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ASSESSING THE IMPACT OF MEDIA RICHNESS AND LEADERSHIP BEHAVIORS ON TEAM-BASED OUTCOMES

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Tyrone Jefferson, Jr.

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The dissertation of Tyrone Jefferson, Jr. was reviewed and approved* by the following:

Susan Mohammed
Associate Professor of Psychology
Director of Graduate Training
Dissertation Adviser
Chair of Committee

James L. Farr
Professor of Psychology

Michael D. McNeese
Professor of Information Sciences and Technology
Affiliate Professor of Psychology

Samuel T. Hunter
Assistant Professor of Psychology

*Signatures are on file in the Graduate School.

ABSTRACT

Much of the research examining the use of virtual teams has been shown to contain some inconsistencies that have led to a poor understanding of how these teams should be set-up and implemented, for what types of problems these teams should be used, and in what instances they would be maximally effective. The present research addresses these literature gaps by examining the influence of a continuum of virtuality, including text-based, video-mediated, and face- to- face communications on team-based outcomes. In addition, the present study examined different leadership methods for improving teamwork quality, team metacognition, team psychological safety and problem-solving ability across virtuality conditions. The present study included 208 ad-hoc triads working together in one of the three media richness conditions. Teams then received a leadership manipulation (centralized or decentralized) and were asked to complete video-based and text-based problem-solving tasks. The results of this study provide empirical support for the theory of media richness for team problem-solving performance; indicating that teams working together using technologies with higher amounts of media richness would have better problem-solving performance when compared to teams working together using technologies with lower media richness. Neither the centralized leadership behaviors, nor the decentralized leadership behaviors influenced team ratings of their teamwork quality or team metacognition, leading the present research to theorize potential reasons for this incongruence. However, across all conditions of media richness, teams using centralized leadership were found to have better problem-solving performance than teams in the decentralized leadership condition.

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Introduction

Over the last decade, the world has moved toward an increasing amount of de-centralization and globalization of work processes, leading to many organizations introducing and fostering the development of virtual teamwork into their workforce. The rapid development of new and innovative communication technologies has spurred this trend, while simultaneously leading to an explosion of theoretical and empirical papers on the usage, utility, and benefits of virtual teams (Alge, Wiethoff, & Klein, 2003; Anderson, McEwan, Bal, & Carletta, 2007; Axtell, Fleck, & Turner, 2004; Carte, Chidambaram, & Becker, 2006; Gajendran & Harrison, 2007; Gibson & Cohen, 2003; Golden, Veiga, & Dino, 2008; Hertel, Geister, & Konradt, 2005; Hinds & Kiesler, 2002; Kirkman, Rosen, Tesluk, & Gibson, 2004 & 2006; Leonard & Haines, 2007; Martins, Gilson, & Maynard, 2004; Scheck, Allmendinger, & Hamann, 2008; Schiller & Mandviwalla, 2007; Staples & Webster, 2008; Walvoord, Redden, Elliott, & Coovert, 2008). With the continuing increases in the technological sophistication of the workplace, co-located (or in person) meetings are no longer the only, or even the most efficient, way for groups of people within and between organizations to communicate, discuss problems and make decisions. In fact, for many large and geographically dispersed groups, electronic messaging and computer conferencing have become more common than having face-to-face (FTF) meetings or tele-conferencing (Alge et al., 2003; Staples & Webster, 2007). The increased use of computer-mediated communication to collaborate and conduct meetings has been stimulated specifically by decreased technological infrastructure costs, increased accessibility of information, as well as global improvements in technology and communications capabilities associated with computer-mediated communication (i.e., rapid exchange of documents, databases, and messages; Dennis, Kinney, & Hung, 1999; Hertel et al., 2005; Martins et al., 2004; Siegel, Dubrovsky, Kiesler, & McGuire, 1986; Staples & Webster, 2007).

However, in spite of the wealth of research available today, there remains a need to better understand precisely how the information virtual teams transmit, or share, between team members differs from the information that is transmitted amongst co-located, or FTF, teams. Also, research is necessary to identify the mechanisms available to enhance the quality of this information exchange. It is critically important to understand the impact of variations in communication medium on the problem-solving ability of virtual teams, in addition to determining which existing communications technologies are best suited for use in virtual environments. In their recent review of the virtual teams literature, Martins et al. (2004) reviewed and categorized the findings from previous virtual teams research according to their team inputs, processes, and outcomes. Martins and colleagues identified and explained several potential routes along which future virtual teams research might adhere. Leadership was specifically identified as being ripe for study in future research as a team input. The interpersonal emergent states of group cohesiveness, shared cognition, and team psychological safety were also identified as candidates for further study. Leadership behaviors in virtual teams may help leaders in these distributed environments better define roles and responsibilities, structure the interactions, motivate the effort, and evaluate the performance of their subordinate team members. It is through this mechanism that leadership may well be a way of addressing the shortcomings of virtual teamwork.

Leadership has been identified as an important factor contributing to the overall effectiveness and success of teams by guiding team behaviors, structuring team tasks, facilitating team activities and supporting team initiatives (Bass, 1990; Yukl, 1998). Previous virtual teams research found that teams using text-based communication (TBC) (e.g., computer based chatrooms) reported significantly higher levels of frustration; both with the task and the process of interacting with their teammates (Graetz, Boyle, Kimble, Thompson & Garloch, 1998). The authors went on to theorize that this frustration was due, in large part, to the virtual team members experiencing greater mental demands due to the nature of computer-mediated communication, as participants noted after the experiment that communicating via text-based computer-mediated communication seemed to restrict their ability to collect information, while also limiting their ability to effectively coordinate their efforts and validate information. In a study designed to examine the ability of training to improve distributed team communication, Warkentin and Beranek (1999) found that, in FTF teams, structuring team tasks improved interaction, trust, and commitment. Also, Lurey and Raisinghani (2001) noted that FTF teams were generally better able to formalize their work responsibilities and work strategies, which the authors noted was critical to teams performing at a high level. Taken together, the findings from these studies seem imply that the enhanced ability of teams to structure their interactions may have been due to emergent leadership. If it is the case that emergent leadership mechanisms allow for these benefits in FTF teams, perhaps the application of leadership behaviors to virtual teams could lead to enhancements in their overall virtual teaming experience, allowing for more effective and efficient interactions and team-based performance outcomes.

Reviews by Martins et al. (2004), as well as Schiller and Mandviwalla (2007), noted that recent virtual teams research pertaining to interpersonal emergent states has focused on conflict, uninhibited behavior, the informality of communication among group members, and interpersonal trust. However, there has been little published empirical research examining the formation and quality of interaction quality (e.g., improving information sharing, increasing the understanding of information presented, or facilitating the capacity to provide feedback) and outputs (e.g., problem-solving performance, decision-making ability). It is also the case that previous research in the area has yet to closely examine how the quality of these emergent states might be different across a variety of media richness conditions (as represented by different types of technology).

In order to fill these gaps in the literature, the present study has three objectives. The primary purpose of the current research was to empirically test the theory of media richness in a synchronous team communication environment using an intellective real time problem-solving task. The second purpose of the present study was to examine and contrast the effects of two distinct types of leadership behaviors on the quality of interpersonal interactions and problem-solving performance in virtual teams. It is expected that the use of leadership behaviors to structure their interactions can have a positive influence on problem solving ability and that this effect will vary as a function of media richness. A third, and final, purpose of the current work was to examine process variables that have been ignored in the previous literature on virtual teams (e.g., teamwork quality, team metacognition, and team psychological safety).

This research will inform the future use of virtual teams, in both empirical and applied settings, with descriptions of the strengths and limitations of virtual teams in problem-solving. The results produced here should also be able to inform the design of future communications technologies, increasing their information storage and transmission capabilities, while also modifying the input mechanisms of these technologies to make them more intuitive. With these adjustments, future iterations of the communication technologies used in virtual teams should be better able to mimic the features of FTF discussions. This would allow for seamless transitions between distributed and real-world conversations, maximizing the ability of individuals to share relevant information and resources with the necessary parties, irrespective of the distances involved.

Virtual Teams and Computer-Mediated Communication

A virtual team is defined as a team in which members use technology to interact with one another across geographic, organizational, and other boundaries (Carte et al., 2006; Gajendran & Harrison, 2007; Gibson & Cohen, 2003; Hertel et al., 2005; Martins et al., 2004). Virtual teams require the use of technologies (e.g., email, instant messaging, phone conferencing and webinars) to interact and perform. Virtual teams are organizational entities in which team members are spatially, geographically, or even temporally dispersed; interacting with one another via electronic communication, such as teleconferencing, email, chat rooms, or group decision support systems (Anderson, et al, 2007; Cascio, 1999; Driskell, Radtke, & Salas, 2003; Hansen, 2004; Staples & Webster, 2008; Walvoord et al., 2008). Virtual team members are typically spread out across several work units, departments or across entire organizations and institutions, using computer-mediated communication to facilitate more spontaneous and continuous team interaction (Anderson et al., 2007; Cramton, 2002, DeSanctis & Poole, 1994; Endsley & Jones, 2001). A primary reason for the popularity of virtual teams is that team members can collaborate across departments, cities, and national boundaries, when FTF meetings and locations are difficult to set-up logistically and financially afford (Mittleman & Briggs, 1999; Zaccaro et al., 2004).

The appeal of virtual teams lies in the fact that their membership can include an organization’s best individuals for a given task, regardless of their physical or geographical location (e.g., Lipnack & Stamps, 1999; Martins et al., 2004; Townsend, DeMarie &

Hendrickson, 1998). However, the increase in the usage of virtual teams has also revealed some of the deficiencies related to their function, qualities, and capabilities to be exposed. In particular, virtual teams can display degraded ability to structure and transmit information to team members, understand the information transmitted from their team members, in addition to accurately comprehending those messages (Gibson & Cohen, 2003). Also, previous virtual teams research has indicated that virtual teams are not always able to respond quickly, or in a timely and appropriate manner. This is likely due to difficulties in processing information, establishing a mutual knowledge base, and developing a shared understanding of their task (Daft & Lengel, 1984; Thompson & Coovert, 2003; Timmerman & Scott, 2006).

Baltes, Dickson, Sherman, Bauer, and LaGanke (2002) identified a great deal of variability in studies assessing the actual impact of computer-mediated communication on group problem-solving, including differences in the type of tasks used by researchers to test the effects of computer-mediated communication in virtual teams (e.g., intellective tasks versus idea generation tasks), disparities in the time allotted for virtual teams to complete the tasks, the type of communication medium used (e.g., synchronous versus asynchronous communication), differences in the experimental samples used in virtual teams research (e.g., students versus actual business managers), and variations in the degree of member anonymity present in the virtual teams as they attempt to solve their appointed task. Baltes and colleagues conducted a meta-analysis to better understand the differences between computer-mediated communication and FTF communication on various dependent variables (e.g., decision quality, group effectiveness, length of decision time, and satisfaction of participants in decision making groups). Compared to FTF teams, results revealed that teams using computer mediated communication do yield superior problem-solving performance when teams had unlimited time to make a decision. However, computer-mediated communication was shown to be generally less effective medium when decision time was constrained. Furthermore, in instances where individuals' identities were kept anonymous, computer-mediated communication performance did not differ significantly from FTF performance. These findings suggest that anonymity allows computer-mediated communication participants to feel more secure, and unlimited problem-solving time allows virtual teams to more fully express their ideas and overcome any potential confusion, or delays in message transmission (and reception), allowing for a higher degree of communication openness and message clarity. While it may be the case that computer-mediated communication can facilitate an individual's ability to express their opinions to their other virtual teammates, the findings from this meta-analysis suggest computer-mediated communication does not seem to enhance an individual's willingness to express, listen and attend to new or dissenting opinions. Baltes and colleagues concluded that group anonymity and unlimited decision time, and not the use of computer-mediated interaction, were most responsible for the previous research findings of increased hypothesized openness and enhancements in team communication and problem-solving quality in computer-mediated communication teams.

The findings from the meta-analysis also showed that although anonymous computer-mediated communication groups were shown to perform at least as well as FTF groups, they tended to be less satisfied with their overall experience in the problem-solving process (Baltes et al., 2002). Thus, while anonymity allows computer-mediated communication group members to share more information and perform at a level comparable to FTF groups, working under conditions of anonymity appears to be frustrating, or at least unappealing, for virtual team members. This increased level of stress associated with anonymous communication could possibly be due to the potential strains related to developing and maintaining trust amongst the members of a virtual team that share only minimal communication cues. It may be that interacting in an environment with reduced communication cues could foster the development of distrust between group members around the level of teammate expertise and knowledge, as well as the legitimacy of the information itself and responsibility for the quality of the end product. It could also be that members of anonymous virtual teams are dissatisfied with the problem-solving process because the anonymous nature of the interaction makes it difficult to identify individual contributions, reward useful contributions, or punish inappropriate behaviors as necessary. Alternatively, it could be that group anonymity interferes with relationship building, which could also lead to similar frustrations with distributed team problem-solving.

Although computer-mediated communication technology has been anecdotally thought to be an efficient, rapid, and cost-effective means of disseminating information amongst people and groups spread out across large distances (Alge et al., 2003; Siegel et al., 1986; Staples & Webster, 2008), the empirical results taken from the Baltes et al. (2002) meta-analysis suggest that computer-mediated communication may not be the most effective means of making group decisions in all situations, particularly those that most closely mirror traditional FTF decision-making situations. While previous research found positive results for virtual teams that communicated anonymously when performing problem-solving tasks (Baltes et al., 2002 meta-analysis), the present research will focus on identifying methods to improve the problem-solving outcomes and emergent states in virtual teams communicating non-anonymously in a real-time synchronized manner. The underlying rationale guiding the present study’s position is that future technological developments in the area of group decision support aids and virtual communication technologies will most likely be focused on the inclusion and continued improvement of a visual component (i.e., non-anonymous) to distributed communications technologies (Driskell et al., 2003; Martins et al., 2004).

Previous research that examined computer-supported work across a variety of tasks has provided support for the present research's study of non-anonymous in virtual teams. For example, Ahuja and Galvin (2003) studied the use, management, and socialization of virtual teams, and found that non-anonymous teams acclimated to their work roles faster than anonymous teams. Several other research studies measured the impact of team-building exercises on the problem-solving abilities of virtual teams, and found that non-anonymous displayed better problem-solving skills when compared to their anonymous counterparts (Hart & McLeod, 2003; Huang, Wei, Watson, & Tan, 2003; Salas, Rozell, Mullen, & Driskell, 1999). Also, previous research found that the use of non-anonymous virtual teams could be used as an effective surrogate for some types of interpersonal interactions, augmenting normal FTF communication (Perry, 1992; Strauss & McGrath, 1994). Considered together, these studies point out important benefits to non-anonymous communication and suggest that the future of computer-mediated communication technologies in cooperative working situations will likely be focused on the development of communication environments that most closely emulate traditional FTF interactions.

As alluded to previously, FTF teams have been shown to possess performance superior, or at the minimum equal, to that of teams using computer-mediated communications (Baltes et al., 2002; Bordia, 1997; Carte et al, 2006; Hertel et al., 2005). Earlier theoretical work by Clark and Brennan (1991) provides some rationale for the superiority of FTF communication. Specifically, these authors assembled a list of characteristics describing different facets of communication environments, which included *co-presence*, *visibility*, *audibility, co-temporality,* *simultaneity*, and *sequentiality*. *Co-presence* was defined as the extent to which team members occupy the same physical location, while *visibility* and *audibility* have to do with whether or not team members can see and hear one another during their team interactions. *Co-temporality* was the speed at which messages were received, after they were generated and transmitted between team members. *Simultaneity* indicated that team members had the ability to send and receive messages at the same time, while *sequentiality* referred to when group members speak in turns according to some determined sequence. FTF communication is the touchstone for this area of problem-solving and communications research. This is due to the fact that it contains the accepted (or customary) amount of each of these characteristics, and allows for the highest level of information exchange; a crucial component in the development of optimal decisions as demonstrated in previous research (Daft & Lengel, 1984; Driskell et al., 2003).

Later work by DeSanctis, Staudenmayer and Wong (1999) identified four dimensions that characterize virtual entities (i.e., teams, departments, and organizations): *space*, *time*, *culture*, and *boundary*. *Space* refers to the extent of spatial dispersion of employees across different locations. *Time* pertains to the degree to which employees operate asynchronously. *Culture* refers to the extent to which an organization consists of employees from different countries or cultures. *Boundary* refers to the degree to which organizational processes extend the boundary of the focal organization. Using DeSanctis et al.'s dimensions, Shin (2004) asserted that the degree of virtuality within an organizational entity depends on the extent to which an organization takes on more of these four characteristics. Kirkman and Mathieu (2005) defined virtuality as the extent to which the members of teams use virtual tools to coordinate and execute team processes, the amount of informational value provided by such tools, and the synchronicity of team member virtual interaction.

While a pure virtual organization would refer to one in which most of its employees operate remotely and communicate exclusively through electronic means, such organizations are not very common (Shin, 2004). In most virtual organizations, only some units or employees engage in virtual work arrangements, and organizational processes are dependent on both traditional and virtual operation. Kirkman et al. (2004) support this by pointing out that the method of communication used by a team, whether that team is physically distributed or not, is not necessarily fixed or immutable. For example, co-located team members can choose the degree to which they will employ virtual means of coordinating their actions. Therefore, making “distinctions” between purely virtual teams and co-located teams can be both unrealistic and artificial (Cohen & Gibson, 2003; Griffith & Neale, 2001; Griffith et al., 2003; Martins et al., 2004). Virtual team researchers argue that future work in this area should move past the conventional labeling of teams as “virtual” or “FTF”, and instead these investigations should be reframed toward questions as to ‘why teams choose’ to employ differing degrees of virtuality and how such choices influence team effectiveness.

While examining virtuality as a continuum has merit, these researchers do concede that there are situations where a team may almost exclusively use computer-mediated communication (e.g., global teams) or FTF communication (Hertel et al., 2005; Kirkman & Mathieu, 2005; Staples & Webster, 2008). It may be that the communication medium used by a team to facilitate their discussions may be restricted to a certain type of technology if all members are geographically dispersed, mobile, or if the impending interaction is unplanned (or spontaneous). While the present research acknowledges that that purely FTF teams may not exist over the lifespan of the project that teams were created to address, one can easily conceive of examples where teams can and will interact in a single communication medium to conduct a specific task, or series of tasks. For example, in early 2015, the United States Army is planning to deploy their Future Combat Systems into active-duty, frontline service (U.S. Army FCS: BCT, 2009). Succinctly, FCS is a new methodology for conducting warfare, fully integrating deployed forces across a variety of mission specialties. This will include complete computer-mediated communication (both text-based and video-based) between land, air, and autonomous forces. In this sort of environment, it is easy to imagine individuals with no prior direct teamwork experience sharing mission objectives, using computer-mediated communications to discuss their approach and accomplish their goals. It is within these domains that the hypotheses and results of the present research are likely to be most conceptually useful toward the continued development of virtual team research.

Furthermore, rather than simply examine FTF and TBC extremes as has been done in the majority of the computer-mediated communication literature (e.g., Connolly, Jessup, & Valacich, 1990; El-Shinnaway & Vinze, 1997; Hollingshead, 1996; Reid, Ball, Morley,& Evans, 1997), the present research acknowledges the existence of a continuum of virtuality by also investigating video-mediated teams. Conceptually, video-mediated communication (VMC) falls in the middle of the continuum between FTF and TBCTBC technologies. The present research aims to identify and explain how the communication cues that can be transmitted across in-person, video, and textual communication environments influence the problem-solving outcomes of virtual teams.

Media Richness

One of the primary factors theorized to determine the quality of interaction between members of a virtual team is the ability of the communication medium to accurately convey or transmit information. In their seminal work on the topic, Daft and Lengel (1984) outlined the concept of information richness, later renamed media richness. In this work, the authors theorized that success in problem-solving and decision-making is based on an entity's ability to process information of appropriate richness, to reduce uncertainty and clarify ambiguity. Media richness refers to the potential information-carrying capacity of data that is created through group interaction and the quality of the information that is shared through interpersonal communication. Interpersonal communication is composed of four critical components: the ability of a communication medium to *transmit multiple communication cues*, *feedback immediacy*, *language variety*, and the *personal focus* of the medium (Baltes et al., 2002; Daft & Lengel, 1986).

According to media richness theory, FTF communication offers the highest level of media richness because of its high level of synchronization and its high presence of nonverbal cues (see Figure 1, Baltes et al., 2002). The degree of synchronization present in any type of communication media has to do with the speed at which performance feedback can be provided to team members as they deliberate. With more immediate feedback, the group's understanding of specific details can be readily checked and misinterpretations can be corrected before any potential confusion impacts both the emergent states associated with group's problem-solving, as well as group's problem-solving outcomes. Language variety is also important as it has to do with the ability of a communication medium to present and convey different types of information rich messages, most importantly those identified as nonverbal cues (Baltes et al., 2002). The presence of nonverbal communication cues in interpersonal communication is an important factor in determining its level of media richness because of the number of different levels at which individuals are able to retrieve useful information embedded in messages shared between team members. In other words, the presence of non-verbal communication cues refers to the depth of the media. In FTF communications, having multiple communication cues allows group members to directly observe and infer meaning across several independent sources from a particular speaker (e.g., body language, appearance, facial expressions, movement, voice inflexion, in addition to the actual verbal message and any meaning that can be “hidden” or inferred within it).

At the other end of the continuum, written communications have much less media richness. Providing feedback using written communication medium tends to be less effective when compared to the FTF medium, as these communications tend to be more protracted and less informative, as only the information that is written down (or displayed as text) is transmitted between the message sender and its receiver. This denotes that written communications have lower concentrations of information, or decreased depth of information, so communication cues are restricted to only those that can be textually documented. The nature and usage of written communication makes it very difficult for message receivers to gain additional communication cues, where possible, by simply observing the generation of the communication. It is possible that message receivers can draw inferences regarding unclear meanings or message purpose based on their prior interpersonal knowledge of the message sender, or even their own intuition (e.g., style of script used, attention to proper grammar and punctuation, legibility, and coherence). However, because these assumptions are typically generated in the absence of directly observable communication cues, they tend to be less accurate on the whole.

Figure 2 is an adaptation of a theoretical framework developed by Daft and Lengel (1984) explaining the relationship between media richness and the complexity of organizational phenomena. This framework posits a relationship between media richness and the complexity of organizational decisions, and corroborates much of the implicit thinking of the field. The figure indicates that while some organizational decisions are routine and repetitive, others tend to be more vague and amorphous. It theorizes that the methods used to share decision relevant information to problem-solving teams can directly impact how well the problem can subsequently be understood, and how well the problem can be successfully addressed. This framework hypothesizes the existence of a positive relationship between the quality of a communication technology's level of media richness and the complexity of organizational decisions. For example, communication technologies possessing rich media would be needed for computer-mediated communication teams to understand and process information involved in solving complex decisions, while communication technologies possessing media low in information richness may be better suited for those teams addressing more simplistic organizational decisions. This is the case because richer media allow groups and teams to access to more of the available communication cues in addition to facilitating feedback immediacy. Less rich media could, hypothetically, oversimplify or fail to highlight the important aspects of such a complex problem, impeding a problem-solving groups' ability to generate informed decision solutions.

Media richness, therefore, impacts team problem-solving by influencing the quality and depth of the information that is identified, considered, and utilized by groups and teams in the formation of solutions to their assigned cognitive tasks. It is in this way that problem-solving teams can be conceptualized as information processors (Hinsz, Tindale, & Vollrath, 1997). While it may seem obvious that group members should share some common information between them, these authors theorized that a high level of shared a priori knowledge was not the primary determinant for group problem-solving effectiveness. Rather, the ability of groups to be effective depended entirely on what information is shared, to what degree that information is shared, and how that information is shared. The level of media richness possessed by any style of communication used in team problem-solving will impact the quality of that team's information processing ability. The present research asserts that by making adjustments in the amount of media richness possessed by computer-mediated communication teams, one could improve the information processing of distributed problem-solving teams, perhaps subsequently improving their problem-solving outcomes.

Recent research conducted on this topic was able to show support for this line of thinking, and provided some support for the theory of media richness. For example, Allen, Van Scotter, and Otondo (2004) investigated how the communication media used by organizations to communicate recruitment messages would influence the assessments and impressions of the individual being recruited. Specific hypotheses were formed to test the impact of media richness on recruitee assessments of the organization's credibility, attitudes toward the organization, attitudes toward joining the organization, and actual intention to join the organization. The authors found support for the theory of media richness, showing that the FTF condition (the richest communication medium) was the most effective medium to share information about a particular recruitment notice. The video condition was consistently rated as the next best medium, followed by the text condition and the audio-only condition.

Later, Kurtzberg, Naquin, and Belkin (2005) explored the effect of using TBCTBC medium (e.g., email), versus handwritten notes, when conducting performance appraisals of peers. The authors initially theorized that employee reactions to paper-form and e-mail media would be identical, as they contain the same information carrying ability. However, findings from the series of studies in this research paper demonstrated that employees had more negative reactions to performance feedback delivered by email than feedback delivered as a handwritten note. The authors speculated that employees rated email more negatively because they perceived the medium as lacking the perceived thoughtfulness of handwritten notes. In spite of the employees' general reaction to the "level of importance" that they feel was associated with the communication medium being used, employees did rate email as a more expedient and efficient form of communication, in accordance with the theory media richness.

Most recently, Liu, Liao, and Pratt (2009) examined users' preference for different types of presentation modalities (i.e., types of technological functionality) for online learning courses. They theorized and found that the perceived ease of use for a given technology was a predictor of that technology's perceived usefulness, as well as the user's intention to use that technology. This study's results showed that technologies that were able to project richer content-presentation were positively correlated with higher concentration levels self-reported by users. The results of this study offer additional support for the media richness theory, as it asserts that online learning technologies that were able to project richer communication cues to users allowed for a faster, less impeded user interaction, as compared to technologies that could only fewer communication cues.

While in each of the previously summarized studies, general support was found for the theory of media richness, it should be noted that these previous studies were examining the influence of media richness theory on subjective ratings of individual preference or affective reactions. In contrast, the present research extends previous work by seeking empirical support for the theory of media richness within the more objective domain of problem-solving performance.

Relating these findings back to the computer-mediated communication discussion, Baltes et al. (2002) indicated that the most common communication medium used in the study of virtual teams has been text-based chat. When evaluated using the media rich criteria outlined by Daft and Lengel (1984), this medium has been shown to possess relatively slow and stunted feedback-providing capabilities, while possessing few communication cues to be transmitted between message senders and receivers. Considering the hypothesized impact of media richness on group problem-solving, slow feedback and poor communication cue transmission seem to be two of the most prominent reasons for the poor results associated with computer-mediated communication. It may be that upgrades in technology could help alleviate many problems with distributed problem-solving; however, that technology would have to emulate many of the same qualities present in FTF interaction. Perhaps one way in which computer-mediated communication technology could be upgraded to facilitate and improve the quality of distributed problem-solving would be through the use of VMC in virtual teams.

VMC is a type of idea sharing and information exchange technology, which previous research has used as a communication bridge for small, distributed problem-solving and problem-solving teams (Harris & Sherblom, 1998). Made possible through the use of Internet capable computers and audio-video cameras, VMC allows team members scattered across disparate locations to brainstorm, communicate, make organizational decisions and solve problems using mostly real-time audio and visual media. As it contains features that typically surpass those of text-based chat discussions, these video-facilitated distributed meeting sessions add another layer of depth to the communications held by these computer-mediated virtual teams. Available research on the subject has touted VMC as an invaluable tool for activities like remote collaboration, tele-conferencing, and computer-mediated distance learning (Finn, 1997).

However, other research has indicated that VMC needs to be better studied empirically, as the proposed benefits of this technology have not yet been clearly demonstrated in the literature. More specifically, findings have ranged from indicating that VMC has no effect on the measured variables included in the study (e.g., user task performance, user satisfaction, or some other measurement (Harrison, Bly, Anderson, & Minneman, 1997), is at least equivalent to FTF communication in its ability to facilitate distributed discussion (O'Connaill & Whittaker, 1997), or that it is significantly less effective as a communication tool in supporting distributed discussion (Chidambaram, 1989; Chidambaram, 1996).

Baltes et al. (2002) conducted a VMC literature and concluded that VMC research has been widely disparate in the areas and types of technology used and features studied, the performance characteristics measured, and the groups tested. Because of these inconsistencies, the authors indicated that a side-by-side comparison of the results from VMC studies would be difficult, and rated VMC lower on their communication media scale, as a result (see Figure 1). For instance, VMC technologies were shown to possess features varying across all facets of media richness, with some being better than others in their ability to transmit and project communication cues to distributed problem-solving teams. Given these inconsistencies, the present study attempts to more correctly operationalize VMC, limiting its included features and capabilities to those consistent with the theory of media richness theory (i.e., Daft & Lengel, 1984; 1986). It may be that utilizing a communications technology comprised of features that more closely mirror the most optimal level of media richness will allow for the true effects of VMC on distributed team emergent states to be correctly researched and documented.

