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Understanding the Effect of Audio Communication Delay on Distributed Team Interaction

Topic(s): Collaboration, Shared Understanding, and Decision Making or Experimentation, Metrics, & Analysis

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ABSTRACT

Distributed teams are geographically separated and rely on networked communication technologies (e.g., audio or video conference, chat, email) to mediate their interaction. A limitation of these networked communication technologies is that they generate transmission delays that result from network congestion or routing issues. Communication delay in distributed environments is an important and challenging problem that has not been adequately addressed. Communication delays are particularly insidious in air traffic control, and space and military operations, where communication and information sharing are paramount to team success. For the purposes of this research, we define communication delay as the time interval between a team member speaking a message (sender) and when another team member (recipient) hears it. The goal of this research is to better understand the effect of communication delays on team collaboration and team processes to maximize distributed team performance. This paper will explore the issue of communication delay in network enabled environments and describe an experiment developed to better understand the effects of communication delays on distributed team member trust, shared understanding, and satisfaction.

INTRODUCTION

One recurring theme in the research literature is that clear and concise communication is critical to team performance, regardless of whether the team is collocated or dispersed (Salas, Burke, & Samman 2001). In the team context, communication is the active exchange of information between two or more team members, or an individual team member providing information to others in an appropriate manner (Dickinson & McIntyre, 1997). A large volume of research shows that communication is the most essential dimension of team performance (Bowers, Jentsch, Salas, & Braun, 1998; Cannon-Bowers & Salas, 1995). In their teamwork model, Dickinson et al., (1997) describe communication as a link connecting all other components of teamwork. The importance of communication, as well as the interdependency and collaboration inherent in team work demands that members be able to communicate without obstruction or delay (Achille, Schulze, & Schmidt-Nielsen, 1995). However, given that remote teams communicate using networked technologies, communication delays are inevitable (Salas et al., 2001). Communication delays can be a result of the type of technology being used. For example, when using email to communicate among team members, responses may be instantaneous or may take several days depending on the availability of team members. However, delays are not confined solely to asynchronous technologies. Delays are experienced even in synchronous or “real-time” communications using teleconferencing or videoconferencing. Depending on the situation, delays may range from relatively imperceptible such as those encountered during cell phone conversations to rather extensive such as communication delays that occur during space missions. Even with advancements in technology, there are still instances where delays occur and as Gutwin, Benford, Dyck, Graser, Fraser, Vaghi, & Greenhalgh, (2004) state, “delays are here to stay.” For the purposes of this research, we define communication delay as the time interval between a team member speaking a message (sender) and when another team member (recipient) hears it. (Note: text-based messages will not be examined in the present study).

The rate at which information travels between distributed team members is a function of several factors including the power of the computing machines, the bandwidth of the network, the distance that messages must travel, the number of routers that the message goes through, and the current traffic/congestion level (Gutwin, 2001). Fluctuations in the status of these network factors may cause delays. For example, pushing large amounts of data through a low data rate system would contribute to rather lengthy delays. In addition, there are instances where delays may be related to organizational protocol. A compelling example is seen in the case study and movie “Black Hawk Down”, which documents military operations in Mogadishu, Somalia in 1993. During the mission, two Blackhawk helicopters carrying U.S. Army Rangers were shot down leaving 18 Soldiers and hundreds of Somali civilians injured or killed. A convoy of U.S. Soldiers attempted to make their way to the crash site to rescue the wounded but they came under heavy enemy fire and couldn’t find their way through the maze of city streets. So, an Orion spy plane and surveillance helicopters, flown by U.S. Navy aviators, attempted to steer the convoy clear of Somali gunfire. However, the Orion pilots were not allowed to communicate directly with the convoy. Instead, their orders were to relay all communications to the Joint Operations Center (JOC) back at the beach. So when the Orion pilots instructed the convoy to “Turn left”, their message went first to the JOC and then to the convoy. As a result, the convoy drove past the place they had been directed to turn, then, getting the delayed message, turned left down the wrong street (Bowden, 1999). Regardless of the cause of delays, be it organizational protocol or network limitations, communication delays can severely disrupt workflow, and may pose barriers for mission success.

