Mixed Media Richness and Computer-Mediated Communications

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Thesis submitted to the Faculty of Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science

In

Industrial and Systems Engineering

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April 18th, 2006

Keywords: social presence, media richness, computer-mediated communications, CMC, computer-supported cooperative work, CSCW, mixed-media communications, mixed-richness communications, mixed-mode communications

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(ABSTRACT)

Mixed richness communications occur when a participant in a conversation receives a different media or combination of media than they transmit. Mixed richness communications occur in the workplace when technical, physiological or practical limitations prevent the use of the same media on both ends of a conversation. Prior research in CMC has focused on same-richness communications, and the design guidelines that are available for same-richness communications may not be applicable to mixed-richness communications. This study attempts to establish a basis for understanding mixed-richness communications by evaluating same-richness communications using concepts and measures previously applied to mixed-richness communications.

Media Richness Theory (Daft & Lengel, 1984, 1986) defines the richness of a communication medium in terms of its ability to reduce uncertainty and equivocality. According to Daft and Lengel's task-media fit hypothesis, communications are most effective and satisfying when the media richness matches the level of uncertainty and equivocality in a task.

Social presence is the perceived ability of a medium to transmit the social cues that lead to a sense that the medium is "warm, personal, sensitive, and sociable" (Short, Williams, & Christie, 1976). Social presence has been suggested to be a predictor of user satisfaction for computer-mediated communications (CMC), and has been used as measure of media richness in previous studies (Rice, 1993; Yoo & Alavi, 2001).

This study examined the effects of communication medium and task equivocality on task performance, communication effectiveness and sense of social presence. Pairs of participants were required to complete high and low equivocality collaborative tasks while communicating with each other using CMC. The communication media varied between participants. During some sessions, participants received and transmitted the same media (video-only or text-only). In other cases, participants transmitted text and received video or vice-versa.

From the recorded transcripts of each user session was extracted task performance in terms of task time-to-complete and communication effectiveness in terms of the frequency of communication breakdowns. Based on the task-media fit hypothesis, it was expected that task performance and communication effectiveness would be affected by the interaction between communication medium and task equivocality. For the most part, task-media fitness was not confirmed. Only one of the four hypotheses supporting task-media fitness was confirmed for time-to-complete, and none of the four hypotheses supporting task-media-fitness was confirmed for communication breakdown frequency.

In the overall analysis of time to complete, Medium was found to have had a significant effect. Sending and receiving text was significantly slower than all other tested media. Sending and receiving video was significantly faster than all other tested media combinations.

After completing each task, participants completed a short questionnaire designed to measure the sense of social presence using the original scales developed by Short and Christie. The sense of social presence reported in video communications was significantly higher for all scales than the sense of social presence reported in mixed-richness environments. The sense of social presence reported in text communications was only significantly lower than mixed-richness environments for one scale, with no significant difference for all other scales.

Acknowledgements

I would like to thank my advisor, Dr. Kleiner for his guidance and for his continued patience, support and encouragement during the lengthy process of completing this document.

Thanks also to Drs. Smith-Jackson and Perez for providing their input and feedback.

Thanks to my graduate colleagues for talking through many issues with me in depth. In particular:

- Thanks to Chuck Perala for his assistance in reviewing and repeatedly talking through my research over breakfast.
- Thanks to Boon Kee Soh for coming to my house at all hours of the night to repeatedly talk through my experiment and help figure out how to input my experimental model in SAS.
- Thanks to Kevin Packard for helping figure out how to input my experimental model in SAS.
- Thanks to Dennis Neale for talking through my topic, the related literature and experimental design at length, and for providing feedback during the dress rehearsal for my proposal defense.
- Thanks to Miranda Capra for providing guidance on developing design goals.

Thanks to my friends and family for providing much needed breaks from work and study, and for understanding my prolonged absences during periods of heavy activity.

Thanks to my supervisor and coworkers for encouraging me to work on my studies and respecting my need to take time off to work on my thesis.

Finally and most importantly, thanks to my wife Elaine for her love and support throughout the seemingly endless process of completing my thesis.

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Chapter 1 - Introduction

1.1 Overview

This section discusses computer-mediated communications and their use in the workplace. Mixed-media communications are also discussed. The concepts of media richness, social presence, and the relationship of social presence to media richness are discussed. A review of the existing literature on computer-mediated communication, media richness, and social presence is included.

1.2 Computer-Mediated Communication

Computer-mediated communication (CMC) is a term used to describe any communication between users in which any combination of audio, video, text or graphics is transmitted from one user to another through the use of a computer. This can range from asynchronous media like email, web pages and stored voice recordings to near-synchronous media like Instant Messaging and Internet Relay Chat to synchronous media like teleconferencing and videoconferencing. In terms of computer-supported cooperative work (CSCW), CMC can be thought of primarily as a group communication support system rather than a group decision support system (Cano, Meredith, & Kleiner, 1998).

The speed of each form of CMC is limited first by the delays inherent in all information processing. This is illustrated in Figure 1-1, which is an extension of a diagram from Wickens and Hollands (Wickens & Hollands, 2000). Outside of the individual's processing, there are delays in transmission between individuals. Where the transmission of content in face-to-face conversations is limited by the speed of sound and light, the transmission of content via CMC is limited by the design and implementation of the medium itself, as well as by variable conditions in the computing environment such as network congestion.

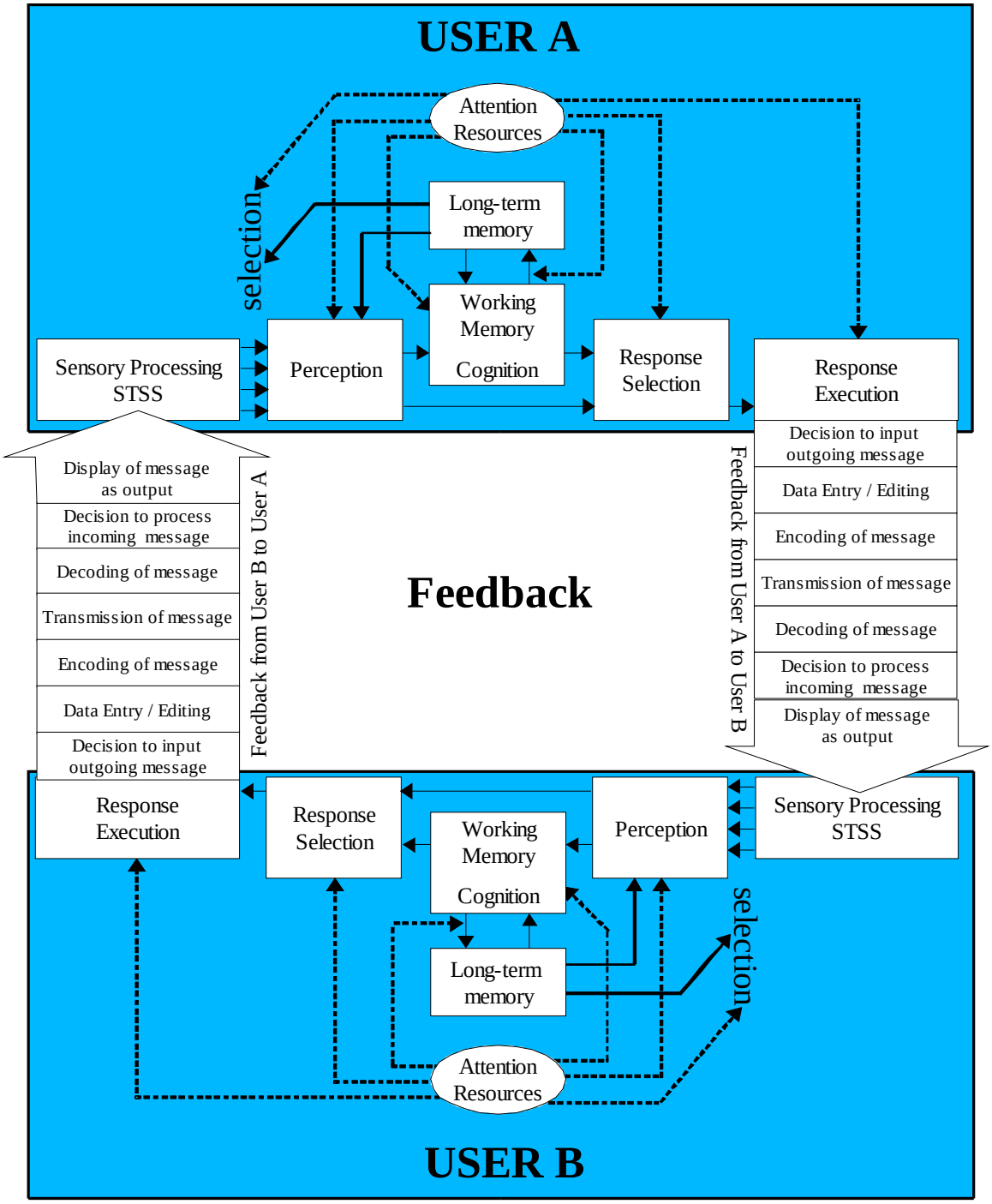

Figure 1-1. Model of human information processing (Wickens & Hollands, 2000) as applied by the author to computer-mediated communication between two users

Synchronous media offer more immediate feedback (see section 1.4 for more detail). As shown in Figure 1-2, synchronous media minimize the delays in communication related to encoding and transmitting messages. In particular, synchronous media do not introduce

enough delay to give users time to concentrate on other tasks. As such, the time required for a user to decide to process an incoming message or to decide to send a response is eliminated.

