This is to certify that the

thesis entitled

Computer-Mediated versus Face-to-Face
Communication in Hierarchical Team Decision Making

presented by

Jennifer Hedlund

has been accepted towards fulfillment
of the requirements for

M.A. degree in Psychology

Major professor

Date 11/17/93

COMPUTER-MEDIATED VERSUS FACE-TO-FACE COMMUNICATION IN HIERARCHICAL TEAM DECISION MAKING

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Department of Psychology

1993

ABSTRACT

COMPUTER-MEDIATED VERSUS FACE-TO-FACE COMMUNICATION IN HIERARCHICAL TEAM DECISION MAKING

By

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Rapidly changing communication technologies have the potential to significantly alter the way individuals interact in groups, particularly in comparison to traditional face-to-face interactions which have received extensive attention in the literature. This study compared face-to-face and computer-mediated communication in decision making teams on various communication and decision making processes as well as decision making accuracy. Face-to-face teams communicated more frequently on each of five types of communication (social, uninhibited, procedural, informational, and decision-related). Participation, or the amount of communications, among team members was significantly more equal in computer-mediated teams, supporting previous findings. Next, three critical variables in the decision making process were identified and compared between the two media. Face-to-face teams were higher on the variables of "team informity" and "staff validity", while computer-mediated teams were higher on "hierarchical sensitivity". Finally, face-to-face teams were significantly more effective in terms of decision accuracy than computer-mediated teams in this task.

ACKNOWLEDGMENTS

First, and foremost, I want to thank my chair Dan Ilgen for his encouragement and assistance in completing this project. I also want to thank the other members of my committee, John Hollenbeck and Mike Lindell. There are also several people who assisted me at some point in this process, whether in the data collection or arduous task of coding video tapes. They are Doug Sego, Jean Phillips, Dale Tuttle, Spence Tower, Linda Barret, Chuck Capps, and my primary coder Karen Oswald.

Of course, I could not have made it through this process without the support of friends and family. I especially want to thank my fiancee, Steve, and my mom for their continuous encouragement and belief in my ability to complete this stage of my graduate career.

This has been an extremely educational and rewarding experience!

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INTRODUCTION

Recent technological advances in computing and communications have created new ways of sharing information. Specifically, the development of computerized networks has led to a variety of new modes of communication including electronic mail and computer conferencing. These new communication technologies generate new questions and lead to the reevaluation of old questions concerning the way people interact in groups.

For decades researchers have been interested in how groups work (Davis, 1992). Recently, much of this interest has focused on teams and teamwork. The use of the term "team" rather than "group" in much of the current literature signifies an attempt to distinguish and further specify the nature of the interpersonal interaction. A team is distinguished from a group by its collective goals and objectives. In other words, teams have a task-oriented purpose (Ilgen, Major, Hollenbeck, & Sego, 1993). However, throughout the literature, the terms group and team are used interchangeably. The discussion presented here will reflect the use of these terms in the literature. In reference to the present research, however, the term team will be used to identify the task-oriented nature of the groups being studied.

Current interest in teams has been generated by competitive economic concerns, highly visible events in which teams have failed, and advances in communication technology (Ilgen et al., 1993). In the area of communication technology, recent developments have made it possible for individuals to share information, exchange ideas, and make decisions through electronic forms of communication. Electronic communications include mail, bulletin boards, and synchronous or asynchronous computer conferencing (Kiesler & Sproull, 1992). The significance of these new communication technologies is emphasized by a transition toward an information-oriented society (Drucker, 1976). Throughout the world, economies are becoming increasingly based on the manipulation and transfer of information rather than goods or services.

This current interest in teams has also involved a focus on decision making teams. Much of the previous research on team decision making has involved studies of jury decision making (Ilgen et al., 1993). In these and other studies, the outcome variable of interest has been consensus (Davis, 1992; Levine & Moreland, 1990). However, the product of decision making teams in organizations is more likely a decision which may lead to certain consequences. In these teams, the more appropriate outcome variable may be decision accuracy. Therefore, it becomes important to examine the decision making process to identify factors that contribute to effective or ineffective decision making.

Until recently, most of the research on group or team decision making has involved face-to-face interactions. This has led to highly predictable conclusions regarding the processes involved in group decision making (McGrath, 1990). For example, in face-to-face groups, members share discussion time unequally, with usually only one person speaking at any one time. New technologies alter many of the conclusions drawn from the research previously involving only face-to-face groups. For instance, in electronic communications there is no constraint on who can "speak"; everyone can be sending a communication at the same time. These technologies will likely have an extensive impact on the decision making process and therefore the conclusions we draw about decision making groups or teams.

The introduction of new communication technologies tends to have large impacts on the social arrangements and interpersonal interactions of the people who use them (Kiesler & Sproull, 1992). Each new technology requires people to develop new methods for organizing and processing information, and new norms for interacting with one another. These technologies can change the nature of group communications in a number of ways. They can affect the physical distance between members, the speed and efficiency of information exchange, the potential size of a group, the participation of members, the availability of contextual cues, and the immediacy of feedback (Hiltz & Turoff, 1978; Kerr & Hiltz, 1982; McGrath, 1990; Steinfield, 1986).

The introduction of electronic communications may have the most significant impacts on people as compared to the introduction of any other communication technology to date. One of the most highly studied electronic medium is networked computers. Computers differ from other communication tools in their ability to manage and store data and messages (Kiesler & Sproull, 1992). Kiesler, Siegel, and McGuire (1984) identify two characteristics of computer-mediated communications. First, computers limit the amount of social context information available to team members. This may reduce the social influence individual members have over the group and direct attention away from the group and more toward the task. Second, there are few norms governing communication through computers. As a result, communications may become more impersonal and less inhibited. The use of uninhibited, or profane, language in computer-mediated communications has been fairly well established and given its own label, that is, "flaming" (e.g., Kiesler & Sproull, 1992).

As the use of electronic communication has grown, researchers have become increasingly interested in the impacts of computer-mediated technologies, particularly on the way people interact and make decisions in groups (e.g., Kiesler et al., 1984; Siegel, Dubrovsky, Kiesler, & McGuire, 1986). An inherent question in this research is how do groups interacting through computers differ from those that interact face-to-face? For example, the communication technology may influence how members exchange information. Members may communicate more frequently in face-to-face groups, but they may participate more equally in computer-mediated groups. New questions also arise regarding the role of communication in decision making. Under certain conditions, groups may be more effective communicating through a computer medium than face-to-face; in other conditions they may be less effective.

The present research is designed to explore the effects of communication technology on decision making in teams and to examine conditions under which one medium of communication may prove to be more effective than another. Team members in this study will hold two types of roles, leaders and staff members. In addition, each member will possess some expertise related to the decision domain that is not shared by all other members. In other words, members will possess specialized knowledge such as is the case when an engineer, line manager, and purchasing agent work together to decide upon the purchase of a new piece of equipment to be used in the production process at a manufacturing firm. For the purpose of description, teams whose members differ in (1) status and (2) areas of expertise, will be referred to as "hierarchical teams with distributed expertise."

This study will examine how the medium used to exchange information, either face-to-face or computer-mediated, affects team decision making effectiveness through its influence on communication processes, and other variables involved in the decision making process. It will also examine conditions under which face-to-face and computer-mediated teams are expected to perform differently in terms of decision making effectiveness.

First, literature relating to communication and information exchange in group decision making will be discussed. Then, research comparing different communication media will be reviewed, with a focus on computer-mediated and face-to-face communications. Next, possible sources for explaining media differences will be addressed. This includes a discussion of individual and group processes, with particular attention to the theory of social presence. Finally, a multi-level theory of hierarchical team decision making developed by Hollenbeck, Ilgen, Sego and Major (in press) will be introduced and discussed as a framework for developing hypotheses about the influence of the communication technology on team decision making.

LITERATURE REVIEW

Communication in Group Decision Making

Communication plays an important role in group decision making (Hirokawa, 1990; Hirokawa & Johnston, 1989; Knutson, 1985). It is essential for exchanging information and opinions, and for allowing members to influence the final group decision. According to Knutson (1985), messages that flow through the communication process can be described in terms of their informational, procedural, or interpersonal focus. Informational messages include data, interpretations, and recommendations about the task. Procedural messages are focused on managing the process, e.g., delegating and integrating group activities, and establishing roles and norms. Interpersonal messages refer to the socio-emotional interactions, including the expression of attitudes toward and the perceptions of other members.

The messages exchanged in any communication process, whether they are of an informational, procedural, or interpersonal nature, do not exist in a vacuum. They are influenced by at least two characteristics of the decision making environment, the nature of the task and the context in which messages are exchanged. Hirokawa (1990) argues that little theoretical attention has been focused on the question of how communication functions to affect group decision making or under what conditions it is expected to exert an influence.

Therefore, he developed a framework to identify task conditions under which communication is expected to have a significant influence on decision making and to describe how communication affects decision making under those conditions.

Three factors of the task situation are identified by Hirokawa (1990) as important determinants of the influence of communication in decision making. He identified these factors as task structure, information requirement, and evaluation demand, each described in terms of a continuum. Task structure refers to the configuration of the task in terms of its goals. This includes clarity of the goal and the means to achieving the goal, the number of steps involved to reach the goal, and the number of obstacles to achieving the goal. The task structure continuum ranges from simple to complex tasks. Simple tasks are identified by high clarity of the goal and the means to achieve the goal, with minimal effort required and few obstacles to achieving the goal. Complex tasks are identified by low clarity and uncertain means to achieve the goal as well as high effort requirement and many obstacles. Group interaction and communication are more critical when a task is complex rather than simple.

The second factor, information requirement, refers to the amount of collaborative, coordinated, and integrated effort required to perform the task (Hirokawa, 1990). It is defined by two factors, information distribution and information processing. It is represented by a continuum ranging from means-independent to means-interdependent. Means-independent implies that all members posses information necessary to perform the task and the amount and complexity of the information to be processed is low. Means-interdependent, on the other hand, involves information that is unequally distributed among members and has a high processing demand. Group communication plays a more important role in decision making effectiveness as the group becomes more means-interdependent. This is illustrated by research that has examined the effect of different communication media on decision making performance. Hiltz, Johnson, and Turoff (1986) found that when the task required an integrated and coordinated effort, media that allow for more group interaction (e.g., face-to-face), led to higher performance than more restrictive media (e.g., audio only).

The last factor, evaluation demand, refers to the amount of effort required by the group in determining the correct decision choice. This is affected by solution multiplicity (the number of acceptable choices), criterion clarity (the extent to which evaluation standards are clear), and objective verifiability (the extent to which a choice can be definitely determined to be correct). Evaluation demand can be represented by a continuum from unequivocal tasks with a single correct choice and a clear, verifiable decision criterion, to equivocal tasks with multiple acceptable choices, and unclear and indefinite criterion. Communication has less influence on effectiveness when the decision task is unequivocal. For equivocal tasks with multiple choices that lack a verifiably correct solution, communication plays a more important role in decision making effectiveness. Therefore, as task complexity, information requirements, and evaluation demand become greater, communications become more critical to effective decision making.

Information Sampling Model

One of the factors identified by Hirokawa (1990), information distribution, has been explored in research conducted by Stasser and his colleagues (Stasser & Titus, 1985, 1987; Stasser, Taylor, & Hanna, 1989). Stasser and Titus (1985) developed a model of information sampling to describe how information is introduced into a group discussion. Information that is distributed among group members can either be shared or unshared. Shared implies that each member is knowledgeable about the information necessary to make a decision. Unshared, on the other hand, refers to information that only certain members know prior to discussion.

Research on group decision making by Stasser and Titus (1985, 1987), suggested that the discussions involved in decision making tended to focus on information about which all members were knowledgeable prior to discussion and to ignore unshared information, that is, information that was unique to certain members. They found little evidence that information not shared prior to the discussion task entered the discussion. In the second study, Stasser & Titus (1987) manipulated information load (the amount of information to be discussed) in addition to the amount of shared and unshared prior information. In this research, pre- and post-discussion recall was used to measure the extent to which members obtained previously unshared information. The results suggested that members recalled more of the previously shared information. However, more of the previously unshared information was recalled when the majority of information was unshared prior to discussion and the information load was low.

In Stasser et al. (1989) groups were studied using a behavioral measure of information sharing rather than recall. They manipulated group size (three or six-person groups) and the structure of the discussion in addition to the amount of shared information. The six-person groups and the structured discussions resulted in more information being discussed. However, most of this additional information was shared prior to discussion. In this study, the sampling advantage of shared information was not expected to affect the final outcome of the decision making because the shared information did not favor one decision alternative over another. Therefore, the consideration of more unshared information was unlikely to have affected the final decision.

The situations depicted above are unlikely to be very realistic representations of actual decision situations, especially when group members are interdependent, that is, the task requires that members interact with one another. Focusing mainly on shared information can lead to the selection of a decision alternative that is not supported by all the information available to the group (Stasser & Titus, 1985). In teams composed of experts, members' diverse knowledge is often as important as their shared knowledge. The quality of the team's decision may depend on the inclusion of that diverse knowledge in the decision making (Stasser et al., 1989). Stasser and Titus (1985) suggested that face-to-face, unstructured discussion may be an ineffective way for members to inform one another of previously unshared information. Task conditions that lead to more unshared information entering into a discussion may lead to more effective group decision making. Alternative modes of communicating, as well as more structured discussion, may increase the amount of unshared or unique information that is discussed. This implies that there may be more effective means of interacting than face-to-face.

Social Context of Communications

According to Sproull and Kiesler (1986), the social context influences the content of communication and the nature of interactions. They identified three sources of variables that contribute to the social context. These were organizational, situational, and geographic. Organizational variables, like hierarchy and job category, affect who will communicate with whom and what the content of the communication will be. People at the same level and in the same job category are more likely to communicate than those from different levels or jobs. In addition, the status of individuals, such as leader or subordinates, will likely determine who dominates a discussion.

Situational variables, including the characteristics of and relationships among the communicators, as well as the topic of the discussion and norms about the interaction, can influence the communications (Sproull & Kiesler, 1986). For instance, it has been found that the more similar or homogeneous a group of people, the more equally its members will contribute to the conversation (Watson, 1982). Therefore, if people perceive themselves to be more similar to other members of the group, they may share discussion time more equally.

Finally, geographic variables refer to a person's position in space and time (Sproull & Kiesler, 1986). For some communication media, geographic location may be a constraint on communications. Face-to-face media require people to be in the same location at the same time, while telephones and electronic communication allow people to communicate across geographic distances. Electronic communication even allows people to cross barriers of time with its ability to store information and retrieve communications at a later time.

The variables identified above are aspects of the context that may have different effects on the communications among team members depending on the medium used to communicate. Status differences, for instance, are not likely to influence the pattern of interactions when they are not readily available, as in computer-mediated situations. On the other hand, when cues about the social context are extremely observable, people may respond the them. When these cues are immediately available, attention tends to focus on them, whereas under conditions where these cues are weak, the focus tends to turn toward one's own behaviors (Sproull & Kiesler, 1986).

The influence of organizational and situational variables on the content of communications and the nature of interactions will most likely depend on the availability of cues regarding the social context. The medium through which people interact is expected to affect the extent to which cues are observable and will likely affect the extent to which they are perceived. Therefore, the medium through which people communicate is expected to moderate the influence of organizational and situational variables on communication by limiting the availability of social cues. The influence of geographic variables is also expected to be moderated by the type of medium. Different media may affect the extent to which barriers of time and space exist. With certain media, such as electronic communication, these barriers are likely removed, which may allow for new interactions among people and possibly change the nature of communications as well. The literature on the influence of different communication media suggests the existence of such effects.

Communication Media

A number of early studies compared different modes of communication to determine how information exchange, social interactions, and performance were effected by different forms of communication (e.g., Chapanis, 1971, 1972; Chapanis, Oschman, Parrish, & Weeks, 1972; Williams, 1975; Weeks & Chapanis, 1976). Williams (1977) reviewed approximately 30 studies that compared various media in which communication took place, including face-to-face interaction, audio only, audio-video, and teletyping modes. The groups involved in these studies ranged in size from two to six people. The tasks and the dependent measures varied greatly across these studies as well. Tasks were categorized as either cooperative or conflictive. Cooperative tasks included problem solving tasks, information exchange, and brainstorming. Conflictive tasks included negotiations and bargaining, "mixed-motive" games, and discussions of personal opinions. Dependent measures included the amount of time to solve a problem, the number of messages exchanged, the quality of solutions, and interpersonal perceptions.

For cooperative-type tasks, there were few significant differences between the types of media examined in these studies and their effects on overall performance. Williams (1977) suggested that cooperative tasks did not require interpersonal communication to be efficient in terms of time or message exchange. He also suggested that compensatory differences between conditions may have accounted for the lack of significant difference with respect to performance. For example, although verbal forms of media resulted in faster problem solving, written forms involved fewer messages and less redundancy. The larger number of redundant messages may have overwhelmed the advantages of speed when voice communications were compared to written communications.