Looking to future military operations, the U.S. Armed Forces envision a modernized, fully integrated battle command network, linking battlefield assets, thereby enhancing information sharing and ultimately decision making (Office of Force Transformation, 2005). To this end, several digital communication systems have been developed. Data from recent field tests of these systems reveals that information latency or delays associated with these systems range from low (< 500 ms) to medium (500 – 1500 ms), and high > 1500 ms. "Low" typically correlates to terrestrial networks where members are within a single network and the neighbors are within reach within one hop. Delays in this group are typically low (<100ms), but can scale due to network loading. The medium range is typically observed under multi-hop conditions, latency across multiple networked systems, or because of network fragmentation & healing. High latencies can be attributed to satellite communication (SATCOM) delay and multi-satellite hops (email correspondence from G. Bricerno, August 13, 2012). In a separate field experiment conducted at Fort Dix, NJ, network performance was assessed in terms of latency and message completion rate. Data indicated that average message latency (one-way) ranged from 0.16 seconds to 1.8 seconds (Bowman & Zimmerman, 2010). These field data suggest that delays are a salient problem with distributed communication.

Empirical studies have also been conducted to shed some light on the issue of communication delay in remote communication. Conversations are managed through the refined timing of speaking turns (i.e., an individual utters something and then waits for an acknowledgement or response from their partner). However, when an auditory delay is present, the utterance does not reach the intended recipient immediately, rather there is some interval of time that passes. Although the recipient believes they responded immediately, their response is delayed, creating a context for interruptions and overlapped speech (Dove-Steinkamp, 2012). Delayed or interrupted responses make it difficult for participants to follow the conversation and extract shared meaning (Olson & Olson, 2000). This effect has been observed with delays as short as 300 msec (Dove-Steinkamp, 2012). Further, Olson et al., (2000) state that when communication is delayed participants tend to communicate less information with their colleagues, become frustrated, and tend to terminate conversations sooner. An interesting finding of Brady (1971) was that participants were unaware that a delay was present despite having completed a 10-minute conversation with a constant 600 msec delay (Dove-Steinkamp, 2012). Brady did observe, however, that conversations were still affected by the delay as participants noted experiencing confusion and overlapped speech. Brady (1971) concluded that even though participants are not aware of the delay, they realize that something is not right and try to make sense of it. In so doing, they tend to attribute communication issues to the other team member involved in the conversation.

Delayed feedback and disrupted turn taking may also have consequences for the social and emotional experience of team members. Parkinson & Lea, (2011), studied immediate feedback and feedback, with a delay of 200 msec. The authors concluded that “lacking immediate interpersonal feedback seems to result in greater disengagement from interaction when you do not share the other’s opinion about a topic.” In general, participants experienced a better sense of connection with their partner when temporal resolution is high (Parkinson et al., 2011). In a study of the effect of communication delay on the intra and inter-group interaction of minimally acquainted ethnic groups, Pearson, West, Dovidio, Renfro-Powers, Buck, & Henning (2008), found that a delay in audio-visual feedback resulted in higher anxiety levels among partners, and diminished their desire for contact among intergroup conversational partners (Pearson et al., 2008).

In summary, the continued proliferation of distributed teams and mediated forms of communication in work settings has ensured that the problems associated with communication delays will not soon disappear (Armstead, 2007). Further, research into the effects of communication delays on performance is needed to fully utilize the flexibility that distributed arrangements allow and to maximize the interactions of teams operating in distributed environments. While previous research has shed some light on the communication delay dilemma there are still some important questions that remain unanswered. While the focus of the majority of studies has been to examine the effect of communication delay on team task performance and conversations, few studies have addressed the effect of communication delay on team processes such as team member trust and shared understanding. Further, group factors such as gender and team member familiarity could potentially moderate the effect of communication delays, as could different communication technologies, but these topics have not been adequately addressed in the literature. Therefore, the objectives of this research are to further the existing literature by: understanding how audio communication delays effect shared understanding, interpersonal trust, team member satisfaction and workload (2) to understand how the rich social cues provided by video technology affect the ability of teams to manage their interaction when their communication is delayed and (3) to understand how group factors such as gender and team member familiarity may moderate the effect of communication delays.