Recent research provides support for present study's method for the examination of the video-based communication medium. Specifically, Hambley, O'Neill, and Kline (2007) used a video teleconferencing system that closely mirrored the capabilities outlined in the Daft and Lengel (1984; 1986) pieces. These authors examined the impact of communication medium on the performance outcomes of virtual teams, and found that those teams that communicated using video teleconferencing had generally lower amounts of interaction, as compared to teams that interacted FTF. The authors also found that there was no difference between video teleconferencing teams and FTF teams on their self-reported levels of team cohesion. Relatedly, with a similar video teleconferencing technology, Rockman and Northcraft (2008) studied how the development of trust is influenced by computer-mediated communication. Their findings suggested that video-based teams were slightly better able to develop both cognitive- and affective-based trust better than text-based teams, but the speed of trust formation and the final "level of trust" ratings reached in video-based teams was significantly lower than in FTF teams.

Teamwork Quality, Team Metacognition, Psychological Safety and Virtual Teams

Teamwork Quality. Integral to the definition of a team, teamwork is the collaborative interaction generated by the participating members of a team, as they work together to manage and solve mutually relevant problems. Member behaviors within the team can be conceptualized as activities, interactions, and sentiments (Homans, 1974; Prislin & Wood, 2005). Activities are observable actions by individuals that can be measured by quantity, as well as quality and effectiveness. Sentiment refers to the combination of emotions, motivations, and attitudes within a team. According Homans (1974), sentiments cannot be directly observed, and must be inferred, as they influence activities and interaction and are influenced by them. Interactions, however, are the key concept to the evaluation of teamwork.

In the team context, the term interaction refers to how connected, or in tune within one another, that the members of a team feel with their teammates, regardless of the team's current activities. When experimentally measuring interaction, the key point is to determine how well teams are able to fully understand the problem at hand and then communicate task-relevant information to one another. Teamwork, in this case, can be operationalized and studied in terms of frequency and intensity of specific behavioral characteristics found within a team's interaction (Hoegl & Gemuenden, 2001). As a way of classifying, categorizing, and measuring the present of such behaviors, Hoegl and Gemuenden (2001) developed the teamwork quality (TWQ) construct. TWQ is a multifaceted, higher order construct that was created by performing a critical review of relevant articles and various exploratory empirical case studies within the teams literature. From this review, six facets of the TWQ were identified as indicators of the collaborative work process in teams and capture both task-related and social interaction within teams. These facets are: *communication, coordination, balance of member contributions, mutual support, effort, and cohesion.*

The first, and most elementary component of TWQ, facet within TWQ is *communication* (Hoegl & Gemuenden, 2001). Communication is the means through which team members are able to exchange information amongst themselves. The quality of communication within a team can be determined by ascertaining how extensively team members communicate, how spontaneous that communication is, whether or not team members are to be able to directly communicate with one another, and whether team members are able to openly share information with one another. The second facet of the TWQ construct is *coordination,* which refers to the bringing together and synchronization of the individual team members' contributions for the development of a solution to their shared problem. Teams that have effective coordination are able to develop and agree upon a method to build solutions that have clear subgoals for each team member, and are free of gaps or overlaps in expertise and responsibility. Consistent with the third facet of TWQ team members must be capable of contributing their individuals KSAs, experiences and relevant task knowledge to the team discussion for teamwork to occur at its highest level. Being able to achieve a *balance of member contributions* is essential to TWQ, because while not every team member needs to bring in the exact same amount of information, no team member should be unable to make relevant contributions to the decision being made. Fourth is *mutual support*, which states that effective team collaboration depends upon a cooperative, rather than competitive, atmosphere. For interdependent tasks, such as teamwork, being respectful of one another, giving assistance when needed, and developing the ideas of team members are more beneficial to the overall goals of the team than competition.

The fifth TWQ facet is *effort*, and is closely related to the norms for behavior within a team. Norms are a team's shared expectations regarding the behavior of team members while working in the team context. Though norms exist across a wide variety of observable team behaviors, the TWQ construct is concerned with the norms regarding team member effort. The construct hypothesizes that to achieve high TWQ and avoid conflict among team members, it is important for team members to know and accept the work norms concerning sufficient effort. A uniformly high level of effort by all team members is primary to the quality of collaboration. The final facet of the TWQ construct is *cohesion*, which refers to the degree to which team members desire to continue to function as a team. There are three types of cohesion within teams: interpersonal attraction of the team members, commitment to the team task, and group pride or team spirit. There must be an adequate level of cohesion if a high level of teamwork quality can be reached. If team members do not wish to keep the team going, then effective collaboration seems unlikely to take place.

Team metacognition. As previously noted, when experimentally measuring team interaction, it is critical to determine not only how well teams are able to fully understand the problem at hand, but also to what extent they share this understanding with their team members. Team metacognition is a multidimensional phenomenon that involves the generation of the cognitions of several connected people and regulation of those cognitions (Schraw, 1998). Put another way, team metacognition is the ability of individuals to access the knowledge of one's team members' cognitions and regulation of those cognitions. It has to do team members understanding their teammates' knowledge and competencies, in addition to their own, and how teams use this awareness to improve their self-regulated learning, problem solving ability, and to develop situational expertise (Fiore et al., 2002). Research has theorized that metacognition has two primary functions within teams: monitoring and control (e.g., Kluwe, 1987; Metcalfe & Shimamura, 1994; Nelson & Narens, 1990). Monitoring, within the team context, includes identifying the task, checking and evaluating one's progress, and predicting the outcomes of that progress. Control is thought to include decisions such as where to allocate one's resources, the specific steps to be used to complete the task, the speed and intensity at which to work on the task, and the prioritization of activities.

Team Psychological Safety (TPS). The concept of team psychological safety is defined as either a tacit or explicit shared belief held by the members of a team, in which the individual members believe that the team is safe for interpersonal risk-taking (Edmondson, 1999). Risk-taking behaviors in the team environment include being able to share one's opinion without fear of reproach, being able to suggest unpopular decision alternatives, or even offering incorrect points of view for the purpose of facilitating discussion. Initially proposed as a measure of a team's level of preparedness and willingness to change in response to organizational shifts (Schein & Bennis, 1965), team psychological safety is not to be confused with group cohesion. Research has shown that high levels of group cohesion can reduce team members' willingness to disagree and challenge each others' views, denoting a definite lack of interpersonal risk-taking (Janis, 1982). In comparison, team psychological safety is derived from shared respect and trust, and should be thought of as an assurance or an agreement shared between teammates that they will each be supportive of the other, will not embarrass each other, nor will they reject or punish someone for speaking up.

Conceptualized as a group-level construct, team psychological safety is comprised of the convergent beliefs of individual team members to form an aggregate measure embodying the collective's ideas about the amount of risk-taking possible within their team structure. The results from Edmondson (1999) indicated that team psychological safety increased the amount of learning behaviors exhibited by organizational work teams, because team members had little fear of being confronted with potential negative reactions from their team (i.e., disapproval, embarrassment, shame); which past research has associated with learning behaviors. While team psychological safety should not be equated with interpersonal trust. Rather, team psychological safety goes beyond interpersonal trust, as it describes a team climate that is made up of interpersonal trust and mutual respect in which individuals are made to feel comfortable to express themselves openly. However, it is important to recognize that building trust may be an important step in creating psychological safety within teams (Edmondson, 1999; Robinson, 1996).

Media Richness Hypotheses

In order for the present research to accurately determine the impact of FTF, VMC, and TBC technologies on all facets of distributed problem-solving, a series hypotheses were developed using to Daft and Lengel's media richness scale to delineate these relationships. These hypotheses have been adapted from several of the propositions proposed and qualitatively examined in a previous study by Bordia (1997), and later retold by Martins et al. (2004). The present study hypothesized that teams with higher amounts of media richness would be shown to have higher quality, more intensive, interpersonal emergent states than teams with less media richness. That is to say, teams with more media richness will report having higher teamwork quality and higher team metacognition scores. Teams with a higher amount of media richness have been shown in previous research to be better able to transmit communication cues and allow individuals to provide feedback within their teams, in addition to being able to transmit a wider variety of languages and be more easily personally focused (Baltes et al., 2002; Bordia, 1997). Given that FTF teams have been shown to possess a high amount of media richness, the present research theorizes that teams that communicate in a FTF context will have better ratings of teamwork quality and team metacognition than teams communicating using VMC or TBC.

Teamwork quality and Team Metacognition. The present research hypothesizes that high media richness teams will be shown to have better teamwork quality and team metacognition, as compared to low media richness teams. There are several reasons why this is thought to be the case. Teams with higher amounts of media richness would presumably be better able to communicate with one another. This would theoretically be due to teams of higher media richness (i.e., FTF teams) not having to overcome message misinterpretations, problems with time lag, or the potentially disruptive effects of transmission difficulties and technological malfunction that have been associated with computer-mediated communication. Having higher media richness would allow teams to speak to their teammates more quickly, seek information from and pass messages to specific members within the team, as well as having the ability to share information with all team members at one time. Being able to communicate more effectively would allow higher media richness through sharing information more quickly and enabling them to coordinate their actions and contribute insights, so that they may quickly identify and solve many elements of their problem space. As higher media richness leads to the ability of teams to clearly communicate, it should also foster mutual support and increased effort within the team. With enhanced communication, individuals would be better able to draw inferences about their team members' expertise, feelings, needs, and meaning. This knowledge would allow individuals to show their support for their teammates', provide development and constructive critique when appropriate, identify and set their expectations for how they should each act within the team, and allow individuals to recognize how much effort their teammates are putting forth.

H1a: FTF teams will have better teamwork quality than VMC teams while solving a distributed problem-solving task.

H1b: FTF teams will have better teamwork quality than TBC teams while solving a distributed problem-solving task.

H1c: VMC teams will have better teamwork quality than TBC teams while solving a distributed problem-solving task.

H2a: FTF teams will have better team metacognition ratings than VMC teams while solving a distributed problem-solving task.

H2b: FTF teams will have better team metacognition ratings than TBC teams while solving a distributed problem-solving task.

H2c: VMC teams will have better team metacognition ratings than TBC teams while solving a distributed problem-solving task.

Team Psychological Safety (TPS). Recent research was conducted examining the ability of psychological safety to help teams overcome the negative aspects associated with virtuality. Specifically, Gibson and Gibbs (2006) hypothesized that the geographic dispersion, dependence on technologically-mediated communication, frequent changes in work roles and personnel, as well as a lack of national diversity, would hinder the amount of innovative behaviors that teams would produce. However, they predicted that creating a psychologically safe climate for communication would help teams overcome the repressive factors related to virtuality. This previous research did find that a psychologically safe communication climate was able to significantly reduce the negative effects of all four elements of virtuality (e.g., geographic dispersion, dependence on technologically-mediated communication, frequent changes in work roles and personnel, national diversity) on innovation. Related to the present study, Gibson and Gibbs found that a climate of psychological safety mitigated the negative effects of geographic dispersion by helping to raise and clarify contextual differences, helping teams coordinate and garner resources for innovation across contexts. These findings suggest that team psychological safety can help the members of computer-mediated teams work together in a more efficient and productive manner.

Considering these results, the present study hypothesized that teams with higher levels of media richness will have higher levels of team psychological safety, as compared to teams with less media richness. It is the contention of the present research that teams with more media richness will be better able to develop high levels of TPS while working together, and subsequently generating better team decision outputs. The rationale behind this is that as teams with increased levels of media richness have been found to send and receive more communication cues while communicating with their team members, these teams may have the requisite levels of openness between team members necessary for team psychological safety to form. As TPS is the result of a shared belief amongst team members based on a mutual trust and respect, it requires that team members be able to communicate efficiently with one another. Because teams with high levels of media richness are better able to share verbal and nonverbal information (Clark & Brennan, 1991; Daft & Lengel, 1984), attend to and understand information passed along from other members, and use that information to formulate responses, it makes sense that they would be able to develop mutual respect between team members, and therefore a higher level of team psychological safety than teams with less media richness.

H3a: FTF teams will have higher levels of team psychological safety than VMC teams.

H3b: FTF teams will have higher levels of team psychological safety than TBC teams.

H3c: VMC teams will have higher levels of team psychological safety than TBC teams.

Regardless of the level of media richness present in a team's operating environment, teams with high levels of team psychological safety will also have better teamwork quality and team metacognition ratings, and higher levels of team problem-solving performance. The reasoning supporting this hypothesis is that teams with a high level of team psychological safety can use their capability of intra-group risk-taking as a catalyst for improving their team decision outputs. As teams with a high level of TPS engage in more risk-taking, this would serve to increase the likelihood that team members will identify, share and be open to receiving more decision relevant ideas. Because TPS allows for more risk-taking, it will also increase the amount of decision relevant communication that takes place between team members, facilitating increased participation amongst team members to the highest degree possible for the amount of media richness present in each type of communication. This increase in decision relevant conversation would enhance the communication and support shown between team members, thereby improving the quality of a team's teamwork quality and team metacognition.

H3d: Across all conditions of media richness, teams with higher team psychological safety will have better teamwork quality than those teams with lower team psychological safety.

H3e: Across all conditions of media richness, teams with higher team psychological safety will have better team metacognition ratings than those teams with lower team psychological safety.

Problem-Solving in Virtual Teams. In addition to teamwork quality, metacognition, and psychological safety, it may also be the case that teams with higher media richness will be shown to have better performance than teams with lower levels of media richness. As some of the more advanced communication technologies, such as VMC, have the ability to transmit a multitude of communication cues in a manner similar to that of FTF communication, it may be that these video-mediated distributed problem-solving teams would be less likely to suffer the task performance decrements that have been shown to be present in text-based distributed problem-solving teams. This may be due to the fact that teams using VMC technologies should be better able to identify and utilize many of the subtle nonverbal communication cues (e.g., body language, facial expressions, voice inflexion) because of the increased information carrying potential of the visual and audio communication mediums. TBC teams possessing low media richness would be unable to identify these cues, and would therefore perform more poorly. However, the distributed nature of VMC teams may prevent them from completely emulating all of the features of FTF communication, and this decreased information quality combined with poorer feedback immediacy, could cause them to have somewhat poorer problem-solving performance as compared to FTF teams.

The present research further asserts that teams with a high level of TPS are likely to have a higher level of problem-solving performance, as compared to those teams with low levels of TPS. Because teams with greater psychological safety are characterized as having a high level of interpersonal risk-taking, they may display more supportive behaviors and be more likely to share potentially relevant problem-based information. The presence of high amounts of support and information sharing will increase the likelihood that teams would be more likely to discuss the problem more fully, regardless of that team's level of media richness. Teams that discuss and share more problem-relevant information should have a better opportunity to attain higher problem-solving performance.

H4a: FTF teams will have better problem-solving performance than VMC teams on a distributed problem-solving task.

H4b: FTF teams will have better problem-solving performance than TBC teams on a distributed problem-solving task.

H4c: VMC teams will have better problem-solving performance than TBC teams on a distributed problem-solving task.

H4d: Across all conditions of media richness, teams with higher team psychological safety will have higher levels of problem-solving performance than those teams with lower team psychological safety.

Leadership Approaches in Virtual Teams Hypotheses

While some organizations may be actively seeking to change and grow technologically, it may also be that many organizations are unwilling or unable to upgrade their technologies, making it necessary for them to implement different strategies for their virtual teams to be successful and generate the best possible results using their current technology. Another possible strategy for improving teamwork, metacognition, psychological safety, and problem-solving in virtual teams may be through the use of different types of leadership as a way of structuring the information team members put into and take away from their virtual interaction. Different approaches to leadership during virtual teams problem-solving sessions could positively impact the ways in which teams identify, comprehend and interpret the limited feedback and communication cues transmitted by text-based media (or any media with a decreased ability to project and transmit a high density of communication cues).

Many research articles have concluded that the practice of leadership makes valuable contributions to the development of successful and effective performance in organizations, departments, groups and teams (Bass, 1990; Yukl, 1998; Zaccaro & Klimoski, 2001, Zaccaro, Rittman, & Marks, 2001). Many teams contain individuals chiefly responsible for defining team goals and supporting team members, as well as structuring the team, by assigning and delegating appropriate duties throughout the group to accomplish their goals. Yukl (1998) stated that the centralized conceptualization of leadership within the team framework describes a process whereby some type of influence is used by one person [a leader] over another person or group of people [followers] and it can be enacted in several different ways. Based on that definition, this suggests that it is the success of the team's leaders in defining the team's overall direction and organizing the team to maximize progress along that direction that contributes to team effectiveness.

Alternatively, Drath (1998, 2001a) later extended leadership beyond its centralized definition, and redefined it into the more decentralized conceptualization of relational dialogue. Relational dialogue is the idea that leadership can be formed from a common direction, and is created when team members share different ideas, compare and discuss them, and in the end develop an agreed upon solution or future action (i.e., shared meaning-making). Leadership, in this case, is the activity of people working together to make sense and meaning of their work, and requires respectful discussion and integration of their different perspectives. The literature on this topic shows that it is through these types of interactions that teams use the results and outcomes of their conversations regarding organizational processes and direction to generate leadership itself (Drath, 2001b, Drath, McCauley, Palus, Van Velsor, O'Connor, & McGuire, 2008). In this sense, leadership is the creation of a shared meaning-making, a team's mutual sense of meaning and value, taking place collectively, as a social process that engages everyone in the team, group, organization or community.

The more centralized view of leadership is based upon the idea that within organizations, group members perform activities according to their specific role specialization, whether they are the "leader" or "follower" (Bass, 1990; Casmir, 2001; Drath, 1998; Drath et al., 2008; Yukl, 1998). Because of their authority, leaders are assigned critical responsibilities and duties that are not delegated to other organizational personnel, as followers may not have the proper training or experience to adequately attend to them. Instead, the followers assist and support the primary leader in carrying out and implementing leadership functions. Two examples of the behaviors that are inherent within the framework of centralized leadership are *task-oriented leadership behaviors* and *relational leadership behaviors* (Yukl, 1998). Task-oriented leadership behaviors are structuring or managing behaviors, such as establishing well-defined patterns and channels of communication, organizing and defining the relationships in the group, trying out new ideas, assigning team members to particular jobs, emphasizing meeting deadlines (Fleishman, 1973), clarifying expectations of team members, scheduling work to be done, specifying procedures to be followed (House, 1971), checking that team members observe rules and regulations, setting deadlines, giving instructions and orders, and pressuring team members to work hard (Misumi, 1985). Contrastingly, relational leadership behaviors have to do more with leaders treating other team members with kindness and respect, emphasizing interpersonal communication with and listening to one another, leaders trusting their subordinates and subordinates trusting one another, and emphasizing the need to recognize the contributions made by team members (Yukl, 1998). Other relational leadership behaviors include providing encouragement, being friendly and approachable, looking out for each other's welfare (House, 1971), reducing team members' stress levels, and expressing appreciation for team members' efforts (Misumi & Peterson, 1985).

Research done Casmir (2001) was done examining the perceptions and effectiveness of these two manifestations of centralized leadership behaviors within organizations has shown evidence that these behaviors (i.e., task-oriented leadership and relational leadership are not necessarily mutually exclusive in the organizational context. Task-oriented and relational leadership may have the best results when enacted simultaneously or sequentially, and that they can be potentially damaging when carried out separately. Specifically, Casmir found that combining behaviors representative of both task-oriented leadership and relational leadership approaches clearly influenced subordinate's perceptions and the overall effectiveness of their leader's statements. The first finding to be taken from this series of empirical studies was that subordinate groups performed better and preferred when their leaders used task-oriented leadership in concert with relational leadership. Second, subordinates performed more poorly and were less satisfied when their leaders used task-oriented leadership behaviors alone. As Casmir reported, there are two important aspects of task-oriented leadership: pressure and instructions. Pressure behaviors were those that had to do with pressuring subordinates to work hard, as well as setting and emphasizing deadlines. Instructing behaviors were those that had to do with giving instructions and orders, in addition to specifying procedures. Both of these types of task-oriented leadership behaviors can be characterized as potentially high pressure and stressful, and have been reported as causing some discomfort within subordinate groups (Komaki, Zlotnick, & Jensen, 1986). When enacted without the support of relational leadership behaviors to psychologically cushion their impact, task-oriented leadership behaviors can cause higher levels of subordinate dissatisfaction with their leadership. This leads subordinates to rate their satisfaction with, and effectiveness of, their leaders lower. Third, Casmir (2001) showed that relational leadership should generally be provided immediately before task-oriented leadership to maximize the interactive effects of the leadership approaches.

More recent theoretical examination conducted by Judge, Woolfe, Hurst, and Livingston (2006) reviewed the concepts of charismatic or transformational leadership, making several assertions relevant to the interaction of task-oriented and relationship leadership. While reviewing the concept of transformational leadership, the authors resolve that although previous research suggests that transformational leadership is superior to transactional leadership, researchers have presented compelling arguments outlining how these two forms of leadership actually complement each other. Transactional leadership is characterized by situations where a leader will pursue interaction with their assigned subordinates for the purpose of seeking a mutually beneficial, though not necessarily equitable, exchange in return for "contracted" services rendered by the subordinate (Bass, 1985); similar to the previous defined task-oriented leadership. In contrast, transformational leadership refers to the process whereby an individual engages with others and creates a connection that raises the level of motivation and morality in both the leader and the follower; similar to relational leadership. The leader accomplishes this by acting as a strong role model for their followers (*idealized influence*), communicating high expectations for their followers and encourage them to commit to the goals of the team or organization (*inspirational motivation*), being creative and challenging "the status quo" (*intellectual stimulation*), and finally by listening to and attending to the needs of their followers (*individualized consideration*; Bass, 1985; Northouse, 2001). Bass (1985) went on to explain that it is through these mechanisms, the "four I's", that transformational leadership both supplements, and augments, the effects of transactional leadership, suggesting that the best leaders tend to be both transactional and transformational (Bass, 1985).

Another examination by Judge, Piccolo, and Ilies (2004) performed a meta-analysis to review and correct previous research-based opinions on the leadership behaviors of consideration and initiating structure. Bass (1990) defined consideration as the degree to which a leader shows concern and respect for subordinates, considers their welfare in decision-making, in addition to expressing appreciation and support for them. Initiating structure, contrastingly, is defined as the degree to which a leader defines and organizes his role and the roles of their subordinates, is oriented toward goal attainment, and establishes well-defined patterns and channels of communication (Fleishman, 1973). Within their meta-analysis, Judge et al. found that both consideration behaviors and behavior classified as initiating structure both had moderately strong, nonzero relations with leadership outcomes. Specifically, consideration behaviors were found to be more strongly related to follower satisfaction (in terms of their general satisfaction with their leader, as well as their satisfaction with their job). Consideration behaviors were also shown to be moderately related to subordinate motivation, and ratings of leader effectiveness. In contrast, behaviors classified as initiating structure were more strongly related to ratings of leader job performance and group–organization performance. Ultimately, the primary "take away points" from this research were that although subordinates did generally prefer leaders that enact considerate behaviors, subordinates performed better for those leaders that more often enacted structuring behaviors. With that said, Judge et al noted that both sets of behaviors were also linked to follower motivation and leader effectiveness, suggesting that both types of behaviors were instrumental to maximizing subordinate effectiveness.

When considering the empirical evidence from Casmir (2001), and the subsequent theoretical expansion presented by Judge et al. (2006), taken together these points outline the useful combinatorial benefits associated with merging the task-oriented and relational leadership approaches, as well as the potential performance decrements linked to using only task-oriented leadership, the present research will also use these leadership approaches in tandem to represent centralized leadership.

In contrast with centralized conceptions of task and relationship oriented leadership, shared meaning-making treats all organizational members as having a stake and role in leadership processes and does not rely on a single individual to enact leadership. As a result, no one person is solely responsible for assessing and guiding team progress towards a goal, or structuring group tasks, as these activities are shared by the team. Teams using the decentralized leadership approach are hypothesized to have superior performance in team-based distributed tasks because of the metacognitive benefits associated with team cognition (Cannon-Bowers & Salas, 1998; Drath et al., 2008). As previously noted, team metacognition is a multidimensional phenomenon in which individuals are able to access the knowledge of one's team members' cognitions and regulation of those cognitions, for the purpose of improving their problem solving and development of situational expertise (Fiore et al., 2002; Schraw, 1998). Whereas decision-making in teams with a centralized, hierarchical leader (e.g., task-oriented and relationship leadership teams) may potentially be limited by the experiences of that leader, decentralized leadership teams must pool all of their own experiences and cognitive resources. It is by sharing and integrating their individual perspectives that decentralized leadership teams are theoretically better able to develop higher quality, more comprehensive solutions. Decentralized leadership is comprised of relational systems used to build commitments among members of a community of practice, and is realized through members' levels of collective goal orientation and shared trust which, in turn, creates value by facilitating meaningful collective action (Day, 2000; Leana & Van Buren, 1999). While being very different from each other, these two views of leadership can both be seen as components of effective leadership, each being useful and efficient across specific situations.

Previous research has examined the implications and the effects of leadership on improving teamwork quality and team metacognition ratings (but primarily teamwork quality) in distributed groups and teams. An example of this research is Marks, Zaccaro, and Mathieu (2000), who examined whether the quality of instructions given by a leader before teams performed their assigned tasks impacted the ability of spatially distributed groups to complete those tasks. In well-trained, highly coordinated, and well informed groups, detailed mission briefings provided by their group leader led to the development of similar and accurate team mental models (Marks et al., 2000). Team mental models are defined as compatible and complimentary mental representations of the knowledge possessed and shared by group members to perform their duties (Klimoski & Mohammed, 1994; Rentsch, Heffner, & Duffy, 1993). Groups that received the detailed leader briefings performed better, and were also shown to be more adaptive to different types of tasks, than those groups that did not receive the detailed leader briefing. Both the information provided by the leader, in addition to the leader's presence, had positive influences on group performance.

The detailed leader briefings used in the Marks et al. (2000) were composed of several parts, including a description of the goals of each task; however only the detailed leader briefings included information about what the leader felt were the most significant risks to solving the problem, the strategies that the leader felt that the team may be able to exploit, and the briefings also included the leader's prioritization of their task objectives. These briefings also advised the teams of how and in what order the leader felt their targets should be engaged. This research was innovative because it examined the ways that directive leadership behaviors would impact team mental model formation, team performance and adaptability in dynamic task environments. The present study is an extension of this work, as it is designed to understand in which media richness conditions leadership behaviors operate most optimally, and provide the maximum benefit to virtual team problem-solving performance and related decision outcomes. To this end, a two-way interaction between the constructs of communication media richness and type of leadership is hypothesized for teamwork quality, team metacognition, problem-solving performance, and ratings of team psychological safety in virtual teams.

When teams interact and communicate with one another solely through the use of TBC technologies, different leadership approaches will have the following hypothesized results. Teams that have centralized leadership are expected to have higher teamwork and higher team metacognition and overall problem-solving performance than teams using decentralized leadership. Teams with leaders using a centralized leadership are hypothesized to have better teamwork quality and team metacognition ratings because the structured nature of centralized leadership will allow them to focus on their tasks more quickly, remain more task-focused over the duration of the task, leading them to interact more and likely at deeper levels. This enhanced interaction will allow to greater information-sharing, as well as improved coordination of effort between the text-based team members, allowing for increased ratings of teamwork quality and team metacognition, Teams demonstrating effective teamwork and high levels of team metacognition have achieved a useful amount of interpersonal communication, possess efficient coordination, receive an equal amount of contributions from all team members, show support for each other's ideas, show sufficient task-relevant effort, exhibit cohesion, as well as clear understanding of their teammates thoughts and feelings with regard to the task being examined. With that, the present research hypothesizes that centralized leadership teams will be better able to meet the basic requirements indicative of the presence of high-quality teamwork quality and team metacognition ratings.

As previously noted, a centralized leadership approach is one where a hierarchical relationship exists within a team, and one individual in a position of authority is responsible for managing a team's behaviors, establishing communication, organizing tasks, and assigning duties; as well as creating a good working atmosphere, fostering an environment of trust, recognizing contributions to the task, and reducing team stress levels. In an environment lacking a high level of communication cues, teams using a centralized leadership approach are hypothesized to have better teamwork quality and team metacognition ratings because of the clear and uncomplicated steps that these teams use to address a problem of interest. As a single individual [the leader] is responsible for setting direction within the team, these centralized leadership teams do not have to spend their time deciding on the best course of action to use while solving a problem or assigning duties to team members. By being able to more quickly start their deliberation, teams with a centralized leadership approach should be better able to more quickly display the behaviors necessary to create good teamwork quality and team metacognition. Also, as centralized leadership teams should be able to more quickly engage in their discussions, they should be better able to avoid the intensive discussions and potential disagreements that have been associated with the metacognitive aspects of team cognition and the decentralized leadership approach (Cannon-Bowers & Salas, 1998). Being to avoid these potential distractions, centralized leadership teams are also able to avoid any resulting negative consequences, which may impact the quality of the team's future teamwork quality and team metacognition ratings.