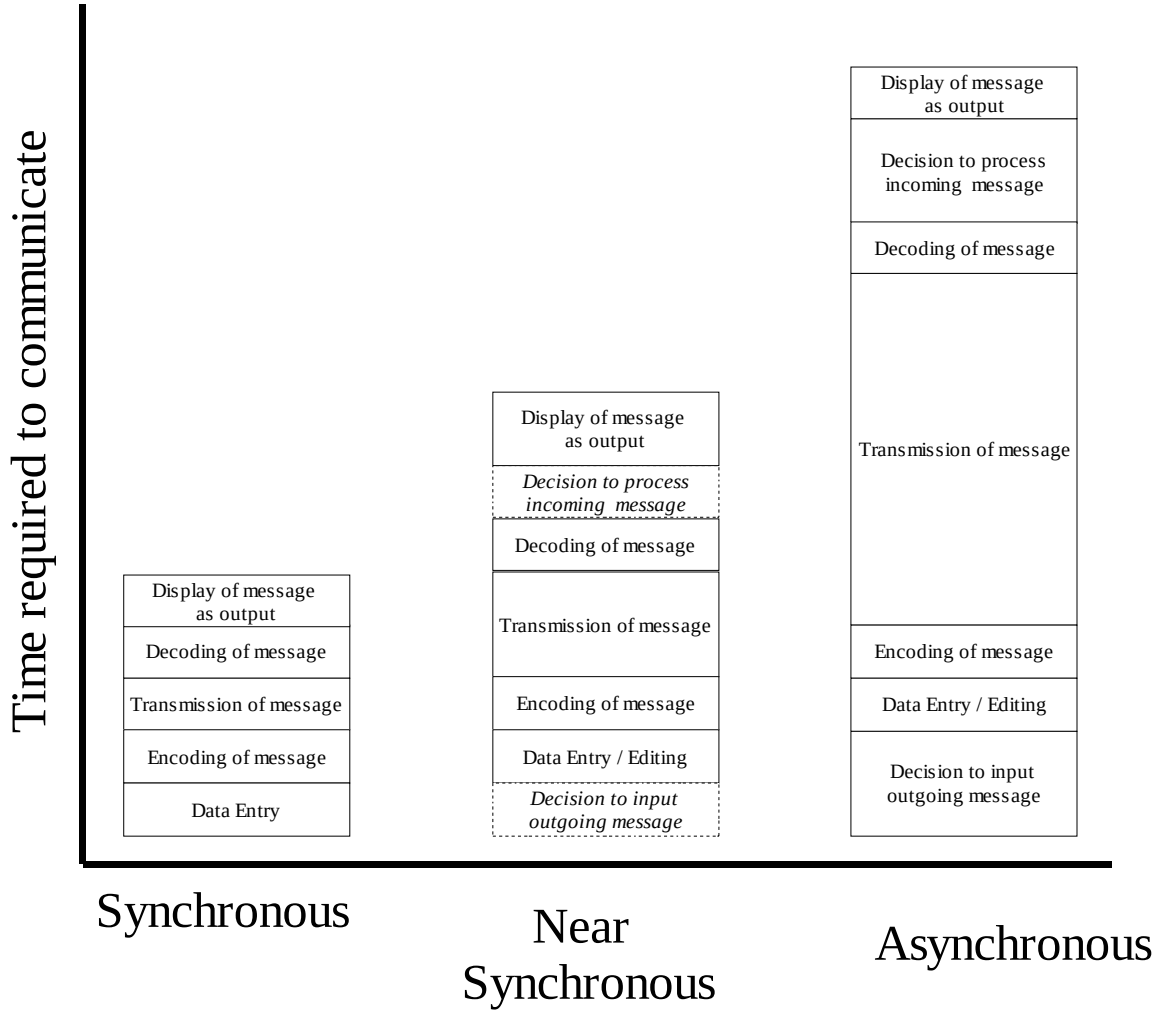

Figure 1-2. Comparison of processing delays in synchronous, near-synchronous and asynchronous CMC

Asynchronous media like electronic mail and electronic reports introduce enough of a delay that other activities often occur between the sending of one message and the receipt of the response. As such, one advantage of asynchronous media is that they can be more easily incorporated into other work, and are less interruptive than synchronous technologies like videoconferencing, which require coordinating the schedules of participants, and do not provide pauses in which other work can be done. Asynchronous media also offer the opportunity to collect information from external sources as well as the opportunity for self-editing, both of which are less possible during synchronous communications.

Near-synchronous media like Instant Messaging still impose a delay in communications, but are closer to synchronous media than to asynchronous media. Instant messaging in particular varies in synchrony as conversants become available for conversation or leave their connection unattended and cease responding immediately to incoming messages. A central assumption of this study is that near-synchronous communications vary in timing between the timing of a conversation and the timing of correspondence.

Mixed-mode communications are a relatively new phenomenon. Mainstream commercial programs like AOL Instant Messenger(America Online, 2004) and iChat (Apple Computers, 2004a) now support the ability to communicate using different media on each end of the conversation. See Figure 1-3 for an example of a conversation between the author (pictured) and an unseen friend. The conversation pictured was conducted using iChat. The author's part of the conversation was conducted using audio and video. The other party in the conversation used text messages to communicate. You can see common features of text chat such as emoticons (see Appendix H) in the text transcript pictured below.

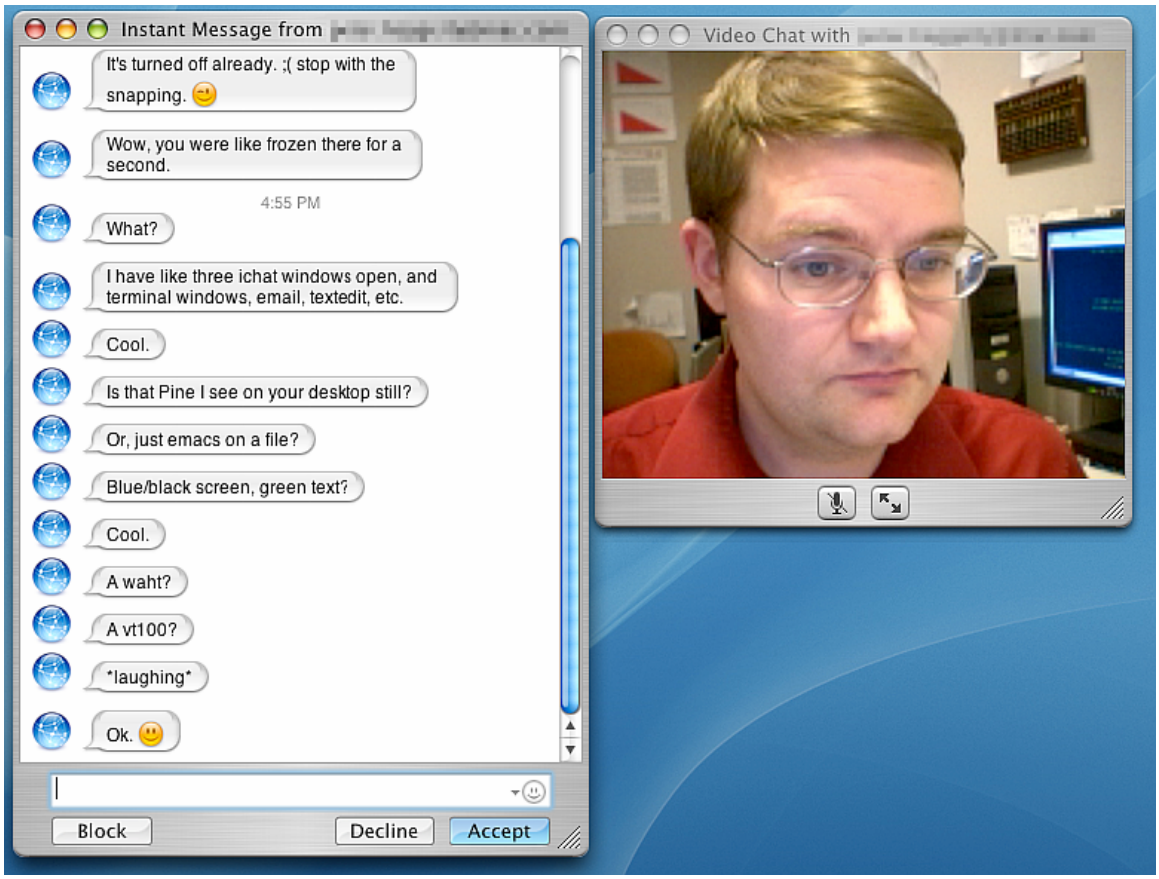

Figure 1-3. Screen shot of a mixed-mode communication session between the author (pictured) and a friend (not pictured).

As the technology available has progressed, so has the technological environment in which CMC has been studied. There is a continued need to apply the body of knowledge

amassed thus far to new media. In particular, the questions that have been asked of same-richness environments have not been asked of mixed-richness environments.

1.3 Workplace Relevance of Computer-Mediated Communication and Mixed-Media Communications

1.3.1 Workplace Relevance of CMC

Given the penetration of broadband internet access into most workplaces and around 60% of U.S. homes (National Telecommunications & Information Administration, 2004), the range of CMC is more extended than ever. Workers communicate with their office from home, with other offices from their home office, and with their office and home while traveling. Meetings and collaborations between workers often involve a mixture of face-to-face contact, videoconferencing, audio conferencing, and text. Technologies like Electronic Mail are already ubiquitous. Technologies like Instant Messaging and Voice over IP (see Appendix H) are growing in usage as well. Factors like the cost and time (Cano et al., 1998; Zmud, Lind, & Young, 1990) involved in traveling to face-to-face meetings also encourage the inclusion of CMC in the workplace.

As an example of new CMC technologies entering the workplace, we now see Instant Messaging (IM) gaining use in the work place (Handel & Herbsleb, 2002; Huang & Yen, 2002; Isaacs, Whittaker, Schiano, & Kamm, 2002). According to Huang and Yen, this is tied to the influx of younger workers familiar with IM in social contexts moving into the workplace. For these and other workers, IM has retained its social uses, but is primarily used for work-related communications (Handel & Herbsleb, 2002; Isaacs et al., 2002). IM is used for obtaining answers to quick questions, clarifying previous discussions, coordination and scheduling (Nardi, Whittaker, & Bradner, 2000). IM is available at a lower cost and with lower bandwidth and equipment requirements than full-motion video or teleconferencing, although many popular IM software packages support video and audio streams where the hardware is available.

Instant Messaging, electronic mail and other text-based communications media are also a means of communication for deaf and speech impaired users (Bowe, 2002). Currently, 4.3% of the population is either hearing or speech impaired (Census, 1992). Using text-based CMC, deaf users can communicate directly with hearing and speaking computer users without the cost of an interpreter. Technologies like Instant Messaging provide one means by which employers can satisfy their obligation to "[make] reasonable accommodations to the known physical or mental limitations of an otherwise qualified individual with a disability" ("Americans with disabilities act of 1990," 1990). Beyond satisfying accessibility requirements, giving deaf users access to computer-mediated communication tools may also increase the speed and ease with which they work with others (Bishop, 2000).

1.3.2 Workplace Relevance of Mixed-media Communications

Work applications where this research is more directly applicable:

- **One-on-one communications between colleagues in private spaces and colleagues in public spaces.**
  Examples: Users working from areas with public internet access.
- **One-on-one professional consultations conducted at a distance.**
  Examples: doctors, lawyers, realtors, accountants, tutors
- **One-on-one interviews conducted remotely.**
- **One-on-one communications with colleagues that can receive rich media but cannot send because of technical or practical limitations.**
  Examples: laptop users, PDA users, public internet workstation users, dial-up users.
- **One-on-one communications with colleagues that can send rich media but cannot receive because of technical or practical limitations.**
  Examples: Truck drivers, cab drivers, delivery personnel
- **One-on-one communications with colleagues that have special needs that prohibit the use of specific media.**
  Examples: Users who can hear but not speak. Users who can speak and hear but who cannot type.

Work applications where this research is less directly applicable:

- **Communications involving groups of more than two persons in any of the contexts mentioned above.**
- **Cases in which one person presents content to a large number of users.**
  Examples: Distance learning, streaming of conference presentations to remote attendees.

Whenever one-on-one communications are conducted, there is the possibility that technical or practical concerns will necessitate the use of mixed-media communications. Technical limitations are typically presented by the hardware, software, and network capacity a user has available to conduct a conversation.

A simple example of a technical limitation occurs when one party in a conversation has the ability to receive audio or video, but does not have a workstation equipped with a microphone. This occurs commonly for laptop users, as embedded video cameras are not widespread and peripheral cameras can be cumbersome to use when traveling. It also occurs for users of PDAs which can commonly play audio and record audio, but which often lack the ability to transmit video.

The limited availability of computing equipment and bandwidth is also a factor in encouraging the use of mixed-media communications. Users who cannot afford a camera and microphone or a computer new enough to support real-time video and audio may also want to explore using text chat as an alternative to video chat. Users without high-speed access may lack the bandwidth to both send and receive audio and/or video.