According to Williams (1977), differences between media were more likely to occur in conflictive tasks. Differences were found in the ease of reaching agreement, competitiveness, and individual opinion change between the various media studied. Williams (1977) suggested that in conflict situations, the relationship between participants may be more important since more discussion is required to reach a solution. Therefore, the effects of different media on the nature of the interaction will likely have a greater affect on outcome variables in conflictual tasks.

Two studies in particular exhibit the different findings of cooperative and conflictive tasks. First, a study by Weeks and Chapanis (1976) provides an example of different media examined in a cooperative task. Two-person teams engaged in one of two problem solving tasks which required the exchange of information to reach a unique problem solution. Participants communicated by one of four communication modes: teletyping, remote handwriting, audio only, and face-to-face. Three dependent measures were examined:

the time it took to solve the problem, behavioral measures of activity, and measures of verbal productivity. More messages were exchanged in the face-to-face and audio only than in the two written modes. Face to face groups also engaged in additional activities that could not be performed by groups in the written modes. Problems also took longer to solve in the two written modes than in the two voice modes. There was no attempt to examine the quality of solutions made by the groups under different conditions.

A study involving a conflictive task was conducted by Short (1974). Participants were divided into pairs to perform a negotiation task. One person was instructed to argue a case that was consistent with his or her personal views; the other was required to argue a case that was inconsistent with his or her views. Pairs communicated through either a face-to-face, audio-video, or audio only mode. The type of medium had a significant effect on the outcome of the negotiation. The person who argued a case that was consistent with his personal views was more successful in the face-to-face condition. The person who argued a case inconsistent with her personal views was more successful in the audio-only condition. The audio-video resulted in similar findings to the face-to-face condition. In sum, the type of medium used to argue a case determined which type of argument (consistent or inconsistent) was more effective. This suggests that media can have strong effects on decision making outcomes.

Conclusions drawn from this literature about the effect of these various media are constrained by the use of mostly dyads. Dyads limit the exploration of certain group phenomena which require the use of larger groups. For example, team leadership and coalition formation can only be studied in groups of three or more persons. Three studies reviewed by Williams (1977) did use groups with three or more participants and found larger effects when comparing different media.

One study focused on coalition formation in four-person groups (Williams, 1975). The group was divided into pairs and placed in separate rooms, communicating by an audio only or an audio-video mode. The physical separation of these two modes of communication resulted in a greater division of the group into two opposing factions than would happen by chance. This division was even more extreme in the audio only condition.

Another study by Strickland, Guild, Barefoot, & Paterson (cited in Williams, 1977), compared four-person groups who met face-to-face or through an audio-video medium. The task was to discuss a human relations problem and answer questions about the quality and quantity of ideas from other group members. Measures of frequency and duration of interactions were obtained and found to correlate less with opinion measures in the audio-video than in the face-to-face mode. This implies that members were making judgments about other members' contributions based on factors other than their actual behavior. In addition, significant differences were found between the audio-video mode and the face-to-face mode in the amount of role differentiation and leader emergence. Role differentiation and leader emergence were more likely to occur in the face-to-face groups. Together, these results suggest that social factors, internal group structure, and hierarchies are more likely to exist and have an influence in face-to-face than in mediated groups (Williams, 1977).

Finally, a study by Kruger (cited in Williams, 1977) compared face-to-face, audio only, and teletyping modes in groups of two, three, and four persons. Differences were found in the levels of participation in each condition as defined by the number of messages contributed by each member. Messages were distributed more equally among members with teletyping, less equally in audio only, and least equally in face-to-face discussions. Kruger (1976) also found differences in the time it took to solve the problem and the number of messages exchanged as did Chapanis et al. (1972).

The types of media examined in these studies may have limited the finding of large differences between modes of communication. Face-to-face, audio-visual, and audio only modes produce incremental changes to the context of the communication. Williams (1977) suggested that the finding of differences between media are likely to be stronger when examining more technologically advanced forms of communication (e.g., electronic communication).

Electronic Communication

Electronic forms of communication are likely to differ more significantly from face-to-face media than the types of media discussed above. Yet, much of the literature comparing communication technologies was generated before electronic media had emerged as a prevalent technology. Since Williams' (1977) review, there has been increasing attention in the literature to electronic modes of communication.

According to Kiesler and Sproull (1992), electronic communication creates a different physical and social context for decision making groups. It reduces barriers of space and time by allowing people to communicate on their own time and from different geographic locations. Any number of people can communicate at one time and prior discussions and information can be stored and retrieved for review. Electronic communication also reduces some social and psychological barriers to communication through the reduction of many social context cues. For example, the reduction of status cues may lower social inhibitions, leading to increased participation and more extreme expression of opinions Kiesler & Sproull, 1992).

Summary

The increasing use of computers in a diverse range of settings has led to a widespread interest in the impact of computers on human interaction. Many organizations are introducing computerized networks that provide a new way for people to communicate (Baird, 1990; Sproull & Kiesler, 1991; "The warming," 1992). Computers may even have an impact on how surgery is performed. In the field of neurophysiology, computer networks will enable doctors at remote locations to attend complex brain surgery by accessing a computer terminal, and may even allow doctors to assist in several operations simultaneously (Alexander, 1991). Obviously this shift to computer-mediated communications has many implications for group processes and outcomes. One means of assessing the effect of computer networks is to examine in what ways computer-mediated communications differ from face-to-face interactions. In the past decade, a growing research base has developed that examines these effects.

Computer-Mediated Versus Face-to-Face Communication

A small number of studies have actually compared people who interact through computers with those who interact face-to-face (Kiesler & Sproull, 1992). These studies have found differences between computer-mediated and face-to-face groups in terms of efficiency, participation, interpersonal behavior (e.g., uninhibited communication), riskiness and consensus in decision making, decision quality, and member satisfaction (Archer, 1990; Dubrovsky, Kiesler, & Sethna, 1991; Hiltz et al., 1986; Kiesler et al., 1984; Kiesler, Zubrow, Moses, & Geller, 1985; McGuire, Kiesler, & Siegel, 1987; Siegel, et al., 1986; Spears, Lea, & Lee, 1990; Weisband, 1992). A number of these findings will be discussed below.

First, a study by Hiltz et al. (1986) compared face-to-face and computer conferencing groups on two types of problem solving tasks, one a qualitative human relations task, the other a scientific ranking task with a criterion. The dependent variables examined in this study were the amount and type of communications, participation, the quality of decisions, and agreement. Hiltz et al. (1986) found more communication in face-to-face groups, yet there was a greater proportion of task-related communication in computer-mediated groups. Although there was no difference in the amount of participation between the two forms of communication, a "leader," indicated by a dominance in the communications, emerged more often in the face-to-face condition when solving the human relations task compared to the scientific ranking task. Finally, there were no significant differences in the quality of decisions between the two conditions. However, for the human relations problem, there was far less agreement in the computer-mediated groups. In computer-mediated groups there were also significantly more opinions generated regarding the decision. The number of opinions generated was found to correlate positively with decision quality and negatively with agreement. Hiltz et al. (1986) suggested that the number of opinions may explain the differences in agreement, yet similarity in decision quality, between the two types of media.

Kiesler and Sproull (1992) provide a useful review of several studies that focused on process differences between computer-mediated and face-to-face groups (Dubrovsky et al., 1991; Kiesler et al., 1984; McGuire et al., 1987; Siegel et al., 1986; Weisband, 1992). The groups used in these studies consisted of two to four members who worked on a decision task that required members to come to a consensus about a dilemma problem. Participants were asked to make choices individually and as a group in order to examine the extent to which their opinions changed in the different media. This type of task has been referred to in the literature as a "choice shift" task. Groups met either face-to-face in a large conference room or were placed in separate offices of the same building and interacted solely through computers. The dependent variables examined in these studies included the time to make a decision, discussion content, equality of participation, consensus, and decision riskiness.

Time to make a decision was defined in this research as the amount of time spent in actual discussion to reach a consensus decision. For three-person groups interacting through a computer, it took almost four times as long to make a decision than groups interacting face-to-face when given a time limit (Siegel et al., 1986). It took as much as ten times longer for four-person groups to make a decision through computers when there were no time restrictions (Dubrovsky et al., 1991).

Kiesler and Sproull (1992) offer several possible explanations for these differences. First, computer networks may have been slow due to technological limitations. A backlog of messages can occur in computer systems when too many people try to send messages at one time. This problem has been improved upon in newer systems, although it can still be a limitation in using networked computers. Second, a commonly cited explanation is that it takes people longer to type and read than to talk and listen. Finally, these differences may be accounted for by the lack of immediate feedback in computer communications, creating greater difficulty in discussing opinions and trying to come to a consensus (Kiesler & Sproull, 1992).

The content and amount of communications has also been found to differ between face-to-face and computer-mediated groups (Kiesler et al., 1984; Siegel et al., 1986). Siegel et al. (1986) found that although face-to-face groups exchanged more messages in a given time, computer-mediated groups exchanged more task-oriented messages as a fraction of their total messages. Computer-mediated groups also exhibited more uninhibited communications, that is, messages containing swear words or insults (Kiesler et al., 1984; Siegel et al., 1986).

In the studies reviewed by Kiesler and Sproull (1992), the level of members' participation was found to be more equally distributed in computer conferencing than in face-to-face discussions. Dubrovsky et al. (1991) found that in computer-mediated groups, high status people did not dominate the discussion as much as they did in face-to-face groups. Kiesler and Sproull (1992) explain these differences in two ways. First, in computer-mediated groups all members can communicate at once. That is, they can send messages simultaneously. However, in face-to-face groups, members must wait for the previous "speaker" to conclude, thus leading to less equal time given to each member. Second, differences in status may determine who will dominate the discussion. In face-to-face groups cues tend to be more readily available from which a member's status can be inferred. Awareness of any status differences will likely have an influence on the communication behaviors of group members. The greater availability of status cues that exists in face-to-face groups may explain the less equality of participation found when people interact face-to-face rather than through computers.

In several of the studies reviewed in Kiesler and Sproull (1992), it took longer to reach consensus on a decision making task for computer-mediated groups, and involved a different process than in face-to-face groups. Weisband (1992) addressed the issue of consensus directly. Her study involved comparing individual decision choices recommended during the group discussion with the group's final decision. She found that in face-to-face groups, each member's decision recommendation tended to conform to prior recommendations of other members. In computer discussions, however, the last decision recommendation was as divergent from the group's final decision as was the first recommendation. This was explained by the stronger disagreements and more extreme views expressed in computer-mediated discussions. As a result, computer-mediated groups may have to work harder to reach consensus than face-to-face groups and therefore take longer to make a decision (Weisband, 1992).

In the studies discussed above (Kiesler & Sproull, 1992), decisions were evaluated in terms of the consensus of group members as to the best decision. Decision quality, although an important outcome of group decision making, was not evaluated. However, other researchers have attempted to evaluate decision quality or effectiveness, but have failed to find significant differences between computer-mediated and face-to-face groups (e.g., Hiltz et al., 1986). Reasons for this failure to find media differences in decision outcomes, other than consensus, may be due to the lack of attempts to control for possible conditions, like time constraints and task difficulty, that may interact with the media to have an effect on those outcomes.

To summarize the above discussion, a number of differences have been found between computer-mediated and face-to-face groups. Most of these differences focused on the processes involved in decision making rather than the outcomes of decision making. Most were also very descriptive in orientation. That is to say, face-to-face groups were compared to computer-mediated groups without much development of sound theory for the differences between the two media. An existing literature in social psychology, however, has the potential to explain differences between face-to-face and other modes of group interaction like electronic communication.

Explaining Potential Differences between Media

The following discussion considers literature that addresses differences between communication media. First, some explanations that have been used in the literature comparing face-to-face with other media will be reviewed. Next, literature regarding individual and group processes will be discussed briefly. In particular, social presence theory and the concept of social distraction will be considered as possible explanations for potential differences between face-to-face and computer-mediated communications in the context of team decision making. Finally, a theory of hierarchical team decision making will be discussed as a means of hypothesizing about the relationship between communication media, team decision processes, and decision making effectiveness.

First, Kiesler and Sproull (1992) talk about the general effects of implementing a new technology. They identify two levels of effects resulting from the use of a new technology. At the first-level are the technical effects such as increased productivity and efficiency which are usually reflected in cost savings. Second-level effects refer to the changes in people (e.g., behaviors) that result from the implementation of a new technology. Different relationships, roles, and norms may develop as people adjust to the new technology. These changes may be important in the sense that they may determine the effectiveness of the new technology.

Based on Griffith and Northcraft (in press), these effects are likely attributable to different features associated with the media. These features can be objective or psycho-social. Objective features refer to the speed of information transmission, documentation (memory and retrieval of information), immediacy of feedback, and other technical aspects associated with the communication medium (Griffith & Northcraft, in press; Hiltz & Turoff, 1978; McGrath, 1990; Steinfield, 1986). Psycho-social features include anonymity, social cues (or richness), urgency of messages, and other characteristics of social interactions that result from the use of a particular medium (Griffith & Northcraft, in press; Kerr & Hiltz, 1982; Kiesler & Sproull, 1992; Short, Williams, & Christie, 1976; Williams, 1977). These features can be useful in explaining why differences may occur between face-to-face and computer-mediated teams.

Technical Factors

Objective, or technical, features may explain differences in the amount of communications or the time it takes to make a decision. For example, the speed of information transmission, which is generally faster in a face-to-face mode, will likely influence the amount of communications. Psycho-social features, however, may be more useful in that they have the potential to explain differences in the content of communications and in performance.

It is important to note that Griffith and Northcraft (in press), argue that these features are distinct from the media. "Communication media are socially constructed convenient fictions for describing and discussing particular constellations of features" (p. 4). In other words, they suggest that features are confounded with media. However, it is is reasonable to assume that the features have an influence in combination, that is , in the form of a communication medium. Therefore, it can be argued that there is a value in comparing the influence of different media. It is, however, important that researchers identify the features that constitute the media being examined. For example, are the members of a computer network anonymous or identified by name or position? Therefore, the reader has the appropriate information to evaluate the findings and compare them with other studies. Although the value of distinguishing features from media as proposed by Griffith and Northcraft (in press) is acknowledged, these features are viewed here as factors that, in combination, help differentiate among media.

Psycho-Social Factors

As stated above, the interest here is to consider the psycho-social features of media, rather than the objective features, as means of explaining media differences. In the early literature comparing various modes of communication, the function of nonverbal cues and the social presence of others were identified as potential explanations for media differences (Rice, 1980; Short et al., 1976; Williams, 1977). More recently, these ideas have been applied to the comparison of electronic versus face-to-face communication (e.g., Sproull & Kiesler, 1986), but the focus has tended to be on the function of cues. The presence of others, although alluded to, has been largely ignored in the current literature. This will be the focus of the remaining discussion.

An extensive literature exists in the field of social psychology that explores the nature of group processes and group performance. There are generally two views in this literature as to the influence of group processes on group outcomes. One view is reflected by Steiner's (1972) term "process loss." This refers to interpersonal activities that are counterproductive to the task (e.g., social communications). The second view, however, considers group process to have a facilitating effect on group performance. For example, group interaction may enhance group performance to the extent that it can help identify and compensate for the errors and limitations in individual performance (Hackman & Morris, 1978). The group may also have a motivating effect on individual performance.

In terms of individual performance, assuming individual performance contributes to group performance, these two viewpoints are reflected by the opposing phenomena of "social facilitation" and "social inhibition". Both of these phenomena have been found to result from the presence of others, either coacting members of a group or observers. The question of whether or not the presence of others affects individual motivations and behaviors has been explored since the early 1900s (Allport, 1924). Zajonc (1966) proposed a theory of "mere presence" in which it was suggested that performance is facilitated by having others present when the task requires an individual to perform a well-learned behavior (simple task), and inhibited when the task requires learning a new response (complex task). Later research found that the presence of others is only expected to have an effect when those present have some influence over the outcomes of one's behaviors (Cottrell, Wack, Sekerak, & Rittle, 1968; Henchy & Glass, 1968), such is the case when the task involves interdependence among team members.

Given that the teams studied here are interdependent, and the task is novel and believed to be fairly complex, it is assumed that the presence of others will be inhibiting. One possible explanation why the presence of others is inhibiting is providing by the "distraction-conflict" theory (Shaw, 1981). Basically, this theory suggests that the presence of others when a person is performing a task may be distracting and thus creates a conflict between attending to the task and attending to the distractor (i.e., the social stimulus) (Sanders & Baron, 1975). Distraction is the result of any stimulus or response requirement that is irrelevant to the task. In a study by Sanders and Baron (1975), it was found that persons who were distracted while working on a copying task performed better when the task was simple but worse when the task was complex as compared to persons who were not distracted. In another study, Baron, Moore, and Sanders (1978) found that the presence of an audience interacted with task difficulty, facilitating performance on the easy tasks, but inhibiting performance on difficult ones.