Teams using the decentralized leadership approach are hypothesized to have lower problem-solving performance compared to teams using a centralized leadership approach. As the basis of the decentralized leadership approach has to do with team members pooling their experiences and cognitive resources, there is an implicit need for these decentralized leadership teams to be able to share information amongst themselves effectively. However, the present research theorizes that as teams working to make decisions in a text-based chat environment are not able to distribute information to their other teammates in an efficient manner, this will decrease the ability of teams using the decentralized leadership approach solve problems better than teams using a centralized leadership approach. It is due to the inability of the TBC medium to quickly exchange information between a sender and receiver, as well as the protracted length of TBCs, that decentralized leadership behaviors would be less effective than more centralized, hierarchical methods of leadership in distributed problem-solving. Teams using a centralized leadership approach may be less negatively affected, as the directive nature of communications within these types of teams may be able to counteract the effects of lowered media richness.

The present study also theorizes a relationship between leadership behaviors and the level psychological safety present in virtual teams, and hypothesizes how that relationship changes across communication technologies with differing levels of media richness. Because of the lack of information depth, TBC teams communicate are subject to increased misunderstandings, increased problem orientation and generally poor performance when compared to other types of virtual teams (Baltes et al., 2002). By using a centralized leadership approach, teams using text-based chat would be better able to structure the information presented in their environment, improving their ability to interact and solve problems. Specifically, it is hypothesized that text-based teams with a centralized leadership approach will have greater amounts of team psychological safety; as compared to text-based teams using decentralized leadership.

Text-based teams using centralized leadership may experience limited interaction, due to limitations in the leadership behaviors themselves and the restrictive nature of that communication medium. However, the combination of text-based teams and decentralized leadership will lead to scattered problem-solving discussions, increased decision times, and a general lack of coordination within these teams. In contrast, using a centralized leadership approach is hypothesized to provide an adequate amount of structure to a team's interaction and problem-solving. Though using centralized leadership could potentially inhibit teams from fully exploring the problem space, and engaging in risk-taking, these teams are theorized to do more of this when compared to those teams with unrealized decentralized leadership. Without the necessary structure present to coordinate team efforts, the present study hypothesizes that text-based teams using decentralized leadership will be found to have less team psychological safety, as compared to those using a centralized leadership approach.

H5a: In the TBC condition, teams using a centralized leadership approach will have better teamwork quality than teams using a decentralized leadership approach.

H5b: In the TBC condition, teams using a centralized leadership approach will have better team metacognition ratings than teams using a decentralized leadership approach.

H5c: In the TBC condition, teams using a centralized leadership approach will have better problem-solving performance than teams using a decentralized leadership approach.

H5d: In the TBC condition, teams using a centralized leadership approach will be found to have higher levels of team psychological safety, compared to those TBC teams using decentralized leadership.

Just as the directive nature of a centralized leadership approach is expected to aid TBC teams, a similar rationale is used for VMC teams. The present research hypothesizes that teams using VMC in conjunction with a centralized leadership approach will have better teamwork quality and team metacognition ratings than VMC teams using a decentralized leadership approach because of the inability of teams using decentralized leadership to sustain meaningful interactions in the video-mediated context. As decentralized leadership has been theorized to require intensive information sharing and in-depth discussion, the lack of co-presence in the video-mediated context impairs the ability of these teams to completely realize decentralized leadership, when compared to teams meeting in person. Decentralized leadership may also be difficult to enact in VMC teams because current communication technologies could limit discussion simultaneity, almost forcing teams to use a more sequential method of communication. Specifically, many of the current VMC technologies can have problems with video and audio transmission when users attempt to transmit too much information, too quickly. For example, in a situation where a group of people are having a conversation using a VMC medium, if two or more people attempt to speak at the same time, the system may “drop” the audio output from one or both of the speakers. Also, if the information volume is too great, the video may start to “freeze” or become “pixilated”, and the information being transmitted begins to place strain on the system and overload it. Users, over time, learn to avoid behaviors that will lead to these “drop outs” of audio and visual information. This adjustment on their part could reduce the spontaneity of the team’s information sharing, as well as their feedback immediacy, causing a potentially negative impact on the effectiveness of the decentralized leadership approach in VMC teams.

Next, the present research hypothesizes that VMC teams with a centralized leadership approach will have better problem-solving performance, when compared to decentralized leadership VMC teams because of their potential discussion simultaneity. The inability for team members to share information in a truly simultaneous manner could reduce the amount and quality of the information that members share with one another. As decentralized leadership VMC teams may be limited to using a more sequential style of communication, the quality of their problem-solving performance may be influenced through the increase of their time to decision. Additionally, it may also be that the decreased amount of feedback immediacy potentially associated with the use of a video-mediated context could cause discussion digressions, misunderstandings, and conflict reducing the accuracy of a team’s answer and the team’s problem-solving performance.

Just as the highly structured and directive nature of the centralized leadership approach is hypothesized to structure TBC team interactions, allowing them an increased opportunity to generate increased amounts of team psychological safety, the present research believes that centralized leadership similarly impacts VMC teams. Specifically, the present research hypothesizes that that the use of decentralized leadership in VMC teams is hypothesized to again be limited by the technology used to transmit team communication, and that VMC teams using centralized leadership will report higher ratings of team psychological safety. The inability of decentralized leadership teams to foster a high amount of discussion simultaneity, combined with their low level of feedback immediacy, will likely lead to longer discussion times. Given the poor quality of these interactions with decentralized leadership, it can be surmised that these conversations are spent acclimating team members to the problem, and include very low amounts of problem-relevant risk-taking. And due to this failure for decentralized leadership VMC teams to build and maintain meaningful interactions, centralized leadership VMC teams will be found to have the highest levels of team psychological safety.

Because VMC teams represent a less rich communication environment than FTF, a centralized leadership approach is hypothesized to provide the necessary structure for teams to engage in decision stages, without restraining their problem-solving ability, allowing them to efficiently operate and perform better than teams using a decentralized leadership approach.

H6a: VMC teams using a centralized leadership approach will have better teamwork quality than VMC teams using a decentralized leadership approach.

H6b: VMC teams using a centralized leadership approach will have better team metacognition ratings than VMC teams using a decentralized leadership approach.

H6c: VMC teams using a centralized leadership approach will have better problem-solving performance than VMC teams using a decentralized leadership approach.

H6d: In the VMC context, teams using a centralized leadership approach will be found to have higher levels of team psychological safety, compared to those VMC teams using decentralized leadership.

In a more media rich communication environment (e.g., FTF), using a centralized leadership approach may very well be an less than optimal means of managing people, as its directive and limiting nature may be viewed as being more restrictive to the team's ability to initiate effective teamwork and metacognitive practices, and their problem-solving processes. It was expected that the FTF communication medium will be able to take full advantage of the sophistication of the decentralized leadership approach. Therefore, decentralized leadership FTF teams will have the highest teamwork quality and team metacognition ratings, as well as the best problem-solving performance levels across all the teams involved in the present study. In text-based and video-mediated contexts, it is hypothesized that the directing nature of centralized leadership will allow teams to develop high level decision solutions, but it is this same directive authority that may inhibit the ability of FTF teams to perform at their optimal level. In a FTF context, the centralized leadership approach is thought to reach the limit of its ability to structure virtual teams problem-solving. Team members would be unable to take full advantage of the richness of their environment, as the information flow within these teams would be constrained by the knowledge and experiences of their leaders. However, the metacognitive function of teams using a decentralized leadership approach, in an FTF context, will be fully realized, giving these teams the highest level of teamwork quality and team metacognition, as well as problem-solving performance in the present experiment.

Teams that meet in a FTF context and use a decentralized approach to leadership will also have higher levels of team psychological safety than FTF teams using centralized leadership. The directive, structured nature of centralized leadership aids teams in communication environments of decreased media richness, but in highly media rich environments the present research theorizes that it would only be restrictive. In comparison, a decentralized leadership approach would allow all team members to engage in free-flowing discussion, adding their contributing information where necessary to build a complete answer. Decentralized leadership teams in the FTF context would also be able to branch off and add in potentially useful information to generate more inclusive responses. Given this, team psychological safety will be highest among teams that convene FTF and use a decentralized leadership approach to guiding their teams' actions.

The rationale supporting these hypotheses is based on the thinking that FTF teams can circumvent the problems associated with the lack of co-presence that plague virtual teams. Team member co-presence, visibility, audibility, and co-temporality all combine to provide FTF teams with the necessary depth of media to properly make use of discussion simultaneity. These characteristics give FTF teams the ability to transmit and receive many different types of cues, give and receive feedback at a high rate, and avoid the previously identified impediments to their intra-team communications and problem-solving sessions. Given this, FTF teams with decentralized leadership should be better able to recount their problem-relevant experiences, both fully and completely share this information amongst the teams, and work together in order to identify the best decision given their collective understanding.

H7a: FTF teams using a decentralized leadership approach will have better teamwork quality than FTF teams using a centralized leadership approach.

H7b: FTF teams using a decentralized leadership approach will have better team metacognition ratings than FTF teams using a centralized leadership approach.

H7c: FTF teams using a decentralized leadership approach will have better problem-solving performance than FTF teams using a centralized leadership approach.

H7d: In the FTF context, teams using a decentralized leadership approach will be found to have higher levels of team psychological safety, compared to those FTF teams using centralized leadership.

Method

Participants

An a priori power analysis was performed to determine the number of team cases necessary for each of the experimental conditions of the present study. With a medium effect size of 0.25, an accepted significance level of 0.05, and the requisite power for the present study set using the value convention of 0.80, a minimum population size of 192 teams (or at least 32 team cases per each experimental condition) was found to be necessary. This analysis was performed using the following: effect sizes reported and calculated from previous studies as comparisons, the Cohen (1977, 1988) texts on statistical power analysis for the behavioral sciences, and the *GPower* statistical program designed to calculate sample size and experimental power needs (Faul & Erdfelder, 1992). Following the results of this power analysis, a total of 624 students participated in this present study forming 208 teams across 6 experimental conditions.

The present study drew its participants from two student subject pools at a large, public university in the Northeastern United States. One subject pool was in the psychology department and the other pool was composed of classes within the school of the information sciences and technology. In exchange for their participation, students received course credit in accordance with their instructor's course syllabus. Participant ages ranged from 18 to 23 years, with an average age of 19. Of the participants, 45.4% were male and 54.6% were female. In terms of their academic classification, 58.7% were freshmen, 25.2% sophomores, 12% juniors, 3.5% seniors, and 0.6% were graduate-level students. And in terms of their reported race/ethnicity, 84.8% of the sample reported themselves as being Caucasian, 6.1% Asian/Pacific Islander, 3.7%

African-American, 2.9% Hispanic, and the remaining 2.6% were “other” or did not report their ethnicity.

Design

Participants were randomly assigned to three-person ad-hoc teams in a 3 (media richness type: text-based chat, video-mediated, or face-to-face) x 2 (leadership briefing behaviors: centralized leadership approach or decentralized leadership approach) between subjects experimental design. The between–subjects variables were media richness type and leadership recorded by the present study included an assessment of teamwork quality, a measure of team metacognition, a measure of team psychological safety, and two task-related problem-solving performance scores (one video-based and one text-based).

Group Task and Materials

The format of the two tasks used in the present study was taken from the JASPER video series originally developed by the Cognition and Technology Group at Vanderbilt University. The JASPER research paradigm is composed of problem-solving tasks based on strategic planning, learning, and making decisions involving complex problem-solving tasks that initially involve ill-defined and emergent operations (CTGV, 1997). The tasks used in the present study were both presented via computer; the first was presented in a video-based story format and the second was presented as a text-based short story. In both problems, the storylines for both videos require participant teams to work on variations of "Distance = Rate x Time" physics problems, given interdependent demands of the environment in which the problem were depicted. Optimal answers can be derived by establishing sub-goals and pursuing various plans that make tradeoffs between spatial, temporal, and practical interdependencies.

The video used in this study was named “Journey to Cedar Creek,” which focuses on a protagonist planning a boat trip up river to purchase a larger boat. Participants need to identify the route they will need to take, whether or not they will need additional fuel, and what time they will need to leave Cedar Creek to arrive home before dark. The text-based task was named “Trip to Huron Lake,” and described the story of a young woman and her grandfather traveling to Lake Huron for their annual fishing trip. Here, participants were presented with a potential medical emergency (e.g., the grandfather has forgotten his heart medication) and had to identify their return route, their fuel points, and when they will need to leave the lake to return home before the grandfather’s next medicinal dosage.

A detailed description of the design principles, situational context, and planning elements contained within the tasks of the JASPER research paradigm was extracted from a research report conducted by Crews, Biswas, Goldman, and Bransford (1997) and is presented later in the present paper (see Appendix A).

The materials used for the present study were PC-computers, a Java-based text-based chatroom applet, a freeware Internet chat program using both audio and video transmission, a secure local area computer network, one digital projector, a set of external speakers, a base microphone, a digital voice recorder, a video-based JASPER problem-solving task (CTGV, 1993 & 1997), a text-based JASPER problem-solving task, a battery of surveys (including the teamwork quality survey, team metacognition survey, team psychological safety survey, and a short demographics survey), scrap paper, and pencils.

Manipulations

Media Richness. Participants that took part in this study did so in teams using one of three communication media richness conditions: *TBC*, *VMC*, and *FTF*. In the *text-based* condition, study participants worked together in spatially distributed teams, communicating with one another via TBC medium (i.e., chat rooms technology). In this condition, participants were assigned their own computer workstation from which to view the video and operate its controls, while communicating with their team members via an Internet chat program to successfully solve the problem. In the *video-mediated* condition, participants worked together in spatially distributed teams, but communicated with each other via VMC (i.e., webcams, video displays, and headset microphones). As with the text-based condition, participants in the VMC condition were assigned their own computer workstations from which to view the video task and work together to solve the problem. In the *face-to-face* condition, participants worked together in co-located three person teams and watched the task on a central monitor, using only one keyboard and mouse to control the video and its related functionalities.

Centralized Leadership. Prior to starting the initial JASPER task, teams in the centralized leadership condition received a briefing from their confederate leader via a short video recording (across all media richness conditions). The centralized leadership manipulation briefing video consisted of several component parts, including general instructions for the task, decision strategies, and personal insights from the leader. In the general instructions, the confederate leader gave their teams direction on the nature of the task they would be working through in this experiment. The following excerpt is an example of the general instructions provided by the confederate leader in the centralized leadership condition:

> *"So, let's get started. In today's experiment, you will be asked to work as a team to develop answers to questions presented in two separate tasks. In the first task, your team will answer a series of questions after viewing a problem presented to you in the form of a short, 15 minutes video. The questions that you will need to answer are presented for you at the top of the interface that you will be working from, while the video is presented in a Quicktime video format."*

The next section of the centralized leadership manipulation video was the presentation of the decision strategies by the confederate leader. A decision strategy is an approach for developing answers while working together as a team (Chemers, 2000). The confederate leader made suggestions to their team about how they should approach their work in the present task using behaviors that could be classified as being both task-oriented and/or relational leadership behaviors. The confederate actor demonstrated task-oriented leadership traits by delivering his lines in a very clear, well-defined and directive manner. In addition, the actor's briefing was written to be role-prescribing and identifying potential team duties, while also outlining potential environmental constraints for the team to monitor. These behaviors are consistent with the task-oriented leadership behaviors outlined in Fleishman (1973), House (1971), and Misumi (1985). Other task-oriented leadership behaviors included exhibiting a high level of focus on getting the job done and being autocratic. Task-oriented leaders tend to have a high focus on defining the work to be done in an organization, as well as the job roles for subordinates, a high emphasis on planning, organization, and monitoring; in addition to a keen focus to assessment activities (Bass, 1989). Finally, task-oriented leaders are very closely focused on timing and schedules (Blake & Mouton, 1985).

The following statements are examples of decision strategies provided by the confederate leader using task-oriented leadership behaviors:

> *"I suggest that you work quickly, as 55 minutes is not as much time as it seems."*

> *"…[Y]ou could also split up the questions, and develop answers to them separately and then check each other's work together. Whichever method you choose to answer the questions, you need to record all of your work neatly so it can be collected and checked at the end of this experiment."*
>
> *"Be careful not to let the time pressure get to you. Be sure to pace yourselves, and work through each of the questions presented quickly, but answering each one completely."*

The previous statements are representative of guidelines that would be made by a leader with a task-oriented focus because they are directive in nature, clearly outlining steps that the leader wants for their team to undertake in progress toward a solution. Next, these statements suggest that the teams think about and adopt specific functions to facilitate their interactions. Also, these sample statements highlight potential environmental constraints (e.g., time pressure) that the team could encounter, and stressed to them the importance of attending to these during their problem-solving sessions.

As a part of the centralized leadership manipulation, the confederate leader also displayed relational leadership behaviors when offering decision strategies to their teams. Some examples of relational leadership behaviors included warning teams about the importance of maintaining group cohesion during the problem-solving and emphasizing the importance of group members talking to one another. Relational leadership was also enacted by the confederate leader praising the potential ability of the group, providing enough encouragement for group members to meet all of the task goals, and giving instructions explicitly designed to reduce subordinates' stress levels. These behaviors traits are consistent with the relational leadership behaviors outlined in House (1971), Misumi and Peterson (1985), and Yukl (1998). Other relational leadership behaviors included the appearance of benevolence and integrity. Also, relational leaders tended to focus on building inclusivity and empowerment, as well as commitment in their teams (Brower, Schoorman, & Tan, 2000; Komives, Lucas, & McMahon, 1998).

The following statements are examples of decision strategies provided by the confederate leader using relational leadership behaviors:

> *"You are to work on and develop answers for all of the problems together, as a team. Be sure to share all of the information that you find that you think is relevant to solving each problem. Remember, your teammates won't know what you are thinking, or what you think is important, if you keep it to yourself."*
>
> *"While developing answers to all of the questions, in such a short amount of time may be somewhat difficult, if you all work together as a team, stay focused, share information, and work diligently, a team with your abilities should be able to produce some of the best answers possible."*

These statements are representative of relational leadership statements because they reinforce the importance of team members talking to and sharing information with one another while they work together during the experiment. These statements offer some potential stress reduction, as they identify facets of this experiment that could cause some problems, but simultaneously offers reassurance that the teams have the necessary skills to successfully solve the problems that they will be presented with in the experiment. Also, the confederate leader was able to express relational leadership behaviors, in addition to the aforementioned statements, through a variety of expressions and other non-verbal communications. These expressions included the confederate speaking in a friendly, approachable, and unthreatening manner. The confederate leader also smiled often during the briefing, and presented a generally positive affect toward the teams.

The third, and closing, component of the centralized leadership video manipulation was the addition of personal insight statements. Different from the general instructions and decision strategies, the personal insight statements by the leader were designed to serve as advice provided by the leader to give their teams context about the importance of performing well in the study, as well as offering some insights about how teams could best make their way through this experiment. Similar to the previously defined decision strategies, the confederate leader gave personal insight statements using behaviors that could be classified as being both task-oriented and/or relational leadership behaviors. The following excerpt is an example of personal insight statements provided by the confederate leader using task-oriented leadership behaviors:

> *"In the past when I have worked on similar problems, I have found it best to pretend that the person who is reading my answers did not read the question that I am answering. That way, I would make sure to include enough background information in my answer to ensure that I fully answered the question I was asked. Just remember to try and give the most complete answers possible to each of the included questions."*

In line with task-oriented leadership, the above statement was a personal anecdote from the leader that the teams would internalize as a set of instructions for how they should answer the questions that they would be presented with in the experiment.

The next excerpts represent personal insight statements made by the confederate leader using relational leadership behaviors:

> *"A useful tip to remember if you get stuck is to remember that you aren't working alone in this experiment. If you are stuck, ask your teammates what they can find out or if they have any information. This tactic helped me out in another experiment I was in just last week. Remember, the more people you have working on a problem, the less likely you are to miss something."*

> *"While you may have some concern about finishing, each of you has all of the knowledge and experience that you need to do very well on this experiment. So, be relaxed, and do your best."*

Different from the previous personal insight statement, the above relational leadership personal insight statements were written to suggest that the confederate leader recognized the benefits of good teamwork and maintaining group cohesiveness while working on similar situations. Also, the above statements offer reassurance and support to the teams, serving as a stress reducing statement. A copy of the complete transcripts used by the confederate leader for each of the conditions of media richness in the centralized leadership manipulation can be found in Appendix B.

Decentralized Leadership. Teams presented with the decentralized leadership manipulation first watched a leadership training video and then were instructed to read a short information sheet about their responsibilities during the experimentation. Where the centralized leadership approach focuses on a specific individual as the primary source of guidance through the espousal of certain traits and behaviors, the decentralized leadership does not depend on a central leader or position of authority for direction. Instead, decentralized leadership is a collectivistic process, requiring contributions from the entire group at all levels, in order to reach a desired end state. The decentralized leadership manipulation was designed to instruct the participant teams on the behaviors necessary to properly enact it through behavioral modeling. Behavioral modeling is a learning theory emphasizing modeling, observation and reinforcement as an effective methodology for training human learners. Based on Bandura's (1969) theory of social learning, individuals are able to acquire new knowledge, skills, and abilities through observational learning of the behaviors of a given target or referent. There are four sub-processes involved in this type of behavioral modeling: *attentional processes* (the ability of the observer to attend to and differentiate between behavioral cues), *retentional processes* (the ability of an observer to remember the behavior over a period of time), *motor reproduction processes* (the physical abilities needed by observers to acquire and perform the behavior portrayed by the model), and *incentive/motivational processes* (the reinforcement conditions existing at the time the observed behavior is performed).

The present study used these four sub-processes to create a behavior modeling training video to present the decentralized leadership manipulation to teams in this experiment. The script for this video can be found in Appendix C of this document. The first step in this process was to introduce members to the topic that they were to be trained on and then familiarize teams with the content of the video and how the behaviors included were going to be modeled. Introducing the behavior to be modeled was an *attentional* process because it focused the attention of the observer and helped them to better identify the behaviors of interest. The following narrative paragraph is taken from the decentralized leadership manipulation video and depicts how attentional behavior modeling processes were used in the present study.

> *Narrator: "Hello. The video that you are now watching is a training tool that has been designed to identify and demonstrate the use of good teamwork behaviors in small groups and teams. The individuals that you are now watching will be shown working together to solve a short problem solving task. As they work together, they will demonstrate several important teamwork behaviors. Each of these behaviors pointed out in this video will be highlighted, defined, and then replayed to explain and emphasize their importance in fostering high quality teamwork. The behaviors that will be acted out in this video are: observation and information gathering, information and idea sharing, respectful discussion, idea acknowledgement, and idea/concept integration."*

In addition to the preceding statement, attentional behavior modeling processes were further activated by overlaying text describing the behaviors being acted out in each scene. This was done to help participants better differentiate between cues for each behavior being modeled.

Next, teams watched the training video, viewing scenes that displayed each of the behaviors and paying close attention to how the actors in the video model them. By viewing scenes in which the individual behaviors were acted out in their entirety, teams were taking part in a *retentional* process. A retentional process provided observers with a clear exemplar for the behavior that they were being trained on, giving them a specific example to draw upon in the future when considering how a given behavior should be performed. The following narrative paragraph is taken from the decentralized leadership manipulation video and depicts how retentional behavior modeling processes were used in the present study.

> *Narrator: "After the video begins, the team watches very closely. So that they can make the highest quality answers, each of the team members takes notes and rewinds the video, to review scenes in which they may have missed something. These types of activities are examples of '<u>observation and information gathering'</u>." In this type of task, observation, as a behavior, would means paying close attention to both the task you will be performing and to your teammates when they are sharing task-relevant information. Information gathering behaviors would include taking detailed notes from the task as the problem is presented, and then recording both your and teammates' recommendations for how to solve the problem.*

The preceding excerpt represents a portion of the narrated decentralized leadership manipulation video in which certain behaviors of interest were being acted out; in this case 'observation and information gathering.' During this scene, the behaviors of interest to study were identified, defined, and observed by the study participants. Retentional processes were further reinforced at the end of the video where the behaviors of interest were quickly redefined and recapped.

In the third step of the decentralized leadership manipulation, teams were instructed to read a briefing on the JASPER tasks (both the initial video-based task and the second textual analogue) once viewing the exemplar team enact the behaviors to be trained. The Decentralized Leadership Manipulation Briefing was a text-based handout that included a general problem description, the teams' instructions for the experiment, the basic functionality of the video interface, and a *motor reproduction* process cue (see Appendix D). The briefing form also contained the learning points covered in the leadership training video, as a way of facilitating transfer of training by giving teams reference points to consult while enacting their trained leadership behaviors during the experimental task (Goldstein, 1993; Latham & Saari, 1979). The general problem description and task instructions were written to mirror the procedural information provided by the confederate leader in the centralized leadership manipulation video. However, the motor reproduction process cue was another step in the behavior modeling process. Specifically, motor reproduction allows an individual the opportunity to practice a trained behavior to further engrain within them the modeled behavior. This was performed by explaining that the experimental task required participants to perform basic mathematics and provided a series of sample word problems for participants to think through. The goal here was not to have participants correctly solve the word problems, but to think about what information in the problem might be important to make note of and share with their team members, reinforcing information that the teams were presented within the decentralized leadership manipulation video (see Appendix D).

The last step in the behavior modeling approach used in the decentralized leadership manipulation was also enacted in the previously discussed briefing. Specifically, before participants began working together on the experimental task, they were told that they would be asked to evaluate and provide feedback to their teammates' regarding their ability to properly demonstrate the trained behaviors while working together, and that they would be awarded study credit at the end of the experiment. These statements served as an *incentive or motivational* process. Previous research on behavioral modeling has shown that motivation, or incentivizing behavior, is the final necessary step to ensure that modeling can actually occur. In order to promote effective modeling, a learner must be motivated to display their mastery of those behaviors. Ormrod (1999) supported this assertion reporting that individuals subject to evaluation and assessment about their performance were more likely to attend to and apply the previously identified training principles. With that as the underlying rationale, the following excerpt was taken from the Decentralized leadership Manipulation Briefing (see Appendix D):

> *"OK. You are now ready to begin the experiment. After you have answered the questions in both tasks, you will be asked to fill out several questionnaires about yourself, your team and your experiences in today's experiment. You will also be asked to provide them with feedback about how well you think that they performed during this experiment. After this is over, you will be given your credit and dismissed."*

The preceding excerpt was designed to represent an incentive, or motivational, processes through two methods. First, by informing the study members that they would have the opportunity to give each other public feedback on their performance in the study, this process would apply subtle pressure on the study participants to be attentive and remain engaged in the study. Second, the mention of the study was included to serve as an explicit reminder of their reason for participating, encouraging participants to remain on task.

After the decentralized leadership manipulation finished, each team member was presented with a list of key learning and reference points covered in the leadership training video to consult while enacting their trained leadership behaviors during the experimental task as a way of facilitating transfer of training to the experimental task.

Experimental Procedure

To participate in the study, students signed up for the study in person or via a computer-based roster. When participants arrived at the lab, they were given a copy of the informed consent form to read, sign and then return to experimenter. Once they had read and signed the informed consent, the forms were collected and participants were seated according to the media richness condition that was being tested that day. It was originally proposed that both the media richness condition and leadership manipulations would be randomly assigned before each experimental session. However, due to the advanced preparation required to set up the lab for video-based teams as opposed to text-based teams, the experimental condition being examined had to be determined prior to participants' arrival at the laboratory.

Participants in text-based and video-mediated teams were seated at private cubicles with PC-formatted desktop computer workstations that were fitted with noise-cancelling headphones to ensure that teams would not be disturbed during the experiment. Participants assigned to video-mediated teams also had computer workstations with microphones and video-cameras. The cameras were all connected, displaying images of the other two team members, to ensure that participants could only communicate with each other via audio transmissions and video images shared between the team members. Participants assigned to FTF teams were seated at a communal work area with a single PC-formatted desktop computer workstation to allow team members to freely communicate with one another in an open environment.

Once seated, the experimenter provided teams with a general outline for how the study would progress and answered questions about the study. Next, participants received a one to two minute explanation of how team members in this experimental session were supposed to interact with each other, whether through text-based, video-mediated, or FTF means. Students then received either the centralized or decentralized leadership manipulation through this medium.