Factors such as ethnicity, economic status, location (rural vs. urban) and age all combine to create a class of users who do not use the internet at home (Lenhart et al., 2003). Whites tend to have internet access more commonly than non-whites do. Households with higher incomes tend to have internet access more commonly than households with lower incomes do. Suburban and urban dwellers tend to have internet access more commonly than rural users. Homes with persons under 50 tend to have internet access more commonly than homes that only have persons over 50.

Those without internet access and/or a computer at home may find themselves communicating from public computers with low-speed access or a fraction of a shared broadband connection, and may need to explore using text chat or other low-bandwidth means of communication. Users of public computers may also face limitations in that public computers may not have a camera or microphone. Users of public computers may also be located in a setting (such as a library or a shared workspace) in which audio communication is not appropriate for courtesy and privacy reasons. Similarly, it may not be feasible to communicate using audio from a public computer in a noisy environment, such as those found in public areas with free or rental internet workstations.

Finally, although 60% of U.S. homes have internet access, only 19% of U.S. homes have broadband access (NTIA, 2004). Users in the 41% of homes with dialup at home may need options that allow them to communicate within the limitations of their bandwidth. Receiving audio/video and transmitting text may be the only way for these users to participate in teleconferences at a reasonable speed.

There are a number of examples of practical limitations. Users who work in crowded or noisy environments may be able to receive audio using portable earphones, but may have privacy concerns about voicing their portion of the conversation for others to hear. Thus, they may prefer to convey their responses using text chat.

Truck drivers and delivery personnel may be able to attend to audio communications or limited textual information while driving, but it would be less appropriate for them to attend to a video image or send textual information. However, transmitting video would not require added attention on their part. Thus, a driver might receive audio while transmitting both video and audio, or might receive limited text and transmit their response using audio. The added video content might be of interest to employers who are concerned about driver alertness, for example.

There are a few classes of users with special needs to whom mixed-media communications offer practical solutions. Users who can hear but not speak might prefer to participate in an audioconference while receiving audio and transmitting text. Users who can speak but cannot type easily might prefer to respond to a text chat using audio. As an example, mixed-media communications are relevant for deaf or speech-impaired users who make use of telephone relay services. A telephone relay service allows a deaf or speech-impaired user to communicate with another user by way of an interpreter. Typically, the technology would be used to communicate with individuals or businesses that do not have assistive devices such as a TTY available. The deaf or speech-impaired user communicates with the interpreter via text-based CMC such as IM or TTY or via videoconferencing in the case of sign language. In cases where the assisted user is deaf and cannot speak intelligibly, the interpreter translates the message typed or signed into

spoken language and speak it to the user receiving the call. The interpreter listens to the spoken response of the user receiving the call and translates it into typed or signed language for the assisted user. In cases where one party to the call is deaf but can speak intelligibly, the interpreter only translates the responses of the user receiving the call. In cases where the user making the call can hear but cannot speak, the translator only translates the typed or signed messages into spoken language. Current systems depend on the use of trained translators. There has been interest in fully automated systems as well, which would increase the privacy of assisted calls. As the quality of speaker-independent automated speech recognition continues to increase, it is more reasonable to assume that fully automated systems for text relay chat will be available.

Mixed-media environments are also commonly found in distance and distributed learning environments. In a distance-learning course with a live instructor, the instructor is typically provided with the richest media available, a video and audio feed. Some students may participate in the class from the instructor's location, while others may view the instructor remotely from another classroom or even at home. Students in the instructor's location may provide their feedback in person. Students in locations equipped with compatible videoconferencing equipment may provide their feedback to the instructor using a video and audio feed. Students viewing the instructor from their home computer may be limited to providing feedback using IM or chat. In the same class session, a group discussion can involve a mixture of face-to-face, audio, video and text-based CMC.

Mixed-media environments are also used in group conferencing settings. A modern conference call is not limited to telephones, and may involve a mixture of face-to-face participation, telephones, streaming audio and video, and text.

1.4 Media Richness and Task-Media Fit

The concept of media richness was originally developed by Daft and Lengel in their landmark papers published in 1984 and 1986. They defined what they originally called the "information richness" of a communication medium in terms of its ability to reduce uncertainty and equivocality.

1.4.1 Task Equivocality

The most useful definition of equivocality for our purposes might well be "The quality or condition of being… ambiguous" (Brown, 1993). Equivocality is a form of uncertainty, but the concept of uncertainty extends beyond equivocality. Tasks are equivocal when the choices presented are difficult to distinguish from one another. Tasks are uncertain when the goals defined or the measures of success are difficult to gauge. High equivocality tasks are also referred to in the literature as decision-making tasks or preference tasks (Tan, Wei, Sia, & Raman, 1999), while low equivocality tasks are also referred to as intellective tasks (Savicki, Kelley, & Lingenfelter, 1996).

1.4.2 Media Richness

According to Daft and Lengel, the qualities that make a communication medium "rich" are as follows: feedback capability, communication channels utilized, language, and source. Feedback capability is conceived in terms of immediacy, which in their terms is

a measure of the time delay introduced by the medium. A medium such as face-to-face interaction offers immediate feedback with little delay beyond that required for a conversant to consider a response. A less immediate medium such as a formal report introduces greater delay, in that it must be prepared in depth, then read and analyzed in detail. In the case of telecommunications media, feedback capability is also affected by lag, or the delay in communications introduced by the medium itself. Lag can take the form of coding delays (the time it takes to prepare the message) or transmission delays. For telecommunications media that are equal in other ways, the lower the perceived lag, the higher the richness.

Communication channels are simply those aspects of the senses that humans have found useful in delivering information to one another. For the most part, the communication channels used in the workplace are limited to vision, audition, and touch. A medium that enables more communication channels is presumably richer than one that enables less communication channels. The width of each channel is also important. A medium that provides more information along a given communication channel is richer than a medium that provides the same number of communication channels at lower quality. In the case of telecommunications media, the quality and number of communication channels is most closely associated with bandwidth. A low-bandwidth videoconference can in fact be lower in richness than a high-bandwidth telephone call, even though the former has more communication channels available.

Language, or the set of symbols used to communicate, is related to communication channel, in that certain types of language can only be transmitted via particular communication channels. With the possible exception of conversations between deaf-mute finger signers who feel each other's hands, natural language (as Daft and Lengel call it) can only be transmitted via audio (spoken) and visual means (written and signed). Signed or symbolic language is transmitted visually, as is what is commonly called "body language". In addition to spoken language, the overlapping language of prosody (timing, pitch, volume) is also embedded in the audio communication channel. Text-based CMC, which is limited to the visual display of written language (except for those who use screen reading technology), can be considered leaner than a medium like the telephone, which also presents natural language, but which preserves the additional prosodic cues of timing, pitch and volume. The visual communication channel also conveys non-verbal cues such as physical appearance, proximity, and direction of gaze including eye contact (T. S. Andres, Kleiner, & Williges, 1998; Argyle, 1969). The concepts of communication channels and language are related, in that communication channels provide the means by which one or more languages can be transmitted, and determine which languages can be used in a given medium.

Daft and Lengel used the term "source" to refer to whether a medium was perceived to be personal or impersonal. As discussed in the following section, this concept of source relates directly to the concept of social presence.

One important aspect of text-based communications not covered by media richness is the presence of a written record of communications. Electronic mail, text chat, and many other forms of text-based communication offer the ability to record a transcript, which can be reviewed in real-time or after the fact (T. S. Andres et al., 1998). This unique

attribute of text-based media may lessen the need for an individual to rely on their own recollection of what was said.

Figure 1-4 displays a range of commonly used media and their richness based on the immediacy of feedback and the number of languages available.

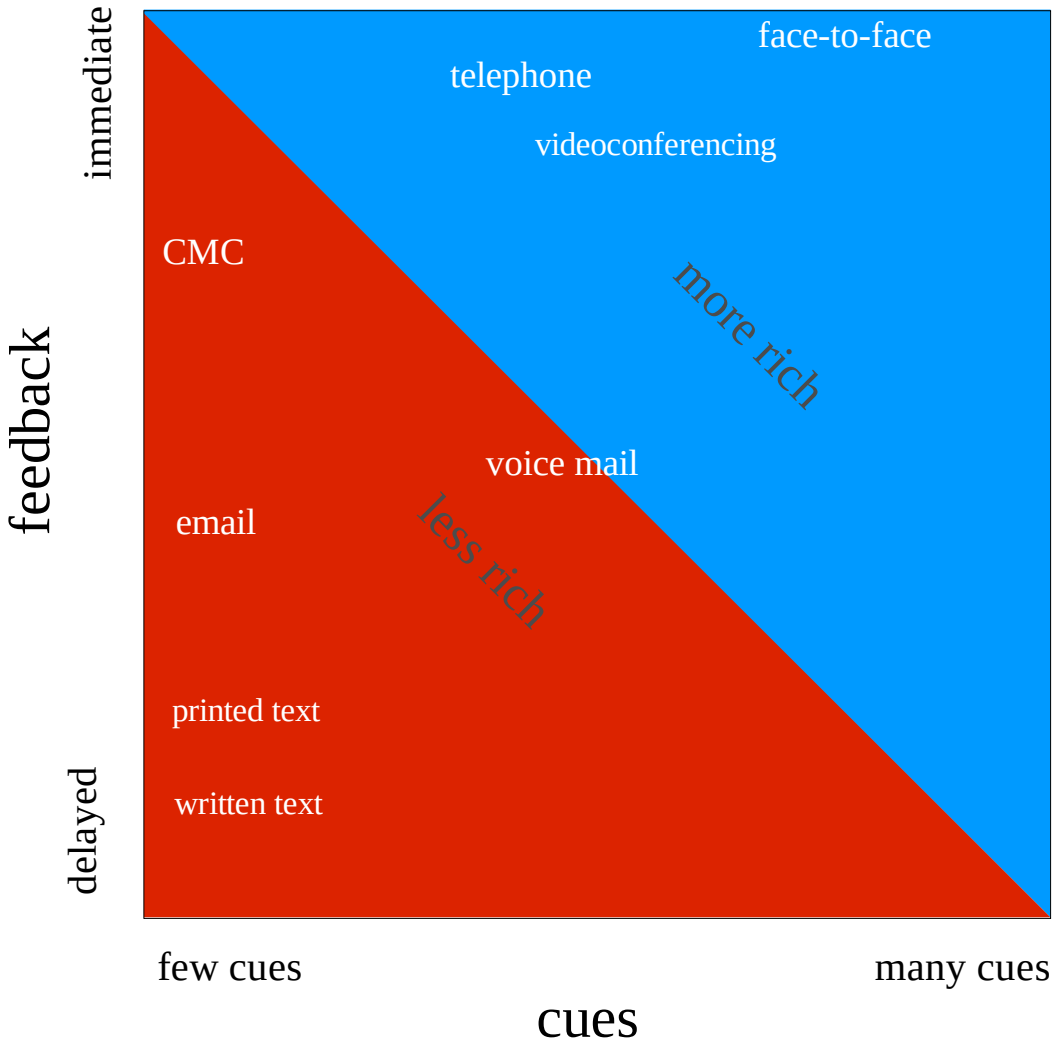

Figure 1-4. Richness of common communications media.

Figure 1-5 displays the relative media richness of the communications media used in this study.

