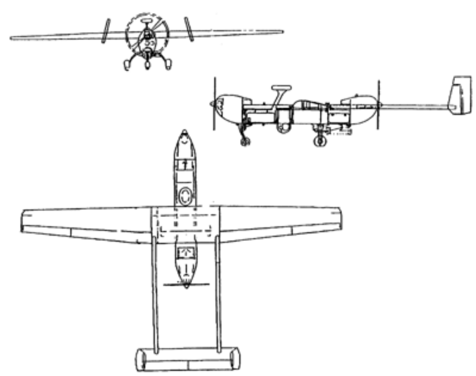
OPERATION ORDER 99-A

References:

Map of Baghdad provided on your computer display. Baghdad is the capital of Iraq. It is the second largest city in Southwest Asia. The city sits on the Tigris River and was once the center of the Islamic civilization. The city is mostly flat, with the western side of the city having wider boulevards, more expensive homes and more government buildings. Low-income housing is generally located in the east. The map provided is an up to date map.

<u>Time Zone Used Throughout the Order</u>: Local Time

<u>Task Organization</u>: There is one asset available for this mission: one unmanned aerial vehicle (UAV). The UAV available for this mission is the Hunter, seen in the pictures below. The Hunter is a short range joint-tactical unmanned aircraft system for surveillance and reconnaissance missions. The endurance of the aircraft is more than 11 hours and the cruise speed is 70 knots. The Hunter aircraft is 23 ft in length and has a 29 ft wingspan. The system operates at an altitude of 15,000 ft and at a range of 200 kilometers. A C-Band datalink ties the vehicle to a ground station. The sensor package sends day television or night infrared imagery to the ground. A sample image taken by a Hunter is shown below. **You will be in charge of planning the route for the Hunter UAV.**



SITUATION

Enemy Forces

Weather and Light Data and General Forecast

Skies: Clear skies morning and night. Partly cloudy over night, cloud base 10,000 ft. There should be no problems with using any aerial assets.

Visibility: Unlimited at flying level.

Winds: North to Northwest. Speed not expected to exceed 10 knots. These conditions will not affect the flying capabilities of the UAV.

Temperatures: from 65 degrees F to 73 degrees F.

Light Data: Sunrise 6:08 AM. Sunset 8:15 PM.

Trafficability: Good.

Precipitation: None predicted. Maximum precipitation per month: 20 inches. Average precipitation per month: 5 inches.

Locations: Previous intelligence suggests that the enemy is at OBJ B, OBJ A, OBJ D. The enemy may or may not be present at OBJ C and OBJ E. The key terrain in this mission is near the Tigris River. In order for us to have use of the river for transportation, we need to secure stations along the river. OBJ A is a drawbridge that is a crucial necessity in controlling the river. OBJ C is the National Assembly building directly on the river. This building is frequented by important officials and therefore needs to be protected. Finally, OBJ E is an open area that would be a good place to establish a military post. In fact, while there are three Objectives, it would be best to travel as much of the river as possible during the mission.

Activity: The enemy has been seen at Saddam Hussein Hall with missile launchers; therefore you should not fly over the area near the Hall because you could get shot down. Also, there has been some activity near the zoo. In order to not alert the enemy that we are in the area, do not fly over the zoo either.

Strength: No data has been provided as to the strength or hostility of the enemy.

Probable Course of Action: Unknown.

Friendly Forces: There are no friendly forces in downtown Baghdad that need to be considered when planning your routes.

Attachments and Detachments: No attachments or detachments.

Assumptions: Even though we have no intelligence confirming, we must assume the enemy is hostile.

MISSION

Commander's Intent: There are two specific purposes for this mission. First, we must take control of that River. That is the primary objective. I want to know everything about those locations on the river first! I want to know if the enemy is there, how many there are, what are they doing, and how they are traveling from one location to the other. The second objective is to gain as much information about the enemy as possible while keeping focus on the river. So, while we need info on the other Objectives as well, they are not the priority. Taking control of that river is key!