In the balance of the paper, we provide a brief description of the associated literature that motivated our research hypotheses. We then detail the design of the experiment and describe our expected contribution to the current body of knowledge.

RESEARCH QUESTIONS:

1. What effect do audio communication delays have on distributed team trust, shared understanding (task accuracy), satisfaction, and cognitive workload?

2. What effect does a video channel have on distributed team trust, satisfaction, and team member cognitive workload, when team member communication is delayed?

LITERATURE AND HYPOTHESES

Communication Technologies

For the purposes of this research, we will focus on synchronous audio and video communication technologies. Text-based technologies will not be used.

Audio

With respect to audio technologies, the audio channel is considered to be the most important communication channel for remote collaboration (Olson et al., 2000). In fact, the literature states that for remote activities, users perceive audio quality and responsiveness as being more important than video (Wainfan & Davis, 2004). Compared to text-based media, audio communication makes conversations more personal and participants less “anonymous” (Kies, Williges, & Rosson, 1998). Audio technology facilitates the rapid transmission of certain verbal backchannels (i.e., “huh” and “ok”), that help regulate the conversation and enables team members to make sense out of the conversation. Along with these advantages of audio conferencing, there are also some drawbacks. For example, “Audio conferencing removes all visual cues about other participants, reducing the ability to show understanding or agreements, forecast responses, enhance verbal descriptions, manage extended pauses, express attitudes through posture or facial expression, and provide nonverbal information” (Isaacs & Tang, 1993). When visual cues are absent it becomes difficult to regulate the timing of feedback, manage turn taking, monitor speaker changes and understand discussions (Isaacs et al., 1993).

Video

Video technologies transmit nonverbal information such as gaze, gestures, and facial expressions that are non-existent in audio-only or text-based technologies (Isaacs et al., 1993). Team members can visually observe their team members actions, their status, what they are doing, the physical objects that are present in their immediate environment and any events that occur (Hinds et al., 2003). An interesting finding of research on communication technologies is that users like each other better when using technologies that include video, perhaps because the “richer” social cues provided by the video channel tend to enhance the “sense of presence” - the degree that team members feel as though they are with their conversational partners (Hinds et al., 2003). In addition, a few studies suggest that visual cues benefit conversations (i.e., turn taking, feedback) and assist team members in interpreting the nonverbal cues that are important for mutual understanding (Gergle, Kraut, & Fussell, 2006). Further, video technology may be advantageous for tasks that rely on social cues such as conflict resolution and negotiation (Olson et al., 2000). Still, other researchers suspect that the rich social cues that video technologies provide may help engender trust among team members (Salas et al., 2001) and facilitate conversational grounding which facilitates shared understanding among distributed team members (Hinds et al., 2003). If nothing else, a reasonable benefit of video technology would be a sense of satisfaction among team members and motivation for them to collaborate more frequently (Isaacs et al., 1993).

INTERPERSONAL TRUST

Trust is needed for teamwork, because as team members work interdependently, they must be willing to accept a certain amount of risk to rely on each other to meet deadlines, contribute to the team task, and cooperate without subversive intentions (Salas et al., 2001). A frequently cited definition of interpersonal trust is provided by Mayer, Davis, & Schoorman (1995): “the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other party will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party.” Two components of interpersonal trust consistently emerge in the literature: a cognitive element and an affective (emotional) element. Cognitive trust is based on beliefs about others competence and reliability. Cognitive trust develops as team members consistently demonstrate their competence (i.e. solving difficult problems) and reliability, as demonstrated by team members when their words are consistent with their actions, for example, meeting deadlines (Rocco et al., 2001). Affect-based trust arises from emotional ties and reflects beliefs about reciprocated care and concern for others (Webber, 2008). It is demonstrated as team members openly share ideas, feelings, and concerns with others, with confidence that teammates care for one another.