Although it has not been shown irrefutably that distraction is the reason for performance decrements, it is suggested here as a possible explanation for differences between media. In the context of media differences, the concept of social distraction makes sense. Social stimuli, in the form of physical cues, are either present or not depending on the medium used to communicate. Therefore, there is either potential for more or less distraction, assuming that social stimuli are only distracting to the task and do not facilitate performance. In face-to-face groups members are present by necessity, but in computer-mediated groups members may or may not be in close physical proximity, and it is more likely they are not. Therefore, the influence of social presence, particularly distraction, is more likely to occur in face-to-face groups.

Summary

Although the above discussion of social presence and distraction helps to explain some potential differences between face-to-face and computer-mediated teams, it does not help to explain why differences are typically not found for certain performance measures. The failure to find significant differences in performance, other than for variables like consensus, may be due to the "compensatory" effect mentioned earlier where the benefits and hindrances of a particular communication mode cancel out one another. For example, the slowness of communicating by typing may be compensated for by having less distraction from social stimuli. Although this is a reasonable explanation, there is still a need to look at performance, particularly under more controlled observational conditions.

Alternative ways the communication mode may effect performance (e.g., through interactions with other factors), have not generally been considered in the literature. Aspects of the task that affect its level of difficulty may interact with the communication mode. For example, under high time pressure to make a decision, face-to-face groups may perform better because they have the advantage of being able to communicate faster. The communication mode may also have an influence on decision making processes that directly relate to team performance, without having a direct effect on performance itself. An additional theory may help to explain how and under what conditions different communication media might influence team decision making effectiveness. A theory will be introduced that helps to relate the effect of the communication mode on team decision making processes to their potential effects on performance. Performance is limited in this theory to the accuracy of decisions in decision making teams.

Multi-Level Theory of Hierarchical Team Decision Making

Hollenbeck et al. (in press) have developed a theory that attempts to explain and predict how and why some teams make more accurate decisions than others. This theory applies to teams with specific characteristics, that is, teams with a leader and two or more persons who report to the leader. In the teams examined here, members differ in their roles. There is typically a "leader" who makes the final team decision, and subordinates, who make recommendations to the leader. Subordinates will be referred to here as staff. The term team member may refer to either a leader or a staff member. Team members also differ in their expertise regarding the task. In other words, teams identified by this theory fit the definition of hierarchical teams with distributed expertise provided earlier in this review.

Teams addressed by this theory engage in a particular type of decision making. It is assumed that a team has available to it a pool of information, with each piece of information called a cue. Access to cues varies such that some team members can directly obtain some information, but not all information. Yet, all pieces of information have some relevance to the decision that the team must reach. Therefore, the team members are responsible for gathering information and sharing that information with each other prior to the time of reaching a decision. Immediately prior to the time when the decision is to be made by the leader, each of the staff members makes a decision recommendation, called a judgment, and passes that along to the leader. The leader then has information about the specific cues he or she was able to obtain during the team discussion and the judgments of each staff member regarding the decision object. At that point the leader makes the overall decision for the team (called the team decision). The quality of the decision can then be judged against the known properties of the cues and the decision rules that have been established for the task, as well as the individual judgments of the team members.

The theory described here deals explicitly with the issue of levels in teams. The levels issue refers to the fact that the study of teams often involves variables from multiple levels (Ilgen et al., 1993). Specifically, there are variables below the team level from which team level variables are generated. The theory identified here involves four levels of analysis. Three of these are the typical between-unit levels -- between-teams, between-dyads within the team, and between-persons. A fourth within-person level is also identified by this theory. It is the decision level when individuals are confronted with a number of decisions to be made over time.

Three core team-level constructs are identified as having direct impact on team decision making effectiveness. These are labeled team informity, staff validity, and hierarchical sensitivity. Team informity is the extent to which all information potentially available to team members is actually obtained by the members. Staff validity is the degree to which team members make accurate judgments about decision objects based on information about the decision objects. Finally, hierarchical sensitivity refers to how effectively a team's leader weighs staff members' judgments in arriving at the team's decision.

For each of these core team-level constructs there is a lower level analog that is averaged to create the higher, team level one. These lower-level constructs occur at either the decision level, the individual level, or the dyadic level, and are labeled <u>decision informity</u>, <u>individual validity</u>, and <u>dyadic sensitivity</u>. Decision informity is the amount of information the team has on any one specific decision object. Individual validity is the predictive validity of any one staff member's judgment in determining the decision criterion. Dyadic sensitivity is the leader's ability to capture each specific subordinate's ability to make accurate judgments.

Finally, the theory identifies all variables other than the six described above as "non-core constructs". These constructs may occur at any of the four levels identified above. This theory uses the framework developed by McGrath (1976) for identifying the set of non-core constructs. Figure 1 illustrates a model of all the variables identified by the theory. According to this theory, non-core constructs affect team decision making effectiveness through their influence on core-level constructs. Thus, the core-level constructs serve as mediators of the relationship between non-core constructs and team effectiveness. As illustrated in Figure 1, the theory also suggests that certain classes of non-core constructs influence certain core-level constructs more than others.

The multi-level theory of hierarchical team decision making is valuable in its isolation of three critical team-level factors that are expected to have direct impacts on decision making effectiveness. It

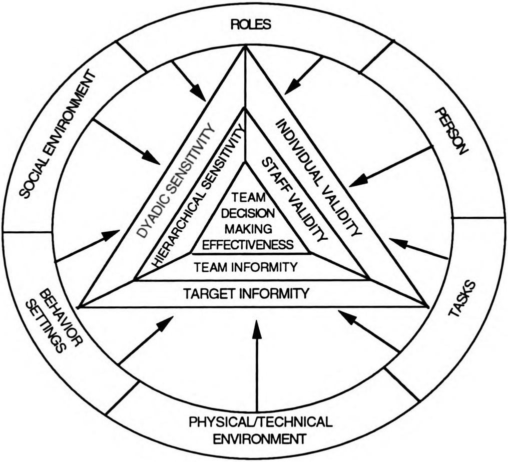


Figure 1. Multi-level model of hierarchical team decision making.

also offers a framework for identifying other constructs that may relate to team decision making effectiveness, and suggests how these non-core variables may relate to the core constructs.

The model in Figure 1 will be used to guide the development of hypotheses about the effects of the communication medium on team decision making effectiveness. Based on this multi-level theory and conclusions from research on computer-mediated versus face-to-face decision making, several hypotheses are made. These hypotheses are organized around the communication processes, core constructs in the decision making process, and the influence of the communication mode and task characteristics on team decision making effectiveness.

Hypotheses

Communication Processes

The discussion of the communication process in the literature on computer-mediated versus face-to-face decision making has tended to focus on the efficiency of communications. There is little agreement in the literature, however, regarding the construct of communication efficiency (e.g., Kiesler et al., 1984; Short et al., 1976; Siegel et al., 1986; Williams, 1977). Some researchers view efficiency in terms of the number of messages or the proportion of messages that are task related (Kiesler et al., 1984; Siegel et al.,1986). Others describe measures of efficiency that involve social and physical context element, called cues (Short et al., 1976; Williams, 1977). These cues either reduce or improve efficiency, by creating either noise or reducing the need to communicate with words.

Although there is a great deal of inconsistency in previous definitions of efficiency, one common focus among these definitions has been the content of the messages or communication units generated by a group. The interest in the communications process here will be to focus on the amount and type of communications rather than attempt to obtain a measure of efficiency.

As discussed earlier, Knutson (1985) identified three types of communication messages: informational, procedural, and interpersonal. The communications in face-to-face and computer-mediated interactions were also differentiated earlier into two types, task-related and social. It can be argued that task-related communications can be of the informational or procedural nature. That is, task-related communications can involve information about the decision object or how to perform the task. Social communications, on the other hand, are interpersonal in nature, and are less likely to be directly related to performance of the task. The above distinctions can be used to organize the development of hypotheses regarding media differences and their influence on the communication process.

The amount and type of task-related and social communications are expected to differ in the two media studied here. As discussed above, task-related communications can be broken down into those that involve information exchange versus those that relate to performance of the task. In the task used here, information exchange can be further differentiated into communication of information about the decision objects or communications about the decision to made. The latter will be referred to as decision proposals as identified in previous research (e.g., Weisband, 1992). Social communications include non-task related messages, including communications that may viewed as fostering team development. Finally, as suggested by previous literature, the amount of uninhibited language is another distinction that will be made in the type of communications that occur in these teams.

It can be assumed that face-to-face teams will engage in a greater total amount of communications, including both task-related and social, than computer-mediated teams simply due to the greater ease of verbal communication over written communication (Hiltz et al., 1986; Siegel et al., 1986). However, the specific types of communications may differ between these two media.

First, it has been found that face-to-face groups engage in more social communications than computer-mediated groups. It is the computer-mediated groups, however, that tend to express more uninhibited communications. Therefore, the following hypotheses are made about the effect of the different modes on the type of social communications.

H1: On average, face-to-face teams will engage in a more social communications than computer-mediated teams.

H2: On average, computer-mediated teams will engage in more uninhibited communications that face-to-face teams.

As mentioned earlier, there are different types of task-related communications. These are communications about the decision object, communications about how to perform the task (procedural), and decision proposals. As a result of being able to communicate faster, face-to-face teams can share information more rapidly than through a computer. There is also more opportunity for members to discuss their recommendations, or judgments, before submitting them, and for the leader to confirm judgments with his or her subordinates. Finally, more communications regarding how to perform the task functions can be expected to occur in the face-to-face conditions due to the immediacy of information about other members' behaviors.

Although there is little reason to doubt that face-to-face teams will be more likely to engage in more communications regarding information about the decision object, more procedural communications, and make more decision proposals than computer-mediated teams, the following hypotheses are made to support these claims.

H3: On average, face-to-face teams will generate more decision proposals than computer-mediated teams.

H4: On average, face-to-face teams will engage in more communications regarding the decision object than computer-mediated teams.

H5: On average, face-to-face teams will engage in more procedural communications that computer-mediated teams.

More communication, however, may not necessarily be favorable to the team. Important information can become lost in the process or members can be overloaded by too many communications occurring at one time. In computer-mediated conditions, individuals can control the reception of information and sometimes even the order it is received. Such differences will be addressed in the consideration of the core variables of staff validity, hierarchical sensitivity, and team informity.

Team Decision Making Processes

Although the above hypotheses address the main interest of previous literature comparing face-to-face with computer-mediated communications, they do not provide much insight as to the effect of the different media on a team's performance. The multi-level theory of hierarchical decision making identified earlier allows one to examine the process in more depth and explore its relation to the outcome variable(s) of interest. Specifically, it is important to understand how the communication mode and types of communications are related to the team decision making process. The core variables identified in Figure 1, team informity, hierarchical sensitivity, and staff validity, can serve to capture some of the variance in the communication process that may eventually influence team decision making accuracy.

The communication process is expected to exert an influence on team decision accuracy through its effect on the core variables described earlier. Briefly, these core variables are team informity (the amount of information the team has related to the decision), staff validity (the accuracy of member judgments), and hierarchical sensitivity (the appropriateness of the weights given to team members' judgments by the leader). Of the communications identified above, uninhibited language and procedural information exchange are not expected to be related to the core variables. Although these two types of communication may indirectly have an effect on the team such as creating a more hostile environment or more positive atmosphere, they do not relate sufficiently well to the core constructs to be considered here. The remaining types of communications will be discussed below and their relation to the core variables. In addition, the relation between the communication mode and these core variables will be addressed.

Team informity. The more communications regarding the decision object, the higher the team's informity is expected to be on that object. Although this sounds tautological, it may not always be the case that more discussion of a decision object leads to more informity. Even though a team may communicate a lot about the decision object, it may not exchange the specific information individual members need to form an accurate judgment (e.g., Stasser et al., 1989). Team informity is based on the number of specific pieces of information each member knows about the decision object. Therefore, the following hypothesis is made.

H6a: More communications regarding the decision object will be associated with higher team informity.

Since it was hypothesized earlier that face-to-face teams would engage in more communications about the decision object, face-to-face teams are also expected to be higher on the variable of team informity leading to the following hypothesis.

H6b: Face-to-face teams will have higher team informity than computer-mediated teams.

Staff validity. As stated above, the communication process is also expected to be related to the core variable of staff validity. Both task-related (decision object communications and decision proposals) and social communications may be related to staff validity. On the one hand, it can be expected that the more a team discusses the possible decision the more likely it is to come up with the correct decision. This discussion should also increase the accuracy of individual team member judgments regarding the decision object. Since staff validity is a measure of how accurate, on average, the team members are in their decisions, it follows that the greater the number of decision proposals exchanged by a team the greater its staff validity. Based on this argument, the following hypothesis is derived.

H7a: The more decision proposals made by a team, the higher its staff validity.

It can also be argued that social communications distract attention away from the task. This task requires that members attend to detail and process information carefully in order to make accurate decisions. Therefore, distraction could easily result in poorer decision making. Based on this argument, a second hypothesis is made regarding staff validity.

H7b: The more social communications engaged in by a team, the lower its staff validity.

Finally, the staff validity of a team may also be influenced by the amount of communications regarding the decision object. As team members gather more information about the decision object, they increase their ability to make accurate decisions. However, excessive communications regarding the decision object may produce an information overload for team members. Although face-to-face teams are expected to engage in more decision proposals, the lower amount of social communications and decision object communications are expected to favor the computer-mediated teams in terms of staff validity. The greater potential attention to the task by the computer-mediated teams is expected to lead to more accuracy and therefore higher validities of their decisions. Given the above argument, the following hypothesis is made regarding the effect of the communication medium and staff validity.

H7c: Computer-mediated teams will have higher staff validity than face-to-face teams.

Participation equality. Before addressing hierarchical sensitivity, another aspect of the communication process that is of interest here is the equality of participation of the team members. Participation has been defined in the literature as the distribution of communication within the group, that is, the amount of messages contributed by each member to the decision making process (Hiltz et al., 1986; Kiesler & Sproull, 1992). Research suggests that members of computer-mediated teams participate more equally in the decision making process than face-to-face teams. In face-to-face teams, however, differences are often found in the amount each member contributes to the interaction (Kiesler & Sproull, 1992).

The research from which these conclusions were drawn deals primarily with groups whose members have a similar knowledge base, what Stasser and Titus (1985) refer to as shared information. In teams with distributed expertise, however, more of the information is unshared. The task demands that each member's expertise be included in the decision making process. This is expected to result in a levelling effect on the equality of participation among members. Therefore, if an effect of the communication medium on participation is found in the present study, it is likely to be small. Based on the consistency of findings regarding this variable in the literature, a hypothesis will be made concerning the level of participation in face-to-face compared to computer-mediated teams.

H8: In computer-mediated teams, as indicated by the amount of communications, members will participate more equally than in face-to-face teams.

Hierarchical sensitivity. Although the equality of participation may be an interesting variable, it does not provide much insight into how teams come to an accurate decision. For hierarchical teams with distributed expertise, the more important variable to consider may be the contribution individual members make to the team's decision. Individual contributions will depend on how the leader responds to his or her staff. Leaders may perceive certain members to be more knowledgeable about the task and therefore give more weight to their judgments in making a team decision. Social factors may lead to inaccurate inferences about the abilities of different members. For example, in a face-to-face team, a boisterous, assertive team members' judgment may be given more weight than a quiet, reserved member based on the assumption that assertiveness and vocalness is an indication of self-assurance about one's judgment. In addition, it has been shown that people who are liked tend to be evaluated more positively across a number of dimensions including knowledge and intelligence (Byrne & Griflitt, 1973). The face-to-face condition creates a greater opportunity for social factors to influence the weight the leader assigns to each individual judgments than the computer-mediated condition.

Leaders of hierarchical teams with distributed expertise are expected to incorporate members' judgments into a final team decision. Members may have different accuracies regarding the decision and therefore may deserve different weights in making that final decision. Based on the above discussion, the weight given to a team member may or may not be the appropriate weight that members deserves given his or her ability to make the correct decision. In terms of the multi-level theory of team decision making discussed above (Hollenbeck et al., in press), the appropriateness of the weights given to staff members' judgments by the leader is called hierarchical sensitivity. The more leaders base the importance of members' judgments on social factors rather than ability, assuming those social factors are irrelevant to determining a member's ability, the less appropriately they will weigh those judgments.

The type of media used to communicate is expected to affect the extent to which leaders weigh members' judgments based solely on ability to make accurate decisions as opposed to social factors such as assertiveness or attractiveness that may be irrelevant. Leaders of face-to-face teams are expected to given inappropriate weight to social factors, rather than strictly weighing members on their ability. As a result of the expected difference between computer-mediated and face-to-face teams in terms of how leaders' weigh members contributions, the following hypothesis is made regarding the effect of the communication medium on hierarchical sensitivity.

H9: Computer-mediated teams will have better hierarchical sensitivity than face-to-face teams.