EXECUTION

Concept of the Operation: The unit has a UAV to complete this task. The asset can be used as seen fit by the operator. The asset should be used to collect all of the information requested by the Commander for each of the Objectives. *Start time is set for midnight and there is a 2 hour time limit*.

Maneuver: It is up to you to task the asset with its route and its specific information collection goals.

Fires: None.

OPERATION ORDER 099-B

References:
Map of Baghdad provided on your computer display. Baghdad is the capital of Iraq. It is the second largest city in Southwest Asia. The city sits on the Tigris River and was once the center of the Islamic civilization. The city is mostly flat, with the western side of the city having wider boulevards, more expensive homes and more government buildings. Low-income housing is generally located in the east. The map provided is an up to date map.

Time Zone Used Throughout the Order: Local Time

Task Organization: There is one asset available for this mission: one unmanned ground vehicle (UGV). The UGV available for this mission is the Talon, seen in the pictures below. The Talon is a powerful, durable, lightweight tracked vehicle designed for reconnaissance, communications, sensing and security. The robot has a top speed of 5.2 miles per hour and a single-charge run time of two to four hours. It weighs less than 100 lbs (45 kg) and can be easily carried and instantly ready for operation. The Talon has all-weather, day/night and amphibious capabilities and can navigate virtually any terrain. The Talon can hold up to seven color cameras, including night vision and zoom options. The Talon's control station and a sample image are shown below. **You will be in charge of planning the route for the Talon UGV.**

SITUATION

Enemy Forces

Terrain

Terrain: For downtown Baghdad, as seen in map. Downtown Baghdad is located in a desert area, characterized by flat, sandy land. The downtown area contains many residential and government buildings. The Tigris River flows through the center of downtown.

Obstacles: The Zawra Park and Zoo should be avoided at all costs, both on the ground and in the air. Frightened animals could alert the enemies of our presence. Additionally, the Jumhuriyah Bridge (Republic Bridge) was bombed last week and can no longer be used to cross the river.

Key terrain: The key terrain in this mission is near the Tigris River. In order for us to have use of the river for transportation, we need to secure stations along the river. OBJ A is a drawbridge that is a crucial necessity in controlling the river. OBJ C is the National Assembly building directly on the river. This building is frequented by important officials and therefore needs to be protected. Finally, OBJ E is an open area that would be a good place to establish a military post. In fact, while there are three Objectives, it would be best to travel as much of the river as possible during the mission.

Decisive terrain: OBJ D is a main intersection on the NE side of the downtown area and is a prime location to observe the traffic coming in and out of the city. It would be an excellent place to set up an observation post. OBJ B is an enemy stronghold. We will need to determine their numbers and weaponry to determine if we should attempt to attack.

Other key terrain: The desert conditions could make ground travel difficult. To avoid any issues, stick to the roads on the map.

Avenues of approach: The main avenues of approach are Port Said Street and the River. This is why it is crucial that we have control of both. You will enter the city from the north. Your line of departure is noted on the map.

Locations: Previous intelligence suggests that the enemy is at OBJ B, OBJ A, OBJ D. The enemy may or may not be present at OBJ C and OBJ E.

Activity: Previous intelligence reports suggest that the enemy has not been engaging in any significant activity that would affect your route planning.

Strength: No data has been provided as to the strength or hostility of the enemy.

Probable Course of Action: Unknown.

Attachments and Detachments: No attachments or detachments.

Friendly Forces: There are no friendly forces in downtown Baghdad that need to be considered when planning your routes

Assumptions: Even though we have no intelligence confirming, we must assume the enemy is hostile.

MISSION

Commander's Intent: There are two specific purposes for this mission. First, we must take control of that River. That is the primary objective. I want to know everything about those locations on the river first! I want to know if the enemy is there, how many there are, what are they doing, and how they are traveling from one location to the other. The second objective is to gain as much information about the enemy as possible while keeping focus on the river. So, while we need info on the other Objectives as well, they are not the priority. Taking control of that river is key!