In the literature, communication processes are described as key for the establishment of interpersonal trust (Gibson & Manuel, 2003; Rocco, Finholt, Hofer, & Herbsleb, 2001). Communication among team members provides a means for members to socialize and learn about each other, engenders development cooperative relationships, and lays a foundation for future interaction (Gibson et al., 2003). Communication frequency and the level of social interaction have been shown to facilitate affect-based trust (McAllister, 1995). In addition, open and prompt communication among members is believed to be essential for trusting relationships, especially with respect to affective trust (Rocco et al., 2001). Without proper communication team members are not able to voice their differences, creating a climate where conflict can arise. Through communication, team members can express themselves and their opinions, so that conflicts can be averted (Gibson et al., 2003).

Trust is presumed to be easier to generate and sustain when team members are proximate because collocation permits greater knowledge of others and aids in the formation of collective identity. Regular face-to-face contact has been shown to facilitate a higher degree of trust suggesting that visual isolation inhibits the development of trust (Wilson, Straus, & McEvily, 2006). Further, Zheng, Veinott, Bos, Olson, & Olson (2002) demonstrated that a photograph may be used to help build interpersonal trust among team members when face-to-face meetings are not feasible because the photo promotes feelings of accountability since team members, will be easily recognizable by their fellow team member in the future.

SHARED UNDERSTANDING

Shared understanding – a collective way of organizing relevant knowledge – can have significant effect on the ability of teams to coordinate work and perform well (Hinds et al., 2003). In distributed teams shared understanding is considered a critical enabling factor for distributed team performance. However, the process of developing shared understanding is more challenging for distributed teams since members rely heavily on mediating technologies to communication, do not share the same work context, and are not geographically proximate. These factors can be barriers for the establishment of shared understanding in teams. In order for team members to develop shared understanding they must be able to communicate and share information. Therefore, we anticipate that communication delays will make it more difficult to share information with their team member and maintain turn taking during their discussion, so team members will be more prone to solve the task without having a complete shared understanding of the solution. Further, distributed teams with no history working together may have difficulty communicating because they have not developed a "shared language" to facilitate their collaboration. Veinott, Olson, Olson, & Fu (1997) found that video can be beneficial for members of a team that do not share the same native language, but need to establish common ground.

HYPOTHESES:

From the literature summarized above, we developed the following research hypotheses:

Hypothesis 1: Increases in communication delay will result in lower task accuracy (shared understanding), less information shared, lower team member satisfaction scores, and lower interpersonal trust scores.

Hypothesis 2: Increases in communication delay will result in subsequent increases in team cognitive workload.

Hypothesis 3: Video technology will moderate the effect of communication delay such that task accuracy will be higher than audio-only, more information will be shared via video than audio, team member satisfaction scores and interpersonal trust scores will both be higher with video than audio.

Hypothesis 4: Video technology will moderate the effect of communication delay such that cognitive workload will be lower in the video condition than the audio condition.

THEORETICAL APPROACH

As an alternative to traditional system design approaches, Hammond, Harvey, Koubek, Compton, & Darispudi (2005) suggest that sociotechnical systems (STS) theory may be an effective framework for studying distributed work groups. Sociotechnical system design is based on the premise that an organization or work system is comprised of three subsystems: a technological subsystem, personnel or social subsystem, and a work system design composed of the organization's structure and processes (Hendrick, 2007). These three elements interact with one another and with the relevant aspects of the external environment to produce physical and social outcomes (Hendrick, 2007). A key emphasis of sociotechnical design is consideration of both the social and technological aspects of work systems (Kleiner, 2008). How well these systems are designed with respect to one another and with respect to the demands of the external environment, determines to a large extent how effective the organization will be (Walker, Stanton, Handy, Monnan, Jenkins, & Salmon (2007). In STS theory, this concept is known as joint optimization. When work systems are "optimized", the social and technological subsystems work in harmony and relationships between the social and technical elements lead to positive outcomes such as greater productivity, employee satisfaction, and lower absenteeism, rather than the all too familiar experience of new technology failing to meet the needs of the user (Walker et al., 2007). With respect to the current research, a sociotechnical systems approach entails systematically analyzing the effect of the technological subsystem (e.g., communication technology and delay) and external environmental factors (e.g., lack of co-location) on the personnel subsystem (i.e. distributed team members) within the organization (Cuevas, Fiore, Salas, & Bowers, 2004). It is our hope that adopting a sociotechnical systems approach to investigate how communication delay alters team member interaction will enable organizations to effectively utilize the technological subsystem's capabilities to support distributed team effectiveness (Cuevas et al., 2004).