Team Decision Accuracy

Up to this point, hypotheses have been made regarding the effect of the mode of communication on the communication process and the core variables in the decision making process. These are largely based on the conclusions drawn from the literature comparing face-to-face and computer-mediated groups. Face-to-face teams tend to exchange more messages and communicate faster than computer-mediated teams. Members of computer-mediated teams, however, have been found to participate more equally in the decision making. The literature has generally failed to find a difference between the two media in terms of performance outcomes, such as decision quality or accuracy. This failure will be addressed by the remaining hypotheses.

Although this failure to find differences in performance between computer-mediated and face-to-face groups has been fairly consistent across studies, previous research has not considered other variables that may interact with the communication mode to influence the team performance. It may be useful to explore other factors, such as characteristics of the task, that may determine whether the communication mode has an effect on performance measures, such as team decision accuracy. One characteristic of the task that has the potential to exert such an influence is task difficulty. Difficulty, as discussed earlier, may be affected by a number of factors. Two factors are of interest here, the certainty of the information and the amount of time to perform the task. Uncertain, or ambiguous, information makes a task more difficult than when the information is clear or certain. Time pressure also makes a task more difficult by putting constraints on how much can be accomplished.

The influence of the two different communication media on decision accuracy will likely depend on the difficulty of the task. First, the uncertainty of the information regarding the decision object will create different demands on the attention of the team. When the information is uncertain, team members may need to be more focused in order to determine how to interpret the information. Given the argument that face-to-face teams will engage in more social communications and be more distracted away from the task, it is likely that they will not perform as well when the information is uncertain. Therefore, an interaction between communication mode and uncertainty is expected to affect the team's performance.

H10: When the information regarding the decision object is uncertain, computer-mediated teams will perform better than face-to-face teams.

The other dimension of task difficulty identified above is time pressure, in other words, the amount of time to perform the task. Time pressure is also expected to interact with the communication mode to influence team decision making effectiveness. Research on computer-mediated and face-to-face groups suggests that computer-mediated groups take longer to make decisions (Dubrovsky et al., 1991; Siegel et al., 1986). Under time limits groups exchanged much less information in electronic discussion compared to face-to-face groups and had greater difficulty in reaching agreement (Kiesler & Sproull, 1992). Face-to-face groups are consistently found to exchange more information in a given time period and make decisions much faster, particularly when those decisions require consensus (Hiltz et al., 1986; Kiesler & Sproull, 1992). Therefore, face-to-face teams are expected to perform more effectively than computer-mediated teams when faced with high time pressure to make a decision.

H11: Under high time pressure, face-to-face teams will perform better than computer-mediated teams.

Finally, a three-way interaction is anticipated between certainty, time pressure, and the communication mode. Under high time pressure, the advantage of computer-mediated teams over face-to-face teams in uncertain tasks will be eliminated. Face-to-face teams are expected to be more effective under high time pressure for both certain and uncertain tasks. Under low time pressure, the relation of certainty and mode to effectiveness is not expected to change. Therefore, this final hypothesis is made.

H12: Under high time pressure and uncertainty, face-to-face teams will be more effective than computer-mediated teams.

METHOD

Research Design

This study involved a 2 X 2 X 2 mixed design with one between team factor, communication medium, and two within team factors, information uncertainty and time pressure, which were varied with two levels of each variables. Participants were randomly assigned to one of two communication media, computer-mediated or face-to-face.

Participants

Participants consisted of 256 students selected from an undergraduate management and an undergraduate psychology class who received course credit for participating in the study. There was a fairly equal representation of males and females (48% male and 52% female). Teams were formed solely based on time availability. Thus, there were no restrictions on the combination of participants who made up a team. A total of 64 teams were studied, 32 computer-mediated and 32 face-to-face. (One team in the face-to-face condition was not included in some of the analyses due to technical problems with the videotaped portion of their participation.)

Task

Participants performed a computer simulation of a naval Command and Control team. In four person teams, they were assigned the task of monitoring the airspace surrounding an aircraft carrier battle group. The task was the Team Interactive Decision Exercise for Teams Incorporating Distributed Expertise ($TIDE^2$) developed by researchers at Michigan State University to study factors that affect team decision making effectiveness (Hollenbeck, Sego, Ilgen, & Major, 1991).

The $TIDE^2$ task involves monitoring the airspace through which planes pass and assessing the level of threat represented by each aircraft. Aircraft range from friendly to hostile. Teams respond to each aircraft by making a decision ranging from ignoring the aircraft to defending against it. Nine pieces of information (cues) can be measured about the aircraft. These cues provide information about the level of threat posed by the aircraft. Cue values vary across a range of values from low to moderate to high threat (see Table 1). In addition, there are five rules describing how to combine cues to determine the overall threat of the aircraft which are also shown in Table 1. (The values for these cues and interactions are provided in Appendix A.)

Each of the four members of the team is assigned to a specific role and is responsible for making a judgment or decision about the level of threat represented by each aircraft that comes into the team's airspace. Three subordinate roles consist of a Costal Air Defense (CAD), a reconnaissance aircraft (AWAC), and a cruiser. The team leader is located on the aircraft carrier. Each subordinate role involves measuring three pieces of information and memorizing the ranges for these cues and two of the rules described above. The leader's specific role is to know which team members are responsible

Table 1

Cue Value Ranges and Interactions for Determining an Aircraft's Threat Level

		Degree of Threat	
Cues	Non-Threatening	Somewhat Threatening	Very Threatening
Speed	100 - 275 mph (slow)	325 - 500 mph	600 - 800 mph (fast)
Altitude	27,000 - 35,000 ft (high)	17,000 - 23,000 ft	5,000 - 13,000 ft (low)
Size	65 - 43 mtr (large)	37 - 23 mtr	17 - 10 mtr (small)
Angle	+15 to +8 dgs (rapid ascent)	+3 to -3 dgs	-8 to -15 dgs (rapid descent)
IFF	.2 - .6 Mhz (civilian)	.9 - 1.1 Mhz	1.4 - 1.8 Mhz (military)
Direction	30 - 22 dgs (far east or west)	18 - 12 dgs	8 - 0 dgs (coming in)
Corridor St.	0 - 8 mi (in the middle)	12 - 18 mi	22 - 30 mi (outside)
Radar	Class 1 & 2 (weather)	Class 5	Class 8 & 9 (weapons)
Range	200 - 110 mi (far)	90 - 60 mi	40 - 1 mi (close)

Rules

1. **Speed** and **Direction** go together, so that fast aircraft coming straight in are most threatening. Speed alone and direction alone mean nothing. There is nothing to fear if fast aircraft are not headed toward the team or if objects headed directly toward the team are moving slowly.

2. **Altitude** and **Corridor Status** go together, so that low flying aircraft that are way outside the corridor are especially threatening. Altitude alone and corridor status alone mean nothing. There is nothing to fear from high flying aircraft well outside the corridor or low flying aircraft in the middle of the corridor.

3. **Size** and **Radar** go together, so that small objects with weapons radar are especially threatening. There is nothing to fear from small aircraft with weather radar only or from large aircraft with weapons radar.

4. **Angle** and **Range** go together, so that descending aircraft that are close are especially threatening. Angle alone and range alone mean nothing. Descending aircraft that are far away, or close targets that are on their way up are not threatening.

5. All else equal, in terms of **IFF** (Indicate Friend or Foe), military aircraft are more threatening than civilian aircraft.

for what information. In addition, the leader has one piece of information in common with each team member and one unique rule.

As stated earlier, the types of teams studied here are characterized by distributed expertise. Expertise is defined by the unique information, or cues, to which a member has access and the rules for which she or he is responsible. In order to obtain information about the cues to which a member does not have access and about which the person does not know how to interpret, team members must communicate with one another. To ensure interdependence among team members, the task requires that members communicate to receive information necessary to perform effectively. Specifically, for members to use their unique rules, they must obtain information from other team members. Therefore, members are expected to interact with one another to exchange information that will be used to make a judgment about the aircraft's level of threat.

Each team member monitors a computer screen. Aircraft appear sequentially on the screen. For each new aircraft, members need to obtain information either directly or from another member. Team members communicate with each other through either verbal or typewritten messages. Members then make a judgment about the threat level of the aircraft and communicate their judgments to the leader. The leader then makes the final decision about the aircraft's threat for the team.

Aircraft range in their level of threat along a continuum from safe to dangerous. Seven verbal anchors are used to describe this continuum. The seven anchors are shown in the upper left hand portion of Table 2. The rules for evaluating the threat level of each aircraft can be expressed quantitatively, and, therefore, for any combination of cues, the correct decision regarding threat level can be determined. Thus, the quality of both individual and team decisions can be determined.

The upper half of Table 2 illustrates the performance possibilities. If, for example, the team decision was to ignore the aircraft but the correct decision was to defend against it, the difference between the two alternatives was the maximum six points, or the worst decision that could be made regarding the aircraft. At the other extreme, had the team decision been to defend against the aircraft, the best score, a zero difference, would result. The matrix in Table 2 shows all possible scores.

Following the team's decision, the team receives feedback on its performance. The feedback is in two forms. First, there is a descriptive feedback. This feedback is based on the similarity of the team's decision to the correct decision. The lower left part of Table 2 shows the relationship between the difference scores in the matrix and the descriptive feedback. In addition, quantitative feedback is provided in terms of numerical values associated with the outcomes shown in the descriptive feedback. These values are used to accumulate performance over trials. The feedback to the teams not only tells of their performance on the aircraft just viewed but on all aircraft they addressed up to that time.

Table 2

Scoring System for Individual and Team Decisions

		Correct Decision						
		Ignore						Defend
		1	2	3	4	5	6	7
	1 Ignore	0	1	2	3	4	5	6
	2 Review	1	0	1	2	3	4	5
Team/	3 Monitor	2	1	0	1	2	3	4
Individual	4 Warn	3	2	1	0	1	2	3
Decision	5 Ready	4	3	2	1	0	1	2
	6 Lock-on	5	4	3	2	1	0	1
	7 Defend	6	5	4	3	2	1	0

Descriptive Feedback	Quantitative Feedback
0 = "Hit"	+2
1 = "Near Miss"	+1
2 = "Miss"	0
3 = "Incident"	-1
4 $\geq$ "Disaster"	-2

Variable Manipulations

Three variables were manipulated in this study: the communication medium, information certainty, and time pressure. These variables are described below. The remaining measured variables are discussed later.

Communication medium. Teams performing this task exchanged information either face-to-face or through networked computers. In the computer-mediated condition, participants were separated into two rooms, each with four computer terminals. No more than two members of the same team were seated in the same room and computers were arranged to reduce the physical proximity between team members, thus reducing the potential for face-to-face interaction. In addition, participants were told that their fellow team members were seated in other locations in the lab and that their only interaction was to be through the computer; no talking was allowed during the simulation. Instead of speaking, these team members used the computer to obtain information about the aircraft, send typewritten messages to other members, and submit judgments or a team decision in the case of the leader. In the use of typewritten messages, members had the option of sending a message to all members or to individual team members.

In the face-to-face condition, four participants were placed in a room with four computer terminals situated in a rectangular format to allow members to communicate easily with one another. As in the computer-mediated condition, members used the computers to obtain information about the aircraft and to submit judgments.

However, verbal communications replaced the use of typewritten messages in this condition.

Information uncertainty. Information uncertainty was defined as the lack of clarity of the information regarding the aircraft teams monitored. When participants were given instructions on the value ranges for the cues regarding the aircraft, there were particular values that were not included in the ranges (see Table 1). For certain aircraft, all nine cues were assigned values that were included in one of the three threat ranges defined in the instructions. Uncertain aircraft had ambiguous information in terms of at least seven cues falling outside these ranges. Therefore, participants had to estimate what these values meant in terms of threat. For example, as shown in Table 1, team members are instructed that information about speed has the following ranges: somewhat threatening (325-500 mph), and very threatening (600-800 mph). A value of 650 mph would clearly represent a very threatening aircraft. A value of 550 mph, however, would be ambiguous since the member would not be sure whether this value represented a somewhat threatening or a very threatening aircraft. Certain and uncertain aircraft were alternated throughout the study, resulting in 14 certain and 14 uncertain aircraft.

Time pressure. Time pressure was defined as the amount of time allowed to make a decision about an aircraft. Low time pressure was operationalized as 240 seconds for the team to make a decision. High time pressure was operationalized as 120 seconds to make a decision. The time to make a decision changed after every seventh aircraft, creating two blocks with 240 seconds and two with

120 seconds. All together, 14 aircraft were monitored under low time pressure and 14 under high time pressure.

Procedure

Participants signed up in blocks of 6 or 10 people at a time to report to the experimental area. More individuals were asked to sign up than were required to ensure that complete teams could be formed from those participants who showed up at the scheduled time.

When participants reported to the experimental area, the first four or eight people were seated in a room where they watched a short video tape introducing the task. Any remaining people were placed in another study. Following the video, participants were randomly assigned to positions in a team and given written instructions on the task for their particular position (see Appendix B). They were allowed fifteen minutes to read the instructions and to memorize certain information required to perform the task.

After 15 minutes, participants were brought into one of two computer rooms based on their assignment and condition. Once participants were situated at their computer stations, they completed paper-and-pencil measures to be used as part of a different study. Next, they were given a brief interactive training session to familiarize them with the computer and the specific functions needed to perform the task. The interactive training consisted of talking participants through a practice trial. Participants were instructed on how to obtain information about an aircraft using the computer, how to send typewritten messages (computer-mediated teams only), and how to submit a judgment to the leader. The leader was given individual instruction on how to send in a final decision for the team.

Once participants completed the training, the actual simulation began. The simulation involved 28 aircraft, each with a preset time, that the team was required to monitor sequentially. At the end of the simulation, participants were asked to complete some additional questionnaires similar to those collected prior to training. They were then debriefed on the general purpose of the study and dismissed.

Coding Procedures

Face-to-face teams' communications were recorded on videotape. In the computer-mediated condition, messages were automatically recorded by the computer and could be easily transformed into written transcripts. Both types of messages were coded for content and frequency by trained coders. Coders were instructed to identify each completed phrase with the person it was communicated by, to whom it was communicated, and a code based on a coding scheme developed by the researcher (see Appendix C).

There were eight possible codes for the type of communications occurring within these teams. These types of communication are briefly discussed here; they are elaborated on in the measures section below. Two types of social communications were identified (team development and non-task related) that were later combined into a single code of social communications. Basically, team development referred to social comments related to the task (e.g., "Your doing a great job"). Social comments that did not pertain to the task were coded as non-task (e.g., "Any parties this weekend?"). Uninhibited words (i.e., profanity) were coded separately.

Three types of task-oriented communications were identified by the coding procedures. These were communications regarding the decision object (informational), procedural communications, and communications regarding the decision (decision proposals). These are described in more detail below. Finally, two codes were used to identify interrupted or incomplete phrases and communications not directed at other team members. These two types of communications were not included in the analyses since they was no reason to believe they were related to the media or team decision accuracy.

Although several coders were initially trained to code both typewritten and verbal messages, only two individuals were used to code the videotaped teams due to their greater accuracy. Coding of the videotapes required concentration and extreme patience. The coders had to view 31 teams with an average of 90 minutes of video and identify each communication by its content, the person from whom it came and the person(s) to who it was intended. The videotaped teams took anywhere from three to seven hours to code whereas teams with typewritten messages took an hour on average to code.

Due to the immense amount of data, random trials from several teams were sampled to assess interrater agreement. For the computer entered typewritten messages the average level of agreement was 85%. Discrepancies were resolved by the researcher. Unfortunately, due to time constraints and accuracy concerns, only one person was assigned the task of coding each video tape. The individuals chosen to code the video tapes were determined to be the most accurate by the researcher. On randomly selected trials, these coders agreed with the researcher at least 80%. Given the difficulty of the coding tasks, this level of agreement was considered rather acceptable.

Measures

This study was designed to examine the effect of two different communication media on a number of processes and outcomes of team decision making. The following discusses how each of the variables to be examined in this study was operationalized. The variables of media, time pressure, and uncertainty were previously described under manipulations.

Team decision making accuracy. In this study, decision accuracy was used as the indicator of team performance. Team decision accuracy was defined as the difference between the team's decision and the correct decision. The difference between the score for the correct decision and the score for the team's decision was computed for each decision object (see Table 2). These difference scores were then averaged across all decisions to obtain a measure of team decision accuracy. The lower the value, the more accurate the team's decision. Measures of team decision accuracy were also obtained for different subsets of decisions based on the within team factors of time pressure and uncertainty.

Communications. As described above, verbal and typewritten messages were coded for content and frequency. The amount of each of five different types of messages were computed and averaged over decision objects (aircraft) for each team. Thus, the average amounts of social, uninhibited, decision object communications, procedural communications, and decision proposals were obtained. A total of all communications was also computed. Each of the five types of communications is described as follows:

Social refers to any communication not related to the exchange of information, but related to interpersonal exchange. These communications can be related to the task (e.g., "Good job!"), or unrelated (e.g., "Want to get a beer later?").