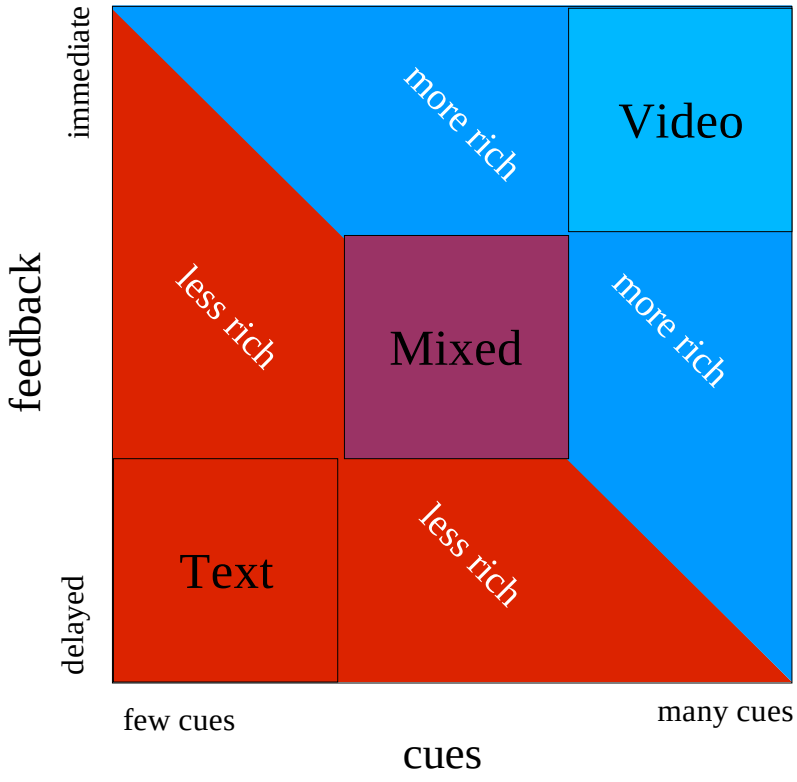

Figure 1-5. Richness of communications media used in this study.

To test whether mixed-richness media are truly somewhere in between text and video, two planned comparisons will be used, as diagrammed in Figure 1-6.

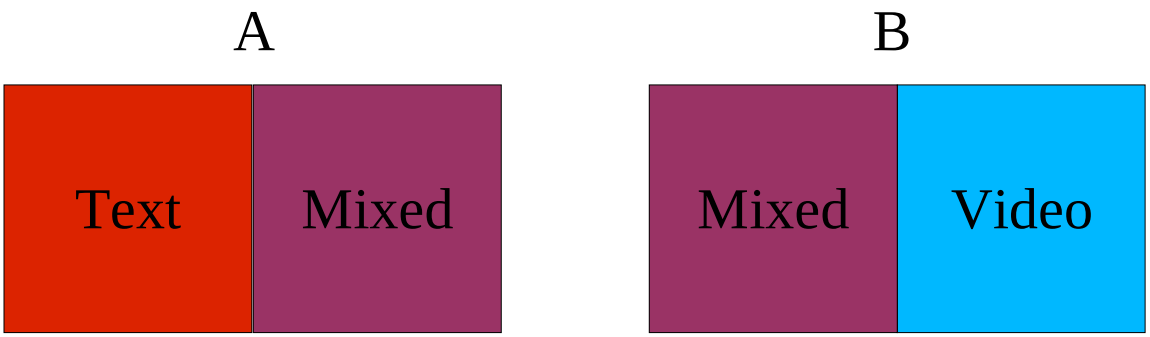

Figure 1-6. Comparisons used to test media richness of mixed-richness communications.

1.4.3 Task-Media Fitness Theory

Daft and Lengel outlined their understanding of the relationship between media richness and task uncertainty and equivocality in what is now called the task-media fit hypothesis.

This hypothesis states that there should be a correlation between the uncertainty and equivocality of the task and the richness of the medium in which the task is performed.

According to Daft and Lengel, high equivocality tasks require high information richness to allow the careful comparison of seemingly equivalent choices. Low equivocality tasks have clearly defined goals and low information richness is required to reduce uncertainty to the point where decisions can be made and tasks can be completed.

Daft and Lengel also theorized that high information richness would provide distracting and unnecessary information for low equivocality tasks, and hence would negatively impact performance.

Figure 1-7 displays task-media fitness for three levels of task equivocality and media richness. According to Daft and Lengel's model, the areas in green would be a good fit, and higher performance and lower error rate would be expected. Conversely, the areas in red are a poor fit, and worse performance and a higher error rate would be expected. The areas in yellow would be expected to be a better fit than the areas in red, but a worse fit than the areas in green.

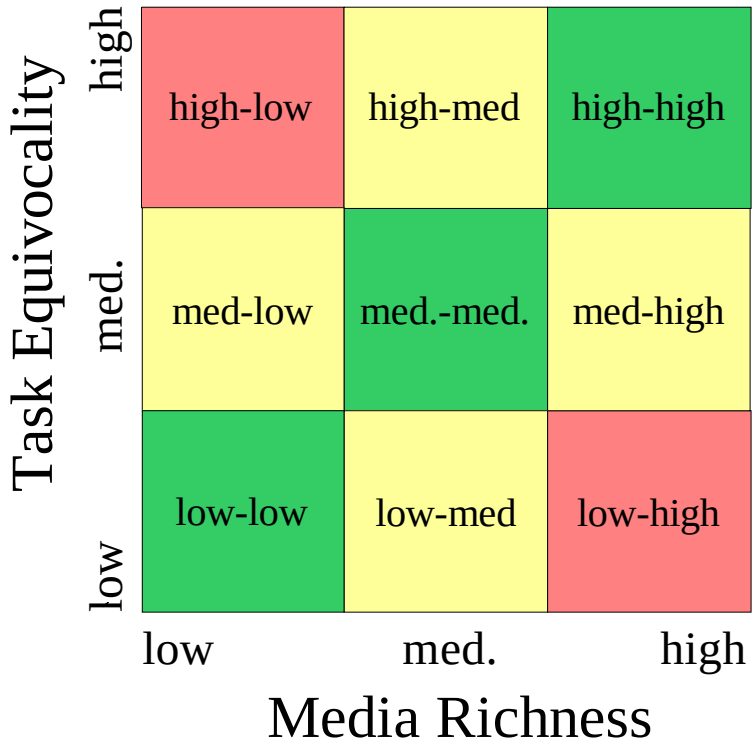

Figure 1-7. Task-media fitness.

This study only involves two levels of task equivocality, as displayed in Figure 1-8.

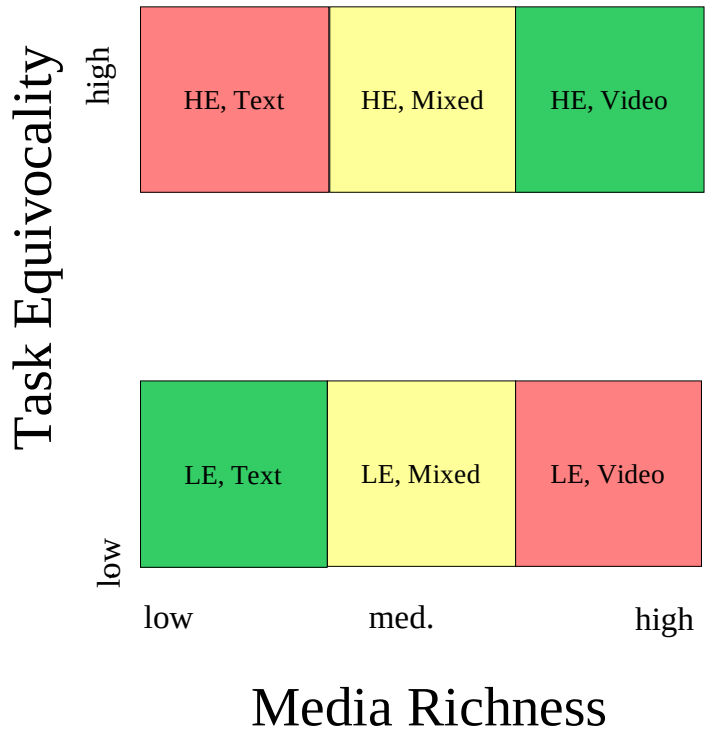

Figure 1-8. Task-media fitness revisited.

To test task-media fitness, this experiment used a series of planned comparisons as outlined in Figure 1-9. Cells in yellow are expected to exhibit higher task performance than cells in red, and cells in green are expected to exhibit higher task performance than cells in yellow.

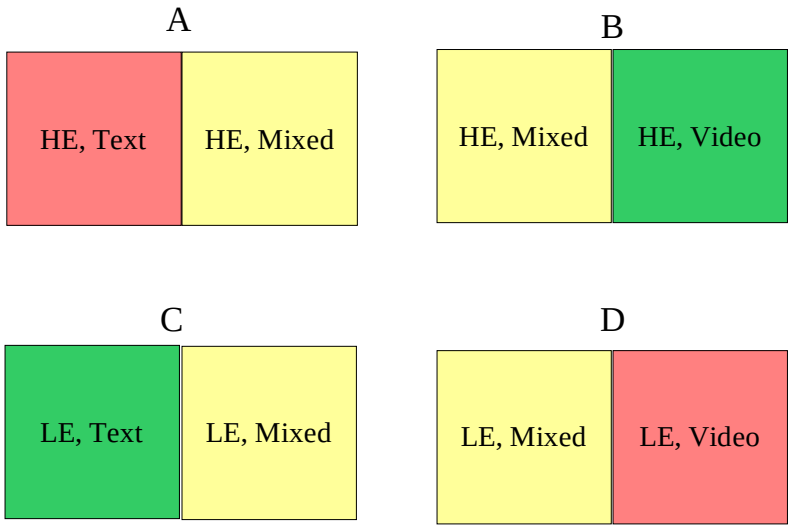

Figure 1-9. Comparisons used to test task-media fitness.

1.5 Social Presence

The concept of social presence arises from the concept of presence (or telepresence). Presence is the state in which a user is more physically aware of a virtual environment than they are aware of the technology with which the environment is presented (Draper, Kaber, & Usher, 1998). Presence is distinct from immersion, or the degree to which a system delivers sensory information that is of high enough fidelity to approximate an equivalent real-world stimulus (Slater, 2003). According to Slater, immersion is physiological, while presence is subjective and psychological. Immersion can be reduced to a series of objective comparisons based on the physiology of the senses and the differences between a real-world stimulus and a simulated stimulus. Presence is the subjective perception of being in a situation equivalent to the real world, which requires some degree of immersion, but is independent of immersion.

Copresence extends the concept of presence between participants. Copresence is the sense of another user's physical presence in a virtual environment. Copresence is related to social presence, but is a more limited concept, as the sense of physicality does not necessarily imply that additional cues (posture, direction of gaze, etc.) are transmitted versus audio or textual environments. Copresence is more concerned with the fact that people behave differently when they are aware of someone else's presence, and attempts to measure the extent to which a virtual environment can give a person the sense that someone who is physically distant is still present.

The concept of social presence extends this concept to the social realm, and expands the application of the concept beyond virtual environments. Social Presence is a condition in which a party in a computer-mediated communication is more aware of the person(s) with whom they are interacting than they are aware of the technology that allows them to communicate (Gunawardena, 1995).

Social presence was first defined by Short and Christie in 1976 (Short et al., 1976). They indicated that social presence is a subjective property of a communications medium, and relates to its perceived ability to transmit "facial expression, direction of looking, posture, dress and non-verbal vocal cues". They feel that a person's awareness of the characteristics of a medium is the best measure of social presence. In their initial study, they found that they were able to distinguish between communications media in terms of their social presence, and that the rating of the social presence of a medium closely corresponded to its relative immediacy.