Once participants acclimated to the task and received either their leadership briefing or their team training, teams were instructed to begin working on the initial JASPER task (Journey to Cedar Creek). All teams had 55 minutes to view the task, communicate with their team members through their respective communication mediums and to solve each of the questions presented about the task. Once finished, teams were presented with a set of instructions for the second experimental task (Trip to Huron Lake), where teams again had 55 minutes to solve the problem. After completing the second experimental task, participants were directed to fill out several surveys individually, including a short survey demographic survey and surveys assessing teamwork quality, team metacognition, and team psychological safety (see Appendices E through H). After completing these surveys, which took approximately 25 minutes to complete, participants were awarded their participation credit and released. In its entirety, this is experimental session lasted approximately 2 hours and 30 minutes.

Measures

The present study made use of four distinct kinds of measures: ratings of teamwork quality, ratings of team metacognition, ratings of team psychological safety, and team problem-solving performance measures. These measures ascertained what information is attended to by teams, how well teams work together, what types of information are shared when working together, and what kinds of information teams use when composing their responses. Measures also gauged the level of learner comprehension and the value of the solution. Measures were specifically chosen to highlight the impact of differing types of communication technologies and leadership behaviors on teamwork quality, team metacognition, and team problem-solving in responding to two problems within the JASPER paradigm.

Teamwork Quality Measure. In order to test the quality of the interactions between team members and how well they work together to develop answers to the JASPER task, the present study used the team quality (TWQ) construct survey (Hoegl & Gemuenden, 2001). The original survey was modified to assess each of the six facet behaviors that comprise the TWQ, including Communication, Coordination, Balance of Member Contribution, Mutual Support, Effort, and

Cohesion. These facets were measured using between three and ten items each, with a total of 36 items in the full scale. This survey previously demonstrated a very high level of reliability in previous research (Cronbach's alpha coefficient of 0.91 reported by Hoegl & Gemuenden, 2001). The TWQ scale appears in Appendix F.

Team Metacognition. This study used a 11 item self-reported survey which was designed to measure how well the teams generated thoughts and knowledge related to the decisions that they were attempting to solve in the task, and to what extent they believed their team member shared those thoughts. The present study used a modified version of the Cannon-Bowers and Salas (1998) survey that was modified by Schmidt and Ford (2003) for use in measuring the impact of goal orientation and metacognitive instruction on learning outcomes (Cronbach's alpha coefficient of 0.92 reported by Schmidt & Ford, 2003; see Appendix G).

Team Psychological Safety. This study utilized a 7 item scale developed by Edmondson (1999) to measure the beliefs of individual team members of how safe their team is for interpersonal risk-taking (Cronbach's alpha of 0.82 reported by Edmondson, 1999). See Appendix H for the full scale.

Problem-Solving Performance Score. The process that was used to score the team transcripts generated by the present study (e.g., problem space analysis) was based on the identification and evaluation of specific elements present within the problem that can be found within the transcript. Problem space elements represent critical pieces of information necessary for teams to interpret, understand and then solve the problems that are presented to them. Using the same style of analysis as McNeese (2000) and adapted from planning net analysis described by Van Lehn and Brown (1980), the present study divided the experimental tasks into sub-problems, identified the core problem space elements that make up the problem, and then analyzed participant team transcripts to determine their performance in solving the task. Analysis of the problem space measures began by identifying and summing all of the core task elements declared within the teams' transcripts of their solution to the initial task (e.g., the Journey to Cedar Creek task). The eight problem space measures that the present study coded as a measure of team task performance were: *complete problem space details*, *partial problem space details*, *math errors*, *recall errors*, *corrected math errors*, *corrected recall errors*, *attempted sub-problems*, and *correctly solved sub-problems*.

A complete problem space detail identification refers to instances where one or more participant team members specifically identified both the particular aspect of the problem, as well as the correct corresponding value (e.g., a team identifies the need for fuel and correctly names the corresponding capacity of the fuel tank as in 5 gallons). A partial problem space detail refers to instances where one or more participants only identify an informational aspect of the problem (e.g., a team identified the need for fuel, but did not explicitly name the maximum capacity of the fuel tank). If any of the team members subsequently added information to a previously identified partial problem space detail, and it was recognized as being "more correct" than the previously asserted information, that partial problem space detail was erased and changed to a complete problem space detail identification.

Math errors were made when one or more team members made an incorrect math calculation, while detail recall errors were recorded when one or more team members incorrectly identified a piece of problem-related information (e.g., a team incorrectly determined that the maximum onboard fuel capacity of an ultralight aircraft was 7 gallons, when it was actually 5 gallons). If any of the team members subsequently corrected a previously made math error or recall error, these were coded as a corrected math errors and corrected recall errors. If one or more of the participants attempted to solve one of the overarching problem categories (e.g., Payload, Time, Distance, or Fuel Consumption), this was coded as an attempted sub-problem. Finally, a correctly solved sub-problem was coded when any of the overarching problems was solved correctly (see Appendix I for an example of the coding process).

There were two measures of team problem-solving performance recorded in the present research. To perform the problem space analysis, raters scored the transcript or recording of a team's discussion using a scoring template (one for the first problem-solving task, "Journey to Cedar Creek", and another for the second task, "Trip to Lake Huron") which contained all of the problem space elements and sub-problems present in each task (see Appendices J & K, respectively). The present study used a set of three independent raters to review the chat text, as well as the audio and video transcripts for the teams tested. These raters would review each team's audio transcript and then generate a total problem space element score for each team. Each transcript was reviewed by at least two raters to ensure consistency in the ratings. With the entire transcript coded, the total number of problem space details was combined, subtracting the number of errors committed, resulting in a task performance score.

Inter-rater reliability checks were conducted to ensure a requisite level of agreement between independent raters before a final team task performance score was aggregated (Gatewood & Field, 2001; James et al. 1984; Kozlowski & Klein, 2000). This analysis revealed good agreement between the raters for the first, video-based problem-solving task (e.g., the Journey to Cedar Creek task); as the Cohen's kappa score of inter-rater reliability was 0.73. And for the second, text-based problem-solving task (e.g., Trip to Huron Lake), this analysis also revealed good agreement between the raters for the second performance task, with a Cohen's kappa (inter-rater reliability) score of 0.72.

Pilot Study

The purpose of the pilot study was to ascertain whether the leadership behavior manipulation was effective in distinguishing between the confederate leader video (enacting centralized leadership) and the leadership training video (enacting decentralized leadership), in addition to illustrating to proper way to initiate the associated leadership behaviors. Because the focus of the pilot study was on leadership, all teams interacted in person and media richness was not manipulated.

Pilot Study Participants

A total of 90 participants were placed into 30 teams and split into two conditions. One condition watched centralized leadership video manipulation, while the other condition watched the decentralized leadership video manipulation. The present study drew its participants from a psychology department student subject pool at a large, public university in the Northeastern United States. In exchange for their participation, students received course credit in accordance with their instructor's course syllabus. Participant ages ranged from 18 to 21 years, with an average age of 19.5. Of the participants, 43.2% were male and 56.8% were female. In terms of their academic classification, 78.3% were freshmen, 10.2% sophomores, 6.8% juniors, and 4.7% were seniors. In terms of their reported race/ethnicity, 88.1% of the sample reported themselves as being Caucasian, 6% Asian/Pacific Islander, 2.9% African-American, 1.5% Hispanic, and the remaining 1.5% marked their ethnicity as "other", or did not report their ethnicity.

Pilot Study Design

Participants were randomly assigned to three-person ad-hoc teams in one of two leadership briefing conditions (e.g., centralized leadership approach or decentralized leadership approach). All of the dependent variables measured in the full study were measured in the pilot study (i.e, an assessment of teamwork quality, a measure of team metacognition, a measure of team psychological safety, and the two task-related problem-solving performance scores).

Pilot Study Tasks and Materials

The pilot study used the same experimental tasks that were described in the main Method section. The tasks were presented via computer, with the first task being a video-based story and the second being a text-based short story. The storylines for both videos require participant teams to work on variations of "Distance = Rate x Time" physics problems, given interdependent demands of the environment in which the problem were depicted. Each team tested in the pilot study worked a small table, with three chairs and a single computer workstation, with large audio speakers. Discussions about the task were captured using a digital voice recorder. After completing the experimental task, the pilot teams completed a battery of paper-based surveys, including the teamwork quality survey, team metacognition survey, team psychological safety survey, and a short demographics survey. Participant teams also received a copy of the leadership manipulation survey.

Pilot Study Leadership Manipulation

After participants completed the task, they were given the leadership manipulation survey and asked to rate the extent to which they agreed with the statements on a rating scale from 1 to 5 (with 1 being equal to strongly disagree and 5 being equal to strongly agree). The pilot study used the leadership manipulations that were described in the main method section. Teams in the centralized leadership condition received a briefing from their confederate leader via a short video recording delivered using task-oriented leadership behavior traits and mannerisms consistent with a relational leadership style. The centralized leadership manipulation briefing video consisted of general instructions for the task, decision strategies, and personal insights from the leader. The briefing informed teams of their specific performance goals, provided a brief description of the problem and example answers that teams were expected to provide, while once again reviewing the functionality of the JASPER task's video interface. The leader briefing was pre-recorded using a digital video capture program and edited for content.

Teams in the decentralized leadership condition were presented with a training video in which a pre-recorded team modeled the behaviors used in a decentralized leadership approach. The training video was designed to educate the participant teams about how they should work together during the experiment. The participants weren't explicitly told that they should work together using behaviors consistent with the theory of decentralized leadership. Instead, they received instruction about how to enact a group of behaviors that were necessary for them to successfully complete the experiment. The training video was able to accomplish this by informing the participant teams of the video's purpose, which was to identify and demonstrate the use of good teamwork behaviors in small groups and teams. Next, the training video identified each of those behaviors (*observation and information gathering*, *information and idea sharing, creating unconventional ideas, respectful discussion, idea acknowledgement*, and *idea/concept integration*). After identifying these behaviors, the video showed the pre-recorded team enacting each of these behaviors while working on a similar problem-solving task. The video ended with a recap of the good teamwork behaviors, as well as along with an abbreviated definition of the concept. As with the leader briefing, the training video was pre-recorded using a digital video capture program and edited for content. In addition to the training video, teams in the decentralized leadership condition were also given the use of an information sheet handout detailing the team's instructions and goals for the task, in addition to a list of the key behaviors and learning points these teams should exhibit during their interaction and problem-solving sessions. These learning points were designed to serve as a reference for study participants to consult to properly enact their trained leadership behaviors during the experimental task as a way of facilitating transfer of training.

Also, consistent with the content of the centralized leadership briefing, the information sheet included a short description of the problem, the team's goals for the experiment, a list of the specific questions that the teams will be expected to answer, and short description of the JASPER interface's functionality.

Pilot Study Experimental Procedure

To participate in the pilot study, students signed up in person or via a computer-based roster. When participants arrived at the lab, they were given a copy of the informed consent form to read, sign and then return to experimenter. Once they had read and signed the informed consent, the forms were collected and participants were seated at a communal work area designed for FTF interactions. Teams were seated at a single PC-formatted desktop computer workstation to allow team members to freely communicate with one another in an open environment.

Similar to the main study, the experimenter provided teams with a general outline for how the study would progress and answered questions about the study. Students then received either the centralized or decentralized leadership manipulation, with those in the centralized leadership condition receiving their instructions and goals for the experimental task in the form of a leader briefing. Teams in the decentralized leadership condition were presented with a training video in which a pre-recorded team modeled the behaviors used in a decentralized leadership approach. The training video was designed to educate the participant teams about how they should work together during the experiment. Teams in the decentralized leadership condition were also given a the use of an information sheet handout detailing the team's instructions and goals for the task, in addition to a list of the key behaviors these teams should exhibit during their interaction and problem-solving session.

Once participants acclimated to the task and received either their leadership briefing or their team training, teams were instructed to begin working on the initial JASPER task (Journey to Cedar Creek). All teams had 75 minutes to view the task, communicate with their team members through their respective communication mediums and to solve each of the questions presented about the task. Once finished, teams were presented with a set of instructions for the second experimental task (Trip to Huron Lake), where teams again had 75 minutes to solve the problem. After completing the second experimental task, participants were directed to fill out several paper-based surveys individually, including the leadership manipulation check (see Appendix L), a short survey demographic survey and measures assessing teamwork quality, team metacognition, and team psychological safety. Together, these surveys took approximately 25 minutes to complete. Participants were then awarded their participation credit and released.

Total experimentation time for the pilot study was three hours, if participants used all allotted time.

Pilot Study Measures

The pilot study used the same five measures from the main study: teamwork quality, team metacognition, team psychological safety, and team problem-solving performance. A sixth survey was added to assess the effectiveness of the leadership manipulation.

Pilot Leadership Manipulation Check. After they viewed the video manipulation, each individual was presented with a ten- item survey, asking them to indicate the extent to which they experienced different facets and aspects of each type of leadership during their respective viewing of the manipulation videos (see Appendix L). Five items were written to be consistent with centralized leadership behaviors, while the remaining five were written to be consistent with decentralized leadership behaviors. The leadership manipulation check was developed from survey items originally created in a study done by Podsakoff, MacKenzie, Moorman, & Fetter (1990); which was originally designed to differentiate between transactional and transformational leadership behaviors. For the present research, some of the language used in these items was modified to be consistent with the experimental task being used.

Five items were originally created for each dimension. After the two reverse coded items were removed, adequate agreement was noted for both conditions. The measure presented in Appendix L contains all the items originally created for the survey. A Cronbach’s alpha of 0.85 was found for the centralized leadership items, and a Cronbach’s alpha of 0.79 was found for the decentralized leadership items.

Pilot Study Preliminary Results

Reliability for Pilot Survey Measures. Cronbach's alpha reliability analyses were performed on the individual measures of teamwork quality (alpha =.92), team metacognition (alpha =.92), and team psychological safety (alpha=.82). The reliability scores fell within an acceptable range.

Inter-rater Agreement in Pilot Problem-Solving Measures. Both of the problem-solving performance scores used in the pilot study were generated using the same processes explained in the in the Methods section of the main study. Inter-rater reliability checks were conducted using the Cohen's kappa statistic. This test is designed to determine if there is sufficient agreement between independent raters. Acceptable agreement was found between the raters for the video-based problem-solving performance task (Journey to Cedar Creek), (inter-rater reliability score of 0.77) and the text-based problem-solving performance task (Trip to Huron Lake; inter-rater reliability score of 0.78).

Justification for Aggregation in Pilot Study. To determine whether the individual ratings across each of these surveys could be aggregated to the team level, the pilot study assessed whether each group exhibited adequate within-group agreement. This was done by calculating intra-class correlations (ICC). James (1982) defines the ICC(1) value as an index of inter-rater reliability. Bliese (2000) defines ICC(2), on the other hand, as an estimate of the internal consistency reliability of group means. Different from ICC(1), ICC(2) factors in the average per-group sample size and increases as the per-group sample size increases.

The ICC(1) value for the teamwork quality measure was 0.60 and .82 for the ICC(2) . The ICC(1) value for the team metacognition measure was 0.67, and .86 for the ICC(2). The ICC(1) value for the team psychological safety measure was 0.43 and .69 for the ICC(2). All values were significant ($p < 0.05$) and support aggregating individual scores into team means, and using these values as team measures.

Pilot Study Leadership Manipulation Check Results

The primary goal for the pilot test was to test if the centralized and decentralized leadership videos were effective in eliciting the desired leadership behavior, as well as being distinguishable from each other. It was expected that participants that had been exposed to the decision strategies identified by the confederate leader in the centralized leadership manipulation (see Appendix B) would be more likely to have higher agreement with the centralized leadership questions. Similarly, participants that had been exposed to the decentralized leadership behaviors training video (see Appendix C) would be more likely to have higher agreement with the decentralized leadership questions. A one-way ANOVA was performed on the survey responses collected from the leadership manipulation check (see Appendix L).

Groups exposed to the centralized leadership condition agreed more with the questions indicative of centralized leadership; $F(1, 28) = 64.98$, $p < .05$. Specifically, teams exposed to the centralized leadership video manipulation had higher levels of agreement with the centralized leadership questions ($M = 3.48$), as opposed to those teams exposed to the decentralized leadership video manipulation ($M = 2.21$). Conversely, groups exposed to the decentralized leadership condition agreed more with the questions indicative of decentralized leadership; $F(1, 28) = 103.80$, $P < .05$. Teams exposed to the decentralized leadership video manipulation had higher levels of agreement with the decentralized leadership questions ($M = 3.53$), when compared to teams exposed to the centralized leadership video manipulation ($M = 2.11$).

Therefore, the findings from this analysis were positive, indicating that the leadership manipulation was indeed effective in distinguishing between the centralized and decentralized leadership conditions. Upon receiving this level of empirical support, the full study was conducted with this leadership manipulation.

Results

Preliminary Analyses

Factor Analyses. To ensure that the three team interaction measures used in the present study (teamwork quality, team metacognition, and team psychological safety) measured three separate constructs, the present study conducted an exploratory factor analysis with all these data. Although not all items exhibited simple structure, results revealed that there were indeed three distinct factors present within the data (see Table 1). However, some of the teamwork quality items loaded on to the metacognition factor.

Reliability for Survey Measures. Cronbach's alpha reliability analyses were performed on the individual measures of teamwork quality (alpha =.94), team metacognition (alpha=.79), and team psychological safety (alpha=.79). These results indicate that the measures used in the present study had an acceptable amount of internal consistency.

Inter-rater Agreement. Cohen's kappa tests were performed to determine agreement between the raters who scored the team discussion chat transcripts and the DVR audio files, from which the team problem-solving performance scores were derived. For the first, video-based problem-solving performance task (JASPER – Journey to Cedar Creek), the Cohen's kappa score of inter-rater agreement was 0.73. For the second, textual problem-solving performance analogue task (Trip to Huron Lake), the Cohen's kappa score of inter-rater agreement was 0.72. These results indicate that the raters used in the present study had an acceptable amount of agreement between them.

Justification for Aggregation. Before data collected at the individual level can be combined into a team score, (using group mean scores), it was first necessary to assess whether each group exhibited adequate within-group agreement for the variables to be conceptualized at the group level of analysis (George & Bettenhausen, 1990). ICCs measure the amount of inter-rater reliability, or the consistency of responses among raters (James, 1982). ICC(1) reflects the extent of within- versus between-group variability. ICC(2), on the other hand, provides an estimate of the reliability of the group means (Bliese, 2000).

The ICC(1) value for the teamwork quality measure was 0.62, and the ICC(2) was 0.83. The ICC(1) value for the team metacognition measure was also 0.62, and the ICC(2) was again 0.83. The ICC(1) value for the team psychological safety measure was 0.41, and the ICC(2) was 0.67. All reported ICC values were significant ($p < .05$) and support the use of the average scores as team measures.

Descriptive Statistics. All analyses were conducted at the group level. Table 2 provides the means, standard deviations, and correlations for all study variables.

Manipulation Checks

Media richness. Following the example set by previous research on the topic, the present research did not include a manipulation check of media richness. Specifically, none of the following studies included a manipulation check on media richness in examining the relationship between media richness and leadership (DeChurch & Marks, 2006), task interdependence (Bachrach, Powell, Collins, & Richey, 2006), team member interaction skills (Driskell, Goodwin, Salas, O'Shea, 2006), and team adaptation (LePine, 2003) none of these studies included a pilot examination, or an explicit check of the effectiveness of media richness manipulation. Similarly, a study by Maruping and Agarwal (2004) that examined the style and quality of virtual team interactions across a variety of communication mediums was also performed without a reported manipulation check.

None of the studies that assessed the relationship between different workgroup outputs and media richness performed manipulation checks to determine the ability of their study participants to distinguish being the various levels of their media richness manipulation. This includes studies that examined the impact of media richness on the team's decision -making strategies (Thompson & Coovert, 2002), the team's perception of decision quality (Thompson & Coovert, 2003), the team's collective openness to experience (Colquitt, Hollenbeck, Ilgen, LePine, & Sheppard, 2002), the team's perception of process and technology (Roch & Ayman, 2005), the team's ability to provide accurate performance evaluations (Weisband & Atwater, 1999), the ability of leaders to form high quality linkages with their direct reports through different conditions of media richness (LMX; Kacmar, Witt, Zivnuska, & Gully, 2003), and the processes through which a team might enhance their ability to transfer knowledge between different types of media richness (Kirkman, Rosen, Tesluk, & Gibson, 2006). With these studies serving as a precedent, the present research chose not include a manipulation check of media richness.

Leadership. The present study did not perform a manipulation check for the main experiment. The rationale for this decision was due primarily to the ability of the manipulation checks to be clearly differentiated in the pilot study, negating the need for further demonstration of the effectiveness of each manipulation.

Test of Hypotheses

Hypotheses looking at teamwork quality, metacognition, psychological safety, and problem-solving performance were conducted using a 3 x 2 between subjects factorial MANOVA, with post-hoc univariate ANOVAs where necessary.

Analysis of Media Richness on Teamwork Quality. The first group of analyses tested how different levels of media richness would impact the teamwork quality. The 3 x 2 between subjects multivariate ANOVA revealed a significant omnibus difference between different media richness conditions on reported teamwork quality, F (2, 202) = 14.05, $p < .05$ (see Table 3). Hypothesis 1a purported that FTF teams would have better teamwork quality than video-mediated teams while solving a distributed problem-solving task. The group means presented in Table 4 show that this relationship was not supported, as there was no significant difference between FTF teams (M_{FTF} = 4.07) and video-mediated teams (M_{VMC} = 4.00) on their ratings of teamwork quality; MD = .07, $p = .59$ (see Table 5). Hypothesis 1b stated that FTF teams would have better teamwork quality than text-based chat teams while solving a distributed problem-solving task. The means presented in Table 4 demonstrate that this hypothesis was supported, as FTF teams (M_{FTF} = 4.07) reported that they had better teamwork quality ratings than did text-based chat teams (M_{TBC} = 3.74); MD = .33, $p < .05$ (see Table 5). Hypothesis 1c stated that VMC teams would report better ratings of teamwork quality than text-based chat teams while solving a distributed problem-solving task. Analysis of the means support this hypothesis (see Table 4), as VMC teams (M_{VMC} = 4.00) reported having better teamwork quality ratings than text-based chat teams (M_{TBC} = 3.74); MD = .26, $p < .05$ (see Table 5).

Analysis of Media Richness on Ratings of Team Metacognition. The second group of analyses tested how different levels of media richness impacted the ratings of team metacognition. Results mirrored the pattern of responses found for the ratings of teamwork quality. Specifically, the 3 x 2 between subjects multivariate ANOVA performed yielded a significant omnibus difference; F (2, 202) = 13.37, $p < .05$ (see Table 3). As it related to Hypothesis 2a, the means presented on Table 4 show that there were no differences found between FTF teams (M_{FTF} = 3.95) and video mediated teams (M_{VMC} = 4.02) on their ratings of team metacognition; MD = -.07, p = .47 (see Table 5). There were significant findings revealed for Hypothesis 2b, with FTF teams (M_{FTF} = 3.95) reporting more metacognition than text-based chat teams (M_{TBC} = 3.75); MD = .20, $p < .05$. Also, VMC teams (M_{VMC} = 4.02) had higher ratings of their team's level of metacognition than did text-based chat teams (M_{TBC} = 3.75); MD = .27, $p < .05$; supporting Hypothesis 2c.

Analysis of Media Richness on Team Psychological Safety. The third group of analyses tested how different levels of media richness impacted team psychological safety ratings. The multivariate ANOVA used to test these hypotheses revealed a significant omnibus difference between media richness conditions on the amount of psychological safety reported, F (2, 202) = 4.06, $p < .05$ (see Table 3). Hypothesis 3a stated that FTF teams would have higher levels of team psychological safety than VMC teams. This hypothesis was unsupported, as Table 4 shows that video-mediated teams (M_{VMC} = 4.33) had higher levels of team psychological safety than FTF teams (M_{FTF} = 4.10); MD = -.24, $p < .05$ (see Table 5). Hypothesis 3b asserted that FTF teams would have higher levels of team psychological safety than text-based chat teams. This hypothesis also went unsupported, as there was a non-significant difference between FTF (M_{FTF} = 4.10) and text-based teams (M_{TBC} = 4.21) on team psychological safety; MD = -.11, p = .36. Also, Hypothesis 3c was unsupported, as VMC teams (M_{VMC} = 4.33) were not found to have higher levels of team psychological safety than text-based chat teams (M_{TBC} = 4.21); MD = .12, p = .28.

The next analyses were performed to ascertain the relationship between team psychological safety, teamwork quality, and team metacognition. Specifically, Hypothesis 3d stated that across all conditions of media richness, teams with high levels of team psychological safety would have better teamwork quality than those teams with lower levels of team psychological safety. The correlation between TPS and teamwork quality was positive and significant ($r = .39$, $p < .01$), indicating support for Hypothesis 3d (see Table 2). Hypothesis 3e stated that across all conditions of media richness, teams with high levels of team psychological safety would have higher ratings of team metacognition than those teams with lower levels of team psychological safety. This was also supported, as the correlation between metacognition and teamwork quality was .32 ($p < .01$).

Analysis of Media Richness on Problem-Solving Performance. The fourth set of hypotheses examined the impact of media richness on team problem-solving performance. The 3 x 2 between subjects MANOVA revealed a significant omnibus difference between different media richness conditions and problem-solving performance, for both Task 1 and Task 2 scores. In the case of Task 1 (the first, video-based problem-solving task), the MANOVA yielded a significant finding, $F\ (2, 202) = 742.17$, $p < .05$ (see Table 3). Hypothesis 4a asserted that FTF teams ($M_{\text{FTF}} = 27.73$) would have better problem-solving performance than video-mediated teams ($M_{\text{VMC}} = 19.60$) on a distributed problem-solving task (see Table 4 for means). This finding was supported; MD = 8.12, $p < .05$ (see Table 5). Hypothesis 4b stated and found that FTF teams ($M_{\text{FTF}} = 27.73$) would have better problem-solving performance than text-based chat teams ($M_{\text{TBC}} = 18.14$) on a distributed problem-solving task; MD = 9.59, $p < .05$. Hypothesis 4c stated that VMC teams would have better problem-solving performance than text-based chat teams on a distributed problem-solving task. This finding was also supported, as Table 4 shows that VMC teams ($M_{\text{VMC}} = 19.60$) had better problem-solving performance than text-based chat teams ($M_{\text{TBC}} = 18.14$); MD = 1.47, $p < .05$.

Hypothesis 4d predicted that across all media richness conditions, predicted that teams with high levels of team psychological safety would have higher levels of problem solving performance than those with lower levels of team psychological safety. As shown in Table 2, the correlation between TPS and initial task performance was negative (-.15, $p < .05$), indicating the opposite of what was expected.

In the case of the Task 2 (the second, text-based problem-solving task), a pattern of findings similar to those revealed for Task 1. Specifically, the 3 x 2 between subjects MANOVA revealed a significant omnibus difference between different media richness conditions and the second problem-solving task, F (2, 202) = 532.14, $p < .05$ (see Table 3). Again, support was found for hypothesis 4a, as FTF teams (M_{FTF} = 24.56) had better problem-solving performance on the second task, as compared to video-mediated teams (M_{VMC} = 19.85; see Table 4 for means). This mean difference was significant; MD = 4.71, $p < .05$ (see Table 5). Again, hypothesis 4b stated that FTF teams (M_{FTF} = 24.56) would have better problem-solving performance on the second task, as compared to text-based chat teams (M_{TBC} = 17.16). This finding was again supported for the second text-based problem-solving task; MD = 7.40, $p < .05$. Hypothesis 4c stated that VMC teams would have better problem-solving performance on the second task, as compared to text-based chat teams. Again, this finding was also supported for the second text-based problem-solving task, as Table 4 shows that VMC teams (M_{VMC} = 19.85) had better performance on the second problem-solving task, as compared to text-based chat teams (M_{TBC} = 17.16); MD = 2.70, $p < .05$.

And similar to the findings for hypothesis 4d and the first video-based problem-solving task, it was found that across all conditions of media richness, teams with high levels of team psychological safety had higher levels of problem solving performance (on the second text-based problem-solving task) as compared to those teams with lower levels of team psychological safety. As shown in Table 2, the correlation between TPS and second, text-based problem-solving task was negative (-.14, $p < .05$), indicating the opposite of what was expected.

Analysis of Media Richness & Leadership Behaviors on Team Outcomes. The fifth set of hypotheses assessed the impact of centralized and decentralized leadership behaviors on teamwork quality, team metacognition, team psychological safety, and problem-solving performance using TBC. For the text-based chat condition, Hypothesis 5a stated that, teams using a centralized leadership approach would report having better teamwork quality than teams using a decentralized leadership approach. As shown in Table 2, the interaction between leadership and media richness was not significant; $F\ (2, 202) = 0.89$, $p = .41$ (see Table 3). Hypothesis 5b stated that teams using a centralized leadership approach would report having better team metacognition ratings than teams using a decentralized leadership approach. The 3 x 2 between-subjects multivariate ANOVA showed that there was not a significant interaction between leadership and media richness conditions; $F\ (2, 202) = 1.39$, $p = .25$ (see Table 2).