EXECUTION

Concept of the Operation: The unit has a UGV to complete this task. The asset can be used as seen fit by the operator. The asset should be used to collect all of the information requested by the Commander for each of the Objectives. *Start time is set for midnight and there is a 2 hour time limit*.

Maneuver: It is up to you to task the asset with its route and its specific information collection goals.

Fires: None

Scenario 1 Materials

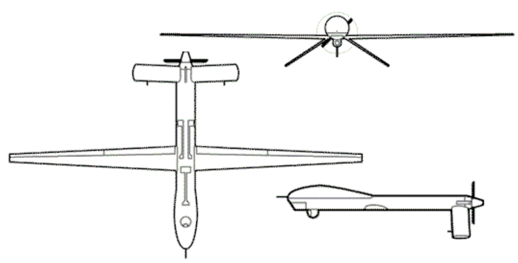
OPERATION ORDER 101-A

References:

Map of Samarra provided on your computer display. Sāmarrā is a town in Iraq situated on the bank of the river Tigris some sixty miles from the city of Baghdad. The city is of outstanding importance because of its two shrines. The map is a satellite image from November 2003.

<u>Time Zone Used Throughout the Order</u>: Local Time

<u>Task Organization</u>: There are two assets available for this mission, one unmanned aerial vehicle (UAV) and one unmanned ground vehicle (UGV). The UAV available for this mission is the Predator, seen in the pictures below. The Predator is a long endurance, medium altitude unmanned aircraft system for surveillance and reconnaissance missions. The endurance of the aircraft is more than 40 hours and the cruise speed is over 70 knots. The Predator aircraft is 27 ft in length and has a 49 ft wingspan. The system operates at an altitude of 25,000 ft and at a range of 400 nautical miles. The synthetic aperture radar, video cameras and a forward looking infra-red (FLIR) can provide surveillance imagery in real time both to the front line soldier and to the operational commander or worldwide via satellite communication. The Predator's camera and sample image taken by a Predator are shown below. **You will be in charge of planning the route for the Predator UAV.**


SITUATION

Enemy Forces

Weather and Light Data and General Forecast

Skies: Clear skies morning and night. Partly cloudy in the afternoon, cloud base 3,000 ft. A cloud ceiling of at least 2,500 ft is desired when using UAVs. There should be no problems with using any aerial assets.

Visibility: Unlimited at flying level. Limited ground level when wind gusts lift sand off ground. This means that a UAV might not get a clear picture of the ground. Remember that limited visibility can benefit the enemy because you might not be able to see them.

Winds: North to Northwest. Speed expected to exceed 20 knots until at least 9:00 PM. Occasional gusts up to 30 knots in afternoon. These conditions will affect the flying capabilities of the UAV. These conditions will also lift sand from the desert floor and hamper observation.

Temperatures: from 90 degrees F to 98 degrees F.

Light Data: Sunrise 6:00 AM. Sunset 8:20 PM.

Trafficability: Good.

Precipitation: None predicted. Maximum precipitation per month: 20 inches. Average precipitation per month: 5 inches.

Locations: Previous intelligence suggests that the enemy is at OBJ Cat, OBJ Dog, OBK Elk, and OBJ Fish. The enemy may or may not be present at OBJ Ant and OBJ Bird.

Activity: Previous intelligence reports suggest that the enemy has not been engaging in any significant activity that would affect your route planning.

Strength: Unknown.

Probable Course of Action: No enemy aircraft are expected to be in the area; therefore you should not concern yourself with avoiding enemy aircraft when planning your route.

Friendly Forces: There are no friendly forces in downtown Samarra that need to be considered when planning your routes.

Attachments and Detachments: No attachments or detachments.

Assumptions: None.

MISSION

Commander's Intent: There are two specific purposes for this mission. First, I want to know if the enemy has strongholds in the positions that our previous intelligence suggests. The goal is to swiftly enter the city, gather the information, and then report back to base. We need to move into the city in full force tomorrow and thus we need all this information ASAP.