Short and Christie's use of the concept of immediacy is different from the form of immediacy used by Daft and Lengel to define feedback. Where Daft and Lengel used immediacy as a temporal measure to write in terms of the delay introduced by the medium, Short and Christie write of immediacy as "a measure of the psychological distance which a communicator puts between [themselves] and the object of [their] communication". They indicate that immediacy can be conveyed not only by the medium itself, but also by the choice of medium used. Their example is a case in which a supervisor contacts a subordinate via telephone when it would take no more time to communicate in person. The medium is chosen because it adds distance between the supervisor and the subordinate. In their conception, immediacy can be varied

intentionally, while the social presence of a medium does not. Their concept of immediacy most closely relates to Daft and Lengel's concept of source.

Short and Christie consider the social presence of a medium as arising from a number of factors. From earlier work by Argyle (Argyle, 1969), they take the following set of signals that can be transmitted by a medium: signals of attention and responsiveness, signals of channel control, feedback, illustrations, emblems and interpersonal attitudes. To these, they add an overlapping set of signals: proximity and orientation, physical appearance, gestures of the trunk and arms, facial signals, direction of eye gaze. Their concept of feedback closely resembles feedback as used by Daft and Lengel in their work. In particular, the concept that feedback for certain tasks requires "moment-to-moment affective reactions" lends itself to the concept of immediacy as affected by communications lag. Most other criteria identified can be thought of in terms of Daft and Lengel's concept of language and hence communication channels. Because social presence is conceived of in terms of many of the same factors used to define media richness, it has been used as to measure media richness and/or task-media fitness (Rice, 1993; Yoo & Alavi, 2001).

1.6 Situational Awareness

Individual situational awareness is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988). It is a measure of how well the individual is in touch with the salient information from the environment that is needed to make decisions. Team situational awareness extends the awareness of the state of the environment to include the awareness of team members.

1.7 Common Ground

Common ground "refers to the mutual knowledge, beliefs, and assumptions of the participants in a conversation" (McCarthy, Miles, & Monk, 1991). Team members building common ground engage in a sequence of ordered utterances, also called a discourse (Clark, 1994). During a discourse, members engage in a cycle of submitting ideas and meanings to the other conversants, and having them accepted, rejected, or refined (i.e. parts are accepted, while others are rejected). The shared understanding that emerges is the "common ground" between conversants. Clark and Schaefer theorized that CMC lacked the cues to achieve common ground (Clark & Schaefer, 1989).

Summarizing and extending this early concept, Clark and Brennan theorized that copresence, visibility, audibility, cotemporality, simultaneity, sequentiality, reviewability, and revisability were the constraints imposed by a communication medium (alternately, the abilities offered by a communication medium) on the building of common ground between participants (Clark & Brennan, 1991).

Clark and Brennan theorized that a medium that did not provide any of these abilities required conversants to expend additional effort to communicate. One example would be face-to-face conversation, which provides copresence, visibility, audibility, cotemporality and simultaneity. Because face-to-face conversation does not provide a mechanism to create rigid sequentiality, people use turn-taking mechanisms (pauses, etc.) to indicate when they have completed an utterance and are ready for a response. Because face-to-

face conversation does not provide reviewability, conversants must ask for any utterances they have forgotten or misheard to be repeated. Because face-to-face communication does not offer the ability to review and edit utterances externally prior to transmission, conversants must either expend additional time carefully choosing their words before uttering them, or must expend additional time correcting misunderstandings using additional utterances. In all cases, the costs of working around limitations in a communication medium identified by Clark and Brennan are presumed to increase the time required to communicate.

Common ground can be thought of as a subset of team situational awareness. Team situation awareness is focused on the awareness of team members on the environment as well as each other. Common ground is focused more narrowly on the awareness of the shared pool of knowledge.

1.8 Problem Statement

Previous studies involving conversations between dyads (Daly-Jones, Monk, & Watts, 1998; Dennis & Kinney, 1998; Kinney & Dennis, 1994; McCarthy & Monk, 1994; Mennecke, Valacich, & Wheeler, 2000) and studies of larger groups (Zmud et al., 1990) have held media richness constant between conversants. Given that the inclusion of richer media in real-world computer-mediated communications varies according to availability of technology and the ability of conversants to use technology, we will continue to see the type of mixed-richness environments that are found in the workplace today. It is thus important to expand the usefulness of social presence theory and media richness theory by applying existing thinking about media richness and social presence in CMC to mixed-richness environments. This research does this by examining the following areas:

1. The combined effect of task equivocality and communication medium on task performance
2. The combined effect of task equivocality and communication medium on communication effectiveness
3. The effect of communications medium on the sense of social presence

1.9 Research Questions

This research examines the areas mentioned by using a number of measures found in previous studies of CMC, social presence, and task performance to address the following research questions:

1. How does task equivocality interact with communication medium to affect task performance?
2. How does task equivocality interact with communication medium to affect communication effectiveness?
3. How does the sense of social presence in mixed-richness environments compare to non-mixed environments?

Questions regarding task performance were addressed by measuring time-to-complete. Questions regarding social presence were addressed by measuring social presence using the original set of semantic differential questions created by Short and Christie. Questions regarding communication effectiveness were addressed by measuring the frequency of communication breakdowns. Questions regarding outcome satisfaction were addressed by measuring the subjective satisfaction using survey questions developed by the author (see Appendix D).

1.10 Research Hypotheses

Each of the research questions above corresponds to a research hypothesis (and sub-hypotheses) which was tested during this study:

1. Task performance is affected by the interaction between communication medium and task equivocality:
    a. For high equivocality tasks, time-to-complete is lower for mixed-richness environments than for text-only environments.
    b. For high equivocality tasks, time-to-complete is higher for mixed-richness environments than for video-only environments.
    c. For low equivocality tasks, time-to-complete is higher for mixed-richness environments than for text-only environments.
    d. For low equivocality tasks, time-to-complete is lower for mixed-richness environments than for video-only environments.
2. Communication effectiveness is affected by the interaction between communication medium and task equivocality:
    a. For high equivocality tasks, communication breakdown frequency is lower for mixed-richness environments than for text-only environments.
    b. For high equivocality tasks, communication breakdown frequency is higher for mixed-richness environments than for video-only environments.
    c. For low equivocality tasks, communication breakdown frequency is higher for mixed-richness environments than for text-only environments.
    d. For low equivocality tasks, communication breakdown frequency is lower for mixed-richness environments than for video-only environments.
3. The sense of social presence reported in mixed-richness environments differs from the sense of social presence reported in same-richness environments:
    a. A higher sense of social presence is reported in mixed-richness environments than in text-only environments.
    b. A lower sense of social presence is reported in mixed-richness environments than in video-only environments.

Chapter 2 – Literature Review

2.1 Introduction

This section reviews the portions of the literature concerned with CMC. The main focus is to highlight previous empirical approaches to measuring the effectiveness of a communication medium as used to facilitate decision-making.

2.2 Task-Media Fitness Theory

As stated in the previous section, Daft and Lengel theorized that there should be a correlation between the uncertainty and equivocality of the task and the richness of the medium in which the task is performed. If this Task-Media Fitness theory is correct, performance and satisfaction should be highest where performing high equivocality tasks using rich media (such as video), or when performing low equivocality tasks using lean media (such as text messaging). Their initial papers did not provide guidance as to how to measure of the fitness of a media to a task.

Later studies have expressed task-media fit in terms of user media preference (D'Ambra, Rice, & O'Connor, 1998; Rice, 1992; Zmud et al., 1990), user satisfaction (H. P. Andres, 2002; Dennis & Kinney, 1998), social presence (H. P. Andres, 2002), and task performance (H. P. Andres, 2002; Dennis & Kinney, 1998; Dennis, Kinney, & Hung, 1999; Kock, 2001; Mennecke et al., 2000). These measures have generated conflicting information regarding the validity of the Task-Media Fitness Theory.

A study of document editing (Chalfonte, Fish, & Kraut, 1991) seemed to confirm Daft and Lengel's hypothesis that richer media are better for tasks with high equivocality and uncertainty, while leaner media are suitable for tasks with low equivocality and uncertainty. A study of intellective and negotiation tasks (Mennecke et al., 2000) confirmed the task-media fit hypothesis, but only for negotiation tasks. Other studies (D'Ambra et al., 1998; Zmud et al., 1990) confirm that managers prefer richer media for tasks with higher uncertainty and equivocality, but found that power relationships had an effect on the choice of media (i.e., managers were more likely to user richer media when communicating with superiors than subordinates or peers). A study of same and mixed-gender teams (Dennis et al., 1999) indicated that the task-media fit was only observed among female participants. Other research (Tan et al., 1999) has confirmed that task-media fit holds true for high equivocality tasks, but not for low equivocality tasks. One explanation offered for the lack of an observed negative effect of rich media on low equivocality tasks has been offered (Walther, 1992). Walther's explanation is that the irrelevant and conflicting cues theoretically transmitted by richer media do not occur frequently enough to affect task performance for low equivocality tasks.

2.3 Social Presence

Presence has most commonly been measured using subjective questionnaires such as the Presence Questionnaire (Witmer & Singer, 1998) and the ITC-Sense of Presence Inventory (Lessiter, Freeman, Keogh, & Davidoff, 2001). Since presence is related to immersion, Witmer and Singer also measured the degree to which users are susceptible to

immersion using an Immersive Tendencies Questionnaire. Presence has also been measured by recording "breaks in presence", or instances in which the individual became aware of the unreality of a virtual environment (Slater & Steed, 2000).

When social presence was first defined by Short and Christie in 1976 (Short et al., 1976), they proposed to measure social presence using the semantic differential technique to ask users to indicate their experience with a medium on each of a series of seven-point scales. These scales range from unsociable to sociable, insensitive to sensitive, cold to warm, and impersonal to personal. They found that they were able to distinguish between communications media in terms of their social presence, and that the rating of the social presence of a medium closely corresponded to its relative immediacy.

In later studies, social presence in CMC has been studied with regard to distance education and online learning (Gunawardena, 1997; Leh, 2001; Rourke, Anderson, Garrison, & Archer, 1999; Tu, 2002) as well as learning in a collaborative conference setting (Gunawardena, 1995). Social presence has also been studied with regard to purely social activities (De Greef & IJsselsteijn, 2001).

De Greef, Gunawardena, Kinney (1994), Tu, and Yoo all measured social presence using a variation on the original scales used by Short and Christie. Leh used an unrelated survey as well as message transcripts to measure user satisfaction and task performance with CMC in a learning environment.

Of the studies that measured social presence, Gunawardena (1997) also measured satisfaction. Gunawardena (1997) found that the higher the richness, the higher the user satisfaction.

Of the studies that measured social presence, Leh and Kinney (1994) also measured task performance. Leh found a positive relationship between social presence and task performance in a learning context. Kinney (1994) found a positive relationship between social presence and task performance.

2.4 Linguistic Approaches to CMC

CMC has also been analyzed using linguistic methods. In general, the quantitative approaches coming out of the linguistic field attempt to identify and count key characteristics of the spoken and/or written portions of a conversation.