Hypothesis 5c stated that in text-based chat, teams using a centralized leadership approach would have better problem-solving performance than teams using a decentralized leadership approach. For the first, video-based problem-solving task, a significant interaction between leadership behavior and media richness conditions resulted; $F\ (2, 202) = 14.79$, $p < .05$ (see Table 3). Supportive of Hypothesis 5c, Figure 3 shows that text-based teams using centralized leadership had higher problem solving performance than text-based teams using decentralized leadership. A univariate ANOVA was also performed as a post-hoc test using only the data for text-based teams, which showed that centralized and decentralized leadership were indeed statistically different from each other; $F\ (1, 72) = 45.51$, $p < .05$ (see Table 6).

Examination of the cell means (see Table 7) showed that text-based teams using centralized leadership ($M_{\text{TBC-TRAD}}$ = 19.35) had better problem-solving performance, as compared to the scores for text-based teams using decentralized leadership ($M_{\text{TBC-MOD}}$ = 16.92).

For the second, text-based problem-solving task, similar to the results for Hypothesis 5c, Table 2 reveals a significant interaction between leadership behaviors and media richness for the second measure of problem-solving performance ; F (2, 202) = 36.88, p < .05. Again, Figure 4 shows that text-based teams using centralized leadership had higher performance on the second, text-based problem-solving performance task. A univariate ANOVA was also performed as a post-hoc test using only the data for text-based teams, which showed that centralized and decentralized leadership were indeed statistically different from each other; F (1, 72) = 29.83, p < .05 (see Table 6). Consistent with what was expected, examination of the cell means (see Table 7) showed that text-based teams using centralized leadership ($M_{\text{TBC-TRAD}}$ = 18.11) had better problem-solving performance, as compared to the scores for text-based teams using decentralized leadership ($M_{\text{TBC-MOD}}$ = 16.22).

Hypothesis 5d stated that for text-based chat teams, teams using a centralized leadership approach would have higher team psychological safety ratings than those teams using a decentralized leadership approach. Table 3 reveals that the interaction between media richness and leadership behaviors was significant, F (2, 202) = 3.45, p < .05 (see Table 2). However, the post-hoc univariate ANOVA was performed and showed that the difference between the team psychological safety ratings made by these teams was not statistically significant, demonstrating that hypothesis 6e was unsupported; F (1, 72) = .37, p = .54 (see Table 6).

The sixth set of hypotheses tested the impact of centralized and decentralized leadership behaviors on teamwork quality, team metacognition, team psychological safety, and problem-solving performance, in teams that communicate using VMC. Hypothesis 6a asserted that VMC teams using a centralized leadership approach would have better teamwork quality than VMC teams using a decentralized leadership approach. As shown in Table 3, the interaction between leadership and media richness was not significant for teamwork quality; F (2, 202) = 0.89, p = .41. Hypothesis 6b asserted that VMC teams using a centralized leadership approach would have better team metacognition ratings than VMC teams using a decentralized leadership approach. Parallel to the results for teamwork quality, a significant media richness by leadership behavior interaction did not result; F (2, 202) = 1.39, p = .25 (see Table 3).

Hypothesis 6c stated that for VMC teams, teams using a centralized leadership approach would have better problem-solving performance, as compared to those VMC teams using a decentralized leadership approach. For the first, video-based problem-solving task, a significant leadership behavior by media richness interaction resulted for problem solving performance; F (2, 202) = 14.79, p < .05 (see Table 3). Supportive of Hypothesis 6c, Figure 3 shows that video-based teams using centralized leadership had higher problem solving performance. The post-hoc univariate ANOVA using only the data for video-based teams also showed a significant interaction F (1, 66) = 104.59, p < .05 (see Table 8). Table 7 shows that VMC teams using a centralized leadership approach ($M_{\text{VMC-TRAD}}$ = 21.56) had better problem-solving performance than VMC teams using a decentralized leadership approach ($M_{\text{VMC-MOD}}$ = 17.65). These findings indicate that hypothesis 6c was supported.

For the second, text-based problem-solving task, similar to the results for Hypothesis 6c, Table 3 reveals a significant interaction between leadership behaviors and media richness for the second measure of problem-solving performance; F (2, 202) = 36.88, p < .05. Again, Figure 4 shows that video-based teams using centralized leadership had higher problem-solving performance on the second task. A univariate ANOVA was also performed as a post-hoc test using only the data for video-based teams, which showed that centralized and decentralized leadership were indeed statistically different from each other; F (1, 66) = 271.13, p < .05 (see Table 8). Consistent with what was expected, examination of the cell means (see Table 7) showed that video-based teams using centralized leadership ($M_{\text{TBC-TRAD}}$ = 22.03) had better problem-solving performance, as compared to the scores for video-based teams using decentralized leadership ($M_{\text{TBC-MOD}}$ = 17.68).

Hypothesis 6d stated that for video-mediated teams, teams using a centralized leadership approach would have higher team psychological safety ratings than those teams using a decentralized leadership approach. While the interaction between media richness and leadership behaviors was significant for psychological safety; F (2, 202) = 3.45, p < . 05; this hypothesis was unsupported, as the post-hoc test showed that there was no difference between the teams on their reported level of team psychological safety; F (1, 66) = 1.97, p = .17 (see Table 8).

The seventh, and final, set of hypotheses assessed the impact of centralized and decentralized leadership behaviors on teamwork quality, and problem-solving performance in FTF teams. Hypothesis 7a, which asserted that FTFFTF teams using a decentralized leadership approach would have better teamwork quality than FTF teams using a centralized leadership approach, was unsupported. The interaction between media richness and leadership behaviors was not significant, indicating lack of support; F (2, 202) = 0.89, p = .41 (see Table 3). Hypothesis 7b was also unsupported. This hypothesis specifically asserted that FTF teams using a decentralized leadership approach would have better team metacognition ratings than FTF teams using a centralized leadership approach. Again, the interaction between media richness and leadership behaviors was not significant; F (2, 202) = 1.39, p = .25 (see Table 3).

Hypothesis 7c stated that FTF teams using a decentralized leadership approach would have better problem-solving performance than FTF teams using a centralized leadership approach. For the first, video-based problem-solving task, the interaction between leadership behaviors and media richness was significant; F (2, 202) = 14.79, p < .05. However, as shown in Figure 3, centralized and decentralized leadership conditions had largely similar scores for problem solving performance. And contrary to what was expected, means were in the direction of centralized leadership ($M_{\text{FTF-TRAD}}$ = 28.21) having better problem-solving performance than decentralized leadership ($M_{\text{FTF-MOD}}$ = 27.24; see Table 7) for FTF teams, but differences were considerably small. The post-hoc univariate ANOVA performed determined that these means were statistically different; F (1, 64) = 6.30, p < .05, indicating that FTF teams using centralized leadership behaviors had better problem-solving performance than those using and decentralized leadership (see Table 9).

For the second, text-based problem-solving task, and similar to the results for Hypothesis 7c, Table 3 revealed a significant interaction between leadership behaviors and media richness for the second measure of problem-solving performance; F (2, 202) = 36.88, p < .05. After an examination of Figure 4, and the means present in Table 7, the present research found that means were not significantly different for centralized leadership ($M_{\text{FTF-TRAD}}$ = 24.76) and decentralized leadership ($M_{\text{FTF-MOD}}$ = 24.36; see Table 7) conditions on problem-solving performance for FTF teams; F (1, 64) = 1.26, p = .27. This finding means that there was no support found for Hypothesis 7c.

Hypothesis 7d stated that in the FTF context, teams using a decentralized leadership approach would have higher levels of team psychological safety, as compared to those FTF teams using centralized leadership. As shown in Table 3, the interaction between media richness and leadership behaviors was significant for psychological safety; F (2, 202) = 3.45, $p < .05$. The post-hoc univariate ANOVA performed determined that these means were statistically different; F (1, 64) = 3.09, $p < .05$. However, contrary to what was expected, Figure 5 reveals that FTF teams in the centralized leadership condition had higher psychological safety than the decentralized leadership condition. In the FTF context, teams using a centralized leadership approach ($M_{\text{FTF-TRAD}} = 4.24$) reported having higher levels of team psychological safety, as compared to those FTF teams using decentralized leadership ($M_{\text{FTF-MOD}} = 3.95$; see Table 7).

Discussion

The present study examined how teams with varying levels of media richness differ in terms of their teamwork quality, team metacognition, team psychological safety, and team problem-solving ability. The present research also compared and contrasted the influence of leadership on these team-based outcomes across different types of virtual teams. The results for the present study indicated that the theory of media richness was fully supported for problem solving, partially supported for teamwork quality and team metacognition, and mostly unsupported for team psychological safety. More specifically, and in accordance with Daft and Lengel's (1984, 1986) theory of media richness, FTF teams examined in the present study were found to have better problem-solving performance (for problems presented in both video-based format and as a short story), as compared to both VMC and TBC teams. VMC teams, in turn, had better problem-solving than TBC teams. This pattern was not replicated for teamwork quality and team metacognition, as there were no differences found between FTF teams and VMC teams for these variables. However, both FTF and VMC teams reported having a higher quality of teamwork and a higher metacognition, as compared to the TBC teams. FTF teams reported having better teamwork quality and higher levels of team metacognition than VMC and TBC teams. And finally, VMC teams were conversely found to have higher team psychological safety than FTF teams. None of the other hypotheses were supported.

The results from the present study support the earlier assertions that the quality of communications between TBC team members is degraded, compared to their VMC and FTF counterparts, in terms of their ability to share detailed information in an efficient manner. It may be that the slower, stilted, and impersonal nature of communication causes frustration to develop in TBC teams, leading to dissatisfaction with their quality of teamwork and decreased team level metacognitive knowledge. A low volume of communication between team members may lead to a decreased amount of information shared between team members and a general lack of coordination of effort in the JASPER problem-solving exercise. With fewer instances to communicate and interactions, it may be that ratings of teamwork and team metacognition suffer. However, the lack of significant differences in the ratings of teamwork quality and the team's shared understanding of one another's cognitions between VMC and FTF teams could likely be due to the speed of communication and increased information carrying capacity of the VMC condition examined in the present study. Overall, these results suggest that while teams with lower media richness may not solve problems as well as those with higher levels of media richness, there is a requisite level of media richness where video-based communication technologies can emulate enough features of co-located (FTF) communication that the interactions between team members in this medium are not noticeably discernable, or of a reduced quality, as compared to traditional in person communications (i.e., FTF teams).

Regarding the impact of leadership behaviors on team-based outcomes, although the results of the pilot study suggest that teams were able to accurately distinguish between the leadership manipulations used in the present study, the hypotheses tested in the main study were not able to yield significant differences between the leadership conditions on the quality of teamwork, the team's reported level of metacognition, or team psychological safety within any of the conditions of media richness tested. When one considers these lack of significant differences between the groups tested against the wealth of previous information pointing to the ability of leadership to impact a team's ratings of the quality of their exchanges (Cannon-Bowers & Salas, 1998; Casmir, 2001; Day, 2000; Fiore et al., 2002; Leana & Van Buren, 1999), there may be some facet of the current study's design may contributes to these null findings. For example, perhaps the intellective task used in the present study is not sufficiently detailed, or even ambiguous enough to require the type of interaction between team members necessary for the leadership behavior manipulation to have a strong effect on a team's method of interaction.

The JASPER series is an anchored instruction environment that can uses video to present complex situations which require users to formulate and sets of interconnected subproblems. The storylines presented help to create a meaningful performance context within which the user is able to more fully consider the ramifications of certain story details on elements of the problem and its solution. More specifically, the video format allows characters, actions, and settings to be depicted in a rich, vivid, and realistic manner that is hard to achieve in text-only presentations. Further adding to the richness of the task is the fact that the JASPER series uses multiple media to present information to the user, allowing for an increased depth of interaction. Users are presented with information through video narratives, audio narratives, and text presentation.

And while JASPER is designed to be complex, through the presentation of detailed information through both subtle and more overt methods, the problems in the JASPER series are essentially intermediate-level physics problems based on the formula "distance = rate x time." Once participants recognize the nature of the problem, and the details necessary to complete this formula have been identified, it is a simple matter to efficiently reach the optimal solution. This is not to suggest that the task is simple. Rather consideration of the problem structure, combined with the findings of the present research, suggest that the JASPER task may not allow users the ability to consider the problem at the appropriate level, debate the facts involved, or intuit new solutions to a situation with more unknown variables.

It may be that a more judgmental task is required for leadership behaviors to have an effect. Judgmental tasks involve evaluative, behavioral, and/or aesthetic judgments, to which there is not a clear right or wrong answer. Rather, these tasks ask users to identify and evaluate a series of solutions along a continuum of optimality. It should be noted that the JASPER series task was purposefully designed to allow both individuals and groups to develop answers with varying quality and effectiveness in their ability to meet the requirements of the problem presented (McNeese, 2000). Further investigation is warranted to confirm, or refute, whether changes in task type would influence ratings of teamwork quality and team metacognitive knowledge.

Contrary to the lack of significant findings for teamwork quality and team metacognition, the present study did find that media richness and leadership behaviors interacted to influence team problem-solving performance, although not always as hypothesized. Specifically, across all conditions of media richness tested in the present study, teams using centralized leadership were found to have better problem-solving performance than teams in the decentralized leadership behavior condition. Results from the present study indicate that certain features of TBC and VMC teams curtail the ability of these teams to effectively share personal experiences, problem relevant information and cognitive resources in an efficient manner, reducing the problem-solving performance ability of teams using decentralized leadership behaviors to facilitate their interactions.

While the results of the pilot study indicated that teams had no difficulty identifying or distinguishing between the two types of leadership behaviors used in the present research, the leadership manipulation seemed to be less effective in the main study. The inability of the leadership manipulation to produce the hypothesized effects may be due to an undocumented, intervening factor present within the study. One potential factor contributing to these findings may have been team tenure. Team tenure refers to the length of time that a team has been working together on a team with common, or interrelated, goals (Struman, 2003; Tyran & Gibson, 2008). As team tenure increases, the familiarity between team members increases. It may be that the ad-hoc teams studied in the present study may require a longer team tenure durations in order for their subjective ratings of the quality of their team performance (e.g., teamwork quality, team metacognition, and team psychological safety) can be positively impacted by leadership behaviors. Teams with more prior experience working with one another would, understandably, spend less time becoming familiar with their team members, their personalities, their mannerisms, and their levels of expertise, as this would already be well-established. As such, it may be that they would have an engrained understanding of how to interact with each other according to the behaviors set forth by the leadership manipulations, leading to the significant differences that were hypothesized.

The present research also provided further support for the notion that reduced team tenure may be the cause of these findings, particularly as they relate to the teams' problem-solving performance scores. The present study hypothesized that FTF teams using decentralized leadership behaviors would have better problem-solving performance because those teams possess the ability to share information more quickly, and at a higher level, than teams using centralized leadership. It may be that even that even though centralized leadership teams rated the quality of their work processes and interactions similarly to decentralized leadership teams, the directive nature of centralized leadership allowed these teams to work more effectively towards their performance goals, in a time pressured situation. Perhaps with increased team tenure, these decentralized leadership teams would be able to interact more effectively, and produce a better quality of work, as compared to those centralized leadership teams.

While contrary to what was hypothesized for decentralized leadership, these findings are consistent with previous leadership research indicating the ability of centralized leadership behaviors to enhance the performance of individuals, groups and teams in a variety of different contexts (Bass, 1990; Casmir, 2001; Podsakoff et al., 1990; Yukl, 1998). Specifically, the present research had originally hypothesized that the directive authority and structuring ability of centralized leadership may have restricted FTF teams, preventing them from taking full advantage of the richness of their environment and reaching their optimal potential. This was not found to be the case. One potential explanation would be that the increased communication cues present in FTF teams, combined with the increased information sharing associated with decentralized leadership behaviors, led to slightly longer and more protracted problem-solving sessions (and slightly decreased performance scores as a result). It could also be that the ad-hoc nature of the teams used in the present study worked against the ability of decentralized leadership to positively influence the problem-solving ability of the FTF teams in the present study. Given that these teams were formed in the laboratory, and not given time to “naturally” acclimate to one another, it may be that they used some of their task time to become familiar with one another, leading to less time applied toward problem-solving, thus leading to lower performance scores. Rather than centralized leadership behaviors being overly restrictive of the problem-solving processes of FTF teams, it may be that centralized leadership behaviors work well in ad-hoc teams, regardless of the communication medium, because the directive nature of these behaviors allows teams to quickly identify their goals, take the steps necessary to reach them, and begin deliberations more efficiently with less distraction or confusions. Future research is necessary to clearly identify the underlying reason for this relationship.

While the present research did not find support to suggest that theory of media richness applies to team psychological safety, this research did find that teams that report having high ratings of team psychological safety were also more likely to have higher ratings for teamwork quality and team metacognition. This relationship was not replicated for the dependent variables of team problem-solving performance. It may be that in teams with increased psychological safety can also develop a better sense of the tolerances and limits of their teammates. Or perhaps having this knowledge of their tolerances would, in turn, influence the members of these teams to be more prone to risk-taking, as they may believe that risk-taking behavior may be well-received, that they will be taking a chance in an area that their teammates have strong tolerances for such actions. In either case, these results suggest that the team's ratings of their openness to risk is, in turn, related to that team's rating of their quality of teamwork.

As it relates to those teams found to have higher ratings of their team metacognition, these findings make some intuitive sense. Specifically, it may be that those teams who reported a high amount of metacognition would also have a good understanding of the information that their team members know and do not know. This may lead teams to develop higher tolerance and openness to risk-taking behaviors is more common in teams with higher amounts of metacognition because of the level of insight team members in teams with high metacognitive ratings have about their team as a whole. Earlier, team metacognition was defined as the extent to which individuals in a team have an awareness of their team members' cognitions, knowledge and competencies. In those instances where teams have an increased understanding of their team members' knowledge and competencies, an increase in the acceptance of risk taking behaviors could be explained as a matter of perspective. It may be that for these teams, the increased understanding of their teammates' competencies provides them insight into their teammates' intentions, potentially mitigating some of the threat or offense that could be associated with risk taking behaviors; leading to a team that may be more accepting of taking calculated risks, or risks where the focus of the chance being taken matches the teams present needs.

As was previously alluded to, each of the hypotheses made by the present research examining the influence of media richness, and the potential interaction between media richness and leadership behaviors, on a the level of psychological safety reported by teams went unsupported. Specifically, this research found that VMC teams reported more team psychological safety than FTF teams. This result leads the present research to theorize that media richness influences team ratings of psychological safety in a way completely different from the previously hypothesized 'parallel' relationship. It may be that the increased amount of media richness associated with FTF communication has an added, negative impact on the amount of interpersonal risk-taking that FTF teams feel is safe. Perhaps it is that the increased amount of communication cues available to FTF teams, in addition to allowing the highest amount of synchronization between team members (Baltes et al., 2002), has the added overwhelming and deleterious effect of increasing the amount of information that team members must attend to and process before they form assertions about how open to increased risk-taking behaviors their group may be. It may also be that because they learn more information about their team members, it is more difficult for persons in FTF teams to make accurate assertions about how open they would be to risk-taking in the team, due to conflicting information about their teammates, or simply due to the quantity of information they are faced with. In either example, the presence of larger amounts of information in these teams could lead to FTF team members becoming more risk averse, and rating their team's level of psychological safety lower.

As has been suggested throughout this research, VMC teams may lack the ability to project many of the same communication cues, as compared to FTF teams.. However, the above results lead the present research to posit that perhaps by interacting in a domain with fewer communication cues, VMC teams may be better able to more quickly form opinions and judgments about their team members. Theoretically, VMC teams may be able to do this because fewer communication cues would be available to their team members during their interactions, allowing them to be less encumbered by additional information and able to more quickly reach an assessment. The present research goes on to note that while less communication cues may make it more expedient for VMC teams to form assessments about the level of risk-taking their teams might except, these ratings may also have a greater likelihood of being more inaccurate. Specifically, as VMC teams have fewer communication cues to work with, it may be that the information that they receive is incomplete, misleading, or potentially distorted, leading teams to make incorrect assumptions about the level of comfort that they should have associated with the notion of risk-taking behaviors in their teams.

And in the case of TBC teams, the decreased communication cues associated with this medium act in manner converse with that previously observed in VMC teams. Whereas VMC teams may have felt they received the requisite amount of information to form assertions about their team members to assess their team's psychological safety rating as being high, TBC teams have very little information from which to determine the affability toward risk-taking present in their team members. As such, they provide lower team psychological safety ratings, suggesting that media richness may have an "inverted U-shaped" effect similar to that identified by Yerkes and Dodson (1908) on the amount of psychological safety reported by teams. It may be that in order to facilitate the development of swift collaboration and coordination in teams, virtual teams would be best served initiating their interactions at an optimal or introductory level of media richness, as a way of expediting their teamwork.

Contrary to the hypothesized relationship, the present research also found that teams with lower amounts of team psychological safety had better problem-solving performance, as compared to teams with high amounts of team psychological safety. The present research posits that this may be due to a second order effect of psychological safety. Specifically, those teams with higher levels of team psychological safety are more willing to make comments that go against the group's norm, or the popular opinions being discussed, as these teams feel very comfortable in expressing themselves openly. This could have the added function of making these teams more talkative, as compared to teams with lower levels of psychological safety. This climate of open expression could lead to increased deliberations and the discussion of information that may only be tangentially related to the topic at hand, leading to the deleterious effect of longer, more protracted problem-solving sessions, resulting in lower problem-solving. Related to this point, it may also be that as teams with high levels of team psychological safety spend more time discussing extraneous information, these teams attend to less of the critical information presented in the problem and have more poor problem-solving performance.

The present research found that FTF teams using centralized leadership reported having more team psychological safety than FTF teams using decentralized leadership. This finding was contrary to the original hypothesis that decentralized leadership would allow teams to more quickly acclimatize to each other, and form higher levels of team psychological safety. However, these results suggest that the structuring ability of centralized leadership behaviors helped teams overcome, or manage, the high volume of communication cues and information projected between FTF team members. In contrast, the “flat” and unstructured nature of the decentralized leadership in the FTF communication environment would project a very high volume of information between team members, providing very little direction for how to sort or parse through this data. It may be that the more rigid characteristics of centralized leadership could apply some necessary structure onto ad-hoc FTF teams, leading to a more controlled, comfortable pace of information sharing and task coordination. It may also be that this more efficient information sharing leads to the formation of a higher level of subsequent team psychological safety. Future research is required to accurately explain the nuances of this relationship.

Study Strengths, Limitations, and Directions for Future Research

The present research has several strengths which enhance its utility and explanatory ability within the domain of empirical research. Specifically, by building upon the lessons learned by previous research, the present study was able to operationalize and manipulate three types of media richness, and accurately represent the continuum perspective of virtuality in an experimental study. By pursuing this line of research, the present study is able to make statements about the utility of the theory of media richness, while also forecasting the outcomes for teams operating in these communication environments. Also, the present study manipulates two types of leadership behaviors, and extends research in the virtual teams literature through the examination of the impact of virtual teams interaction and team-based social emergent states. These findings extend the research on virtual teams, and provide information to the literature that can be used to shape the development of future technologies and organizational development, helping interested entities to avoid the potential negative outcomes discussed earlier. Further enhancing the utility of the results of this research is the fact that these data are bolstered by the large team sample size. Specifically, the present research examines experimental six conditions with over 30 teams per cell. By testing these hypotheses on such a large population, the present research was better able to ensure the veracity of this study's findings were due to variability from the constructs being studied, and not necessarily from issues contained within the population itself.

In contrast, the present research has several limitations which serve to temper the generalizability of these findings. First, and principally, the present study is a laboratory examination of 'real-world' phenomena and conditions. Although the media richness conditions were designed to closely approximate the media richness criteria for each type of team, the issue remains that the tasks and underlying motivations for individuals taking part in the study are artificial. In keeping with a theme discussed earlier, an ideal testing environment may be in the U.S. Army Future Combat Systems environment. Although the organizational culture and mission of the Army would have definite effects on the generalizability of any information collected, both of these factors would serve to add a requisite level of realism to task being conducted. Future research should focus on the study of virtual teams and the concept of virtuality, through the field-based observation of both novel and established 'real-world' teams.

Related to a previous point, the present study used an artificial and complex leadership manipulation to enact decentralized leadership. The manipulation used for centralized leadership is both straightforward and directive in its approach. However, the decentralized leadership manipulation was significantly more complex and involved the dynamic interplay between multiple factors. In addition, the decentralized leadership manipulation was, in many respects, similar to a team training manipulation. Therefore, the decentralized leadership manipulation may have been more about training than leadership in the way that it was enacted. The potential “missed focus” of this manipulation could have influenced the findings generated by the present study. It could also be that the decentralized leadership manipulation, combined with the ad-hoc and unfamiliar team structure, made the present research environment unsuitable test of decentralized leadership. To address this shortcoming, future research should move toward training intact teams to enact these leadership behaviors. Studying intact teams allows for the potential of longitudinal study of team performance across a variety of task types.

There are several other potential limitations that further hamper generalizability of the findings generated in the present research. Specifically, the present research lacked a manipulation check for leadership in actual study. An examination of the results begs the question of how similar team members perceived the VMC and FTF conditions of media richness. More specifically, what elements of each media richness condition, from the perspective of the teams involved, had the greatest influence on their ability to share information, form solutions, and interact with their teammates? The present study was not able to address these issues because no media richness manipulation check was performed in the present study. While the present work was following the example set forth by other research examining similar constructs, the lack of an explicit manipulation check for an independent variable degrades the ability of this research to generalize its findings with confidence that the manipulations functioned as intended. Future research, whether lab-based or field-based, should include a manipulation check to avoid this problem.

Next, the present study did not counterbalance the problem-solving tasks. In all cases, teams were presented with the video-based task first, which was subsequently followed by the second, text-based problem-solving task. The consistent presentation of the tasks in a fixed order prevented the present research from determining whether any of the findings resulting from this study are due to issues associated with the videos themselves, or the way in which teams react to the videos. In addition to counterbalancing the tasks, future research should examine the potential influence of the presentation media of the task on virtual team performance. While the type of task that the teams are asked to complete may influence the outcomes of the study, it may also be the case that the methods used to present these tasks would have an effect on the team's ability to perform. Future research investigating the relationship between the communication medium used by virtual teams, and the medium used to present team task, would be a useful extension to this field of study.

Another study weakness was that the length of the manipulations used in the present study was not the same duration. Specifically, the centralized leadership manipulation was approximately eight minutes in length, while the decentralized leadership manipulation was nearly ten minutes long. In order to hold all factors constant within the experimental examination, the two manipulations should have been the same length. The general problem structure for scenarios within the JASPER research paradigm would suggest that the more time spent attempting to develop a solution leads to superior responses as indicated by Crews et al. (1997). Given the discrepancy in the length of the manipulations, and the results of the study, it is conceivable that teams using centralized leadership were able to spend slightly more time developing a higher quality answer as compared to decentralized leadership teams. Nevertheless, future research studies should record and compare data on the amount of time that teams take to generate solutions, as having these data would allow for the examination of temporal influences on problem-solving performance.

As was previously noted, an intellective task is a task with a demonstrably correct solution (e.g., mathematics problems). As the present study used an intellective task, it was possible for one member of the teams tested to have figured out the solution to the problem on their own, with minimal or even no contributions from their teammates. Given the lack of interdependence required, it may be that this task paradigm is somewhat biased negatively against the decentralized leadership condition, which emphasized teamwork and the importance of working closely together. To the extent that the task did not require high interdependence, it may be that members may not have perceived the information presented in the decentralized leadership manipulation to be relevant or necessary to complete the task. A theoretical piece by Pearce (2004), which reviewed the conditions for which decentralized leadership behaviors should employed, provides support for these assertion. Specifically, Pearce (2004) identified three specific characteristics of knowledge work directly related to the need for decentralized leadership: *interdependence*, *creativity*, and *complexity*. Pearce stated that the more interdependent task is, the greater the need for decentralized leadership. Conversely, in situations where task work is largely independent, the need for shared leadership is minimal. In light of this, the JASPER task may not been interdependent enough to allow the benefits of decentralized leadership to manifest. The present study recommends that future research use a sufficiently engaging task, designed to require a moderate to high level of team member interaction, to achieve an appropriate problem solution.

Continuing in the identification of limitations, the present study also did not include a specific measure of leadership in the teams being examined. Had such a measure been included, the present research would have been able to identify the existence of emergent leadership behaviors in the group. Including a few survey items asking team members if their team members displayed leadership behaviors, or acted like the team's leader, would have added a further layer of explanatory ability for this research's findings.