Uninhibited communications refer to any use of profanity, whether in the context of another statement (e.g., "Let's blow this f-- ship up"), or a word said alone such as in response to a bad decision.

Decision object communications are any communications that involve the exchange of information about the aircraft or one's specialized knowledge (e.g., "What is the value for speed?"; "Three miles away means it is threatening.").

Decision proposals are distinct from decision object communications in that they refer strictly to any communication in which a judgment is offered or discussed (e.g., "Do you think we should ignore this one?"; "Shoot this plane down.").

Procedural communications are messages that involve asking or providing information about the performance of the task such as how the computers work or the amount of time left. For example, a leader may have to remind subordinates to send their judgments in earlier. This would be coded as a procedural communication.

Equality of Participation. The level of each member's participation was determined by the number of messages contributed to the discussion of each aircraft. As an estimate of the equality of participation, Siegel et al. (1986) suggested using the standard deviation of communications made by team members. First, the average total communications per decision was calculated for each member. Then, the standard deviation of the communications made by the four team members was computed. The closer this averaged value was to zero, the more equal participation was among team members.

Core Variables of the Decision Process. The operationalizations of team informity, hierarchical sensitivity, and staff validity are based on Hollenbeck et al. (in press), and each can be expressed in terms of an equation. Team informity, which is the number of pieces of information (cue values), on average, about which a team had knowledge for each decision object, is represented by the following:

$$TI_j = \sum_{i=1}^{k} 1/k \ (a_{ij} / a_{it})$$

where a_{ij} is the number of cues, a, known on the decision object i by team j; a_{it} is the total number of cues that could possibly be known on decision object i; n_j is the number of members in team j; and k is the number of decisions made.

Hierarchical sensitivity is the average difference between the weight given to each member's judgment by the leader and the actual weight of each member's judgment in determining the correct decision (based on a least squares regression). The equation for hierarchical sensitivity is:

$$HS_j = \sum_{m=1}^{n_j} | B_{mt} - B_{ml} | / n_j$$

where B_{mt} is the b weight for team member m's judgment in predicting the "true score" on the decision object; B_{ml} is the b weight for team member m's judgment in prediction the leader decision; and n_j is the number of staff members in team j.

Finally, staff validity is the average of the validities of each staff member in predicting the correct decision and can be computed as follows:

$$SV_j = \sum_{m=1}^{n_j} |r_{mj}| \,/\, n_j$$

where r_{mj} is the predictive validity of team member m on team j; and n_j is the number of staff in team j.

Data Analysis

Data analytic procedures are discussed in the results as each set of hypotheses, which involve different procedures, is addressed.

RESULTS

Three subsets of hypotheses were described earlier. The first set deal with the types of communications (social, uninhibited, procedural, decision object, decision proposals) that occur within teams studied under the two types of communication modes. The basic interest was to determine how face-to-face teams differ from computer-mediated teams in the amount of these various types of communications. Analysis of variance (ANOVA) was used to test mean differences between the two conditions for the five types of communications.

The next set of hypotheses addressed the relation of the communication mode and type of communications to the variables identified in the Hollenbeck et al. (in press) model of team decision making effectiveness. These hypotheses involved examining how the communication mode influences the decision making process. First, ANOVA was used to examine differences between the two modes in relation to the core variables. Then, hierarchical regression was used to test for possible mediation by various types of communication.

Tests of mediation require that, first, relationships between the independent, dependent, and possibly mediating variable be established. Then a hierarchical regression is performed in which the linear component of the potential moderator is controlled for while regressing the dependent variable on the independent variable. If the independent variables has an effect on the dependent variable, and this effect is negated by controlling for the potential moderator, then it can be concluded that there is a mediation effect.

Finally, the last set of hypotheses addressed the effect of the communication mode on team decision making accuracy. As proposed by Hypotheses 10 through 12, the communication mode was anticipated to interact with characteristics of the task, specifically time pressure and uncertainty, to influence decision accuracy. These hypotheses were tested using repeated measures regression where the between variable (mode) was entered first, followed by the within variables (time pressure and uncertainty), and finally their interactions.

Repeated measures regression is a useful technique for research on teams which is typically faced with problems of low statistical power and the categorization of continuous variables in ANOVA designs (Hollenbeck et al., in press). This technique allows within team factors to be "nested" inside between team factors so that the effects of the within factors can be tested against the partitioned variance appropriate to their effects. The technique of repeated measures regression is described in detail in Chapter 11 of Cohen and Cohen (1983).

Results regarding the effect of the communication mode on the types of communications will be discussed first. Next, the effects of the mode and communications on the decision making process will be addressed. This will be followed by a discussion of the relation of the communication mode, time pressure, and uncertainty to team decision accuracy. The means, standard deviations, and intercorrelations of the variables considered in the first two sets of hypotheses are presented in Table 3.

Communications

Hypotheses 1 through 5 addressed the types of communications occurring within teams interacting through different media. As indicated in Table 3, all types of communications were significantly related to the communication mode and indicated that face-to-face teams communicated significantly more than computer-mediated teams on every type of communication. Further tests of the hypotheses revealed similar findings. Hypothesis 1, that face-to-face teams would engage in more social communications than computer-mediated teams, was supported by the data. As indicated in Table 4, face-to-face teams engaged in .99 social communication per decision object on average while computer-mediated teams, on average, engaged in .58 social communications per decision object ($t = 2.18$, $p < .05$). Hypothesis 2, however, was not supported. It was proposed that computer-mediated teams would engage in more uninhibited communications than face-to-face teams due to greater anonymity of the computers. The results suggested otherwise. Face-to-face teams had more uninhibited communications on average ($x = .21$ per decision object) than computer-mediated teams ($x = .06$ per decision object; $t = 2.58$, $p < .05$).

Hypotheses 3 through 5 addressed communications that were more task-oriented (see Table 4 for results). Hypothesis 3 suggested that face-to-face teams would engage in more communications regarding the decision than computer-mediated teams. Results

Table 3

Variable Means, Standard Deviations, and Intercorrelations (N=63)

	x	s.d.	2	3	4	5	6	7	8	9	10	11	12
1. TDA[a]	1.92	.21	-.29*	-.40**	.12	-.51**	.03	-.25*	-.35*	-.25*	-.16	-.32*	-.21
2. Media[b]	.50	.50	1.00	.77**	.43**	.58**	.27*	.31*	.83**	.65**	.66**	.84**	.64**
3. TeamInf	.65	.19	--	1.00	.26*	.64**	.22	.36**	.85**	.53**	.54**	.81**	.60**
4. HierSens[a]	.18	.11	--	--	1.00	.32**	.10	.08	.31*	.17	.21	.30*	.26*
5. StaffVal	.62	.14	--	--	--	1.00	.13	.26*	.59**	.29*	.32*	.54**	.42**
6. Social	.78	.77	--	--	--	--	1.00	.52**	.33**	.20	.27*	.39**	.32*
7. Uninh	.13	.24	--	--	--	--	--	1.00	.43**	.06	.30*	.43**	.23
8. DecObj	11.90	9.86	--	--	--	--	--	--	1.00	.62**	.72**	.98**	.62**
9. Proced	1.36	1.58	--	--	--	--	--	--	--	1.00	.62**	.71**	.56**
10. Decision	3.33	3.08	--	--	--	--	--	--	--	--	1.00	.84**	.52**
11. Totcomm	17.51	13.74	--	--	--	--	--	--	--	--	--	1.00	.65**
12. EqPart[a]	1.28	1.08	--	--	--	--	--	--	--	--	--	--	1.00

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

[a]For the variables of Team Decision Accuracy (TDA), Hierarchical Sensitivity and Equality of Participation, a lower value represents a better score.

[b]The variable of communication medium was dummy coded (0=computer-mediated; 1=face-to-face).

indicated that face-to-face teams did discuss the decision more than computer-mediated teams ($t = 6.80$, $p < .01$). Similarly, as suggested by Hypothesis 4, face-to-face teams engaged in more communications regarding the decision object than computer-mediated teams ($t = 11.63$, $p < .01$). Finally, Hypothesis 5 suggested that face-to-face teams would engage in more procedural communications (e.g., how to work the computers) than computer-mediated teams. This hypothesis was also supported ($t = 6.69$, $p < .01$).

Table 4

Effect of the Media on the Type of Communications

Communication type	Computer-mediated (n=32) M	SD	Face-to-face (n=31) M	SD	*t*
Social	.58	.65	.99	.84	2.18†
Uninhibited	.06	.13	.21	.31	2.58†
Decision object	3.91	1.81	20.15	7.69	11.63**
Procedural	.36	.34	2.40	1.69	6.69**
Decision proposals	1.35	1.01	5.37	3.18	6.80**

† $p < .05$; ** $p < .001$, two-tailed

Decision Making Process

The second set of hypotheses (Hypotheses 6 through 9) addressed issues related to the decision making process. Specifically, they involved looking at the three core variables (team informity, staff validity, and hierarchical sensitivity) identified in the

Hollenbeck et al. model as being directly related to team decision making accuracy. These hypotheses examined the extent to which the communication mode and certain types of communications were related to these core variables. The possible mediating effect of the communications on the relationship between the mode and the core variables was also examined. First, however, it was important to establish a relationship between the core variables and team decision accuracy.

Hierarchical regression was used to test the proposition that the three core variables were related to decision accuracy. This analysis was used to show that a significant amount of variance in decision accuracy was accounted for by these variables. The three variables of team informity, staff validity, and hierarchical sensitivity were entered into the regression in an order based on the level of analysis from which they were aggregated. Team informity, which is based on the level at which the decision occurs, was entered first. Next, staff validity was entered because it is based on a variable occurring at the individual level, that is, individual validities. Then, hierarchical sensitivity was entered into the regression, since it occurs at the level of the leader-member dyad. Interactions among the core variables were also included in the regression based on the previous finding that the interaction of staff validity and hierarchical sensitivity tends to account for a significant amount of additional variance in decision accuracy.

Together the core variables of team informity, staff validity, and hierarchical sensitivity and their interactions accounted for 43% (see Table 5) of the variance in team decision making accuracy. Each variable separately accounted for a significant portion of the variance. Team informity accounted for 16%, staff validity 11%, and hierarchical sensitivity 10%. The interaction of staff validity and hierarchical sensitivity accounted for an additional 6% of the variance. Given that each core variable was significant, it was reasonable to examine the second set of hypotheses.

Hypothesis 6a proposed that teams with more communications regarding the decision object would be higher on team informity. Since face-to-face teams were expected to engage in more decision object communications, they were expected to be higher on team informity (Hypothesis 6b). Team informity refers to how well-informed teams are of the cues related to the decision object. A significant correlation of .85 (see Table 3) was found between decision object communications and team informity, thus supporting the first part of the hypothesis. Results of an ANOVA, shown in Table 6, indicated that face-to-face teams had higher team informity ($t = 9.32$, $p < .001$), also providing support for the hypothesis.

To further support the argument that the reason that face-to-face teams were higher on team informity was a result of decision object communications, a mediational analysis was performed. This involved examining if the effect of the communication mode is eliminated by controlling for the communications using regression analyses. (In the test of mediation, the media, which has been manipulated, necessitates that it be examined as an independent variable, and the communications, which are measured, examined as a potential mediator.) Initially, the communication media was significantly related to team informity ($R^2 = .59$) and decision object

Table 5

Relation of the Core Variables to Team Decision Accuracy (N=63)

Independent variable	R^2	ΔR^2	*b*
Team informity	.16*	.16*	-.40
Staff validity	.27**	.11*	-.42
Hierarchical sensitivity[a]	.37**	.10*	.34
SV X HS	.43	.06†	-1.35
TI X SV	.43	.00	-.25
TI X HS	.43	.00	.01

† $p < .05$; * $p < .01$; ** $p < .001$

[a]A lower score on hierarchical sensitivity reflects better sensitivity

Table 6

Effect of the Media on Team Informity, Staff Validity, and Hierarchical Sensitivity

	Computer-mediated (n=32)		Face-to-face (n=31)		
Communication type	M	SD	M	SD	*t*
Team Informity	.506	.121	.798	.128	9.32**
Staff Validity	.537	.114	.702	.126	3.59*
Hierarchical Sensitivity[a]	.129	.076	.220	.122	5.47**

* $p < .01$; ** $p < .001$, two-tailed

[a] A lower score on hierarchical sensitivity reflects better sensitivity.

communications (R^2 = .69). Decision object communications, with an R^2 of .73 for team informity, apparently mediated the effect of the communication medium. When decision object communications was entered first in a hierarchical regression, the effect of the media became nonsignificant thus indicating full mediation (see Table 7).

Table 7

Test of Mediation of Decision Communications in the Media--Team Informity Relationship (N=63)

Predictor	R^2 DecComm	R^2 Informity	ΔR^2
DecComm		.73**	.73**
Medium	.69**	.59**	.01

* p < .01 ** p < .001

Hypotheses 7a through 7c addressed the variable of staff validity, the validity of the staff members judgments in predicting the final team decision. Hypothesis 7a suggested that the more decision proposals, the higher the team's staff validity. The amount of decision proposals was significantly correlated with staff validity at .32 (see Table 3), thus supporting the hypothesis. Hypothesis 7b, that social communication would be negatively related to staff validity was not supported (r=.13, n.s.). Hypothesis 7c suggested, based on the previous two hypotheses, that computer-mediated teams would have higher staff validity than face-to-face teams. This hypothesis was not supported by the results (see Table 6). Instead, face-to-face teams had significantly higher staff validities than computer-mediated teams ($t = 5.47$, $p < .001$).

Further analyses indicated that this could be explained by the strong relationship between communications regarding the decision object and staff validity. Face-to-face teams had significantly more decision object communications than computer-mediated teams, and decision object communications were found to be significantly correlated with staff validity ($r=.59$, $p < .01$). The greater amount of decision object communications did not produce an overload effect as was suggested in the discussion of hypothesis 7c. As with team informity, further analyses were performed to examine the possibility of a mediation effect by the type of communications.

Although the amount of decision proposals was significantly correlated with staff validity, it did not eliminate the effect of the media on staff validity (see Table 8). The amount of communications regarding the decision object, which was more highly correlated with staff validity than decision proposals, did reduce the effect of the medium to nonsignificance (see Table 9). Therefore, it can be concluded that decision object communications fully mediated the relationship between the medium and staff validity.

Next, the variable of participation equality was examined. As suggested by previous literature, Hypothesis 8 stated that computer-mediated teams would have more equal participation among team members than face-to-face teams. This hypothesis was tested by first computing a score for the equality of team member participation. This score was computed such that the closer the value was to zero, the more equality of participation. Results of an ANOVA supported the hypothesis that computer-mediated teams have more equal participation among team members than face-to-face teams (x = .604 and 1.98 respectively; t = 6.52, p < .001).

Table 8

Test of Mediation of Decision Proposals in the Media--Staff Validity Relationship (N=63)

Predictor	R^2 DecProp	R^2 Staff Val	ΔR^2
Dec Proposals		.10†	.10†
Medium	.43**	.33**	.23**

† p < .05 ** p < .001

Table 9

Test of Mediation Decision Communications in the Media--Staff Validity Relationship (N=63)

Predictor	R^2 DecComm	R^2 Staff Val	ΔR^2
DecComm		.35**	.35**
Medium	.69**	.33**	.02

* p < .01 ** p < .001

Finally, Hypothesis 9 addressed the core variable of hierarchical sensitivity. Hierarchical sensitivity refers to how effectively the team leader weighs his or her staff members' judgments in making the final team decision. It was argued that hierarchical sensitivity was a more appropriate variable to study in these teams than participation equality because each team member's contribution is important to the accuracy of the team's decision. The leader needs to be sensitive to the validity of each member's contribution rather than the amount they contribute. As was hypothesized, computer-mediated teams did have higher hierarchical sensitivity than face-to-face teams ($t = 3.59$, $p < .01$; see Table 6).

Team Decision Accuracy

The final set of hypotheses (10, 11 and 12) involved examining the influence of the communication mode on team decision accuracy. Based on previous literature, it was not anticipated that the mode would have an effect on decision accuracy. Therefore, an attempt was made with the hypotheses to identify characteristics of the task that may interact with the communication mode to have an influence on team decision accuracy. Two aspects of task difficulty, time pressure and uncertainty, were hypothesized to interact with the communication mode. Each of these variables was dummy coded in the analyses.

Hypothesis 10 suggested that, under conditions of task uncertainty, in other words, when information was ambiguous, computer-mediated teams would perform better than face-to-face teams. Hypothesis 11 proposed that under conditions of high time pressure to make a decision, face-to-face teams would perform better than computer-mediated teams. Finally, Hypothesis 12 suggested a three-way interaction between the mode, uncertainty, and time pressure. Only under conditions of low time pressure and uncertainty should computer-mediated teams perform better than face-to-face teams.

A repeated measures regression was used to test the hypotheses identified above. This involved entering the between-team variable of communication mode first, followed by the within-team variables of time pressure and uncertainty, and then all the interaction terms as described earlier (see Table 10).