One measure coming from the linguistic field is social presence density (Rourke et al., 1999), a measure of the total number of social presence indicators for a given medium divided by the total number of words used in the conversations measured. The social presence indicators used include expressing emotions, use of humor, self-disclosure, continuing a thread, quoting from others' messages, referring explicitly to others' messages, asking questions, complimenting/expressing appreciation, expressing agreement, vocatives (addressing others by name), the use of inclusive pronouns (we, our), and phatics/salutations (such as "Hi, All" and "So long for now").

Similar linguistic approaches have been used to analyze CMC (Clark & Schaefer, 1989; McCarthy, Miles, & Monk, 1991; McCarthy & Monk, 1994). Clark and Schaefer analyzed a computer-mediated conversation in terms of the role of individual utterances within the conversation. The conversational roles they assign to utterances include

presentation of a concept, acceptance, rejection, evidence of understanding, and evidence of trouble understanding.

McCarthy and Monk identified and counted the instances of various conversational devices, such as the use of first and second person pronouns, the correct interpretation of coreferring expressions (pronouns that could conceivably refer to one of a number of participants), and breakdowns. McCarthy and Monk also measured common ground in terms of the number of arguments one party in a conversation could recall that were presented by the other party.

2.4.1 Communication Breakdown Frequency

> "Breakdowns occur when the routine of work is interrupted, by straightforward technical failures, such as the loss of a communication line, by social problems, such as interpersonal conflict, or by mismatches of expectation, when users become frustrated that the equipment does not fit with their needs or preconceptions." (Sharples, 1993)

Communication breakdowns are failures in communication requiring repair (Schegloff, Jefferson, & Sacks, 1977). Often, these are failures in turn-taking behavior (Sacks, Schegloff, & Jefferson, 1974).

Communication breakdown analysis has been used to analyze CMC (Doerry, 1996; Kies, 1997; Tatar, Foster, & Bobrow, 1991). Tatar, et al used communication breakdowns observed to identify shortcomings in groupware and make needed improvements. Kies developed a new measure, communication breakdown frequency, which can be used to compare breakdowns in task trials that require different amounts of time to complete. To derive this measure, Doerry outlined operational definitions to help categorize communication breakdowns observed during conversations. This taxonomy divides communication breakdowns into categories (verbal turntaking, reference, topic, audio, video, and shared conversation).

Verbal turntaking breakdowns occur when two or more conversants communicate at the same time. In Kies' study, verbal turntaking breakdowns were further categorized by the way in which they were resolved (one conversant stopped talking, one asked the other to stop talking, both talked simultaneously for more than 3 seconds, and other).
Reference breakdowns occur when there is contention for a shared resource (mouse pointer, pencil, printout). In Kies' study, reference breakdowns were not categorized further.
Topic breakdowns occur when a participant loses track of the topic and asks to be updated. Topic breakdowns were further categorized by the way in which they occurred (a side conversation occurred which drew the conversant's attention away from the topic, another activity occurred which drew the conversant's attention away from the topic, and other).

Audio breakdowns occur when a conversant is unable to hear the audio content because of loudness, feedback, etc. In Kies' study, audio breakdowns were identified when a conversant asked for a sentence to be repeated, and were further categorized according to whether or not any other conversant repeated or summarized the content of the last sentence.

Video breakdowns occur when a conversant is unable to see an object or person in a video feed, usually because of the relative position of the camera to the object. In the taxonomy used in Kies' study, video breakdowns are categorized according to the means by which the breakdown was reflected in the conversation (for example, a request for a conversant to move their seat relative to the camera.

Shared conversation breakdowns are unique to the type of meeting Kies studied, in which more than one conversant in a larger group shares the same physical location. Shared conversation breakdowns occur when a conversant engages in a side conversation with a conversant in the same physical location without making the attempt to include distant conversants. In Kies study, shared conversation breakdowns were further categorized according to the number of shared conversations that occurred simultaneously.

Having categorized the communication breakdowns observed during a trial, Kies derived the communication breakdown frequency by simply dividing the number of communication breakdowns by the time required to complete a trial. Communication breakdown frequency can be derived not only for total communication breakdowns, but also for each specific category of communication breakdown.

The disadvantage of many linguistic approaches is the high ratio of analysis time to sequence time (T. S. Andres et al., 1998). A researcher can spend many hours deriving measures from each hour of recorded data. Andres, Kleiner and Williges recommend the use of ASR (automated speech recognition) to reduce the audio portion of recorded data to transcripts that can be more readily analyzed.

2.5 Situation Awareness

The situation awareness global assessment technique, or SAGAT (Endsley, 1988), attempts to measure situation awareness without respect to the awareness of success or failure in a given mission. This is accomplished by pausing mid-task and administering a subset of an overall battery of survey questions. In addition to reducing the effect of task success or failure on subjective ratings, the SAGAT method is intended to provide better recall than surveys administered after the completion of the task.

2.6 Common Ground

Common ground is a measure of how well participants in a conversation have built a shared understanding. Common ground has been measured by questioning each team member individually regarding what solutions and arguments have been presented (McCarthy, Miles, Monk et al., 1991). In cases where common ground has been achieved, team members tend to remember arguments and solutions they have presented as well as arguments and solutions presented by others. In cases where common ground has not been achieved, team members tend to remember only those arguments and solutions they themselves have presented.

2.7 Review of Prior Experimental Designs

Table 2-1 contains a review of prior experimental designs of studies involving group communications and CMC. Articles are categorized by the number and type of participants, the communications media, the tasks selected, and the measures used.

Table 2-1. Review of Prior Experimental Designs

Article	Participants	Media	Tasks	Measures
(Adrianson, 2001)	Swedish doctoral students, 4-5 person groups, mixed gender	FTF, Email	Forest Ranger problem and Chemist problem, both are work-related conflict resolution problems for managers.	Private self-awareness, Public self-awareness, Subjective Satisfaction, Number of messages sent, Types of communicative statement used
(H. P. Andres, 2002)	MIS undergraduates, 4 person teams composed of 2 dyads. No mention of gender.	FTF, Videoconferencing	Adding requested functionality to an existing Student Information System. Required to produce design documents outlining team solution to problem.	Completeness of developed design, subjective interaction quality, subjective process satisfaction
(Barkhi, Jacob, Pipino, & Pirkul, 1998)	Undergraduate business students, 3 or 4 person teams. No mention of gender.	FTF, GDSS	Mixed-motive cost optimization purchasing problem. Individuals were required to agree on ordering information based on their costs as advertised to others versus their actual cost (which they were not required to disclose).	Revenue derived from selected solution, % of statements made that were truthful, subjective satisfaction with solution, subjective frustration with process
(Bocker & Muhlbach, 1993)	Participants between the ages of 20 and 30 paired, both participants communicated with trained researchers via videoconferencing equipment	Videoconferencing	Dyads were required to complete a conflictive and cooperative task. The conflictive task was discussing a current and controversial issue. The cooperative task was to develop an advertising strategy for a product.	Subjective sense of communicative presence, subjective satisfaction
(Cano et al., 1998)	Participants were assigned to 3 to 6 person teams. No mention of gender, but team assignment was random.	FTF, GDSS	Study One: Groups worked together on a design task. Study Two: Groups worked together on a decision-making task.	Study One: Design performance vs. cost of design solution, subjective satisfaction. Study Two: perception of process structure, group consensus, decision time, decision accuracy, subjective satisfaction with the group process
(Connell, Mendelsohn, Robins, & Canny, 2001)	Undergraduate students, assigned to dyads. Dyads were randomly assigned (i.e. gender was randomized).	FTF, Telephone, CMC (chat)	Dyads were required to "get acquainted" with each other using the selected medium.	Subjective feeling of sincerity, Subjective intentionality, subjective satisfaction
(Daly-Jones et al., 1998)	Students from University of York. Assigned to dyads or 4 person groups. No mention of gender.	Videoconferencing, Audioconferencing	Participants were required to review 10 scholarship applications and select 3.	"number of spoken turns, the mean length of these turns in words, and instances of overlapping speech"

Table 2-1. Review of Prior Experimental Designs

Article	Participants	Media	Tasks	Measures
(Dennis, 1996)	Undergraduate business students.	FTF, GSS	Participants were required to review 4 admissions applications and select 1.	Correct pieces of information transmitted, amount of information available to participant versus amount shared, time to reach decision, amount of common information exchanged versus total amount of common information available to all participants, Individual decision before meeting versus group decision after meeting and individual decision after meeting.
(Dennis & Kinney, 1998)	Undergraduate business students assigned to dyads. No controls for gender.	Videoconferencing, CMC	Low Equivocality: questions similar to those used on the SATs, with information required to reach a solution split among dyad members. High Equivocality: Undergraduate admissions problem (see table entry for Dennis 1996)	Time to complete task, consensus, decision quality, subjective communication satisfaction, perceived richness, perceived equivocality, perceived task complexity.
(Dennis et al., 1999)	Undergraduate business students assigned to dyads. Genders were neither controlled nor randomized.	FTF, CMC	Low Equivocality: questions similar to those used on SATs, with information required to reach a solution split among dyad members. High Equivocality: Undergraduate admissions problem (see table entry for Dennis 1996).	Subjective satisfaction with the communication, decision time, decision quality, consensus change, perceived task complexity, perceived task equivocality, perceived media richness
(Fussel, Kraut, & Siegel, 2000)	Undergraduate and graduate students (novices) and bike repair specialists (experts) assigned to dyads. No controls for gender.	FTF, Videoconferencing, Audioconferencing	A novice participant attempted to repair a bicycle while being advised by an expert.	Time to complete repair, observer rating of communication quality, number of utterances, type of utterances, utterance duration, use of gestures by utterance type in video condition
(Fussel, Kiesler, Setlock , & Scupelli, 2004)	Undergraduate students assigned to four person working groups, but only interacted with one partner at a time. No controls for gender.	FTF, IM	Participants worked to design web pages. Work could be allocated between participants in the group.	Work effort in terms of keystroke activity, word counts per task, perceived division of labor, perceived quality of teamwork, perceived task performance
(Hancock & Dunham, 2001)	"Members of the university community" assigned to dyads	IM	Participants worked to complete tangram patterns.	Errors in identifying tangrams between participants, time to complete, frequency of linguistic coordination devices used

Table 2-1. Review of Prior Experimental Designs

Article	Participants	Media	Tasks	Measures
(Hian, Chuan, Trevor, & Detenber, 2004)	**Undergraduates assigned to dyads. Gender fully balanced (equal number of male-male, female-female, and female-male dyads).**	**FTF, CMC**	**High and low equivocality tasks were selected from previous publications (Kirby, 1992; Kirby, 1992; Morris, 1998; Savicki and Kelley, 2000). Morris outlined a decision-making scenario involving allocating scarce resources among survivors of a nuclear war (designed as a high equivocality task). Kirby's work provides example scenarios for trainers in a number of fields. See later entry in this table regarding Savicki and Kelley.**	**Perceived relational intimacy**
(Kinney & Dennis, 1992)	**Undergraduate communication students assigned to dyads. No controls for gender.**	**FTF, Audioconferencing, CMC ("synchronous email")**	**Low Equivocality: SAT questions with information required to arrive at an answer divided between dyad members. High Equivocality: "Foundation Task", allocation of limited funds among competing charities.**	**Time to complete task, change in consensus between initial review of information and dyadic interaction**
(Kinney & Dennis, 1994)	**Undergraduate business students assigned to dyads. No controls for gender.**	**Videoconferencing, CMC**	**Low Equivocality: Problems similar to those used on the SATs, with information required to arrive at an answer divided between dyad members. High Equivocality: Undergraduate Admissions Problem (see table entry for Dennis 1996)**	**Time to reach decision, decision quality, consensus, social presence, perceived media richness, perceived communication satisfaction**
(Matheson, 1991)	**Male and Female participants were paired with a computer (which they thought was a human). They were told either that their partner was the same gender as themselves, or not told the gender of their partner.**	**CMC**	**Task was to negotiate 10 financial contracts while balancing short-term financial gain and long-term good will between negotiators.**	**Perception of gendered characteristics in self and partner, negotiating behavior as derived from "initial and final profit demanded on each contract, how many offers subjects exchanged on a given contract and how many of these offers showed no concession, and how many messages the subjects sent"**
(McCarthy, Miles, & Monk, 1991)	**Participants were paired. No controls for gender.**	**CMC (chat window plus shared workspace)**	**Collaborate on the redesign a bank lobby based on criteria given.**	**Percentage of solutions recalled individually by both participants after the negotiation.**