EXECUTION

Concept of the Operation: The unit has a UAV and a UGV to complete this task. The assets can be used as seen fit by the operators. The assets should be used to collect all of the information requested by the Commander for each of the Objectives. The assets have *3 hours* to collect all of the information.

Maneuver: It is up to you to task the assets with their route(s) and their specific information collection goals. The UAV and UGV are equal assets in that one does not command the other. They can work together or separately as you, the operators, see fit.

Fires: None.

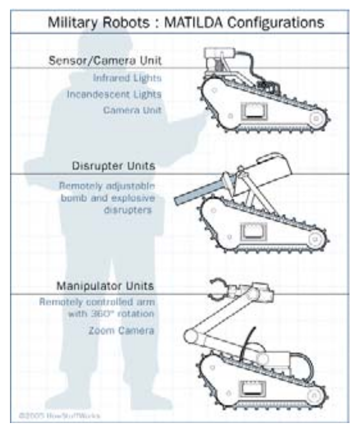
OPERATION ORDER 101-B

References:

Map of Samarra provided on your computer display. Sāmarrā is a town in Iraq situated on the bank of the river Tigris some sixty miles from the city of Baghdad. The city is of outstanding importance because of its two shrines. The map is a satellite image from November 2003.

Time Zone Used Throughout the Order: Local Time

Task Organization: There are two assets available for this mission, one unmanned aerial vehicle (UAV) and one unmanned ground vehicle (UGV). The UGV available for this mission is the Matilda, seen in the pictures below. The Matilda is a small-scale, tracked vehicle designed for remote reconnaissance, inspection, assessment and sampling. The robot has a top speed of 3 feet (1 meter) per second and a single-charge run time of four to six hours. It weighs 61 lbs (28 kg) with the batteries, can be carried by one or two people and fits in the trunk of a car. Matilda provides reconnaissance in limited-access areas, including under vehicles, aircraft, and inside buildings. Matilda is a tele-operated robot that responds to radio signals and the technology allows vehicles it get from one ground point to another and avoid obstacles on its own. The Matilda's control station and cameras are shown below. **You will be in charge of planning the route for the Matilda UGV.**



SITUATION

Enemy Forces

Terrain

Terrain: For downtown Samarra, as seen in satellite map. Downtown Samarra is located in a desert area; therefore any open spaces are sandy. The buildings are both residential and commercial. Samarra sits in a valley, with the center of the downtown area being the low point of that valley.

Obstacles: The Tigris River only has one main road that crosses over it to depart from downtown Samarra. This bridge is very well guarded and cannot be crossed by any ground vehicles.

Key terrain: OBJ Ant and OBJ Bird are two intersections that are essential to ensuring safe routes for friendly patrols and caravans that need to travel through Samarra. Both of these intersections will need to be visited and assessed in order to determine if the enemy has patrols there and what their capabilities are. OBJ Dog is the station in the middle of the bridge that crosses the Tigris River. Because that bridge is currently heavily guarded, it would be in our best interest to gain control of the area near OBJ Dog. By gaining control of the bridge, we could control who comes in and out of the city from the west side. This would be extremely beneficial in terms of both offensive and defensive future missions.

Decisive terrain: OBJ Cat, OBJ Elk, and OBJ Fish are three areas in Samarra where we believe the enemy has strongholds. We need to determine whether these are in fact strongholds before we can develop a plan of attack.

Other key terrain: The white building in the middle of downtown Samarra is the al-Askari Mosque. It is a holy building and no US forces should go near it. To the NE of that Mosque is a large rectangular wall with the open sands around it. That is the Great Mosque of Samarra and should also be avoided when planning your mission. No ground vehicles should approach either Mosque and no aerial vehicles should fly over them.

Avenues of approach: The main roads in Samarra are the only ones that should be used. All of the smaller roads and alleyways that connect the main roads are potentially enemy territory. In the past, US forces have been ambushed in these alleys. You will enter the city from the south. Your line of departure is noted on the map.

Locations: Previous intelligence suggests that the enemy is at OBJ Cat, OBJ Dog, OBK Elk, and OBJ Fish. The enemy may or may not be present at OBJ Ant and OBJ Bird.