Table 10

Effect of Communication Mode, Time Pressure, and Uncertainty on Team Decision Accuracy (N=256)[a]

Independent variable	R^2	ΔR^2	*b*
Communication Mode	.03**	.03**	-.17
Time Pressure	.03†	.00	-.03
Uncertainty	.06**	.03**	-.18
Mode X Time	.06**	.00	-.16
Mode X Certainty	.06**	.00	.19
Time X Certainty	.11**	.05**	.34
Mode X Time X Certainty	.11**	.00	.27

† $p < .05$; ** $p < .01$

[a]N=64(teams) X 2(levels of time pressure) X 2(levels of certainty)

Although no explicit hypothesis was made regarding the influence of the communication mode on team decision accuracy, this relationship was analyzed as part of the hierarchical regression. Unlike previous research, a direct effect of the communication mode on performance (decision accuracy) was found. The communication mode accounted for 3% of the variance in team decision accuracy which was significant at $p < .01$. As indicated by the regression weight, face-to-face teams performed significantly better than computer-mediated teams. The uncertainty of information about the decision object also accounted for a significant amount of variance, $\Delta R^2 = .03$. However, this relationship was not in the expected direction. Teams apparently performed better on uncertain targets ($b = -.18$). Possible explanations for this results will be addressed in the discussion.

Although there were some direct effects, the results did not support any of the hypotheses stated above. The interaction of both time pressure with mode and uncertainty with mode accounted for no significant variance in decision accuracy (see Table 10). There was a significant effect for the interaction of time pressure and uncertainty which accounted for an additional 5% of the variance in decision accuracy. It appears that teams performed best under low time pressure and high uncertainty (see Figure 2). This again indicates a problem with the variable of uncertainty which will be addressed in the discussion. Finally, the hypothesized interaction between time pressure, uncertainty, and communication mode was not supported.

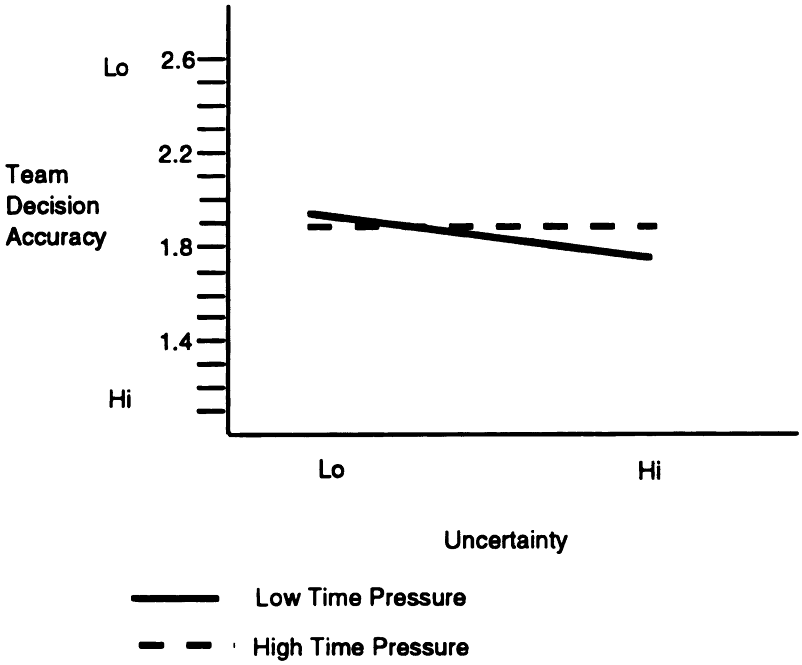


Figure 2. Interaction of time pressure and uncertainty.

DISCUSSION

The purpose of this study was to compare face-to-face with computer-mediated teams on a number of variables involved in the decision making process, from the communications to team performance. First, it was found that face-to-face teams engaged in more of each type of communication. These results are not totally consistent with previous findings as will be discussed later. Second, the media were compared on the three core constructs from the multi-level model of hierarchical team decision making (Hollenbeck et al., in press). Face-to-face teams were better informed on average about decision objects (team informity) and, on average, staff members made more accurate decisions (staff validity) in the face-to-face condition. Computer-mediated teams, however, were higher on hierarchical sensitivity. In other words, leaders of computer-mediated teams weighed members' judgments more appropriately than leaders of face-to-face teams. Hierarchical sensitivity did not account for as much variance in team decision accuracy as did staff validity and team informity. Therefore, as shown by the final stage of analyses, face-to-face teams performed better in terms of decision accuracy than computer-mediated teams.

A specific hypothesis regarding the effect of the media on team decision accuracy was not made, but rather it was proposed that the medium would interact with the task characteristics of time pressure and information uncertainty. None of the hypothesized interactions were found to be significant. As already stated, there was a direct effect for the medium. In addition, there was an effect for certainty as well as the interaction of time and uncertainty. The above findings will be addressed further in the remainder of the discussion.

Communication Processes

Face-to-face teams engaged in significantly more of the five types of communication identified through the coding process. This included the three types of task-related communications, decision object communications, decision proposals, and procedural communications, as well as social and uninhibited communications. In at least two ways, these results differ from previous findings in the literature.

First, it has been suggested that computer-mediated teams are as task-oriented, and perhaps more task-oriented, than face-to-face teams as indicated by a higher proportion of task-related to total communications (Hiltz et al., 1986; Kiesler et al., 1984; Siegel et al., 1986). Therefore, proportions were examined in order to compare the present findings with previous ones. Looking at the proportion of the five communication types to the total communications, it appears that the majority of the communications were of the decision object type (68%), followed by decision proposals (19%), procedural (8%), social (4%), and uninhibited communications (1%). More importantly, it was discovered that face-to-face teams had a slightly greater proportion of task-related messages (decision object, decision proposals, and procedural communications combined) than computer-mediated teams (96% versus 90%).

A possible explanation for the slightly greater proportion of task-related communication in the face-to-face condition is that the physical presence of other team members created social pressure to stay on task. It is more difficult to ignore the task or the team when it is salient, in other words, when the people in your immediate environment are performing the task and working as a team. In the computer-mediated condition, people may be able to distance themselves psychologically from the task and the team. They may feel less responsibility to contribute to the team. Social psychologists have shown that when individuals are physically separated from one another, and believe other people are available to perform the task, they are less likely to assume responsibility for taking action in a situation (e.g., Darley & Latane, 1968).

Even though there was a difference in proportion favoring the face-to-face teams, teams in both conditions had a fairly high proportion of task-related as compared to social communications. The proportion of social communications in each condition was much smaller, 9% in the computer-mediated condition, and 3% in the face-to-face condition. It might be assumed that face-to-face teams would be more social since the medium is more conducive to social interaction. Computer-mediated teams, however, were more social in this study. A possible explanation is that a social atmosphere may develop more readily in the face-to-face condition, while in the computer-mediated condition individual members may need to work to create such an environment. Computer-mediated teams may attempt to develop a social atmosphere by exchanging more social messages.

A second inconsistency with previous findings concerns the amount of uninhibited communications. In neither condition was the amount of uninhibited communications more than 1% of the total communications, but face-to-face teams engaged in significantly more of these communications than computer-mediated teams. It has been suggested that electronic, or computer-mediated communication leads to the expression of extreme thoughts or opinions, including the use of profanity (Kiesler & Sproull, 1992). This phenomenon has been labelled "flaming" by the computer science community (Kiesler et al., 1984). However, in this study, flaming does not appear to be a significant event nor unique to computer-mediated communications.

One possible explanation for more uninhibited communications in the face-to-face condition is that there were a few extremely profane teams in this condition. In order to determine if this was the case, the frequencies of uninhibited communications as well as the proportion of uninhibited to total communications across teams were examined. Slightly less than half the teams (24) engaged in no uninhibited communications, 80% of these teams were in the computer-mediated condition. Of the remaining teams, twenty engaged in one or two uninhibited communications across the entire simulation (nine computer-mediated and eleven face-to-face), a rather small amount considering the average total communications across all trials was 486. Finally, nineteen teams had between three and 36 uninhibited communications over the entire simulation; only four of these teams were in the computer-mediated condition. The four computer-mediated teams, however, were not necessarily at the low end of this range; one computer-mediated team had 18 uninhibited communications.

These frequencies do not completely resolve the question of whether or not a few extreme teams in the face-to-face condition contributed to the significant difference found when the amount of uninhibited communications was compared between conditions. Teams with more uninhibited communications may have also had more total communications. Therefore, the proportion of uninhibited to total communications was calculated for each team. The team with the highest proportion of uninhibited to total communications (6%) was actually a computer-mediated team. Of three teams with the next highest proportions, between 4% and 5%, two were in the computer-mediated condition. Therefore, it does not appear that the finding that face-to-face teams had significantly more uninhibited communications was due to a few "extreme" teams since these "extreme" teams tended to be in the computer-mediated condition.

The finding that the largest proportions of uninhibited communications tended to be among computer-mediated teams is interesting. It suggests that there may be a phenomenon such as "flaming" that is a result of communicating through computers. However, the average proportion across teams in each condition indicates that computer-mediated teams engaged in the same proportion of uninhibited communications as face-to-face teams (1%), and it should be reiterated that this is a very small proportion.

Another interesting and possibly valuable way of examining the difference between uninhibited communications in face-to-face versus computer-mediated teams is to investigate the nature of the profanity used. Examining the specific content of the uninhibited communications in each condition indicated that while face-to-face teams used profanity in reaction to certain behaviors or decision outcomes, computer-mediated teams tended to be more deliberate and used profanity in the context of other phrases (e.g., "Destroy this bastard!!"). It is easy to argue that typewritten words involve more thought and are therefore communicated with more intention than spoken words. Verbal communications can be responses that involve little or no thought such as when a person yells "damn" after hitting her finger with a hammer. If the uninhibited communications occurring in computer-mediated teams are more deliberate, it may be argued that they are more problematic. If this is so, the phenomenon of "flaming" deserves further attention.

Team Decision Making Processes

Although findings regarding the communications are interesting, they are only important to the extent that the mode and the communications affect the decision making process. Therefore, relationships between the communication mode, the type of communication, and the core variables associated with team decision accuracy were examined. As a necessary precondition, it was first established that the core variables of team informity, staff validity, and hierarchical sensitivity were related to team decision accuracy. Together, these variables and their interactions accounted for 43% of the variance in decision accuracy, each variable accounting for a significant portion of variance.

The next step was to examine the relationship between the communication mode and these variables. Significant differences were found between the two media for team informity, staff validity, and hierarchical sensitivity. First, face-to-face teams were higher on team informity than computer-mediated teams. This relationship was explored further by examining the types of communication that were associated with team informity. As expected, communications regarding the decision object were highly correlated with team informity (r = .85), but it was argued that this relationship should not necessarily have been assumed. More decision object communications did not ensure that specific information regarding the threat of the aircraft was shared.

One alternative is that only common information is brought into a discussion. Stasser and colleagues (Stasser & Titus, 1985; Stasser et al., 1989) found that information shared prior to a discussion is more likely to be brought into the discussion; information that is unique tends to be ignored. They also suggested that certain task conditions, such as face-to-face interaction, may lead to less sharing of unique information and therefore, less effective decision making (Stasser & Titus, 1985). Most of the information in the present task was unique, that is, only known by one member of the team. However, a third of the information was shared by two members. It was possible that not all of the necessary information entered the discussion, even when the teams communicated more. Therefore, further analyses were performed.

The increased communications in face-to-face teams apparently led to the sharing of unique information as indicated by higher team informity. A test of mediation indicated that it was through the decision object communications that face-to-face teams became more informed. This is contrary to the suggestion by Stasser & Titus (1985) that face-to-face interaction would result in less sharing of unique information. Rather, it may be that face-to-face conditions promote the discussion of unique information. The physical presence of others may create a greater sense of responsibility to the team or pressure to contribute. It is more difficult to ignore a request for information if someone is staring at you than if a typewritten message is in front of you. This is not to say that there is not pressure from other members in computer-mediated teams.

In several cases, a team member in the computer-mediated condition repeatedly asked for information from another member but did not receive it. This sometimes led to increasingly hostile requests for information (e.g., "Wake up lazy ass!" and "Send me speed now!!"). Pressure from team members, therefore, is not unique to face-to-face teams, but the opportunity to ignore the team and individual requests seems much greater in the computer-mediated condition.

Since face-to-face teams were more informed on average about the decision object, it is possible to argue that they would make more accurate decisions. However, it was hypothesized that computer-mediated teams would have higher staff validity. This was based on the assumption that too much communication can be distracting. Greater amounts of communication may simply be due to redundancy of information. Members may also be overwhelmed by too much information to the extent that they cannot focus on the task and make accurate decisions. Individual judgments may become less precise as the members' expert knowledges become clouded by excessive and unnecessary information.

Although it was hypothesized that computer-mediated teams would be higher on staff validity than face-to-face teams, the opposite relationship was found. This finding can be explained by considering the relationships between the types of communication and staff validity. It was hypothesized that the amount of decision proposals would be related to staff validity. Although decision proposals were significantly correlated with staff validity ($r = .32$), and face-to-face teams had significantly more decision proposals, this did not explain why face-to-face teams had higher staff validities. As with team informity, it appeared that the more decision object communications engaged in by face-to-face teams explained their higher staff validities. Team informity was also significantly correlated with staff validity ($r = .64$) suggesting that teams who are more informed, face-to-face teams here, will have higher staff validities.

Although face-to-face teams were better on the variables of team informity and staff validity, computer-mediated teams were better on equality of participation and hierarchical sensitivity. The variable equality of participation was studied as it has been frequently identified in previous research comparing face-to-face and computer-mediated groups (Kiesler & Sproull, 1992). It was found that computer-mediated teams had more equal participation among team members than face-to-face teams, thus supporting previous findings. This variables was not expected to relate to any other variables in the decision making process and therefore was not considered further. Instead, hierarchical sensitivity was examined.

Computer-mediated teams were expected to have better hierarchical sensitivity. In computer-mediated conditions, social factors (e.g., physical appearance) that may lead to particular judgments about team members are less available or altogether absent. In addition, certain individuals may not dominate the discussion in computer-mediated interactions because everyone can communicate at one time. From the leader's standpoint, perceptions of staff members' abilities are less likely to be influenced by factors that may be irrelevant to determining ability such as assertiveness or attractiveness. As was expected, leaders of computer-mediated teams weighed staff members' judgments more appropriately in determining the team's decision. Unlike the previous variables of team informity and staff validity, there was no reason to expect that this relationship was due to a particular type of communication.

Team Decision Accuracy

The final set of analyses addressed the effect of the medium on team decision accuracy. Previous studies comparing face-to-face and computer-mediated groups or teams have looked at a relatively small number of outcome variables such as decision quality and consensus. Differences have only been found for the variable of consensus. The variable of consensus seems more amenable to the influence of the mode than other performance indicators. It is probably much more difficult to discuss opinions in computer-mediated conditions since people cannot provide immediate feedback, and it will likely take much longer because typing is generally slower than speaking. Media effects on performance measures like decision quality or accuracy are assumed to be less likely. However, if such effects occur, it may be argued that they are stronger indicators of the influence of communication media on team performance. This study used decision accuracy as the indicator of team performance.

Since the literature has suggested there is no difference between face-to-face and computer-mediated teams in terms of decision quality, no specific hypothesis was made regarding a direct effect of the mode on team decision accuracy. Instead, it was hypothesized that the medium would interact with the task characteristics of time pressure and information uncertainty. None of the hypothesized interactions were found to be significant. Face-to-face teams, however, performed significantly better than computer-mediated teams in terms of decision accuracy.

The finding of a direct effect of the communication mode on decision accuracy can be explained by the previous findings regarding the core variables in the multi-level model of team decision making. As stated earlier, the three variables of team informity, staff validity, and hierarchical sensitivity and their interactions accounted for 43% of the variance in team decision accuracy (see Table 5). Individually, team informity accounted for 16%, staff validity 11% and hierarchical sensitivity 10%. Face-to-face teams were found to be higher on both team informity and staff validity which together accounted for 27% of the variance in team decision accuracy. Computer-mediated teams, however, where higher on hierarchical sensitivity, but this variable accounted for only 10% of the variance. For this particular task, informity and staff validity were more important in determining decision accuracy than hierarchical sensitivity. Therefore, face-to-face teams, who were more informed and had higher staff validities, performed better. If hierarchical sensitivity had been more important in determining decision accuracy, computer-mediated teams may have performed better.

It is important to note that, in some tasks, hierarchical sensitivity may be more critical than how informed a team is about the decision object. By using the multi-level model, it is possible to (1) show how a particular variable relates to team decision making accuracy, and (2) identify different aspects of the decision making process that may be influenced in different ways by that variable. If these core variables had not been examined, it would not have been discovered that computer-mediated teams do better than face-to-face teams in at least one aspect of the decision making process.