Table 2-1. Review of Prior Experimental Designs

Article	Participants	Media	Tasks	Measures
(McCarthy, Miles, Monk, Dix, & Wright, 1993)	**Psychology and Computer Science students and graduates were grouped in triads, in some cases with a single expert.**	**CMC (chat window plus shared workspace)**	**"Vi Exercise": Two UNIX novices ask the same expert for help on an editing task simultaneously. Survival Exercise: Group members asked to rank 15 items in terms of their usefulness in a survival situation. Joint-Submission Exercise: Groups were asked to prepare an application to study abroad.**	**Analysis of text transcripts**
(Mennecke et al., 2000)	**Students from business and speech courses were assigned to dyads. No controls for gender.**	**FTF, Videoconferencing, Audioconferencing, CMC (synchronous)**	**Low Equivocality: "Physician Location Problem", in which two people find the nearest doctor when one has the address and the other a map. High Equivocality: "Legislative Dilemma", in which participants negotiated the allocation of funds among competing funding bills.**	**Optimality of decision for low equivocality task, time to complete for high equivocality task**
(Rivera, Cooke, & Bauhs, 1996)	**Participants were paired with a researcher, who gave canned responses except when asked a direct question.**	**CMC (IM)**	**One task was to select the best applicant for a teaching position at an elementary school. The other was a survival task in which users selected the most useful item for survival from a list of 8 items.**	**"User satisfaction, user frustration, conformity, length and focus of message, satisfaction with CMC system, and recall of communication events. "**
(Savicki et al., 1996)	**Undergraduate psychology students were assigned to dyads. Gender was fully controlled by creating an equal number of male-male, female-female, and male-female dyads.**	**CMC (email)**	**Low Equivocality: "Fallout Shelter" survival scenario in which participants were asked to rank items they would take with them into a fallout shelter. High Equivocality: "Lover's Scenario", which various characters' moral dilemmas were described as well as the character's choice under the circumstances. Participants were asked to rank the relative morality of each character's choice.**	**Number of messages sent, length of messages, subjective satisfaction, perceived team development, accuracy with regard to expert analysis of each task, categorization of choice of language**
(Sellen, 1995)	**Adult participants were grouped into foursomes. No controls for gender.**	**FTF, Videoconferencing, Audioconferencing**	**Participants debated current events based on newspaper clippings.**	**Analysis of video transcripts, Subjective rating of communication medium**

Table 2-1. Review of Prior Experimental Designs

Article	Participants	Media	Tasks	Measures
(Watson, 1987)	**Undergraduate and graduate business students were assigned to three and four person groups. No controls for gender.**	**FTF, GDSS**	**Individuals were asked to complete a series of fund allocation tasks between different charities. They were then asked to negotiate one of the fund allocation tasks with the group.**	**Post-meeting consensus, perceived decision quality, satisfaction, and equality of influence (how closely group decision was an average of individual decisions)**
(Yoo & Alavi, 2001)	**Undergraduate business students were assigned to triads. Gender mix was even, but gender was not controlled in the creation of triads.**	**Videoconferencing, Audioconferencing**	**"The Van Management Task", in which participants were asked to select the recipient of a new van from a list of 5 sales managers.**	**Consensus change**

Chapter 3 – Methodology

3.1 Experimental Design

This experiment used a 4 x 2 within-subjects design. The independent variables were communication medium (M) and task equivocality (T). Communication medium and task equivocality were within-subjects factors. The dependent variables in this study were time to complete, communication breakdown frequency and sense of social presence. Confounding variables controlled during screening included previous computer experience, previous experience with CMC, typing speed, and gender.

There were three combinations of communications media used in this study (see Table 3-1). Each dyad experienced all four combinations of communications media.

Table 3-1. Combinations of Communications Media

Medium	Participant A Transmitted/ Participant B Received	Participant B Transmitted/ Participant A Received
M1	Text only	Text only
M2	Text only	Video + Audio
M3	Video + Audio	Video + Audio
M4	Video + Audio	Text only

There were two types of tasks used in this study: low equivocality tasks involving the selection of a part from a catalog and high equivocality tasks involving hiring scenarios. See Table 3-2 and section 3.5 for more detail on tasks, or see Appendix C for the full text of all task scenarios. Each dyad completed both types of tasks under all four combinations of communications media.

Table 3-2. Task types

Task	Equivocality	Description
T1	Low	The selected low equivocality tasks were designed to reach a single correct outcome. The information provided to participants is unambiguous, and no information given conflicts with any other pieces of information.
T2	High	The selected high equivocality tasks were designed to allow for multiple possible solutions. The best possible solution is a subjective matter to be argued between participants. The information provided to participants satisfies conflicting criteria, such that participants must evaluate trade-offs between one choice and another.

A total of eight pairs of participants engaged in free-form conversations oriented towards goals given by the researcher under a total of eight treatment conditions (see Table 3-3). The number of participants used was the minimum required to allow for the desired number of planned comparisons.

Table 3-3. Treatment Conditions

Treatment	Abbreviation	Description
1	M1, T1	Participant A uses Text-only to communicate. Participant B uses Text-only to communicate. Low Equivocality Task
2	M2, T1	Participant A uses Text-only to communicate. Participant B uses Video + Audio to communicate. Low Equivocality Task
3	M3, T1	Participant A uses Video + Audio to communicate. Participant B uses Video + Audio to communicate. Low Equivocality Task
4	M4, T1	Participant A uses Video + Audio to communicate. Participant B uses Text-only to communicate. Low Equivocality Task
5	M1, T2	Participant A uses Text-only to communicate. Participant B uses Text-only to communicate. High Equivocality Task
6	M2, T2	Participant A uses Text-only to communicate. Participant B uses Video + Audio to communicate. High Equivocality Task
7	M3, T2	Participant A uses Video + Audio to communicate. Participant B uses Video + Audio to communicate. High Equivocality Task
8	M4, T2	Participant A uses Video + Audio to communicate. Participant B uses Text-only to communicate. High Equivocality Task

The order in which each group received the treatment conditions was balanced using a randomized complete block design (Hicks, 1973), in which each group received each of the treatment conditions in random order. The treatment ordering was generated using a PHP script written by the author, and is detailed in Table 3-4 below.

Table 3-4. Treatment Ordering Balanced Using Randomized Complete Block Design

	Dyad (D)							
Treatment	D1	D2	D3	D4	D5	D6	D7	D8
	1	2	3	4	5	6	7	8
	7	3	4	8	7	4	1	6
	6	1	2	2	8	2	2	4
	2	5	6	7	6	8	5	3
	8	6	8	1	1	5	8	7
	5	4	5	6	3	1	4	5
	3	8	1	3	2	3	3	2
	4	7	7	5	4	7	6	1

As the study involved communication between individuals, participants were paired into dyads, and two participants participated in each experimental session. To ensure that the groups were nominal groups (groups of individuals with no power relationship to one another), the tasks and task outcomes were constructed to avoid explicit competition and external incentives that would encourage a participant to dominate the group process.

At least one previous study suggested that media richness has a greater effect on conversations between female participants than on conversations between male participants or between male and female participants (Dennis et al., 1999). It has also been suggested that men and women have different styles in using CMC, with women

using more frequent messages that contain more facts, and men using longer messages that contain more opinions (Sussman & Tyson, 2000). Additionally, in negotiation based tasks such as those used in this study, gender differences have been observed for some types of negation outcomes (Walters, Stuhlmacher, & Meyer, 1998). Potential gender effects were controlled by limiting the gender combinations to a single combination, such that each pair consisted of one male participant and one female participant.

In part because of the growing adoption of CMC among younger computer users (Huang & Yen, 2002), participants were selected from the population of 18-30 year olds in the area. Their age was reported as part of the demographic questionnaire found in Appendix B.

Previous studies of CMC have been concerned with the effect of prior computer experience (Hancock & Dunham, 2001; McCarthy, Wright, & Monk, 1992; Perse, Burton, Kovner, Lears, & Sen, 1992). As in those studies, computer experience was assessed via self-reported questions during prescreening (see Appendix B for the full text of the questionnaire). The demographic questionnaire includes questions related to previous experience with computers in general and with CMC in particular. Participants who indicated that they use a computer 1 hour a day or less were excluded from the study. Participants who indicated that they use instant messaging 1 hour a day or less were excluded from the study. Participants who indicated that they were not able to comprehend text written using IM conventions (acronyms, simplified spellings, incomplete sentences) were excluded from the study.

The written and spoken communications used in this study were conducted in English. Previous studies (Gong & Lai, 2001; Lai, Wood, & Considine, 2000) have controlled for this by selecting only native English speakers. Participants who indicated that English was not their primary language were excluded from the study.

Because the study involved gestural language and prosody which are in part culturally determined (Baum & Nowicki, 1998; Bradford, 1995), participants were asked to identify their country of origin in the demographic survey. After narrowing down the pool of potential participants using the above criteria, only participants native to the U.S. remained.

Previous studies (Dennis et al., 1999; Gergle, Millen, Kraut, & Fussel, 2004; Hancock & Dunham, 2001) have expressed concern over the effect of typing speed on performance in CMC. However, the results of the Hancock and Dunham study suggested that typing speed did not have an effect at the average corrected typing speed of their participants (30 words per minute). To control for differences in performance related to CMC, only pairs of participants with an average corrected typing speed of 30 words per minute or higher were included in the study. The prescreening included a short typing test, administered using the test mechanism built into the Ainsworth Keyboard Trainer (Ainsworth & Partners, 2004), which was used in the Gergle, Millen, Kraut, & Fussel study. This screening criterion was designed to reduce the effect of typing speed on communication time in the text-based CMC.

3.1.1 Dependent Variables

In this experiment, the dependent variables were:

- time to complete
- social presence
- frequency of communication breakdowns

Time to complete was determined during a review of taped conversations using the timestamp on the recording made of each task. The start of each task was keyed on the signal from the researcher to the participants to begin the task. The end of each task was keyed on the signal from the participants that they completed the task.

As mentioned previously, social presence was measured in the post-task questionnaire using the semantic differential method used extensively in prior studies. The post-task questionnaire also contains questions designed to measure perceived task complexity and perceived task ambiguity.

Communication breakdowns were determined by observing the recorded conversations and flagging communication breakdowns using the relevant operational definitions (Kies, 1997) outlined in Appendix E. The total number of communication breakdowns observed while completing the task was divided by the time to complete expressed in terms of seconds to arrive at the frequency of communication breakdowns.