PROPOSED RESEARCH

To accomplish the objectives of this research, a laboratory experiment will be conducted. In the next section we will describe the proposed experiment.

Participants

Seventy-two participants will be recruited from the civilian and military population at Aberdeen Proving Ground. Detailed information about the experiment will be given to participants, and upon giving their consent to participate, will read and sign a Volunteer Agreement Affidavit. After giving their consent, participants will be assigned to a team comprised of two members (a dyad). Dyads will be same gender or mixed gender. Half of the dyads will have prior experience working together and half will have no prior experience (i.e. a nominal, ad hoc team). Dyads will remain the same for the duration of the experiment. A coding scheme will be employed to identify the data by participant number only (e.g., Subject 1) to maintain anonymity. All video recordings will be kept confidential and will be erased after data reduction.

Task Environment

The Experimental Laboratory for Investigating Collaboration, Information Sharing, and Trust (ELICIT) software platform is the experimental task selected for this experiment (Ruddy, 2007). ELICIT is a computer-based multiplayer intelligence game in which participants "play" the roles of networked intelligence analysts whose goal is to uncover a fictitious terrorist plot and prevent the attack from occurring. To successfully solve the plot and win the game, team members must collaborate and share pieces of information called clues or "factoids". There are four types of factoids that represent information about the anticipated attack: *who* factoids provide information about the likely actors involved, *what* factoids describe the target, *where* factoids describe the place of attack (i.e. a country), and *when* factoids describe the month, day and time of the attack (Table 1). Some of the factoids provide key information, some provide supporting information and some provide non-relevant information or "noise". There are a number of factoid sets included in the ELICIT software; each factoid set contains different factoids related to different terrorist plots, and has a different solution.

Table 1. Sample factoids

Who Factoid: The Chartreuse group is not involved
What Factoid: A new train station is being built in the capital of the country of Tauland
When Factoid: The attack will be at 11:00
Where Factoid: The Azur, Brown, Coral, and Violet groups have the capacity to operate in Tau, Epsilon, Chi, Psi, and Omega lands.

During each experimental session, groups of factoids are distributed to team members' computer displays. The experimenter controls which factoids are distributed to each team member and at what time during the scenario they are distributed (i.e., every 7 minutes). This is accomplished through setting the time parameters in ELICIT. For this experiment, different factoids will be distributed to each team member, to ensure that the task is truly collaborative and creates a context where team members are interdependent and must share the information with one another. Factoids will be distributed in 3 waves: at the start of a trial after 5 minutes, and after 10 minutes. Task success (i.e. arriving at a correct solution) requires team members to communicate and discuss the factoids. Teams will be encouraged to solve the task quickly without sacrificing accuracy and will be given 15 minutes to complete each session of ELICIT. After sharing and discussing the factoids, team members will enter their proposed solution consisting of *who, what, where, and when* using the ELICIT Identify window.

Experimental Facility

The experiment will take place in the Cognitive Assessment and Engineering Laboratory (CASEL) at Aberdeen Proving Ground, Maryland. The CASEL is a unique research facility that provides resources for conducting separate or networked studies of individual, team, and human-robot performance. For the present study, each participant will be seated in a separate sound-attenuated room interconnected through a local area network. A video camera mounted on the ceiling of each experimental room will be used to monitor participants. In addition, each room is equipped with a Dell desktop computer hosting the ELICIT client software, a Samsung 22 inch LCD flat panel display, a computer desk, and a video camera that is used to both facilitate the video-mediated environment and video recording during the experimental sessions.