Activity: Previous intelligence reports suggest that the enemy has not been engaging in any significant activity that would affect your route planning.

Strength: Unknown.

Probable Course of Action: If the enemy is moving, it is likely they will do so via the alleyways and small roads. Therefore, it is advisable to keep ground vehicles to the main road.

Friendly Forces: There are no friendly forces in downtown Samarra that need to be considered when planning your routes.

Attachments and Detachments: No attachments or detachments.

Assumptions: Even though we have no intelligence confirming, we must assume the enemy is hostile.

MISSION

Commander's Intent: There are two specific purposes for this mission. First, I want a coordinated move into the city. I want to collect specific information about the two intersections so that we know whether these are safe routes for us to move through. I want as specific as possible information about the bridge facilities and whether we can capture that location easily.

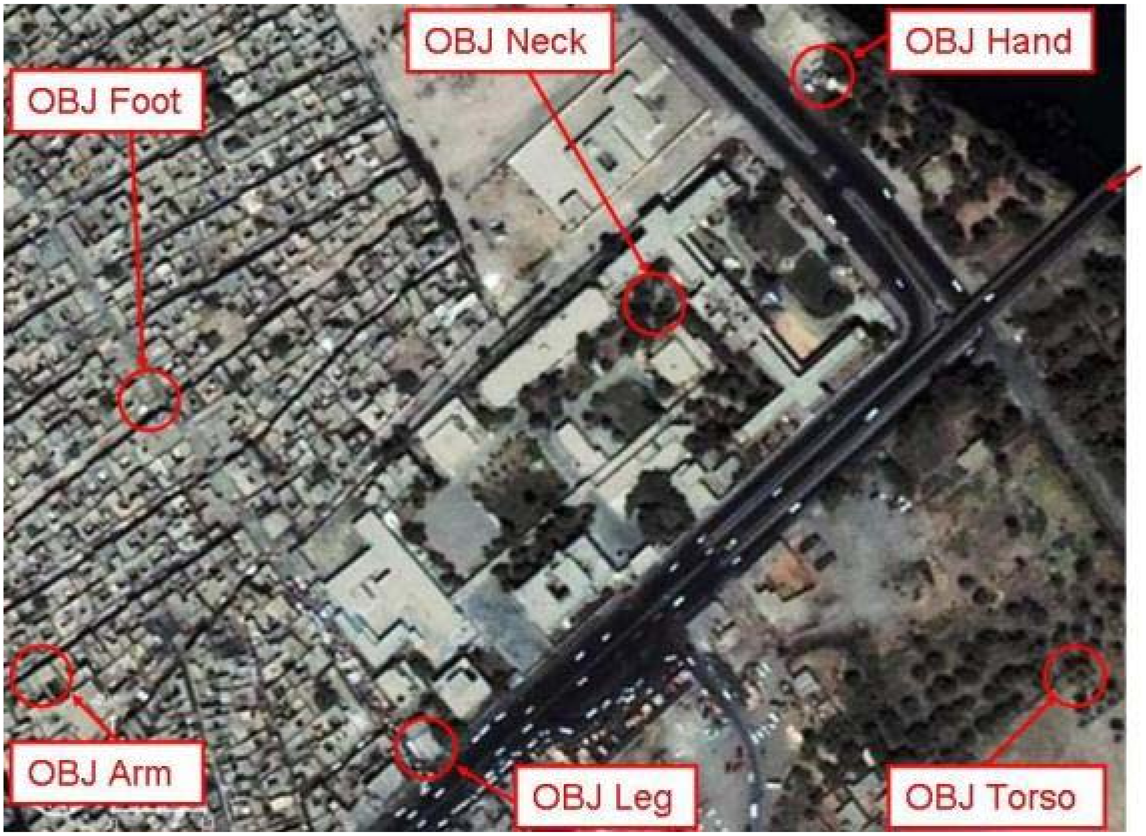
EXECUTION

Concept of the Operation: The unit has a UAV and a UGV to complete this task. The assets can be used as seen fit by the operators. The assets should be used to collect all of the information requested by the Commander for each of the Objectives. *Start time is set for noon.*

Maneuver: It is up to you to task the assets with their route(s) and their specific information collection goals. The UAV and UGV are equal assets in that one does not command the other. They can work together or separately as you, the operators, see fit.