As mentioned above, the hypothesized interactions between the communication mode, time pressure, and information uncertainty were not significant. There were, however, significant effects for uncertainty as well as the interaction of time and uncertainty on decision accuracy. Unfortunately, the direction of these effects were contrary to what would be expected. Teams appeared to be more accurate when making decisions about uncertain aircraft. Further investigation indicated that information uncertainty was confounded with the difficulty of the decision for each aircraft.

Decisions ranged on a seven point scale from "ignore" to "defend" (see Table 2). Decisions at either end of the continuum tended to be easier than those in the middle because the majority of the information about the aircraft represented one extreme or the other. For decisions in the middle (i.e., "monitor," "warn," and "ready"), there was a mix of threatening and non-threatening information, making the aircraft more difficult to judge accurately. In the case of the uncertainty manipulation, the majority of uncertain aircraft (nine out of fourteen) were at the extreme ends of the decision continuum while the majority of certain aircraft were in the middle. Therefore, uncertain aircraft were the easier aircraft in terms of the decisions. This provides a reasonable explanation why the results suggested that teams performed better on the uncertain targets. Instead, the finding appears to indicate that teams were more accurate for decisions at the extremes than decisions in the middle of the continuum. This also helps to explain the interaction of time and certainty which suggested that teams performed best under low time pressure and uncertainty (see Figure 2).

Although the communication mode did not interact with time pressure or uncertainty, such relationships should not be ruled out. The manipulations used here may not have produced the desired effects. In addition, other variables may alter the relationship between the communication medium and team decision accuracy that should be explored, particularly if they result in better performance among computer-mediated teams.

Study Limitations

An explanation has already been suggested for the reverse effect uncertainty had on decision accuracy. However, time pressure did not have the intended effect on decision accuracy either. The reason time pressure did not have an effect on decision accuracy is likely attributable to the manipulation. There are two potential explanations why this manipulation had no effect. First, time pressure was manipulated in blocks. On every seventh trial the amount of time to make a decision about an aircraft alternated between 120 and 240 seconds. Having a series of aircraft with 120 seconds may have allowed teams to adjust to having less time to make a decision. A better alternative might have been to randomize the appearance of aircraft with 120 and 240 seconds throughout the simulation.

The second possible explanation is that 120 seconds may have not been sufficient to put a constraint on the decision making process. Teams in both face-to-face and computer-mediated conditions may have had enough time to exchange information and submit judgments whether they were given 240 or 120 seconds. Perhaps there is a threshold time (e.g., 90 seconds), at which teams, particularly in the computer-mediated condition, become less capable of making accurate judgments because they cannot exchange the necessary information.

It was possible to explore the impact of the 120 second manipulation by examining the effect of introducing an aircraft with 120 seconds to make a decision following an aircraft with 240 seconds. Scores were obtained and averaged for the two aircraft occurring at the time change from 240 to 120 seconds, and two comparable (in terms of uncertainty) aircraft with 240 seconds immediately preceding this change. Significant mean differences were found when these aircraft were compared. The aircraft with

120 seconds had a mean decision accuracy of 2.06, while the aircraft with 240 seconds had a mean of 1.55 (lower score indicating greater accuracy; $t = 4.90$, $p < .001$). This suggests that there may be an effect for time on decision accuracy. The relationship of time and communication mode may deserve further attention, but with a better time manipulation.

Although the type of communications were differentiated more in this study than in previous research, there may be better distinctions. Three types of task-oriented communications were identified theoretically as being distinct in content, but methodologically, they may not be distinct. Similar relationships were found for these three variables with the communication mode. However, these communication types had different relationships with the core variables and decision accuracy (see Table 3). It is unclear whether these communications are best represented by one category or if there are finer distinctions worth making in the future. For example, was raw data being communicated as opposed to information that was already interpreted? Did the decision proposals include some indication of the confidence in one's judgment (e.g., "Definitely monitor" versus "Maybe we should defend")?

Before further distinctions are made, it is important to first consider whether there is reason to expect differences between the two media, for instance, in the amount of raw data provided. Secondly, there should be some speculation that these distinctions will explain some difference in the decision making process that may affect the team's performance. Whether the above distinctions were too specific or not specific enough, they do suggest that not all task-related communications are significantly related to team decision accuracy.

Another issue related to the communications is that a rather small portion of the communications were social (4%). These communications tended to become more frequent toward the end of the simulation. Many of the messages were in reference to boredom with the task (e.g., "Aren't we done yet?") or to activities following completion of the study (e.g., "Want to get a beer after?"). One explanation why there were so few social communications is that not enough time was allowed for participants to get to know one another. Participants attended one 3-hour session, and were only engaged in the actual simulation for half of that time. If social communications are of interest to researchers, it may be necessary to conduct longitudinal studies in which participants have a greater opportunity to develop social relationships with one another.

Finally, the type of teams and the task used here are potential limitations. The teams were hierarchical with distributed expertise. In other words, there was a leader and staff members who were responsible for unique information. Thus, there is a limit to the types of teams to which conclusions can be generalized. However, it can be argued that the basic characteristics of these teams (hierarchical and interdependent) are representative of many teams found in the "real world".

The task was a naval command and control task where participants were expected to obtain information about aircraft and make decisions based on threat levels. These decisions were objective in that there was one correct decision, as opposed to a subjective decision task where participants offer opinions and are judged as to the quality or consensus rather than accuracy of their decisions.

As discussed earlier in a review of the literature, Hirokawa (1990) identified three factors of the task that determine the influence of the communication. These were task structure, information requirement, and evaluation demand. Interaction, or communication, becomes more critical as the task structure increases in complexity. Information requirement refers to the distribution of and processing of information. This was characterized by Hirokawa (1990) by means-interdependency, or the extent to which all members possess information necessary to perform the task and the complexity of the information processing. Communications are more critical the more means-interdependent the task. The third factor, evaluation demand, was represented on a continuum from unequivocal to equivocal tasks. Communication has less influence when the task is unequivocal, that is, when the task has a single, correct choice and a clear, verifiable decision alternative.

In regards to Hirokawa's (1990) first factor, the present task was assumed to be complex. Some of the arguments developed in this study, particularly in reference to the variable of staff validity, were based on the assumption that this task was fairly complex. For example, on complex tasks the presence of others tends to have an inhibiting effect on performance (e.g., Zajonc, 1966). It is easily argued that this task was novel to all participants, although the novelty may have dissipated with time on the simulation. It is uncertain, however, how complex this task was for these participants. Participants worked on one task the entire time, thus allowing them to focus on the task. It could be argued that complexity involves more variety of task demands. Attempts might be made to manipulate the complexity of the task by requiring participants to work on a secondary task while monitoring aircraft. Under these conditions, one might better observe the effects of distraction in terms of performance deficits for face-to-face teams.

The second factor, information requirement, is clearly mean-interdependent in this task. Members each possessed certain knowledge regarding the task, but no one member had access to all the informational cues. Therefore, communication was required; information had to be shared in order for the team to make the correct decision. This was discussed previously in terms of Stasser and colleagues' (Stasser & Titus, 1985, 1987; Stasser et al., 1989) research on shared information.

Finally, in terms of evaluation demand, this task is arguably unequivocal in the sense that there is one correct choice or decision criterion. Consensus tasks are more representative of equivocal tasks and thus require more communication. Teams, however, can be more or less accurate in their choices. When there is one correct decision, communication can have a significant influence on the outcome. The outcome will depend on how and what information is shared and how individual members influence the decision. Therefore, it may be argued that when the task is means-interdependent, communications will be important whether or not the decision is unequivocal.

It is useful to examine the task in terms of a typology like Hirokawa's (1990) in order to assess how much influence the communications can be expected to have. If the communications are relatively unimportant, then it is futile to compare different communication media in such a task.

Implications and Directions for Future Research

This study raises important questions regarding the effect of the communication medium on the decision making process in teams. In several ways, the findings here are incongruent with previous conclusions made about face-to-face versus computer-mediated decision making. In regards to the communications, it was found that face-to-face, not computer-mediated, teams had more uninhibited communications, although in neither condition was the amount of communication great. It appears that there were differences in the nature of these communications (e.g., reactive versus intended). This difference in content should be explored further because it may have both positive and negative implications for team interactions. Individuals may express their opinions or views regarding a topic more freely through computers. But, this freedom of expression may lead to offensive communications that, in turn, alienate other team members. Perhaps, new norms will have to be established among computer-mediated teams in order to encourage expression yet minimize the use of insulting or profane remarks.

There was also some inconsistency regarding the amount of task-related and social communications. It has been assumed that computer-mediated teams will be more focused on the task than face-to-face teams, and, therefore, they should be at least as equally task-oriented in their communications. As discussed earlier, it was the face-to-face teams who had a higher proportion of task-oriented communications. Computer-mediated teams, however, had a slightly higher proportion of social communications even though face-to-face teams had more total social communications.

The growing use of computers and electronic mail may make it more acceptable to interact socially through electronic media. Therefore, it may no longer be interesting to compare teams on the amount of social or task-oriented communications, but rather on the reasons for and purposes of these interactions. For example, are computer-mediated teams compensating for the lack of face-to-face interaction by exchanging more social-oriented messages? Do computer-mediated teams have less norms regarding the types of communications, task versus social? Is there a greater sense of responsibility in face-to-face teams which leads to greater attention to the task? In other words, researchers should extend beyond looking at differences in the amount or proportion of communications to consider why there are differences, if any, and what implications those differences have for the decision making process. This study has begun to address this latter issue.

Three critical variables in the decision making process were identified, team informity, staff validity, and hierarchical sensitivity. Each was shown to relate to decision accuracy and the communication medium. In addition, the effects of the medium on team informity and staff validity were shown to be mediated by decision object communications. These findings suggest that communications are important in the decision making process. They also suggest that the medium may have different influences on the decision making process. Here it was shown that although face-to-face teams performed better on the variables of team informity and staff validity, computer-mediated teams were better on hierarchical sensitivity. Future research might consider the type of task teams are performing. For some tasks, hierarchical sensitivity may be more important in determining team effectiveness. Thus, for some tasks, computer-mediated teams may perform better.

Finally, the most interesting and significant finding was that face-to-face teams performed significantly better than computer-mediated teams in terms of decision accuracy. Previous literature has generally concluded that face-to-face and computer-mediated teams do not differ significantly in terms decision quality. If differences do occur, Kiesler and Sproull (1992) suggest that electronic, or computer-mediated, teams would perform better. This was based on the assumption that social factors (e.g., norms, status differences), which are believed to exert more influence in face-to-face teams, are debilitating to high quality decision making. This assumption does not support the finding that face-to-face teams actually performed better. Therefore, researchers need to explore further the factors that may distinguish face-to-face from computer-mediated interactions. Some of these have been already suggested such as social pressure to contribute and responsibility. In addition, researchers should examine tasks and task conditions to help explain why teams perform better using one medium versus the other. Tasks with high time pressure may be better performed by face-to-face teams because they can communicate faster. Idea generation tasks, however, may be better performed by computer-mediated teams because individuals are less inhibited.

These are just a few of the issues that need to be addressed by future research. This study has challenged some basic assumptions regarding computer-mediated and face-to-face decision making. Hopefully, through more comprehensive research and better theory we can improve our understanding of the impact advanced communications technologies have on individuals and teams.

APPENDICES

APPENDIX A

CUE AND INTERACTION VALUES

	Cue values									Interaction values					Decision
Trial #	1	2	3	4	5	6	7	8	9	1	2	3	4	5	(1-7)
1	0	1	0	2	2	2	1	2	2	0	1	0	4	4	4
2	0	2	1	0	1	1	0	2	1	0	0	2	0	2	2
3	2	2	2	2	1	1	2	2	2	2	4	4	4	2	6
4	2	2	2	1	2	2	2	2	2	4	4	4	2	4	7
5	2	0	0	2	1	1	0	2	2	2	0	2	4	2	3
6	0	1	0	0	1	0	0	0	1	0	0	0	0	2	1
7	2	2	2	2	2	0	2	2	0	0	4	4	0	4	5
8	2	1	1	2	2	0	2	2	2	0	2	2	4	4	5
9	1	2	1	2	2	1	0	1	1	1	0	1	2	4	3
10	1	2	2	2	2	2	2	2	2	2	4	4	4	4	7
11	2	0	1	0	2	2	2	1	2	4	0	1	0	4	4
12	2	2	0	1	1	0	1	2	1	0	2	0	1	2	2
13	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1
14	0	2	2	2	2	2	2	0	2	0	4	0	4	4	5
15	2	2	2	1	2	2	2	1	2	4	4	2	2	4	6
16	2	1	2	2	2	1	2	1	0	2	2	2	0	4	4
17	1	2	2	2	2	2	0	0	1	2	0	0	2	4	3
18	1	1	2	0	1	2	1	0	1	2	1	0	0	2	2
19	2	2	2	1	2	2	2	2	2	4	4	4	2	4	7
20	2	1	1	1	0	1	0	1	0	2	0	1	0	0	2
21	1	1	0	0	0	0	1	1	1	0	1	0	0	0	1
22	2	1	2	2	2	2	2	2	1	4	2	4	2	4	6
23	2	2	1	2	0	2	2	1	2	4	4	1	4	0	5
24	1	0	0	0	0	1	1	1	0	1	0	0	0	0	1
25	0	1	2	0	2	2	0	2	2	0	0	4	0	4	3
26	0	2	2	0	2	2	2	1	2	0	4	2	0	4	4
27	2	1	1	0	1	1	2	0	2	2	2	0	0	2	3
28	1	2	0	2	2	2	0	1	1	2	0	0	2	4	3

Interactions:
(1). "1"(Speed) X "6"(Direction)
(2). "2"(Altitude) X "7"(Corridor Status)
(3). "3"(Size) X "8"(Radar)
(4). "4"(Angle) X "9"(Range)
(5). "5"(IFF) X 2

APPENDIX B

HANDBOOK OF INSTRUCTIONS

HANDBOOK FOR TEAM MEMBERS

NAVAL COMMAND AND CONTROL SIMULATION

Team Effectiveness Laboratory

Michigan State University

EXP 8

NAVAL COMMAND AND CONTROL TEAM SIMULATION

INTRODUCTION

The year is 1996 and you are a part of a U.S. naval carrier task force command and control team stationed in the Middle East. A regional conflict between two nations in this area has recently broken out, and your mission is to protect seagoing commercial traffic in the area from accidental or intentional attacks.

THE TASK FORCE

A naval carrier task force is an awesome array of ships and support units. The carrier's 90 planes can unleash air strikes against targets at land, sea and even under water. A standard carrier task force consists of 6 ships: the carrier itself, 2 Aegis Cruisers, 2 anti-air destroyers, and a submarine. The carrier task force is also supported by AWACs reconnaissance planes and a land based Coastal Air Defense (CAD) unit. Although the carrier itself is equipped with some air patrol capacities, the cruiser, AWACs and CAD units provide the bulk of the air traffic patrol. Taken together, the air patrol groups on the Carrier, the Cruiser, the AWACs and the CAD unit make up the command and control team.

TEAM MISSION

The team of which you are a part, will play the role of the Commanding Officers of various units of the command and control team. Your mission is to monitor the air space surrounding the carrier task force, making sure that neutral ships are not attacked. In performing this role, you must make certain that you do not allow loss of life resulting from attacks on ships in the carrier's task force. At the same time, it is also of paramount importance that you do not inadvertently shoot down friendly military aircraft or any civilian aircraft.

OVERVIEW OF ROLES

There are four roles in this simulation, one for each member of a four person team. The leader is the Commanding Officer (CO) of the Aircraft Carrier. The other team members include the CO of an AWACs air reconnaissance plane; the CO of an Aegis Cruiser, and the CO of a Coastal Air Defense (CAD) unit. The team's task is to decide what response the carrier task force should make toward incoming air targets. Teams base their decisions on data they collect by measuring characteristics of aircraft targets that enter the task force's airspace.

COMMMAND AND CONTROL TASK

You and your teammates are responsible for monitoring air traffic in your designated area. You will be stationed at a computer monitor whose screen will consist of four icons representing the different units of your team (Carrier, CAD, AWACs, and Cruiser). When the simulation begins you will see a blinking red dot indicating that a target has enterred your airspace and needs to be assessed. You are responsible for collecting information about that target, evaluating its level of threat, and submitting a judgment to the carrier if you are the CAD, AWACs, or Cruiser.

AREAS OF EXPERTISE

The CO of the carrier is the team leader and the person who ultimately makes the team decision about what to do for each target. The other team members make recommendations to the leader in the form of judgments. Each of you has expertise that is unique to your role. That expertise comes from (a) your ability to measure certain attributes about the target and interpret their values, and (b) your knowledge of certain rules for using the information about the attributes to determine the target's degree of threat. The CO of the CAD, AWACs, and Cruiser is responsible for 3 of the 9 pieces of information about a target that are described below. The CO of the Carrier has access to one piece of information that each team member is responsible for knowing. In addition, each of you is responsible for two rules, one of which is unique to you (i.e., one that you are an expert on).