Audio-Mediated Environment

For the audio condition, team members will be seated at a computer desk in separate rooms. Factoids will be displayed on a Samsung 22" flat screen LCD monitor located on the computer desk. During the experiment, participants will discuss the ELICIT factoids using a Labtec® stereo 342 headset with microphone over a full-duplex audio channel. Participants in the audio condition will not be able to see one another during the experimental trials. Their conversation will be recorded throughout the duration of the experiment for analysis purposes. Following data reduction and analysis, all recordings will be destroyed.

Video-Mediated Environment

For the video condition, team members will be seated at a computer desk in separate rooms. A Samsung 22" flat screen LCD monitor will be placed on the desk in front of each team member. Factoids will be displayed on the left side of the flat screen LCD monitor. Video images of each team member will be captured using a desktop mounted video camera, a Sabrent USB 2.0 video capture dongle, and the video capture software package ULEAD Video Studio. Video is captured at 30 frames per second (FPS) and will be displayed on the upper right hand corner of the LCD computer monitor. Approximate size of the video image displayed on the LCD is 3 inches x 4 inches. As in the audio condition, participants will communicate using a Labtec® stereo 342 headset with microphone. Conversations for the video-mediated teams will also be recorded for analysis purposes.

Delay technology

The DelayLine Video and Audio Delay System (Allen Avionics, Inc.), a commercially available product will be used to delay the audio messages being exchanged between team members. NOTE: for trials using video, the video will be synchronized with the audio. The length of audio delay can be adjusted in 200 msec intervals to arrive at desired delay levels up to a maximum delay of 3.2 seconds.

EXPERIMENTAL DESIGN

The proposed study is a 2 x 3 repeated measures design. Independent variables are, delay length and type of communication technology. The independent variables and their associated levels are shown in Table 2. Treatment conditions will be counterbalanced. Dependent variables are task completion time, shared understanding, conversational parameters, interpersonal trust, workload, and team member satisfaction. Conversational parameters will help us better understand how conversations are influenced by technology and delay and will help us understand how team members manage their conversations in the presence of delays. Each dependent measure is described in more detail below.

Table 2. Independent variables and levels

Variable	Levels	Factor type
Delay	800, 1600, 3200 msec	Within-subject
Technology	Audio, Audio-visual	Within-subject

MEASUREMENTS

Objective measures:

Shared understanding – measured as accuracy of the solution to the fictitious terrorist plot. Each Identify action is scored with a value of 1 for each correct answer to the Who, What, and Where aspects of the solution. The When aspect consists of three components (i.e., month, day, and time), so, to avoid weighting this aspect more heavily than the other three, each Identify action is scored with a value of 1/3 for each correct answer. The resulting sum is divided by four to construct a [0-1] scale. For instance, if a team correctly identifies the Who, What, and Where aspects, but is correct only on the day and not the month or time components of the When aspect, their accuracy score would be calculated as: accuracy = (1 + 1 + 1 + 1/3)/4 = 0.83.

Percentage of factoids shared. Calculated by taking the number of factoids shared between team members and dividing by the total number available * 100.

Subjective measures:

Demographic and Computer Experience Questionnaire. A questionnaire will be used to obtain demographic data and assess participant's familiarity with various communication technologies.

Workload Rating Scale. The NASA Task Load Index (TLX) workload rating scale will be used to assess the perceived cognitive workload of each team participant after each experimental trial.

Interpersonal Trust Questionnaire. Interpersonal trust (composed of cognitive and affective trust) will be measured using a trust scale, originally developed for use with dyads. (McAllister, 1995). Respondents will rate statements about their teammate use using a rating scale from 1 (strongly disagree) to 5 (strongly agree). Trust measures will be taken after each experimental session.

Satisfaction Questionnaire. This questionnaire was adapted from van der Kleij, Schraagen, Werkhoven, & De Dreu (2009) and includes five items pertaining to satisfaction about the task, other members, and the process of interacting with team members. All items will be scored using a rating scale from 1 (very satisfied) to 5 (very dissatisfied). Satisfaction measures will be taken at the end of each experimental session.