Fires: None.

Scenario 2 Materials



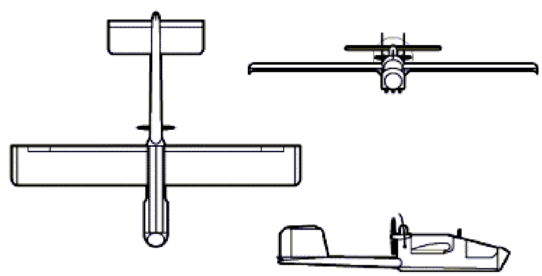
OPERATION ORDER 202-A

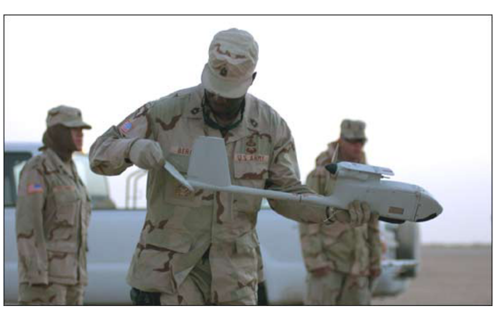
References:

Map of Al Kufah provided on your computer display. Al Kufah is a city in Iraq situated on the bank of the middle river Farut some 88 miles south of Baghdad. The city is almost 22 meters above sea level. It was a center of Arab culture and learning from the 8th to the 10th century. The map is a satellite image from November 2003.

<u>Time Zone Used Throughout the Order</u>: Local Time

<u>Task Organization</u>: There are two assets available for this mission, one unmanned aerial vehicle (UAV) and one unmanned ground vehicle (UGV). The UAV available for this mission is the Raven, seen in the pictures below. The Raven is a small, short endurance, low altitude unmanned aircraft system used for surveillance and reconnaissance missions. With a wingspan of 4.5 feet and a weight of 3.8 pounds, the hand-launched Raven airplane provides aerial observation at line-of-sight ranges of 10 to 15 kilometers at altitudes up to 1,000 feet. (Most missions are flown at 100 to 300 feet.) The Raven can only fly for 45 to 60 minutes on one battery. The Raven has three different cameras that attach to the nose of the plane, an electrical optical camera that sends data either through the nose or a side camera, an infrared camera in the nose, and a side-mounted infrared camera. A sample image taken by the Raven is shown below. **You will be in charge of planning the route for the Raven UAV.**





SITUATION

Enemy Forces

Weather and Light Data and General Forecast

Skies: Cloudy skies and heavy fog, cloud base 200 ft. A cloud ceiling of at least 1,000 ft is desired when using small UAVs, such as the Raven. The clouds will impact the visibility of the UAV as well as the flying capabilities.

Visibility: Limited at flying level and partially at ground level. Limited visibility will definitely hinder the UAV's ability to see targets on the ground. Limited visibility will also make maneuvering the UAV more difficult.

Winds: North to Northeast. Speed expected to exceed 10 knots. Occasional gusts up to 15 knots in early evening. The winds will not be strong enough to impact the UAV.

Temperatures: from 72 degrees F to 80 degrees F.

Light Data: Sunrise 7:04 AM. Sunset 5:04 PM.

Trafficability: Fair.

Precipitation: Uncharacteristic thunderstorms with heavy rains throughout the day and night. Intermittent thunder and lightning expected. Possibility of lightning striking the UAV is minimal, but still a risk. Rain can limit the visibility of the UAV. Maximum precipitation per month: 6 inches. Average precipitation per month: .2 inches.