Another general study limitation is common method variance. Common method variance refers to the variance that can be attributed to the method of measurement in a particular experiment, rather than variance that would be due to the construct of interest (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). These method variances can be a wide variety of things, including the content of specific items, scale type, response format, and the general context used to form the survey items. The present study had participants fill out all of the surveys are the same time, and as a part of the same questionnaire. Future research should limit the number of constructs that they will collect data on, in addition to alternating the methods that they use to collect these data. Using the present study as an example, it may be that a future replication of this study would have the teams fill out the team metacognition survey, but teamwork quality would measured through direct observation by a trained experimenter, or through other non-survey based methods.

Also, the results of the present study lead to this research to suggest that future studies be conducted to identify the particular elements associated with VMC teams that allow individuals working in these types of teams to rate their teamwork experiences analogous to those of FTF teams; even as their true performance is reduced by comparison. It may be that dealing with problems that require a different type of interaction between distributed personnel could adversely impact VMC teams. Concurrently, it may be that using distributed teams to work on longer termed tasks may lead to very different ratings of teamwork quality, as the features of the communication medium bear out over a longer period of time, which would obviously have many implications for the use of this communications medium.

With respect to the inclusion of leadership behaviors into virtual teamwork, future research should identify the circumstances under which decentralized leadership behaviors can positively influence team-based outcomes. The results from the present research all indicated that decentralized leadership behaviors were ineffective in producing significant differences, over and above those of centralized leadership behaviors, in the team level dependent variables measured. Future research should focus on studying whether this inability to positively influence team level dependent variables extends to other types of problems. It may be that decentralized leadership behaviors require more time for team members to cognate, interact, and generate responses. It may also be the fact that decentralized leadership behaviors have their maximum effectiveness with established teams interacting over long durations, performing multiple tasks and multiple task types, producing multiple products. Future research will be necessary to de-conflict the findings from the present study with the theorized benefits associated with decentralized leadership behaviors.

Some final recommendations for future research have to do with the study of team psychological safety in virtual teams. Specifically, there was no support for the theory that as media richness improves ratings of team psychological safety will also increase. However, results from the present study indicate that VMC teams reported having more team psychological safety as compared to FTF teams. This finding needs to be replicated, as well as studied to determine whether this finding is only germane to ad-hoc teams and intellective tasks, or if they are more generalizable to all types of teams and tasks. Future research should also identify whether there is a longitudinal component to team psychological safety ratings, studying whether or not these fluctuate over time and whether this fluctuation changes at different rates depending upon the level of media richness used to facilitation the session of distributed communication.

Implications for Future Technology Design and Virtual Team Facilitation

The findings of the present study have implications for the design of future communications technologies, in addition to the usage of leadership behaviors in virtual teams. With respect to the design and implementation of future communications technology, the present research suggests that designers focus on identifying and developing communication systems that allow virtual teams to share more types of information, as well as share that information more quickly. Though VMC teams are shown to rate their teamwork quality and levels of metacognition at levels equal to FTF teams, the fact remains that VMC teams still do not perform at the level of their FTF counterparts. Enhancing the intuitive "look and feel" of video-based communication technologies to more closely emulate natural in person interactions, while also adding some of the digital information sharing components associated with both VMC and TBC teams may lead to the creation of an optimal medium for distributed communication.

An example of a digital information sharing component would include the capability of users to live record their communication sessions, and rewind during the session to capture thoughts and avoid process loss. Also, post-conversation text extraction would be very useful for offline decision-making, and significantly enhance the ability of distributed team members to focus on their conversation, rather than note taking. Having the ability to save and send out full, or even amended, video presentations of distributed conversations would be an excellent way of preserving an organization's transactive memory. It should be noted that video conversational recording, though seemingly very intuitive, would require a large amount of processing power and data storage capability. At the present state of technological advancement, the use of this sort of capability would be extremely limited and cumbersome. Future infrastructure development would be necessary to allow this sort of feature to be more widespread amongst potential users, and convenient for organizations to store these conversations easily.

As it relates the usage of leadership behaviors to facilitate virtual team interaction, though the results indicated no effect on a team's ratings of teamwork quality, the findings from the present study suggest that given the current state of distributed communication media, problem-solving performance of ad-hoc virtual teams can be enhanced through the use of centralized leadership behaviors to guide team interaction. The present results also indicate that decentralized leadership behaviors may not be the optimal choice to expedite team-based emergent states in intellective types of problems.

Closing thoughts

As the world moves forward further increasing the amount of de-centralization and globalization of work processes, many organizations have incorporated the development and full-time use virtual teamwork into their workforce. The overarching goal of this research to inform the future use of virtual teams, in both empirical and applied settings, with specifications for the optimal usage for virtual teams, as well as their strengths and limitations in problem-solving. The results produced here should also be able to inform the design of future communications technologies, increasing their information storage and transmission capabilities, while also modifying the input mechanisms of these technologies to make them more intuitive. With these adjustments, future iterations of the communication technologies used in virtual teams should be better able to mimic the features of FTF discussions. This would allow for seamless transitions between distributed and real-world conversations, maximizing the ability of individuals to share relevant information and resources with the necessary parties, irrespective of the distances involved.

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APPENDIX A: Explanation of the Problem Structure of the JASPER Woodbury Adventure Series Task

Anchored Instruction

The Cognition and Technology Group at Vanderbilt (CTGV) was an interdisciplinary team of researchers at the Learning Technology Center, Peabody College for Education at Vanderbilt University. Members of CTGV developed and tested a variety of technology-based programs that are consistent with constructivist theories (e.g., von Glasersfeld, 1987; Bransford, Goldman, & Vye, 1991; Resnick & Klopfer, 1989; Scardamalia & Bereiter, 1991; Spiro et al., 1991) and generative learning in meaningful contexts (CTGV, 1990; 1991; 1992a; 1992b; 1992c). The essence of this approach was to “anchor" or situate instruction in the context of meaningful problem solving environments. These anchoring environments are referred to as *macrocontexts* as they involve complex situations that require students to formulate and solve a set of interconnected subproblems (Bransford, Sherwood, & Hasselbring, 1988).

The CTGV has experimented with anchored instruction programs in a variety of areas including mathematics (e.g., CTGV, 1991b, 1992, 1993), science (e.g., CTGV, 1993; Goldman, 1996; CTGV, 1991), and literacy (e.g., Bransford, Schwartz, Barron, Vye, & CTGV, 1996; CTGV, 1991). These anchoring environments were designed to invite the kinds of thinking and reasoning necessary for students to develop (i) the general skills and attitudes necessary for effective problem solving, and (ii) the specific concepts and principles that allow them to think effectively about particular domains. The focus had been on promoting thinking and reasoning in problem-solving situations because there is considerable research and anecdotal evidence to suggest that student of that day were not particularly strong in these areas (e.g., Bransford et al., 1991; Nickerson, 1988; Resnick, 1987).

CTGV developed a series of macrocontexts with corresponding classroom material for the purpose of supporting anchored instruction learning activities (CTGV, 1997). These macrocontexts (presented as scenarios or short stories) were designed to incorporate seven important cognitive learning and instructional design principles and presented to students through use of the Adventures of Jasper Woodbury series.

Design Principles

There are seven primary principles that the CTGV followed in the creation of an anchored learning approach to instruction. They were a *generative learning format*, *video-based presentation format*, *narrative format*, *problem complexity*, *embedded data design*, *opportunities for transfer*, and *links across the curriculum*. In the case of the generative learning format, the macrocontext storyline creates a meaningful context for problem solving. The end of the story, however, is generated by the student through the resolution of the challenge. Having students generate the story's ending provides motivation: students like to determine for themselves the story's outcome. An additional advantage of the generative format is that students must become active learners when generating and solving the subproblems required by the challenge. Research findings suggest that there are important benefits to having students generate information (e.g., Soraci, Franks, Bransford, Chechile, Belli, Carr, & Carlin, 1994).

The video-based presentation format allows students to comprehend complex and interconnected problems much better than if the information were presented in a text form. This is especially true for students who have difficulty with reading. The video format allows characters, actions, and settings to be depicted in a rich, vivid, and realistic manner that is hard to achieve in text-only presentations. A second advantage of the video-based format is that it provides the ability to weave in related background information which might motivate the study of other problems in mathematics and other domains.

Third, the video narrative (narrative format) is designed to contain setting information, a slate of characters, an initiating event, and consequent events. The challenge at the end of the video follows naturally, creating for students the impression that they are solving a realistic problem rather than responding to a lecture on video. Furthermore, the more vivid and graphic depiction of events creates for students a more authentic use of mathematical concepts (e.g., Brown, Collins, & Duguid, 1989).

Next, the challenge presented to students is a complex problem with many interrelated steps (problem complexity). The complexity is intentional and based on a very simple premise: students cannot be expected to learn to deal with complexity in the real-world unless they are trained to do so. Unfortunately, traditional classroom activities do not routinely provide students with the opportunity to engage in the kind of sustained mathematical thinking necessary to solve complex problems. The video presentation of the challenge does not hide the complexity of the task, but at the same time makes is look interesting and solvable.

Embedded data design is an important design feature of the mathematics macrocontexts for several reasons. All the data necessary to solve the challenge are seamlessly embedded in the video story along with a great deal of extraneous information. Unlike typical word problems, the video does not explicitly identify the mathematical problems that need to be solved to complete the challenge. The result is that students must first identify and understand the problem, determine what information is relevant, remember where this information was presented, and then extract that information from the story. In other content areas, the macrocontext introduces students to additional resources they can use to gather necessary data (Goldman, 1996; Sherwood, Petrosino, Lin, Lamon, & CTGV, 1995).

As it relates to opportunities for transfer, cognitive science literature on learning and transfer suggests that concepts acquired in only one context tend to be welded to that context and hence are not likely to be spontaneously accessed and used in new settings (Bransford, Sherwood, & Hasselbring, 1988). The adventures in the Jasper series are designed so that there are at least three episodes for each problem type: trip planning, statistics and business planning, algebra and geometry. This provides students with the opportunity to use and reuse mathematical concepts in a variety of contexts, thus considerably increasing the likelihood of skill transfer to new situations and reducing the likelihood of inert learning. There are also a set of analog problems associated with each adventure, which help reinforce and extend mathematical concepts that students use in the original adventure.

And finally, links across the curriculum. Each video story contains all the data necessary to solve the challenge. In addition, the story also provides many opportunities to introduce topics from other subject matters. For example, in the trip planning episodes, maps are used to help figure out the solutions. These provide a natural link to geography, navigation, and famous events in which trip planning was an important component, such as Charles Lindbergh's solo flight across the Atlantic.

These seven design principles mutually influence one another and operate as a gestalt rather than as a set of independent features. For example, the use of video brings the world into the classroom in a manner that motivates students. I t makes complex mathematical problem solving accessible to students who have difficulties comprehending complex situations from text material. The narrative format, the generative design of the stories, the complexity of the challenge, and the fact that the adventures include embedded data present learning opportunities on subgoal generation, finding relevant information, and engaging in logical decision making tasks while keeping the complexity of the task manageable. The narrative format also makes it easier to embed information and allude to related problems that provide opportunities for links across the curriculum.

The Macrocontext: Rescue at Boone's Meadow

Rescue at Boone's Meadow is one of 12 video-based anchors in the Jasper series designed to teach mathematical problem finding and problem solving in traditional classroom environments for students in grades five and higher (CTGV, 1992a; CTGV, 1997). The 12 adventures are organized in triples and cover complex trip planning, statistics and business plans, geometry, and algebra. Each of these adventures provides a very rich environment that creates multiple opportunities for problem solving, reasoning, communication, and making connections to other areas such as science, social studies, literature, and history (CTGV, 1997). Rescue at Boone's Meadow is one of three adventures that deal with complex trip planning.

The adventure's storyline begins with one of the primary characters, Larry Peterson, flying his ultralight into Cumberland City. Larry is teaching his friend Emily Johnson how to fly. During Emily's lessons, she (and the viewers) learns much about the ultralight, including information on payload, fuel capacity, fuel consumption, speed, landing requirements, and how the shape of the wing produces lift. To celebrate Emily's first solo flight, Larry and Emily join Jasper Woodbury for dinner at a local restaurant. During dinner, Jasper reveals that he will soon be taking his annual fishing trip. He plans to drive to Hilda's gas station, park his car there, and then hike 15 miles to his favorite fishing spot in the woods, a remote location known as Boone's Meadow.

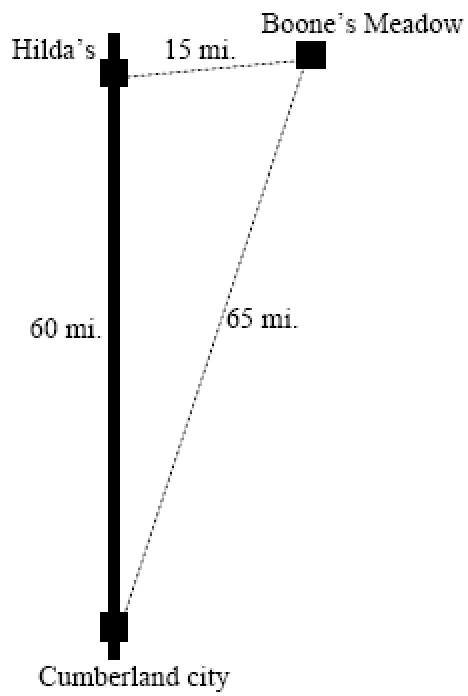

Figure A: Rescue at Boone's Meadow Map

While camping in the Meadow, Jasper finds a bald eagle that has been wounded by a gunshot. He radios for help. Emily consults the local veterinarian, Doc Ramirez, who warns that time is the critical factor in saving the eagle. Emily consults a map on the wall that reveals there are no direct roads leading to Boone's Meadow from either Cumberland City or Hilda's. She also learns the distances from the City to Hilda's gas station and Boone's Meadow are 60 and 65 miles, respectively (see Figure A). The video narration ends with the challenge: “What is the fastest way to rescue the eagle, and how long will it take?" At this point, students shift from passive viewing to active problem solving.

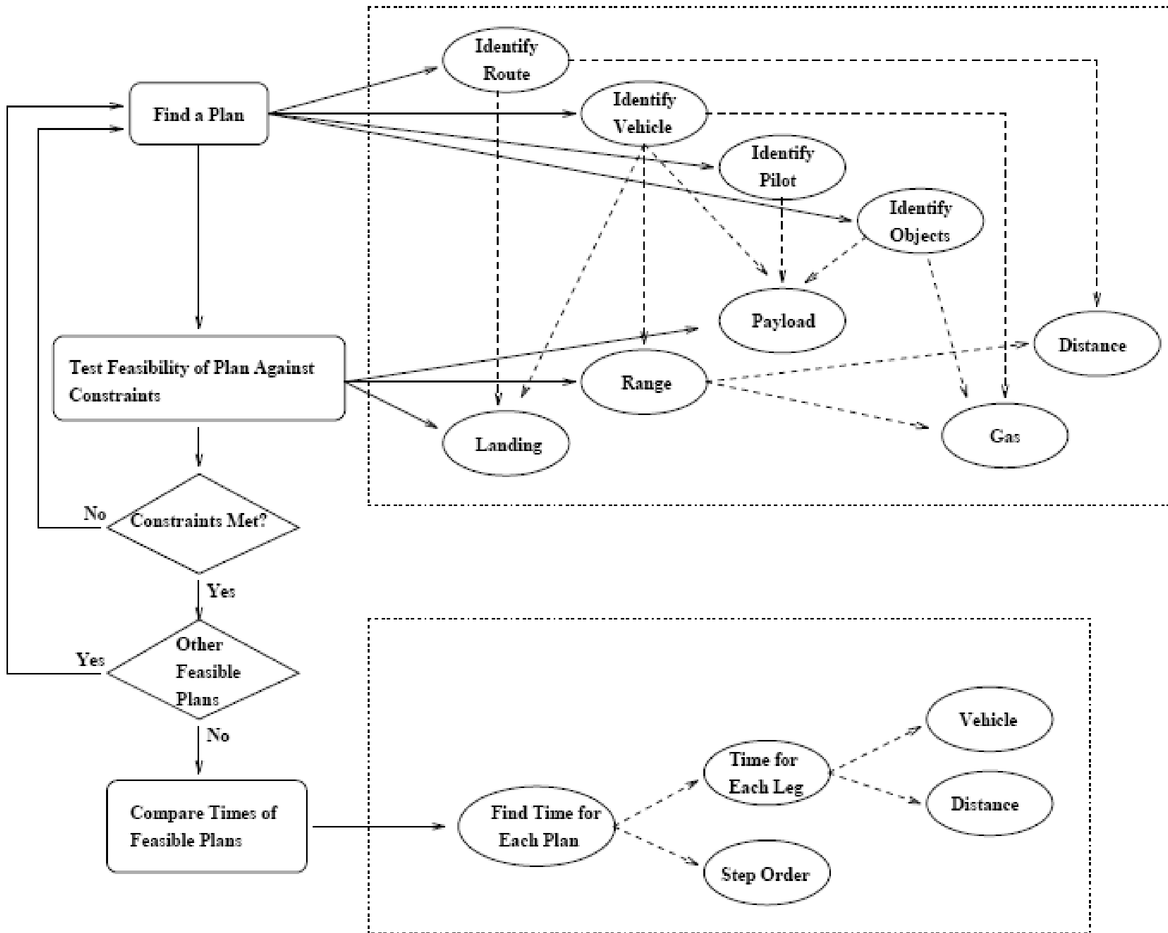

Figure B: RBM Planning Net (adapted from Goldman et al., 1991)

The RBM challenge of rescuing the eagle appears simple, but in fact requires a variety of problem solving skills. To find the quickest way to rescue the eagle, one must generate multiple rescue plans, validate them against the constraints of the domain, and determine how long each plan would take to implement (see Figure B). There are a large number of distinct rescue plans that the student may consider since there are three different people who can assist in rescuing the eagle (Emily, Larry, and Jasper), three methods of travel (Emily's truck, Larry's ultralight, and walking), and multiple possible route combinations.

Each plan proposed by students must be evaluated with respect to the appropriate constraints. For example, if the ultralight is used for the rescue, several constraints, such as payload, landing requirements, and range of the ultralight, will determine the feasibility of each leg of a given route. An additional complication is that payload and range are interrelated constraints. The range of the ultralight will depend upon the amount of available gas, and the weight of the gas must be considered when calculating payload. Once the students have assessed the plan as feasible, the total time required to complete the plan must be determined. The student will then select the plan that satisfies the challenge of rescuing the eagle in the shortest possible time. The optimal solution requires that:

- both Emily and Larry be involved,
- both the truck and the ultralight be used, and
- the rescue route include a stop at Hilda's gas station.

Furthermore, to satisfy payload constraints, the optimal solution requires that Emily pilot the ultralight while Larry drives the truck. Computations also determine that additional gas must be taken on the ultralight to enable it to y two consecutive legs from Cumberland City to Boone's Meadow, and then from Boone's Meadow to Hilda's.

It is clear from the above discussion that the RBM challenge is quite complex. In protocol studies conducted in the fifth and sixth grades in middle school (CTGV, 1997; Goldman, et al., 1991), students often came up with a solution in a relatively short amount of time. Unfortunately, most student solutions are non-optimal and incomplete. Such data indicate students may benefit from appropriate technology-based learning tools that promote learning and reflection by providing appropriate feedback during the problem solving process.

APPENDIX B: Confederate Leader Scripts for the Centralized Leadership Manipulation

[Text-Based Chat]

"Hello, my name is <u>Joaquin</u>, another student involved in today's experiment. I have been assigned to be your team's leader and I have recorded this message to guide you through today's experiment. The message you are watching contains instructions on what you need to do to successfully complete today's experiment. It also has strategies you can follow to effectively work together, and some advice on how you should proceed. So, let's get started. In today's experiment, you will be asked to work as a team to develop answers to questions presented in two separate tasks. In the first task, your team will answer a series of questions after viewing a problem presented to you in the form of a short, 15 minutes video. The questions that you will need to answer are presented for you at the top of the interface that you will be working from, while the video is presented in quicktime format."

<u>"You will get your audio from the headphones provided to you, and you will communicate with your group members using a chatroom, similar to AOL or MSN Instant Messenger. There is no talking during the experiment.</u> You start the video by pressing the 'triangle play' button. There are several things to remember about the chatroom as you chat with your teammates. First, you will notice that as you chat, your chat screen will fill with the text of your previous messages. Once the screen is full, the text from older messages scrolls off the screen. In order to view messages that have scrolled off the screen, you first have to press the pause button at the bottom of the screen and then use the scroll bar on the right side of the screen to view previous text. After you finishing viewing the older text, you may either press unpause or simply type and send another message to re-enter the chat interface.

There is also a keyword search feature that you may use to re-watch scenes from the video that you may have missed, or that you need to see again. For example, say you that you want to search for the word 'car'. All you would need to do is type 'car' into the search term box and press enter. The search function will then give you a list of links that will allow you to go directly to each scene in the video where that word is said. To watch a scene, just click one of the desired links. The questions you will need to answer are presented for you at the top of the page. You will have 55 minutes to complete this part of today's experiment, and after 45 minutes have passed you will be given a ten minute warning to wrap up and submit your answers." I suggest that you work quickly, as 55 minutes is not as much time as it seems.

"In the second task of today's experiment, you will again be asked to work as a team to solve a problem; this one presented in the form of a short story. To begin this task, you are to read the story together and then answer several questions about that story. The questions that you will need to answer are presented for you at the top of the page.

Again, you will be given 55 minutes to complete this part of the experiment, and after 45 minutes you will be given a 10 minute warning to wrap up and submit your answers. ”

Remember to work as a team and be sure to share all of the information that you find relevant to solving each question posed. Keep in mind that it is important to communicate with your team members. You must work as a team to produce the best answers. Remember that your teammates won't know what you are thinking if you keep it to yourself. Another strategy for working through these questions could be for you, as a group, to split up the questions and develop answers to them separately. Once you have answers to each of the question, you could then check each other's work together before you submitting your responses. With whichever method you choose, be sure to record all of your work neatly so it can be submitted at the end of this experiment.

When I worked on similar problems in the past, I have acted as if the person who is reading my answers did not read the question that I am answering. That way, I have to try and give the most complete answer I could. Just remember be thorough while creating your answers, show all of your work, and give the most complete answers possible to each of the questions. Be careful not to let the time pressure get to you. Pace yourselves, and work through each of the questions presented quickly, but answering each one completely. A useful tip to remember if you get stuck is that you aren't working alone in this experiment. Ask your teammates if they have any information you could use to answer your question. Remember, the more people you have working on a problem, the less likely you are to miss something.

If you all work together, stay focused, share information, and work diligently, a team with your abilities should have plenty of time to produce some of the best possible answers to these questions. Each of you has all of the knowledge and experience that you need to do well on this experiment. I will be monitoring your progress throughout this experiment, so relax and do your best.

“Once you finish with this, you will be asked to fill out several questionnaires about yourself, your team and your experiences in today's experiment. When you have finished the questionnaires, be sure to see the experimenter so they can dismiss you. Thanks for your attention. Good luck. ”

Confederate Leader Scripts for the Centralized Leadership Manipulation
[Video-Mediated Chat]

"Hello, my name is <u>Joaquin</u>, another student involved in today's experiment. I have been assigned to be your team's leader and I have recorded this message to guide you through today's experiment. The message you are watching contains instructions on what you need to do to successfully complete today's experiment. It also has strategies you can follow to effectively work together, and some advice on how you should proceed. So, let's get started. In today's experiment, you will be asked to work as a team to develop answers to questions presented in two separate tasks. In the first task, your team will answer a series of questions after viewing a problem presented to you in the form of a short, 15 minutes video. The questions that you will need to answer are presented for you at the top of the interface that you will be working from, while the video is presented in quicktime format."

<u>"You will get your audio from the headphones provided to you, and you will communicate with your group members using streaming internet chat, that shows a visual image of each of your teammates and plays the audio from your conversations, both in real time.</u> You start the video by pressing the 'triangle play' button." There is also a keyword search feature that you may use to re-watch scenes from the video that you may have missed, or that you need to see again. For example, say you that you want to search for the word 'car'. All you would need to do is type 'car' into the search term box and press enter. The search function will then give you a list of links that will allow you to go directly to each scene in the video where that word is said. To watch a scene, just click one of the desired links. The questions you will need to answer are presented for you at the top of the page. You will have 55 minutes to complete this part of today's experiment, and after 45 minutes have passed you will be given a ten minute warning to wrap up and submit your answers." I suggest that you work quickly, as 55 minutes is not as much time as it seems.

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Remember to work as a team and be sure to share all of the information that you find relevant to solving each question posed. Keep in mind that it is important to communicate with your team members. You must work as a team to produce the best answers. Remember that your teammates won't know what you are thinking if you keep it to yourself. Another strategy for working through these questions could be for you, as a group, to split up the questions and develop answers to them separately. Once you have answers to each of the question, you could then check each other's work together before you submitting your responses. With whichever method you choose, be sure to record all of your work neatly so it can be submitted at the end of this experiment.

When I worked on similar problems in the past, I have acted as if the person who is reading my answers did not read the question that I am answering. That way, I have to try and give the most complete answer I could. Just remember be thorough while creating your answers, show all of your work, and give the most complete answers possible to each of the questions. Be careful not to let the time pressure get to you. Pace yourselves, and work through each of the questions presented quickly, but answering each one completely. A useful tip to remember if you get stuck is that you aren't working alone in this experiment. Ask your teammates if they have any information you could use to answer your question. Remember, the more people you have working on a problem, the less likely you are to miss something.

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"Once you finish with this, you will be asked to fill out several questionnaires about yourself, your team and your experiences in today's experiment. When you have finished the questionnaires, be sure to see the experimenter so they can dismiss you. Thanks for your attention. Good luck. "

Confederate Leader Scripts for the Centralized Leadership Manipulation
[Face-to-Face Chat]

"Hello, my name is Joaquin, another student involved in today's experiment. I have been assigned to be your team's leader and I have recorded this message to guide you through today's experiment. The message you are watching contains instructions on what you need to do to successfully complete today's experiment. It also has strategies you can follow to effectively work together, and some advice on how you should proceed. So, let's get started. In today's experiment, you will be asked to work as a team to develop answers to questions presented in two separate tasks. In the first task, your team will answer a series of questions after viewing a problem presented to you in the form of a short, 15 minutes video. The questions that you will need to answer are presented for you at the top of the interface that you will be working from, while the video is presented in quicktime format."

"You start the video by pressing the 'triangle play' button. There is also a keyword search feature that you may use to re-watch scenes from the video that you may have missed, or that you need to see again. For example, say you that you want to search for the word 'car'. All you would need to do is type 'car' into the search term box and press enter. The search function will then give you a list of links that will allow you to go directly to each scene in the video where that word is said. To watch a scene, just click one of the desired links. The questions you will need to answer are presented for you at the top of the page. You will have 55 minutes to complete this part of today's experiment, and after 45 minutes have passed you will be given a ten minute warning to wrap up and submit your answers." I suggest that you work quickly, as 55 minutes is not as much time as it seems.

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Remember to work as a team and be sure to share all of the information that you find relevant to solving each question posed. Keep in mind that it is important to communicate with your team members. You must work as a team to produce the best answers. Remember that your teammates won't know what you are thinking if you keep it to yourself. Another strategy for working through these questions could be for you, as a group, to split up the questions and develop answers to them separately. Once you have answers to each of the question, you could then check each other's work together before you submitting your responses. With whichever method you choose, be sure to record all of your work neatly so it can be submitted at the end of this experiment.

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APPENDIX C: Decentralized Leadership Behaviors Training Video Script

(All Media Richness Conditions)

OPENING SCENE
Video/Visual: The video will open with a shot of the lab, or working space, where the team will come together socializing, sit down, and await the beginning of the experiment.
Narrator: "Hello. The video that you are now watching is a training tool that has been designed to identify and demonstrate the use of good teamwork behaviors in small groups and teams."

Video/Visual: The video narrator will indicate that this is a training video that teaches teamwork behaviors. Using callouts, the video will list the behaviors (observation and information gathering, information sharing & creating unconventional ideas, respectful discussion, idea acknowledgement, and idea/concept integration); in addition to informing the viewer of how the video will model these behaviors.
Narrator: "The individuals that you are now watching will be shown working together to solve a short problem solving task. As they work together, they will demonstrate several important teamwork behaviors. Each of these behaviors pointed out in this video will be highlighted, defined, and then replayed to explain and emphasize their importance in fostering high quality teamwork. The behaviors that will be acted out in this video are: observation and information gathering, information and idea sharing, respectful discussion, idea acknowledgement, and idea/concept integration."