CHARACTERISTICS OF TARGETS

The incoming air targets can be measured on nine attributes. These are listed below along with the a brief description:

Speed How fast a target is flying in miles per hour (mph)
Altitude How high above sea level it is flying in feet (ft)
Size How long aircraft is from nose to tail in meters (mtr)
Angle The extent to which it is ascending/descending in degrees (Dgs)
IFF The radio signal indicating civilian/military status in Mega-Hertz (Mhz)
Direction The extent to which it is flying straight in or passing wide in degrees (dgs)
Corridor The distance from center of a commercial airline corridor in miles (Mi)
Status
Radar The type of radar ranging from weather to weapons arranged in classes
Type
Range How far away the target is from the carrier in miles (mi)

POSSIBLE DECISIONS

Once information is collected and interpreted, a judgment is made. There are seven possible choices to make for each incoming target. These responses are graded in terms of their aggressiveness. Each of these is described below, ranging from least to most aggressive:

IGNORE: This means that the carrier task force should devote no further attention to the target and instead focus on other possible targets in the area.

REVIEW: This means to leave this target momentarily, so that the team can monitor other targets, but to return to this target after a short period of time to update its status.

MONITOR: This means that the carrier task force should continuously track the target on radar.

WARN: This means that the carrier task force sends a message to the target identifying the task force and alerting the target to steer clear.

READY: This means to steer the ship into a defensive posture and to set defensive weapons on automatic. A ship in a readied position is rarely vulnerable to attack. A ship in this position, however, cannot readily take offensive action toward the target.

LOCK-ON: This synchronizes the ship's radar and attack weapons so that the weapons fix themselves on the target. A ship in Lock-On position can take offensive action at a moments notice.

DEFEND: This is "weapons away" and means to attack the target with Tomahawk cruise air-to-air missiles.

FEEDBACK

Once a team decision has been submitted, a "Feedbak Screen" will appear informing the team how well they performed on the previous target. Specifically, the feedback screen informs the members of the team's decision as well as the individual members'judgments, and the "correct decision." There are five possible outcomes from an encounter. The team's total performance will be expressed in terms of points associated with each outcome:

HIT - A "hit" means that the team made the correct decision about the target. For example, if the target should have been "warned" and the team submitted a "Warn" decision, the outcome is a "hit". A "hit" is worth 2 points to the team's overall score.

NEAR MISS - A "near miss" means that the team was off by one level in its decision (i.e., the team was a little too passive or a little too aggressive towards the target). For example, if the team decision was "Warn," and the correct decision is "Monitor," this would be a near miss (i.e., the team was a little too aggressive). A near miss is a pretty good outcome, however, since the team will be able to adjust to the target if the initial stance is this close. A "near miss" is worth 1 point.

MISS - A "miss" means that the team decision was off by two levels. For example, if the team decision was "Review" when it should have been "Warn," the team was too passive and the outcome would be a miss. The team will usually be able to adjust if the initial stance is this far off, but this is not guaranteed. Thus, a "miss" is worth 0 points.

INCIDENT - An incident means that the team was off by three levels in its decision regarding the target. An incident means that the team just narrowly avoided disaster (i.e., being hit itself or mistakenly shooting down a friendly target). This outcome results in a loss of 1 point.

DISASTER - A disaster means that the team decision was off by four or more levels. That is, the team's decision was to "Ignore" or "Review" when the correct decision was to "Lock-on" or "Defend," or vice versa. This results in either one of the ships in the carrier task force being struck by a missile (if overly passive), or the task force shooting down a friendly target (if overly aggressive). This outcome results in a loss of 2 points.

Your Specific Role

<u>Role of Carrier (Leader)</u>: The Carrier is the leader who makes the team's final decision. The carrier can measure and interpret three things (1) Range, (2) Angle, and (3) IFF. The range of values and degree of threat associated with each are shown below. You do have the unique responsibility of knowing 2 rules.

<u>Degree of Threat</u>

	Non-Threatening	Somewhat	Very
Range	200 to 110 mi (far)	90 -60 mi	40 to 1 mi (close)
Angle	+15 to +8 Dgs (rapid ascent)	+3 to -3 Dgs	-8 to -15 Dgs (rapid descent)
IFF	.2 to .6Mhz (civilian airliner)	.9 to 1.1Mhz	1.4 to 1.8Mhz (military aircraft)

As the leader, you are also uniquely informed about what the other members' expertise is as listed below:

<u>Member</u>	Speed	Altit	Size	Angle	IFF	Direct	Corr.St.	Radar	Range
CAD	X			X			X		
AWACs		X			X			X	
Cruiser			X			X			X

<u>Determining level of threat</u>:
In general, the degree to which an incoming target is threatening depends on its values for all nine attributes. There are also five rules for determining the danger associated with any target. Your rules are:

* All else equal, in terms of **IFF**, military targets are more threatening than civilian targets.

** **ANGLE** and **RANGE** go together, so that descending targets that are close are especially threatening above. Angle alone and range alone mean nothing. Descending targets that are far away, or close targets that are on the way up are not threatening.

The most threatening target is one where the target is very threatening on all five rules; the least threatening where the target is non-threatening on all five rules. Not all targets will be this straightforward; it is important that all information be condsidered in making a judgment about a particular target.

Your Specific Role

Role of CAD: The Coastal Air Defense (CAD) unit is a specialist in the measurement and interpretation of three attibutes: 1) Speed, 2) Angle, and 3) Corridor Status. The range of values and degree of threat associated with each are shown below. In addition, you will be responsible for learning 2 rules described below. It is also your responsibility to exchange information with other team members, and to send a judgment to the carrier.

Degree of Threat

	Non-Threatening	Somewhat	Very
Speed	100 - 275mph (slow)	325 - 500mph	600 - 800mph (fast)
Angle	+15 to +8 Dgs (rapid ascent)	+3 to -3 Dgs	-8 to -15 Dgs (rapid descent)
Corridor Status	0 to 8 Mi (in the middle of the corridor)	12 to 18 Mi	2 to 30 Mi (way out of the corridor)

Determining the level of threat:

In general, the degree to which an incoming target is threatening depends on its values for all nine attributes. There are also five rules for determining the danger associated with any target. Your rules are:

* All else equal, in terms of **IFF**, military targets are more threatening than civilian targets.

** **SPEED** and **DIRECTION** go together, so that fast targets coming straight in are most threatening. Speed alone and direction alone mean nothing. There is nothing to fear if fast targets are not headed toward the task force or from objects headed directly toward the task force that are moving slowly.

The most threatening target is one where the target is very threatening on all five rules. The least threatening target is one where the target is non-threatening on all five rules. Of course, not all targets will be this straightforward, therefore it is important that all information be condsidered in making a judgment about a particular target.

* This rule is known by all. ** This rule is known only by you.

Your Specific Role

Role of AWACs: The AWACs unit is a specialist in the measurement and interpretation of three attributes, (1) Altitude, (2) IFF, and (3) Radar. The range of values and degree of threat associated with each are shown below. In addition, you will be responsible for learning 2 rules described below. It is also your responsibility to exchange information with other team members, and to send a judgment to the carrier.

Degree of Threat

	Non-Threatening	Somewhat	Very
Altitude	27,000-35,000ft (high)	17,000ft-23,000ft	5,000ft-13,000ft (low)
IFF	.2 to .6Mhz (civilian airliner)	.9 to 1.1Mhz	1.4 to 1.8Mhz (military aircraft)
Radar Type	Class 1 & 2 (weather)	Class 5	Class 8 & 9 (weapons)

Determining level of threat:

In general, the degree to which an incoming target is threatening depends on its values for all nine attributes. There are also five rules for determining the danger associated with any target. Your rules are:

* All else equal, in terms of **IFF**, military targets are more threatening than civilian targets.

** **ALTITUDE** and **CORRIDOR STATUS** go together, so that low flying targets that are way outside the corridor are especially threatening. Altitude alone and corridor status alone mean nothing. There is nothing to fear from high flying targets well outside the corridor or low flying targets in the middle of the corridor.

The most threatening target is one where the target is very threatening on all five rules. The least threatening target is one where the target is non-threatening on all five rules. Of course, not all targets will be this straightforward, therefore it is important that all information be condsidered in making a judgment about a particular target.

* This rule is known by all. ** This rule is known only by you.

Your Specific Role

Role of Cruiser: The Cruiser is a specialist in the measurement and interpretation of three attributes, (1) Size, (2) Direction, and (3) Range. The range of values and degree of threat associated with each are shown below. In addition, you will be responsible for learning 2 rules described below. It is also your responsibility to exchange information with other team members, and to send a judgment to the carrier.

Degree of Threat

	Non-Threatening	Somewhat	Very
Size	65 to 43 mtr (large)	37 to 23 mtr	17 to 10 mtr (small)
Range	200 to 110 mi (far)	90 -60 mi	40 to 1 mi (close)
Direction	30 to 22 dgs (far east or west)	18 to 12 dgs	08 to 00 dgs (coming straight in)

Determining the level of threat:

In general, the degree to which an incoming target is threatening depends on its values for all nine attributes. There are also five rules for determining the danger associated with any target. Your rules are:

* All else equal, in terms of **IFF**, military targets are more threatening than civilian targets.

** **SIZE** and **RADAR** go together, so that small objects with weapons radar are especially threatening. There is nothing to fear from small targets with weather radar only or from large targets with weapons radar.

The most threatening target is one where the target is very threatening on all five rules. The least threatening target is one where the target is non-threatening on all five rules. Of course, not all targets will be this straightforward, therefore it is important that all information be condsidered in making a judgment about a particular target.

* This rule is known by all. ** This rule is known only by you.

APPENDIX C

CODING INSTRUCTIONS

Instructions for coders:

1. First read through and become familiar with Handbook for experiment #8. In particular, you will need to understand the 9 attributes, 7 decision alternatives, and 4 distinct roles (Carrier, CAD, AWAC, Cruiser) and corresponding rules. This will enable you to better understand the type of communications that occur in these teams as well as the coding procedures on the next page.

2. After having read the Handbook, read through the coding procedures and coding tree on the next two pages.

3. Once you have read the procedures, we will slowly go through part of a video taped session and discuss how each communication should be coded.

4. After everyone is familiar with the procedures, I will have each coder watch a segment of a tape and code that segment based on the instructions provided. We will then compare results among coders and discuss any disagreements. We will continue with this procedure until a reasonable level of consistency is reached among the coders.

5. Finally, video tapes/text messages will be divided among coders so that at least 2 people are responsible for coding a session. We will then set a goal to meet and review the tapes that have been coded and settle and discrepancies.

Coding Procedures for Typewritten Text Messages:

1. The group # is indicated on the top of the first sheet of the text message printouts (it is the first 3 numbers of the 8 digit number at the top). Write this on the coding sheet as you would for the video taped sessions. The first column of numbers next to the M indicates the trial #. Start coding with trial # 3 and count this as trial #1 on your coding sheets. The second column is a code for the person sending the message. This is also written out immediately preceding each message (e.g., "CAD I have speed and direction"). The third column of numbers is a code indicating who the message was sent to (1=Carrier, 2=CAD, 3=AWAC, 4=Cruiser). The next number just indicates the time left in the trial when the message was sent -- you do not need to record this.

2. Code the text messages using the same coding scheme for the videos. You may not have many verbal pauses (7) or interrupted phrases (8), but if you do, indicate those as well. For instance, if there is a line but no message, code that an 8. For these text messages, first write your code next the line in the left hand margin. Then go back and mark them on the coding sheets. This will make it easy to check for any discrepancies later.

3. If a message is in triplicate, that means it was sent to ALL. These will be easy to pick out as they are usually grouped together. Occasionally, these sets will be broken up by another message. Still identify them as a message sent to ALL as long as the message was sent to three different team members at the same time.

Coding Procedures for Video Taped Sessions:

1. When you start a video, you will see a team of four people sitting at computer terminals. At the beginning of the tape, they will be in a "Feedback" screen for the preceding practice trial. They will go through 28 targets while you are viewing them. Each target/trial will be either 4 minutes long or 2 minutes long. (A list of trial times is included). The "Feedback" screen will always last for 25 seconds.

2. The first thing you need to do is record the start time (on the video) when the team begins the next target. (You will learn how to identify the start of a new target in training). Then you will go through the video, pausing as many times as necessary, to code all the communications.

The following information is needed from the video:

-- The initiator of the communications (see position diagram and codes)

-- The receiver of that communication (1,2, or all members)

-- The type of communication based on the coding tree

-- Who knew what attributes by the end of the trial (see step #4 for details)

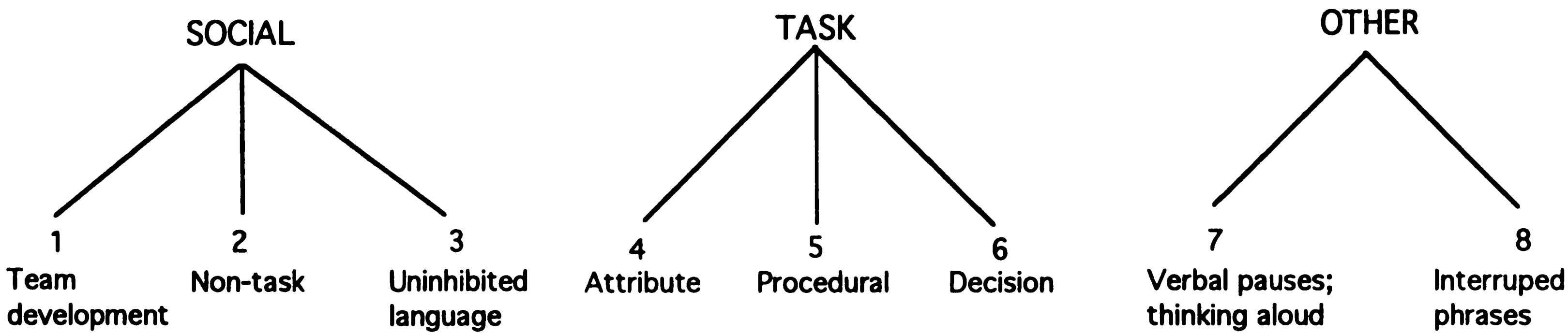
3. A communication is considered any phrase or coherent remark. These remarks can be as short as "Oh, really?" to as long as "I think we should Ignore or Review because it's not threatening". Communications can be directed toward one or two other members of the team, or to everyone at once. You will record on coding sheets what the content of each communication was based on the codes listed below and on the coding tree. Code the communications in order that they appear in the video in the appropriate box on the coding sheet. If you are unsure how to code a communication, take your best guess and circle or highlight that code on your sheet so we can review it later.

<u>Codes for verbal communications</u>:

1 = *Team development:* a social communication that has some value to the team or task (e.g., encouraging, motivating other team members)
2 = *Non-task/social:* a social communication that has nothing to do with the task (e.g., talking about drinking, eating, partying)
3 = *Uninhibited language:* any use of profanity which may also be part of another type of message (record each word used)
4 = *Task-Attribute:* a communication that either is seeking or providing information about target attributes (including raw data, interpretation, or information about a person's role)
5 = *Task-Procedural:* a communication regarding the performance of the task (e.g., computer use, submitting judgments)
6 = *Task-Decision:* a communication that addresses the decision to be made about a target
7 = *Verbal pauses; Thinking aloud:* a communication that informs another team member that a response is coming or that the person is thinking; or any communication to oneself not intended for another team member
8 = *Interrupted phrases:* any communication that is not completed to the point of coherency before another member begins to speak.

4. In addition to coding the communications, it is also necessary to identify all team members who had knowledge of each *attribute* during a trial (see coding sheets). For example, if CAD tells the Cruiser what Speed is, and no one else is paying attention, then only the Cruiser "received" information about Speed. If, however, everyone was listening, then you would record that "All" members "received" information about Speed. You only need to indicate if a person "received" information about an attribute, not who provided the information (that is captured elsewhere). Only record attribute information if the actual word was said during the communication (e.g., "What is Direction?" (CAD to AWAC-- "It's threatening" (AWAC to CAD) --> put a check for Direction for the CAD. But "Two are threatening, one is not" CAD to ALL --> do not check anything.)

TYPE OF MESSAGE



* Indicate start and stop time for feedback, but do not code this information

Examples:

1 -- "Good job"; "Maybe we have a chance of winning"
2 -- "Are you going out tonight"; "When do we get out of here?"
3 -- Any use of profanity ("damn", "shit")
4 -- "What is speed?"; "Angle is in threatening range"; "100-275 mph is non-threatening"
5 -- "How do you measure something?"; "Make sure you send in a judment"
6 -- "Should we defend?"; "I think it's dangerous"; "I put Warn but I meant Lock-on"
7 -- "I'll look at it in a second"; "I think -- hold on"; any talking to oneself not intended for another team member
8 -- "I would say ..." "But direction indicates ..."

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