Procedures

Two volunteers will arrive at the CASEL facility and will be seated in separate rooms. They will receive information describing the purpose of the experiment and what is expected of them. Afterwards, participants will read and sign a Volunteer Agreement Affidavit indicating their consent to participate in the study. Any questions participants may have will be answered. When all questions have been fully answered, participants will fill out a demographic questionnaire to obtain information about their current level of experience with computers, as well as experience with either audio or video communication technologies.

Following the demographic questionnaire, participants will complete a training session. During the training session, participants will complete a training version of the ELICIT task to familiarize them with the factoids, how to use the communication technology to communicate with their team member, and how to identify the "who, what, when, and where". The training version uses a different factoid set from the factoid sets being used in the experiment. During the training session, participants must interact, using either audio or video technology, and discuss the factoids to arrive at a solution. No delays will be used during the training. The training session takes approximately 10 minutes to complete. Any questions will be answered following the training session and then participants will be given a brief break. For the break, each team member will be escorted to separate waiting areas to reduce their interaction between sessions.

For the experiment, team members will perform the ELICIT task. At the beginning of the experiment, each participant will receive different "factoids" related to the problem they are trying to solve. This will be done so that neither team member has enough information to solve the problem on their own; team members must communicate and share their factoids to arrive at a feasible solution. Again, team members will communicate via either audio or video technology and they will experience a delay as they communicate and share information with their team member: either 800, 1600, or 3200 msec. So, a team member will speak a message during the conversations and the transmission of the message to the other team member will be delayed. When the team is ready to solve the problem they will enter their proposed solution into the ELICIT Identify window and click OK. This provides both the solution to the problem and a measure of task completion time. Each session of ELICIT will take approximately 15 minutes to complete. After completing a session, participants will fill out their questionnaires and will be given a short break, after which they will perform another session of ELICIT. Participants will complete a total of six experimental sessions. Approximately 2.5 hours is needed to complete the entire experiment.

Data analysis

Data will be analyzed in a 2 (technology) x 3 (delay) repeated measures ANOVA. The probability of a Type I error will be maintained at Alpha Level .05 for all analyses. Significant effects will be further analyzed using Tukey's Honestly Significant Difference (HSD) test. In addition, a supplemental data analysis, including descriptive statistics and ANOVA, will be conducted to examine the relationships that exist between gender, familiarity, and delay. Although these factors were not factors that were manipulated in study 1, the data will enable us to select the most logical variables and levels for inclusion in a follow-on study.

CONTRIBUTION

To date, few studies have examined the effect of audio communication delays on team processes and performance, especially with respect to how delay affects the development of critical team processes such as shared understanding and trust. Results from the present study will help expand on our current knowledge of distributed team communication and provide insight into how communication delays affect distributed team interaction in a network enabled environment.

Although results of existing research examining the benefit of a video channel have been mixed with respect to how video affects team task performance, studies have shown that visual cues are an important aspect of conversations. In the present research, we will further the findings of the existing research by providing information concerning the effect of video-mediated communication on the development of shared understanding and trust in remote teams. Specifically, we expect that the inclusion of a video channel will help moderate the effects of communication delays, resulting in increased task accuracy (shared understanding) and a higher level of trust than in conditions with just audio technology since the video provides more social context cues and will enable team members to establish rapport more quickly than if video was not present. Consequently, we expect participant perceptions of trust and satisfaction to be higher for video-mediated teams than for audio-mediated teams. Further, we expect that, compared to audio-mediated communication, video communication will lead to lower mental workload.

Finally, gaining an understanding of the effect of audio delays on team interactions will enable organizations to fully utilize the flexibility that distributed arrangements provide without compromising team effectiveness. Moreover, what we glean from the present research will enable us to propose strategies to minimize the deleterious effects of delay, thereby optimizing those team processes that are essential to successful team performance. It is our hope that adopting a sociotechnical systems approach to investigate how communication delay affects team member interaction will enable organizations to effectively utilize the technological subsystem's capabilities to support distributed team effectiveness.

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