NEXT SCENE
Video/Visual: The video will then show a scene of a team of three people talking together, preparing to begin working on the JASPER task. It will show them reading the instructions for the task, followed by starting and watching the JASPER video.
Narrator: "You will notice that everyone is being very attentive, and making sure that they each read all of the instructions completely and carefully before they start watching the video. Once the team members have a good understanding of what they have to do, and the questions that they will need to answer, then they play the video. "

Video/Visual: The video will show the team watching the video, one watcher intently taking notes and another person rewinding the video to search for specific scenes.
Narrator: "After the video begins, the team watches very closely. So that they can make the highest quality answers, each of the team members takes notes and rewinds the video, to review scenes in which they may have missed something. These types of activities are examples of '<u>observation and information gathering'</u>

Video/Visual: [DISPLAY '<u>observation and information gathering</u>' AS A CALLOUT!]."
Narrator: In this type of task, observation, as a behavior, would means paying close attention to both the task you will be performing and to your teammates when they are sharing task-relevant information. Information gathering behaviors would include taking detailed notes from the task as the problem is presented, and then recording both your and teammates' recommendations for how to solve the problem.

NEXT SCENE
Video/Visual: The video continues with the team beginning to work together to solve the questions. Team members will be shown engaging in involved conversations and communications.
Narrator: "After they have watched the video completely, the team starts to develop answers to the posted questions. While interacting, reviewing their notes, and rewatching scenes from the video, team members share information with each other. This is an example of '<u>information sharing'</u>
Video/Visual: [DISPLAY '<u>information sharing</u>' AS A CALLOUT!]."
Narrator: An example of information sharing would simply be when teammates share information that they have observed from task or that they have produced from their interactions with their other teammates.

NEXT SCENE
Video/Visual: The video will show team members speaking to each other, and listening attentively. Show a disagreement. Show building consensus.
Narrator: "While developing answers to the questions asked, team members respectfully interact with one another. Each team member is allowed the opportunity to speak and share any information that they may have that they feel is relevant to solving the question being addressed. This doesn't mean that ideas are not challenged; rather, everyone recognizes that they each have knowledge that may be useful in solving the task at hand. If they were to devalue another team member's comment or contribution, they could potentially decrease the chances of generating a correct answer. This is an example of '<u>respectful discussion'</u>
Video/Visual: [DISPLAY '<u>respectful discussion</u>' AS A CALLOUT!]."

NEXT SCENE
Video/Visual: Show team members discussing their answers and pointing out each others contributions.
Narrator: Another point to remember is that while developing answers to the posted questions, team members are sure to credit each other for their contributions to the team's answers.
Video/Visual: [DISPLAY Acknowledgement AS A CALLOUT!]
Narrator: Acknowledgement is important, as it encourages the team members to continue to share information and ideas, as the team values their contributions."

NEXT SCENE
Video/Visual: Show team members entering their final answers into the webform, and show them entering a full/complete answer.
Narrator: "And lastly, while developing their responses, team members can in some instances combine ideas, in order to form a superior answer. Integration happens in teams that are verbally working to solve of a problem, or in those teams that are using different types of equations to solve the problems and make a decision. It is important to realize that when integrating information, teams can sometimes create unconventional responses to problems. It should also be noted that these unconventional responses can, in some cases, be highly effective solutions. This is an example of 'idea integration'.
Video/Visual: [DISPLAY idea integration' AS A CALLOUT!]."

FINAL SCENE - RECAP
Video/Visual: Video Recap (Behaviors to be modeled) - [Show team members talking in the background.]
Narrator: "To recap, this video displayed the most important components to building good teamwork behaviors. As a review, here is a list of those behaviors presented again for your information:" (Listed is narrated as they appear on the scene.)
Video/Visual: [DISPLAY THE FOLLOWING TERMS AS A CALLOUT LIST!]

1. ***Observation and Information gathering (paying attention)***
2. ***Information sharing (passing along knowledge to teammates)***
3. ***Respectful discussion (equality of viewpoints)***
4. ***Acknowledgement (mutual acknowledgement of shared work)***
5. ***Idea Integration (creating routine and unconventional solutions)***

Video/Visual: (Video fades out to black.) **[THE END]** *Video end*

APPENDIX D: Decentralized Leadership Manipulation Briefing

[Text-Based Chat]

This form will contain instructions on what you need to do to successfully complete today's experiment, goals for the team, a brief description of the task that you will be working on in today's experiment, instructions for the controls present on the video interface, in addition to the learning points covered in the leadership training video."

Briefing:
In today's experiment, you will be asked to watch a short video and then read a short story. After each of these presentations, you will be asked to answer a series of questions. To successfully complete this experiment, it is your goal to generate the best possible responses to all of the questions that you are given, before time expires.

In the first task, your team will answer a series of questions after viewing a problem presented to you in the form of a short, 15 minutes video. The questions that you will need to answer are presented for you at the top of the interface that you will be working from, while the video is presented in a quicktime format."

"You will get your audio from the headphones provided to you, and you will communicate with your group members <u>using a chatroom, similar to AOL or MSN Instant Messenger. There is no talking during the experiment.</u> You start the video by pressing the 'triangle play' button. There are several things to remember about the chatroom as you chat with your teammates. First, you will notice that as you chat, your chat screen will fill with the text of your previous messages. Once the screen is full, the text from older messages scrolls off the screen. In order to view messages that have scrolled off the screen, you first have to press the pause button at the bottom of the screen and then use the side-scrolling bar on the right side of the screen to view previous text. After you finishing viewing the older text, you may either press 'unpause' (at the bottom of the screen) to continue chatting or simply type and send another message to reset the screen to chat interface. There is also a keyword search feature that you may use to rewatch scenes from the video that you may have missed, or that you need to see again. For example, say you that you want to search for the word 'car'. All you would need to do is type the word 'car' into the search term box and press enter. The search function will then give you a list of links that will allow you to go directly to each scene in the video where that word is said. To watch a scene, just click one of the desired links. The questions that you will need to answer are presented for you at the top of the page (I may be excluding this, don't need the data associated with it.). You will have 55 minutes to complete this part of today's experiment, and after 45 minutes have passed you will be given a ten minute warning to wrap up and submit your answers."

"In the second task of today's experiment, you will again be asked to work as a team to solve a problem; this one presented in the form of a short story. To begin this task, you are to read the story together and then answer several questions about that story. The questions that you will need to answer are presented for you at the top of the page. Again, you will be given 55 minutes to complete this part of the experiment, and after 45 minutes you will be given a 10 minute warning to wrap up and submit your answers. "

Learning Points from the Video:
Remember to use the effective team behaviors that you learned about previously as you work through the experiment. They are listed below.

1. Observation and Information gathering (paying attention)
2. Information sharing (passing along knowledge to teammates)
3. Respectful discussion (equality of viewpoints)
4. Acknowledgement (mutual acknowledgement of shared work)
5. Idea Integration (creating routine and unconventional solutions)

Preparation:
To help you prepare yourself to perform well in the experiment, please read through the following word problems. You will notice that these word problems are similar to the task performed by the team in the training video you watched a few minutes ago. You do not have to answer these problems. Instead, please take only a few minutes to read through them all and think about what would you need to know to answer the question, what information is contained in each problem that you would have to share with your team, and what parts of the problem might be confusing.

> Dana needed to borrow some money from James. She agreed to pay him back one and a half times the original sum, plus $60. She paid James a total of $228. What was the original amount she borrowed?
>
> Two cars belonging to two brothers are in two towns two hundred miles apart. The brothers decide to meet for a cup of coffee. The first brother starts at 9:00 a.m. driving 60 mph. The second brother starts at 9:00 a.m. driving 40 mph. What time do they meet?
>
> John eats three lollipops in one minute. Karen eats two lollipops per minute. How many do they eat in total in 12 minutes?
>
> For a new car priced at $24,000, Marva takes a five-year loan with an interest rate of 6.5%. By the time she owns the car, how much will she have paid including principal (the original cost) and interest? (note: the formula for Interest = Principal x Rate x Time)

Closing:
OK. You are now ready to begin the experiment. After you have answered the questions in both tasks, you will be asked to fill out several questionnaires about yourself, your team and your experiences in today's experiment. You will also be asked to provide them with feedback about how well you think that they performed during this experiment. After this is over, you will be given your credit and dismissed.

Decentralized Leadership Manipulation Briefing
[Video-Mediated Chat]

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Decentralized Leadership Manipulation Briefing
[Face-to-Face Chat]

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APPENDIX E: Demographics Questionnaire

1. Age (in years)________________

2. Gender
    a. Male
    b. Female

3. Academic Classification (year)
    a. Freshman
    b. Sophomore
    c. Junior
    d. Senior
    e. Other (please specify)________________

4. Race/Ethnic Group
    a. African American
    b. Asian/Pacific Islander
    c. Caucasian
    d. Hispanic
    e. Native American
    f. Other (specify)________________

5. How well were you acquainted with your partner <u>before taking part in this study</u>?

1	2	3	4	5
not at all acquainted	slightly acquainted	acquainted	fairly well acquainted	very well acquainted

6. In this study, a team is defined as a number of individuals interacting interdependently and dynamically to achieve a common objective (e.g., work group, sports team). Team experience may be acquired by working on many different teams and/or by working for a long time on one or a few teams. Given this definition, how much team experience did you have <u>before taking part in this study</u>?
    a. I had no team experience
    b. I had very little team experience (1 to 2 teams)
    c. I had some team experience (3 to 4 teams)
    d. I had a lot of team experience (5+ teams)

7. Based on your opinion of their performance during the experiment, how much team experience do you think your partner(s) had before this study?
    a. I think they had no team experience
    b. I think they had very little team experience
    c. I think they had some team experience
    d. I think they had a lot of team experience

Please rate (circle) your level of satisfaction, and how much you agree with the following statements.

8. How satisfied were you with your team's performance?

1	2	3	4	5
very dissatisfied	Dissatisfied	undecided	satisfied	very satisfied

9. How satisfied were you with the teamwork on your team?

1	2	3	4	5
very dissatisfied	dissatisfied	undecided	satisfied	very satisfied

10. I would want to work on a similar type of task again.

1	2	3	4	5
strongly disagree	disagree	undecided	agree	strongly agree

11. I would want to work with the same person (or people) again on another task.

1	2	3	4	5
strongly disagree	disagree	undecided	agree	strongly agree

12. How effective was the performance that occurred on your team?

1	2	3	4	5
very ineffective	ineffective	average	effective	very effective

APPENDIX F: Teamwork Quality (TWQ) Survey

Communication –

1. There was frequent communication within in the team.
2. The members of my team stated their thoughts aloud, without having to be asked.
3. The members of my team communicated directly and personally with each other.
4. Some members of my team acted as mediators, passing messages to other team members. (R)
5. My team members openly shared information related to the problem at all times.
6. Important information was kept away from other team members in certain situations. (R)
7. My team had conflicts regarding the openness of information flow and information sharing during the problem-solving task. (R)
8. My team members were happy with the speed at which they received information from other team members.
9. My team members were happy with the usefulness of the information received from the other team members.

Coordination –

1. The work done on subproblems within the project was closely harmonized.
2. My teammates fully understood how to solve the subproblems.
3. The goals for subproblems were accepted by all team members.
4. There were conflicting interests in our team regarding subproblems. (R)

Balance of Member Contributions –

1. This team recognized the strengths and weaknesses of its individual team members.
2. My team members used their specific strengths to help the team achieve its goals.
3. Some of my team members did not make equal contributions while working to solve the problem. (R)

Mutual Support –

1. My team members helped and supported each other as best they could.
2. If conflicts came up, they were easily and quickly resolved.
3. Discussions and controversies were conducted constructively.
4. All suggestions and contributions of team members were respected.
5. All suggestions and contributions of team members were discussed and further developed.
6. Our team was able to reach consensus regarding important issues.

Effort –

1. Every member of my team fully supported and worked hard to solve the problem.
2. Every member of my team acted as though solving the problem, and its subproblems, was their highest priority.
3. Our team put much effort into solving the problem.
4. There were conflicts regarding the effort that team members put into the project. (R)

Teamwork Quality Survey (continued)

Cohesion –
1. My team felt it was important to work together to solve this problem.
2. My team did not see anything special about working on this experiment. (R)
3. My teammates felt very strongly about the outcomes of this experiment.
4. Solving this problem was important to our team.
5. All of my team members felt as though they were apart of a team.
6. There were many personal conflicts in our team. (R)
7. The members of my team would work together in the future.
8. My team worked very well together.
9. My team members were happy they were apart of this team, and not another team.
10. My team members felt responsible for producing a high quality answer to represent the team well.

The scale items were modified for the purposes of the present study, and used to measure the quality of teamwork present in teams across six sub-dimensions. Individuals responded on a 5-point scale ranging from 1 = *almost never* to 5 = *almost always*.

(R) = Reverse coded

APPENDIX G: Metacognition Scale

1. During the experiment, my teammates and I sometimes asked questions to help focus the team on solving the problem.

2. During the experiment, my teammates and I asked ourselves questions to make sure we understood the problems that we had been trying to solve.

3. During the experiment, we tried to change the way we developed answers to fit the demands of each sub-problem.

4. During the experiment, we tried to think through each sub-problem and identify what we were supposed to solve for, rather than just jumping in without thinking.

5. During the experiment, we tried to determine which things we didn't understand well and adjusted our problem-solving strategies accordingly.

6. During the experiment, we set goals for ourselves in order to direct our activities.

7. If we got confused while attempting to solve this problem, we made sure to stop and sort it out as soon as we could before moving on.

8. During the experiment, we thought about how well our problem-solving tactics were working.

9. During the experiment, we thought carefully about how well we knew material from the video that we had previously watched.

10. During the experiment, we thought about what things we needed to know in order to solve the problems.

11. During the experiment, we noticed where we made mistakes and worked to correct those answers.

The scale items were reworded to assess the degree to which trainees engaged in metacognitive monitoring and control activities. Individuals responded on a 5-point scale ranging from 1 = *never* to 5 = *always*.

APPENDIX H: Team Psychological Safety

1. If you made a mistake on this team, it would be held against you.
2. Members of this team are able to bring up problems and tough issues.
3. People on this team sometimes reject each other because they present different ideas.
4. It is safe to take a risk on this team.
5. It is difficult to ask other members of this team for help.
6. No one on this team would deliberately act in a way that undermines my efforts.
7. Working with members of this team, my skills and strengths were valued and utilized.

Individuals responded on a 7-point scale ranging from 1 = *"very inaccurate"* to 7 = *"very accurate"*.

APPENDIX I: A Description of Coding Responses in the JASPER Paradigm

This document presents an example the textual analysis techniques and coding schemes used to analyze tasks from the JASPER paradigm. This particular document demonstrates these techniques using an excerpt of a chat transcript saved from an experimental session using the JASPER task, “Rescue at Boone’s Meadow”.

The JASPER task, Rescue at Boone’s Meadow, tells the story of a man named Jasper camping in a place called Boone’s Meadow. During his vacation, Jasper finds an injured eagle. He uses his radio to contact friends (Larry and Sharon) in town and let’s them know the problem. The three of these friends each have skills, resources, and vehicles that can be used to solve this problem. Jasper has money and a radio. Larry owns an ultralight aircraft, and is a capable pilot. Sharon also knows how to fly the ultralight and owns a pick-up truck. Students are asked to find an answer to the following questions:

- Can the ultralight be flown into Boone’s Meadow and back without running out of fuel?
- How much fuel will this trip require?
- How long will this rescue take?
- Should it be necessary, will the group have enough money to buy gas?

With that information, raters would begin coding by reading through a transcript. As they read, they may come across a comment similar to this one:

```
User A (1:53:28 PM): larry flies the little plane
```

In this case, the rater would record a complete problem space detail mention or CDM, as the team has correctly noted that Larry is able to pilot the aircraft. As they continue reading through the transcript, they could come across the following comment:

```
User B (1:56:20 PM): 100 miles in the tank
```

In this case, this comment is scored as a ‘mention’. As no conversion or other math was performed or referred to, this is not a math error. Rather they simply note the distance that the ultralight could travel based on a max fuel load. Had they mentioned the tank's 5 gallon capacity, a check would be placed under CDM. Since this is related to capacity, but not a fact, it is only a Mention. Consider the following line:

```
User B (1:56:32 PM): 30 miles per hour
```

This comment refers to speed, but whose or what's speed? From the context of the transcript, it seems they are discussing the ultralight’s speed. In the coding matrix, this would be coded as a mention of the ultralight’s speed, and not as a CDM, because that is reserved for instances where a fact is explicitly mentioned. So, if User B had said "the plane travels 2min/mile which is equivalent to 30mph..." (or something to that effect), the rater would have coded that statement as a CDM. Review User A’s next comment:

```
User A (1:56:49 PM): 65 miles it has to go?
```

The above statement is a reference to the distance traveled (flying) from Boone's Meadow to the city of Cumberland (where the eagle must be brought to receive medical care). A review of the problem shows that in the actual problem, this value was never identified as in terms of mileage, but rather was described in minutes (130 min). As such, this statement is coded as a mention. It is that User A knows the original value, or can at least infer it. However, since that value was not explicitly identified, this can not be scored as a CDM.

```
User A (1:58:35 PM): id say it takes about 2 hours and 15 mintes
```

The above excerpt shows User A attempting to provide a solution to a sub-problem. Ultimately, this excerpt is not coded. At the bottom of every coding matrix you must note their final decisions. If later in the discussion another participant/team member suggests a different time (or answer), then the final mention is the category that is coded. For this task, there is a category to mark if the group compares multiple options. To properly score this section, this part of the discussion has to be read and considered as a whole.

```
User A (1:58:57 PM): 70 miles

User B (1:59:24 PM): 70 miles is what

User A (1:59:28 PM): cuz there was an extra five miles

User A (1:59:34 PM): the lady pointed to

User B (1:59:42 PM): 5 extra minutes

User C (2:00:07 PM): isnt it 5 extra minutes?

User A (2:00:13 PM): yea

User A (2:00:27 PM): what route though?

User A (2:00:35 PM): straight route?

User A (2:00:52 PM): why would the plane have to make stops?

User B (2:01:03 PM): because the plane only has a 75 mile gas tank
```

Users A and B mention "70 miles." Reading further down the transcript, it is revealed that they were trying to figure out the range of the plane's fuel tank. A rater would place give this group a mention for identifying a critical route that they need to consider to solve the problem, and then a CDM as they correctly identified the mileage for that route. Within this larger segment, there is another coding element:

```
User B (1:59:42 PM): 5 extra minutes

User C (2:00:07 PM): isnt it 5 extra minutes?
```

User C asks for clarification. Specifically, asking about an extra 5 minutes. In the actual problem, the team is informed that for every landing, they need to add five minutes of "turnaround time" before the plane could takeoff again. So, a rater would mark a CDM for mentioning that. Consider the next comment:

```
User B (2:03:16 PM): plus the plane takes 72 minutes to get from a to
be and back
```

The group is now discussing the time required to travel between two points (twice), but what two points? Unless further info is presented, it's impossible to assign a code and thus is ignored. As it isn't clear where they are referring, the rater cannot infer their meaning, so this is not coded.

Consider the following excerpt that attempts to solve a sub-problem:

```
User B (2:04:52 PM): I think the plane only gets 75 miles in the tank

User B (2:04:58 PM): anyone confirm?

User B (2:05:59 PM): ok, so 125 minutes to A with the plane (including
fuel)

User B (2:06:06 PM): 41 minutes there

User B (2:06:37 PM): 41 minutes back

User B (2:06:42 PM): car takes an hour to get back to c

User B (2:06:49 PM): 125 + 41 + 41+ 60
```

The 60mph speed for the car is a CDM. However, what they are referring to as a 41 minute trip is difficult to discern. Given that they are referring to using the ultralight and flying into Boone's Meadow, the rater can infer that this likely points to a math error as most travel times are whole numbers (e.g. 30 + (5x2).

APPENDIX J: Journey to Cedar Creek Scoring Sheet (First, Video-Based Problem-Solving Task)

Journey to Cedar Creek Scoring Sheet (JASPER)

Condition:________

TeamParticipant ID:_________

		CDM	Mentioned	Attempted	Solved	Math Error	Corrected Math Error	Violation	Corrected Violation	Uncodable errors	Misinterpretation/ Recall Error	Corrected misinterpretation/ Recall error
Time												
Travel Time												
from Willie's to Cedar Creek	80 mins											
Time of Day												
time when leaving for home	2:35pm											
time of sunset set	7:52pm											
Question 1: What is the latest time that Jasper could leave Cedar Creek and make it home before sunset?		4:52pm no WD 3:00pm Willie's										
Mode of Transportation												
Jasper's Boat												
fuel in tank	5 gallons											
fuel from home to Cedar Creek	5 gallons											
Sal's Boat												
fuel in tank: before final fill-up	6 gallons											
fuel in tank: after final fill-up	12 gallons											
rate of fuel consumption	5 gal. per hr											
rate of travel/speed	7.5 min per mi (8mph)											
Question 2: How much fuel will Jasper need to make it home?		15 gallons										
Question 3: How long will Jasper's trip take?		3 hours										
Range & Locations												
from home/port to Cedar Creek	24 miles											
Home/Dock	132.6											
Willie's Shop	140.3											
Cedar Creek/Sal's Boat	156.6											
Willie's Hours	8am - 5pm											
Gas Prices/Boat Maintenance/Cash Expenditures												
at Larry's	$1.29 - $6.50 total											
at Willie's	$1.10											
Repairs at Willie's	$8.25											
Question 4: Does Jasper have enough money to buy the fuel that he will need to take the boat home?		Yes, $5.45										
Sum of columns												

APPENDIX K: Trip to Huron Lake Scoring Sheet (Second, Text-Based Problem-Solving Task)

Trip to Huron Lake Scoring Sheet (REPSAJ) **Condition:_________** **TeamParticipant ID:__________**		CDM	Mentioned	Attempted	Solved	Math Error	Corrected Math Error	Violation	Corrected Violation	Uncodable errors	Misinterpretation/ Recall Error	Corrected misinterpretation/
Time												
time when leaving Lake Huron	12:30pm											
time of sunset	8pm											
last time Grandpa took meds	8pm											
1. What is the latest time that Rachel and her Grandfather could leave Lake Huron and make it home before it is time to take his next dosage of medication?		5:00pm										
Mode of Transportation												
Grandpa's Boat (both engines)												
fuel in tank	6 gallons											
fuel (extra)	2 gallons											
rate of fuel consumption	1.5 gal. per hr											
rate of travel/speed	10 min per mi (6mph)											
fuel from home to Killian	5 gallons											
2. How much fuel will they need to make it home from Lake Huron?		9 gallons										
3. How long will their trip take?		6 hours										
Range & Locations												
Distance												
from home to Lake Huron	36 miles											
from home to Killian	20 miles											
from Killian to Lake Huron	16 miles											
Gas Prices/Boat Maintenance/Cash Expenditures												
Rachel money for trip	$40.00											
Grandpa's money for trip	$200.00											
at local dock master's	$2.75 - $22 total											
at Killian	5 gal. for $2.45 per gal											
spinner bait from Killian	6 for $2.00 ec = $12.00											
live bait from Killian	$10.00											
new engine cost	$180 - $15 = $165											
4. Should it be necessary, do Rachel and her Grandfather have enough money to buy enough gas to make it home?		yes,										
Sum of columns												

APPENDIX L: Manipulation check and Pilot study Questionnaire

Please rate the extent to which you agree or disagree with the following statements. Rate each statement from 1 (strongly disagree) to 5 (strongly agreed).

Centralized Leadership *(Single Leader Speaking to the Group)*

1. The video helped you to understand your team's goals for this experiment.
2. The video structured your team's tasks very well.
3. The video was unclear in communicating the expectations for your team.
4. I thought the video was very respectful of my team.
5. The video made you feel like your team could accomplish this task.

Decentralized Leadership *(Disembodied Voice, Viewing a Team Interacting)*

1. This video helped you to understand how your team should work together.
2. After watching this video, you felt like you had to contribute in order for the team to perform its best in this experiment.
3. This video did a poor job of showing you how to communicate with your partners.
4. This video helped you to trust that your teammates can help you to perform well in this experiment.
5. This video made you feel like you were accountable to your teammates for your performance.

APPENDIX M: Tables

Table 1. Exploratory Factor Analysis Pattern Matrix For Teamwork Quality, Team Metacognition, and Team Psychological Safety Surveys

	1	2	3
TWQ1	**0.63**	-0.03	-0.04
TWQ2	0.48	0.17	-0.20
TWQ3	0.44	0.20	-0.14
TWQ4	0.39	-0.50	0.16
TWQ5	**0.67**	0.13	-0.04
TWQ6	**0.75**	-0.35	0.12
TWQ7	**0.90**	-0.40	0.01
TWQ8	0.44	0.23	-0.21
TWQ9	0.42	0.31	-0.11
TWQ10	0.39	0.34	-0.14
TWQ11	0.38	0.35	-0.21
TWQ12	**0.54**	0.18	0.02
TWQ13	**0.71**	-0.18	0.07
TWQ14	-0.02	**0.43**	-0.01
TWQ15	0.08	**0.54**	0.03
TWQ16	**0.62**	-0.18	0.14
TWQ17	**0.47**	0.15	0.10
TWQ18	**0.57**	0.11	0.08
TWQ19	0.48	0.25	0.08
TWQ20	0.40	0.31	0.06
TWQ21	0.37	0.41	0.02
TWQ22	0.53	0.21	0.02
TWQ23	**0.58**	0.12	0.05
TWQ24	0.56	0.23	0.08
TWQ25	0.28	0.55	-0.10
TWQ26	**0.61**	-0.14	0.09
TWQ27	0.41	0.36	0.09
TWQ28	-0.04	**0.38**	0.18
TWQ29	-0.13	**0.61**	0.22
TWQ30	0.06	**0.64**	0.16
TWQ31	0.31	0.33	0.08
TWQ32	**0.54**	-0.18	0.15
TWQ33	**0.54**	0.19	-0.06
TWQ34	**0.57**	0.22	-0.11
TWQ35	0.04	**0.66**	-0.07
TWQ36	-0.04	**0.71**	-0.04

	1	2	3
TMC1	-0.04	**0.46**	0.01
TMC2	**0.33**	0.16	-0.03
TMC3	0.01	**0.45**	0.01
TMC4	0.14	**0.39**	0.00
TMC5	0.18	**0.33**	0.03
TMC6	-0.13	**0.55**	-0.02
TMC7	0.10	**0.55**	-0.08
TMC8	-0.17	**0.74**	0.10
TMC9	-0.09	**0.61**	0.13
TMC10	0.25	0.10	0.06
TMC11	0.08	**0.56**	-0.01
TPS1	0.18	-0.18	**0.64**
TPS2	-0.18	0.47	0.40
TPS3	0.18	-0.03	**0.72**
TPS4	-0.08	0.09	**0.59**
TPS5	0.16	-0.01	**0.71**
TPS6	-0.01	0.07	**0.63**
TPS7	-0.13	0.42	0.56

Extraction Method: Principal Component Analysis.

Rotation Method: Promax with Kaiser Normalization.

Table 2. Descriptive statistics and intercorrelations at the team level

	Variables	Mean	SD	1	2	3	4	5	6	7
1	Leadership Behaviors	1.50	0.50	1						
2	Media Richness	1.96	0.82	0.00	1					
3	Task 1 Score	21.66	4.67	-0.26**	0.83**	1				
4	Task 2 Score	20.39	3.61	-0.31**	0.84**	0.85**	1			
5	Team Psychological Safety	4.21	0.49	-0.03	-0.09	-0.15*	-0.14*	1		
6	Teamwork Quality	3.93	0.41	0.01	0.33**	0.25**	0.25**	0.39**	1	
7	Team Metacognition	3.89	0.35	0.03	0.25**	0.14*	0.18**	0.32**	0.73**	1

** $p < 0.01$; * $p < 0.05$.

Note: N = 208 teams; SD = standard deviation; Leadership Behaviors (1 = Traditional Leadership; 2 = Modern Leadership); Media Richness (1 = text-based chat; 2 video-mediated communication; 3 = face-to-face communication).