Locations: Previous intelligence suggests that the enemy has used each of the Objectives in the past as hideouts. OBJ Arm, OBJ Foot and OBJ Leg are all buildings located in a residential area of Kufah. OBJ Neck and OBJ Hand are commercial buildings where the enemy may be hiding. OBJ Torso is a small building located in a wooded, uninhabited area of the city.

Activity: The enemy has kidnapped three US soldiers and is holding them hostage at one of the Objectives. It is likely they are all being held in the same location, but that has not been confirmed. They should be staying at the stronghold for the next 48 hours, before moving the hostages again.

Strength: There is a group of 50 enemy soldiers who are heavily armed and dangerous guarding the hostages.

Probable Course of Action: It is likely that the enemy will remain in its current location for approximately 48 hours before relocating to an unknown location outside of Kufah. Once the enemy has moved, it will be much more difficult to track them and to recover the hostages.
Friendly Forces: Unknown.

Attachments and Detachments: No attachments or detachments.

Assumptions: We can assume that the enemy will be waiting for our approach; therefore, we must take the most extreme cautions when nearing each OBJ. If the enemy detects our presence, the chances of recovering the hostages will greatly decrease.

MISSION

Commander's Intent: This mission has one main goal. The enemy has captured three of our own men. We need to go in there, find out where they are, and rescue them. We only have a limited amount of time to gather R&S information. The enemy will be moving out within 48 hours and thus we need to know where they are ASAP. The first part of this task will be to send in the robotic assets to determine exactly where the hostages are being kept. Once we have that information we can begin the rescue mission. This is a time-critical mission and it is imperative we get to those men before anything happens to them!

EXECUTION

Concept of the Operation: The unit has a UAV and a UGV to complete this task. The assets can be used as seen fit by the operators. The assets should be used to collect all of the information requested by the Commander for each of the Objectives. The assets have *only 1 hour* to collect the necessary information.

Maneuver: It is up to you to task the assets with their route(s) and their specific information collection goals. The UAV and UGV are equal assets in that one does not command the other. They can work together or separately as you, the operators, see fit.

Fires: None.

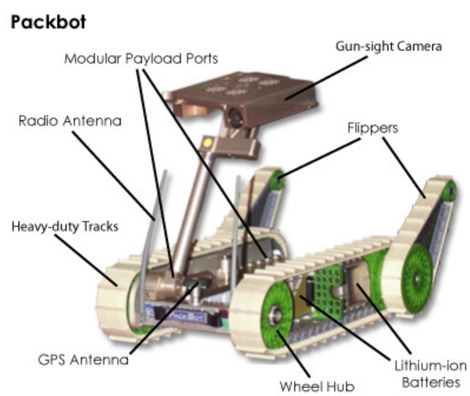
OPERATION ORDER 202-B

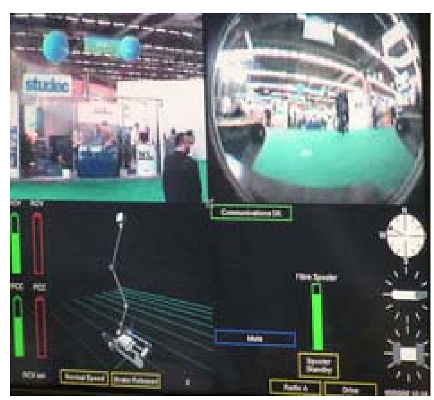
References:

Map of Al Kufah provided on your computer display. Al Kufah is a city in Iraq situated on the bank of the middle river Farut some 88 miles south of Baghdad. The city is almost 22 meters above sea level. It was a center of Arab culture and learning from the 8th to the 10th century. The map is a satellite image from November 2003.

<u>Time Zone Used Throughout the Order</u>: Local Time

<u>Task Organization</u>: There are two assets available for this mission, one unmanned aerial vehicle (UAV) and one unmanned ground vehicle (UGV). The UGV available for this mission is the PackBot, seen in the pictures below. The PackBot is a rugged, lightweight robot designed to conduct search, surveillance and reconnaissance, hostage rescue and other tasks. The robot can move more than 8 mph and has a run time of up to 2 hours. It weighs 40 lbs (18 kg) with the batteries and is designed to fit in the Army's new standard backpack. With its compact profile and patented mobility platform, PackBot operates with confidence on the toughest terrain – from the stairs, curbs and rubble of urban terrain to the rocks, sands and mud of the battlefield. A sample display from a Packbot is shown below. **You will be in charge of planning the route for the Packbot UGV.**





SITUATION

Enemy Forces

Terrain

Terrain: For downtown Kufah, as seen in satellite map. Downtown Kufah is densely populated with both residential and commercial inhabitants. Kufah sits on flat land, approximately a mile above sea level.

Obstacles: The major highway that divides the downtown area is well traveled at all hours and would be extremely difficult for the small PackBot to cross. The PackBot could travel down the side of the highway but must stay on one side or the other because crossing would be too difficult.

Key terrain: OBJ Foot is one of the more likely hiding places. It is a small apartment on the first floor of a three story building. The building is located on a fairly well traveled intersection, so pedestrians will likely be present on any given day. OBJ Hand is far enough away from the residential area that it would require vehicles. A quick check for vehicles would tell us whether the enemy is there. OBJ Leg is a local hangout for enemy trainees. There is only a slight chance the hostages may be there, but some specifics about who is there may shed light on where the hostages are.

Decisive terrain: OBJ Torso and OBJ Arm have seen some recent activity; though that activity may be unrelated to the kidnappings. OBJ Torso is in a wooded, sandy area. This area would be quite difficult for a UGV to navigate, especially in adverse weather conditions.

Other key terrain: OBJ Neck, while being the possible location of the hostages, is also the likely command base for the enemy. This location must be surveyed for the hostages, but also for its general characteristics and enemy strength. If possible, *both assets should be sent to OBJ Neck.*

Avenues of approach: Any routes throughout the city should follow the established roads. No ground assets should take shortcuts through buildings or parks. The main highway should be used to get into the city and back out of the city after the mission is complete.

Locations: Previous intelligence suggests that the enemy has used each of the Objectives in the past as hideouts. OBJ Arm, OBJ Leg and OBJ Foot are all buildings located in a residential area of Kufah. OBJ Neck and OBJ Hand are commercial buildings where the enemy may be hiding. OBJ Torso is a small building located in a wooded, uninhabited area of the city.

Activity: The enemy has kidnapped three US soldiers and is holding them hostage at one of the Objectives. It is likely they are all being held in the same location, but that has not been confirmed. They should be staying at the stronghold for the next 48 hours, before moving the hostages again.

Strength: There is a group of 50 enemy soldiers who are heavily armed and dangerous guarding the hostages.

Probable Course of Action: It is likely that the enemy will remain in its current location for approximately 48 hours before relocating to an unknown location outside of Kufah. Once the enemy has moved, it will be much more difficult to track them and to recover the hostages.

Friendly Forces: Unknown

Assumptions: We can assume that the enemy will be waiting for our approach; therefore, we must take the most extreme cautions when nearing each Objective. If the enemy detects our presence, the chances of recovering the hostages will greatly decrease.

MISSION

Commander's Intent: This mission has one main goal. The enemy has captured three of our own men. We need to go in there, find out where they are, and rescue them. We only have a limited amount of time to gather R&S information. The enemy will be moving out within 48 hours and thus we need to know where they are ASAP. The first part of this task will be to send in the robotic assets to determine exactly where the hostages are being kept. Once we have that information we can begin the rescue mission. The safety of our men depends on the accuracy of our information. If we send our rescue team to the wrong location, the hostages might not survive. So make sure we get the most accurate and specific information as possible!

EXECUTION

Concept of the Operation: The unit has a UAV and a UGV to complete this task. The assets can be used as seen fit by the operators. The assets should be used to collect all of the information requested by the Commander for each of the Objectives. Start time is set for *10 am*.

Maneuver: It is up to you to task the assets with their route(s) and their specific information collection goals. The UAV and UGV are equal assets in that one does not command the other. They can work together or separately as you, the operators, see fit.

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