Table 3. 3 x 2 Between-Subjects MANOVA Assessing the Impact of Media Richness and Leadership Behaviors on Team Performance Dependent Variables

Source	DV	df	Mean Square	F	Sig.
Media Richness	TWQ	2	2.16	14.05	0.00
	METCG	2	1.43	13.37	0.00
	Task 1 Score	2	1818.37	742.17	0.00
	Task 2 Score	2	969.31	532.14	0.00
	TPS	2	0.94	4.06	0.02
Leadership Behaviors	TWQ	1	5.53	0.04	0.85
	METCG	1	2.54	0.24	0.63
	Task 1 Score	1	308.35	125.85	0.00
	Task 2 Score	2	254.05	139.47	0.00
	TPS	1	7.13	0.31	0.58
Media Richness * Leadership Behaviors	TWQ	2	0.14	0.89	0.41
	METCG	2	0.15	1.39	0.25
	Task 1 Score	2	36.24	14.79	0.00
	Task 2 Score	2	67.18	36.88	0.00
	TPS	2	0.80	3.45	0.03
Error	TWQ	202	0.15		
	METCG	202	0.11		
	Task 1 Score	202	2.45		
	Task 2 Score	202	1.82		
	TPS	202	0.23		

$p < .05$

Table Legend

TWQ: Teamwork Quality

METCG: Metacognition

Task 1 Score: Team Decision-Making Performance Score for Task 1

TPS: Team Psychological Safety

Table 4. The Group Means for the 3 x 2 Between-Subjects MANOVA Assessing the Impact of Media Richness on Dependent Variables

DV	Media Richness	Mean	Std. Error
TWQ	TBC	3.74	0.05
	VMC	4.00	0.05
	FTF	4.07	0.05
METCG	TBC	3.75	0.04
	VMC	4.02	0.04
	FTF	3.95	0.04
Task 1 Score	TBC	18.14	0.18
	VMC	19.60	0.19
	FTF	27.73	0.19
Task 2 Score	TBC	17.16	0.16
	VMC	19.85	0.16
	FTF	24.56	0.17
TPS	TBC	4.21	0.06
	VMC	4.33	0.06
	FTF	4.10	0.06

Table Legend

TWQ: Teamwork Quality

METCG: Metacognition

Task 1 Score: Team Decision-Making Performance Score for Task 1

TPS: Team Psychological Safety

TBC: Text-Based Chat

VMC: Video-Mediated Communication

FTF: Face to Face Communication

Table 5. The Mean Differences for the 3 x 2 Between-Subjects MANOVA Assessing the Interaction of Media Richness and Leadership on Dependent Variables with Tukey's Post-Hoc Analysis

DV	(I)	(J)	MD (I-J)	Std. Error	Sig.
TWQ	TBC	VMC	-0.26	0.07	0.00
		FTF	-0.33	0.07	0.00
	VMC	TBC	0.26	0.07	0.00
		FTF	-0.07	0.07	0.59
	FTF	TBC	0.33	0.07	0.00
		VMC	0.07	0.07	0.59
METCG	TBC	VMC	-0.27	0.05	0.00
		FTF	-0.20	0.06	0.00
	VMC	TBC	0.27	0.05	0.00
		FTF	0.07	0.06	0.47
	FTF	TBC	0.20	0.06	0.00
		VMC	-0.07	0.06	0.47
Task 1 Score	TBC	VMC	-1.47	0.26	0.00
		FTF	-9.59	0.27	0.00
	VMC	TBC	1.47	0.26	0.00
		FTF	-8.12	0.27	0.00
	FTF	TBC	9.59	0.27	0.00
		VMC	8.12	0.27	0.00
Task 2 Score	TBC	VMC	-2.70	0.23	0.00
		FTF	-7.40	0.23	0.00
	VMC	TBC	2.70	0.23	0.00
		FTF	-4.71	0.23	0.00
	FTF	TBC	7.40	0.23	0.00
		VMC	4.71	0.23	0.00
TPS	TBC	VMC	-0.12	0.08	0.28
		FTF	0.11	0.08	0.35
	VMC	TBC	0.12	0.08	0.28
		FTF	0.24	0.08	0.01
	FTF	TBC	-0.11	0.08	0.35
		VMC	-0.24	0.08	0.01

$p < .05$

Table 6. Post-hoc Univariate ANOVA for 3 x 2 Between-Subjects MANOVA Assessing the Effect of Leadership on Dependent Variables in Teams Using Text-Based Chat

Source	DV	df	F	Sig.
Leadership Behaviors	TWQ	1	0.01	0.92
	METCG	1	0.62	0.43
	Task 1 Score	1	45.51	0.00
	Task 2 Score	1	29.83	0.00
	TPS	1	0.37	0.55
Error	TWQ	72		
	METCG	72		
	Task 1 Score	72		
	Task 2 Score	72		
	TPS	72		

$p < .05$

Table Legend

TWQ: Teamwork Quality

METCG: Metacognition

Task 1 Score: Team Decision-Making Performance Score for Task 1

TPS: Team Psychological Safety

Table 7. Study Means for 3 x 2 Between-Subjects MANOVA Assessing the Influence of Leadership Behaviors on Dependent Variables Across Conditions of Media Richness

	Media Richness	Leadership Behaviors	Mean	Std. Deviation	N
TWQ	TBC	TRAD	3.74	0.46	37
		MOD	3.74	0.39	37
	VMC	TRAD	4.04	0.31	34
		MOD	3.96	0.41	34
	FTF	TRAD	4.02	0.36	33
		MOD	4.12	0.41	33
METCG	TBC	TRAD	3.71	0.35	37
		MOD	3.78	0.35	37
	VMC	TRAD	4.06	0.24	34
		MOD	3.97	0.29	34
	FTF	TRAD	3.91	0.32	33
		MOD	3.99	0.38	33
Task 1 Score	TBC	TRAD	19.35	1.70	37
		MOD	16.92	1.38	37
	VMC	TRAD	21.56	1.64	34
		MOD	17.65	1.52	34
	FTF	TRAD	28.21	1.93	33
		MOD	27.24	1.09	33
Task 2 Score	TBC	TRAD	18.11	1.27	37
		MOD	16.22	1.69	37
	VMC	TRAD	22.03	1.17	34
		MOD	17.68	1.01	34
	FTF	TRAD	24.76	1.62	33
		MOD	24.36	1.19	33
TPS	TBC	TRAD	4.18	0.35	37
		MOD	4.24	0.41	37
	VMC	TRAD	4.27	0.39	34
		MOD	4.39	0.31	34
	FTF	TRAD	4.24	0.34	33
		MOD	3.95	0.87	33

Table 8. Post-hoc Univariate ANOVA for 3 x 2 Between-Subjects MANOVA Assessing the Effect of Leadership on Dependent Variables in Teams Using Video-Mediated Communication

Source	DV	df	F	Sig.
Leadership Behaviors	TWQ	1	0.83	0.37
	METCG	1	1.68	0.20
	Task 1 Score	1	104.59	0.00
	Task 2 Score	1	271.13	0.00
	TPS	1	1.97	0.17
Error	TWQ	66		
	METCG	66		
	Task 1 Score	66		
	Task 2 Score	66		
	TPS	66		

p < .05

Table Legend

TWQ: Teamwork Quality

METCG: Metacognition

Task 1 Score: Team Decision-Making Performance Score for Task 1

TPS: Team Psychological Safety

Table 9. Post-hoc Univariate ANOVA for 3 x 2 Between-Subjects MANOVA Assessing the Effect of Leadership on Dependent Variables in Teams Using Face to Face Communication

Source	DV	df	F	Sig.
Leadership Behaviors	TWQ	1	1.14	0.29
	METCG	1	1.02	0.32
	Task 1 Score	1	6.30	0.02
	Task 2 Score	1	1.26	0.27
	TPS	1	3.09	0.04
Error	TWQ	64		
	METCG	64		
	Task 1 Score	64		
	Task 2 Score	64		
	TPS	64		

$p < .05$

Table Legend

TWQ: Teamwork Quality

METCG: Metacognition

Task 1 Score: Team Decision-Making Performance Score for Task 1

TPS: Team Psychological Safety

APPENDIX N: Figures

Figure Captions

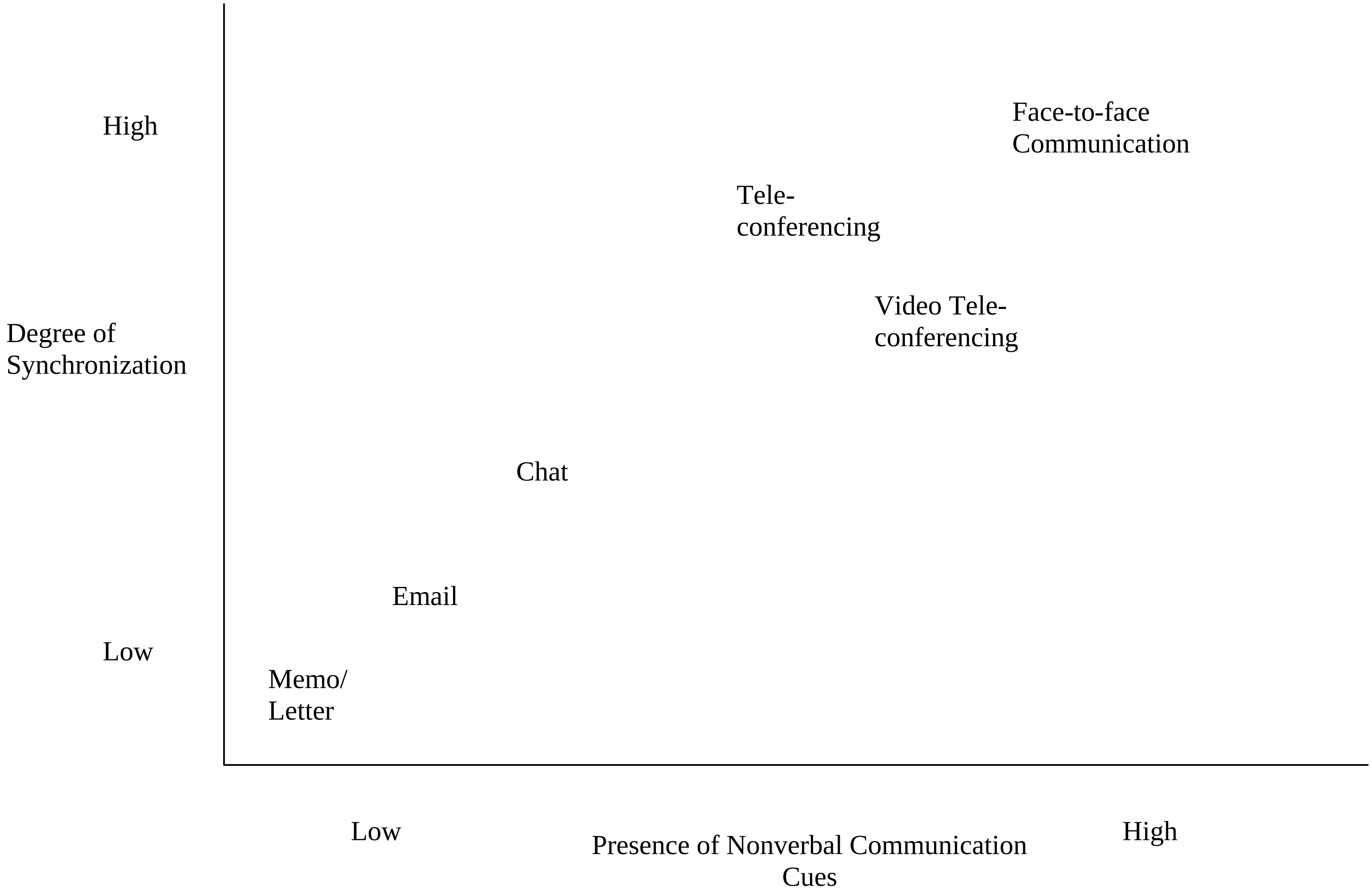
Figure 1. Placement of Communication Media According to Degree of Communication Synchronization and Presence of Nonverbal Cues.

Figure 2. The Relationship Between the Media Richness of Organizational Communication and the Organizational Decision Complexity.

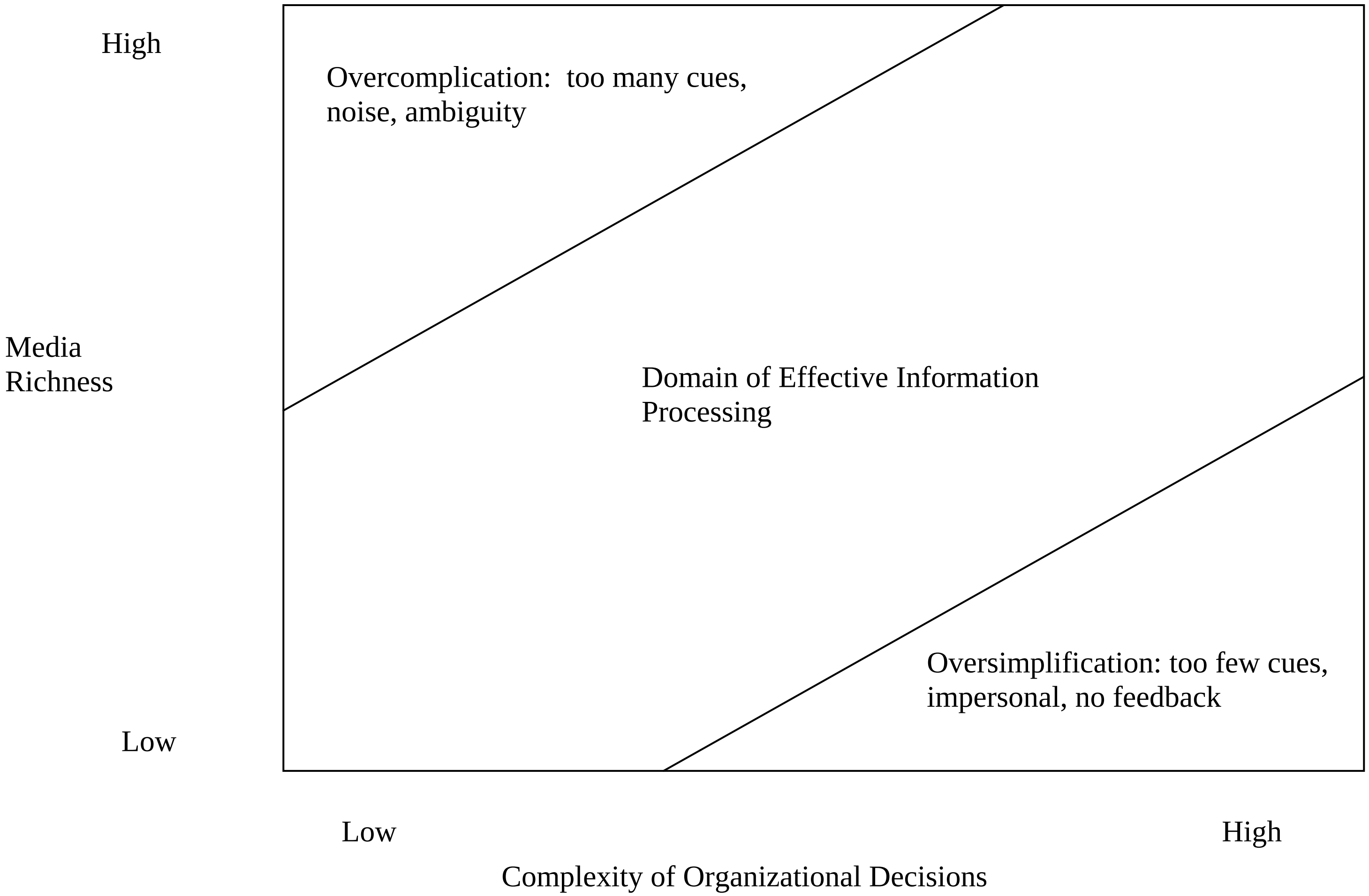
Figure3. The Interaction Between Media Richness and Leadership Behaviors on Task 1 Problem-Solving Performance.

Figure 4. The Interaction Between Media Richness and Leadership Behaviors on Task 2 Problem-Solving Performance.

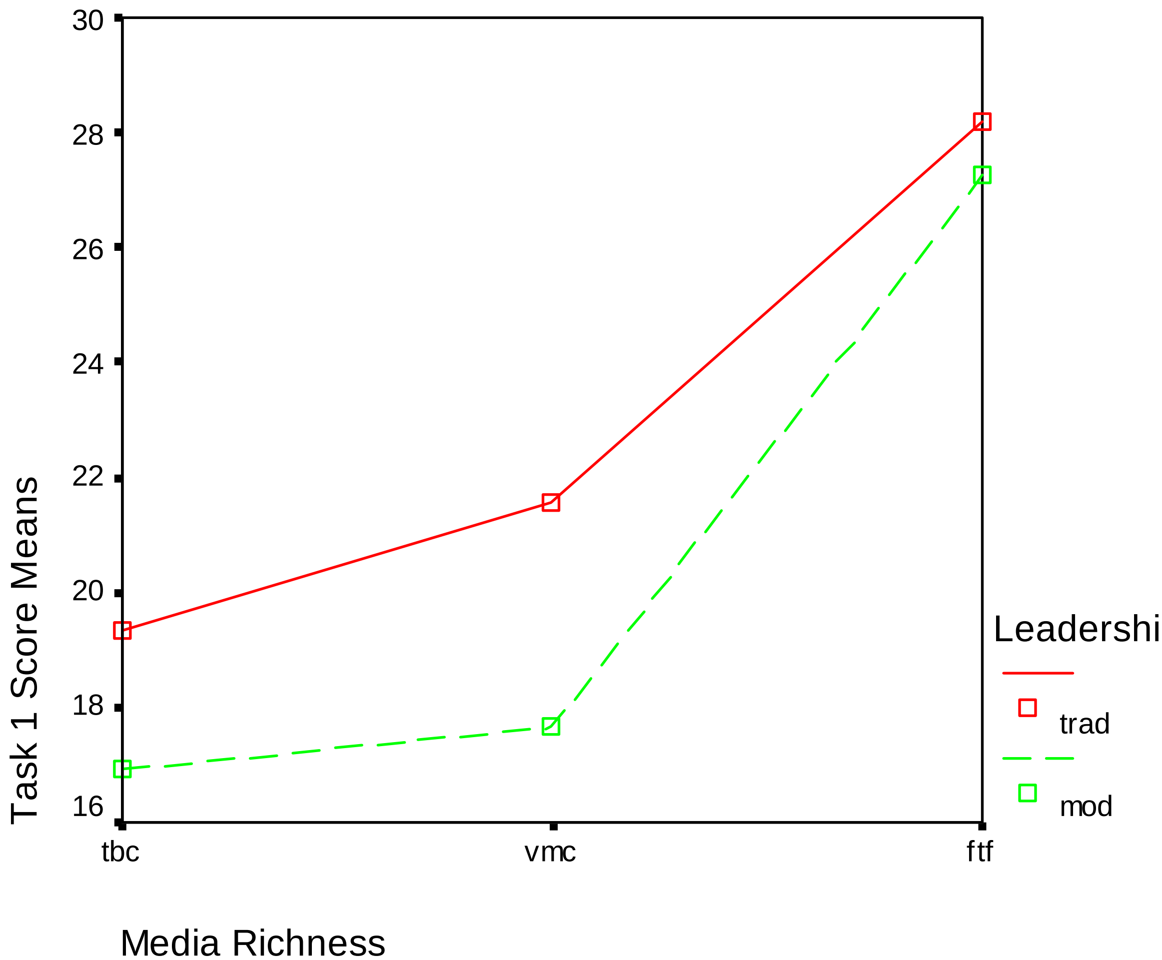
Figure 5. The Interaction Between Media Richness and Leadership Behaviors on Team Psychological Safety Scores.



Baltes, Dickson, Sherman, Bauer, & LaGanke (2002). Virtual Team Synchronization and Available Technology



Daft & Lengel (1984, 1986) Media Richness and Decision Complexity



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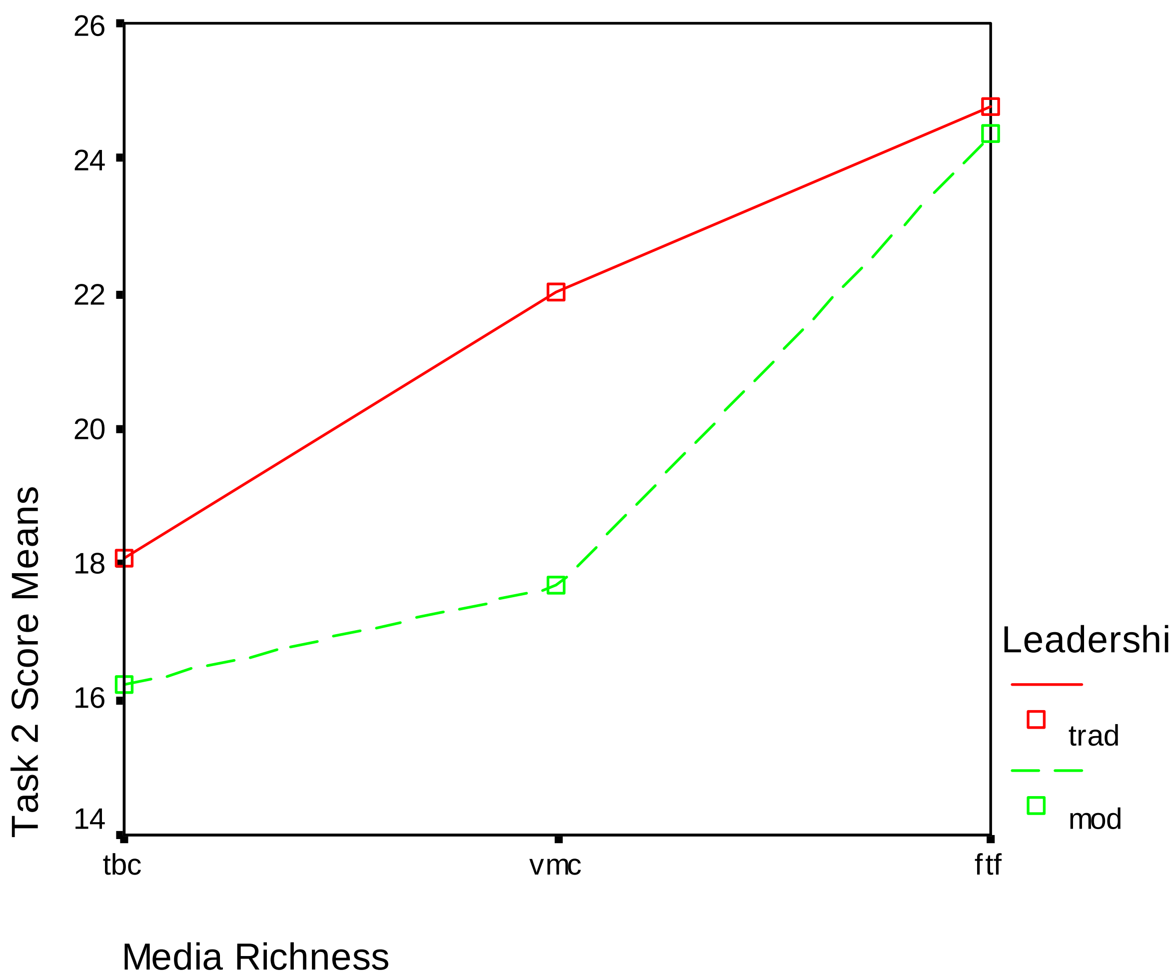
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Media Richness
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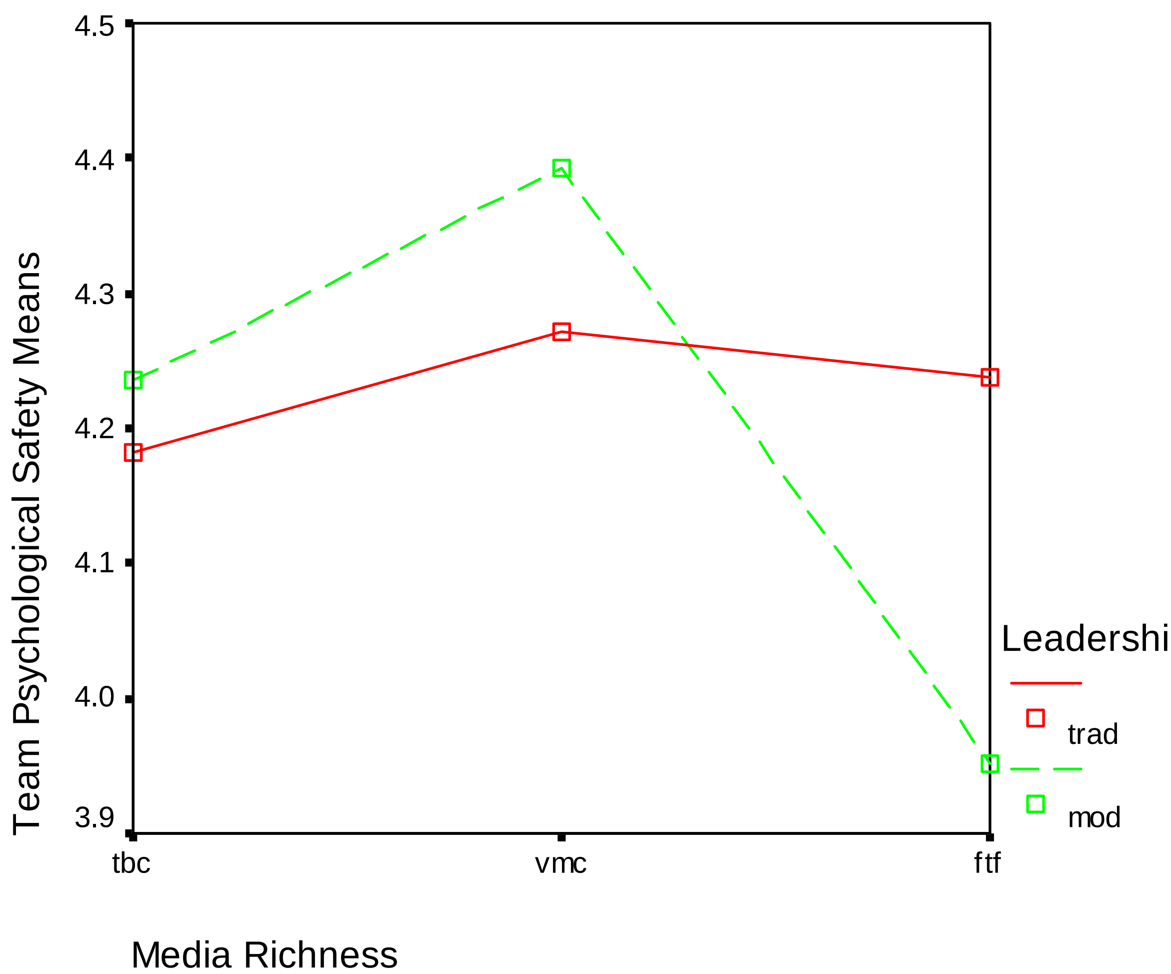
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Team Psychological Safety Means
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Media Richness
Leadershi
trad
mod

Tyrone Jefferson, Jr. - Ph.D.

Vita

EDUCATION

The Pennsylvania State University

- Ph.D. in Industrial & Organizational Psychology. Degree awarded in August 2009.
  Advisor: Susan Mohammed, Ph.D.
  Dissertation Title: Assessing the Impact of Media Richness and Leadership Behaviors on Team-Based Outcomes.
- Master's of the Arts in Industrial & Organizational Psychology. Degree awarded in May 2003.
  Advisor: David V. Day, Ph.D.
  Thesis Title: An Analysis of Organizational Leadership Development Needs.

Morgan State University

- Bachelor of Science in Psychology, with a minor in Philosophy. Degree awarded in May 1999.
  Advisor: Earl Walker, Ph.D.
  Honors Thesis Title: The Effects of Symmetry Detection on the Repetition Blindness Phenomenon.

PRESENT POSITION

Aptima: Human-Centered Engineering – Washington, D.C.
Industrial and Organizational Psychologist
Training and Design Area for the Training Development Team
Team Lead: Kara Orvis, Ph.D.

- Responsible for task accomplishment, implementation, and consulting activities for projects with government and private sector clients involving conducting occupational and tasks analyses, the development of training, creation and analysis of surveys, and other organizational research topics.
- My research and applied interests target the effective, efficient development and use of human and intellectual capital across a broad range of operational, applied and educational settings. These include requirements development and assessment; individual, group, and organizational performance enhancement via occupational analysis; assessment and change of work-related attitudes; skill development using both individual and group training and individual assessment.

RESEARCH SKILL SET

- **Subject Matter Expertise**: Performance requirement development, training design, leadership, coursework design and implementation, team assessment, team dynamics, and the usage of communication technology in the workplace.
- **Coursework**: Survey development, training, performance appraisal, personnel selection, organizational development, psychometrics, group facilitation, and emotion management.
- **Quantitative Skills**: Well-versed in a variety of descriptive and inferential statistical analysis techniques including, but not limited to: ANOVA, regression, and structural equations modeling.
- **Statistical Software Skills**: SPSS, computer-aided statistical graphing; and Microsoft Excel.
- **Productivity Software Skills**: Microsoft Office Suite (including Word, Excel, PowerPoint, Project Publisher & Visio), SurveyTracker and similar programs, the PsycARTICLES and PsycINFO research databases, and Lotus Notes.
- **Other Skills**: A variety of survey methods, verbal presentation skills, report writing, proposal writing, and experimental design.