3.1.2 Confounding Variables

The confounding variables in this study were:

- familiarity with English
- prior experience with computers
- prior experience with CMC
- gender
- network lag

The first three variables are participant variables, which were controlled through screening measures. Participants were selected for a minimum level of familiarity with English, familiarity with computers, and familiarity with CMC. Gender was controlled by limiting the study to pairs consisting of a single male participant and a single female participant, such that all dyads experience the same gender combination. For individual analyses (social presence), there were not enough degrees of freedom to test for the effect of gender on the experiment. For dyadic analyses (time to complete, communication breakdown frequency), it was not possible to test for the effect of gender, as both genders were represented in each dyad.

As time to complete was one of the measurements used, network lag from computers not directly involved in the study was a potentially relevant confounding variable. For the purposes of the study, the two participant workstations and the researcher's station were isolated on a private network.

3.2 Participants

This study required the involvement of 16 participants, all of whom were compensated for their participation. Participants were required to attend a single session. A call for participants was sent to mailing lists targeting students in the psychology department. Interested persons completed a prescreening survey online (see Appendix B) and indicated their availability for one or more session times. The majority of participants who responded were undergraduate psychology majors. Although participant ethnicity was not recorded, the majority of participants were Caucasian, with a handful of Asian participants as well.

Eligible participants were scheduled for sessions based on eligibility and availability. When participants arrived for their session, they first completed an informed consent form. They were then given a typing test. Once their eligibility was verified, participants worked together to complete two practice tasks and eight experimental tasks. The total time of participation was typically between one hour and one and half hours.

3.3 Apparatus

This section describes the hardware configuration used for the experiment. The primary concern in the selection of hardware was that it be representative of that which is available at low cost in most workplace settings. This experiment used hardware available to businesses today and inexpensive enough to be commonly found at individual workstations and not solely in dedicated videoconferencing facilities. The selected hardware was chosen as a representative example of the type of equipment in use on the campus and in the workplace today. It is hoped that the results of this experiment can be applied to a range of communication hardware in use in the workplace both today and in the future.

3.3.1 Video

The technical requirements for video as used in this study were based on studies of sign language and lip reading over video, which presumably requires a higher frame rate and quality than less complicated gestures and facial expressions.

The picture quality was required to be sufficient to distinguish clearly facial features and expressions as well as hand and body positions. If any compression artifacts were present, they were not severe enough to distort the view of the participant's face, arms, or hands.

The video frame rate as captured, transmitted, and presented to the remote user was required to be high enough to preserve the distinct stages of a gesture or facial expression. Based on a previous project that developed a video phone for deaf users (Sarris & Strintzis, 2001), the required frame rate was 10 frames per second. A second study (Dugenie, Munro, & Barton, 2002) indicated that 8 frames per second at medium image quality was adequate.

As in previous studies of CMC (Daly-Jones et al., 1998) and communicative gestures (Quek, 2002), the video used in this experiment provided a field of view sufficient to display the head, arms and upper body of a seated figure. The field of view allowed for gestures that include most of the range of arm extension in all directions except for the

table surface, which the participant was able to reach without overextending the arms. The field of view was balanced with the image quality, particularly the image of the face area.

The initial preference was to use Apple's iSight camera (Apple Computers, 2004b), which has been cited as one of the best suited for sign-language videoconferencing (Evangelista, 2003). However, as the recording software and equipment available were all Windows workstations, it was decided to use an alternate choice. The video camera selected for this study was a Logitech QuickCam Pro 6000, which at time of purchase was available for around $75.

This camera was evaluated during pretesting to ensure that it met the stated requirements. It proved capable of outputting 30 frames a second at a resolution of 640x480 pixels. The only problem with this camera was the lag observed when transmitting video over the network using any of the programs tested. To minimize the lag, long USB 2.0 extension cords were run between the workstations, such that each user was viewing the output from a camera attached directly to their computer rather than a remote feed (see Figure 3-1). This reduced the lag from around 3 seconds to less than 1 second. This idealized scenario was based on the common assumption that bandwidth will continue to increase over time and hence network lag will decrease.

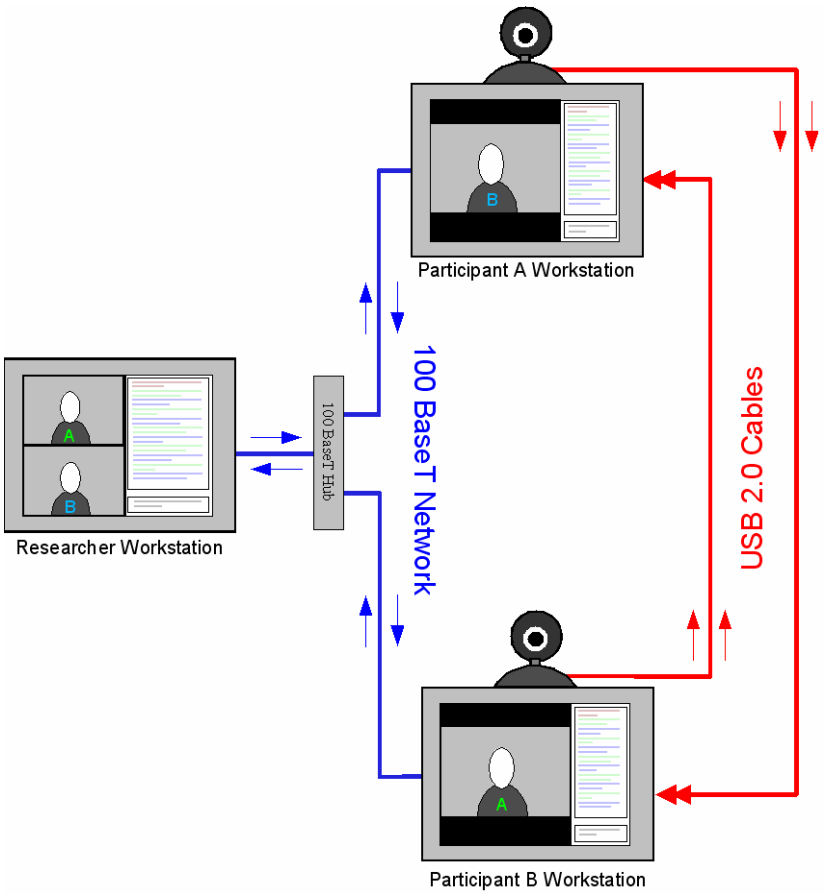

Figure 3-1. Workstation cable diagram.

3.3.2 Audio

Based on previous studies involving the audio component of videoconferencing (Grenville, Kleiner, Denson, & Anderson, 2000), the audio in this experiment was configured to reduce the transmission of irrelevant noise, and to present speech data at high enough quality that prosodic cues were preserved.

The first goal, the reduction of irrelevant noise, was addressed by reviewing the noises produced in the testing environment not only as perceived in the testing environment, but as conveyed through the selected microphones. The main sources of noise were the air conditioning system inside the room and the larger air conditioning units outside the room. This noise was reduced by closing doors between the participants and the outside world and by turning off the room's air conditioning during test sessions.

The second goal, presenting speech data at high enough quality and intelligibility involved selecting microphones and speakers that capture a wide enough range of frequencies to cover changes in pitch throughout the range of male and female speaking voices. Given the desire to preserve facial expressions, a headset microphone was not chosen for this study. Given the desire to allow for body motion and hand gestures, the microphone needed to be mounted near the participant, but not on the participant's body. To meet these criteria and other technical considerations, the microphone built-into the Logitech camera was used.

It was initially decided that headphones would not be used in this experiment, as it was feared they would interfere with facial expressions and range of motion. However, because of feedback concerns, it became necessary to use lightweight headphones.

3.3.3 Networking

Even though the cameras used by study participants did not require a network, a network was required for the researcher to be able to record the ongoing conversations and to control the workstations remotely. The communications bandwidth available needed to be high enough to allow a high quality picture to be transmitted at an acceptable frame rate. Based on a previous study of the effect of bandwidth on lip reading and signing (Kamphuis, Frowein, Rikken, & Spoor, 1999), the bandwidth was required to be greater than or equal to 128 kilobits per second. This is roughly twice the speed of a modem connection and one half the speed of an entry-level DSL connection.

During the study, the participant and researcher workstations were connected to each other over a private network (see Figure 3-1). This eliminated the chance of network traffic from other computers introducing network lag. This idealized scenario was based on the common assumption that bandwidth will continue to increase over time and hence network lag will decrease.

3.3.4 Displays and Controls

The workstations used by the participants used monitors of the same size and screen resolution. The workstations were equipped with a standard keyboard, but were not equipped with a mouse. All controls related to turning off or resetting the computer were removed from reach or disabled. All power strips related to the computer and peripherals

were placed out of reach of the users' hands, arms, feet, and chair, so that there was no possibility of deactivating the computer by accident.

3.4 Software

This section describes the requirements that the experimental software had to meet as well as the selected software. This experiment was designed to have real world applications to a wide range of businesses with a range of budgets. For this reason, the preference was to use software that provided the highest quality at a low enough cost to install on end-user workstations.

3.4.1 Videoconferencing Software

After reviewing a range of conferencing programs for quality and ease of use in a laboratory setting, the selected software was VLC, a program designed to stream media locally and over a network. Where many video chat programs require the use of a centralized server and thus raise privacy concerns for human participants, VLC can be easily configured for peer-to-peer use without the need for registering for accounts or transmitting over the network at large. VLC was also the only program that could deliver the required quality in terms of image size and frames per second. VLC was also the only package tested capable of transmitting with less than a second of lag.

3.4.2 Audioconferencing Software

The selected audio software was required to be capable of recording, encoding and transmitting audio at CD quality (16-bit, 44 KHz sampling rate). The audio was required to be continuous and free of audible skips or pauses. The audio quality produced by VLC met these criteria.

3.4.3 Chat Software

The selected chat software was required to distinguish between what the local user was currently typing, what the local user had transmitted to the remote user, and what the remote user had typed. It was also required to display a sequential history of the messages each user had transmitted. The conversational history was required to capture a large number of previous messages, and to allow the user to scroll through the conversation using cursor keys.

It was hoped to find chat software should support both video and audio, and that could support the mixed-mode communications central to this study. The initial first choice was Apple's iChat AV software (Apple Computers, 2004a), which is designed for use with the iSight camera. It supports the combination of text, audio, and video required for this experiment. iChat AV is included with newer versions of the Macintosh operating system. However, as stated before, the recording software and hardware available for this experiment made it unfeasible to use iChat. Instead, the jabber client PSI was used. PSI meets the requirements specified, and supports group chats, which were needed to support recording user sessions. PSI also conforms to the most common IM conventions (enter to send, conversion of emoticons, etc.).

3.4.4 Combined Software Interface

The combination of operating system, video software, and recording software was configured to reduce the possibility of participants activating software outside the scope of the study, deactivating software used by the study, or otherwise putting the computer in a state where data could not be collected. Toward this end, all software used was configured to disable or hide unnecessary interface elements and keyboard shortcuts.

Where possible, operating system elements not needed for the experiment were disabled or hidden. The priority for the operating system modifications was to hide or disable the interface elements and keyboard shortcuts used to shut down or restart the system, to launch an application outside the scope of the study, or to change from one application to another.

Within the video, audio and chat software, interface elements that allow a user to deactivate the software were disabled or hidden. Interface elements that allow the user to disable features required for the study were disabled or hidden. Interface elements that allow the user to enable features outside the scope of the study were disabled or hidden.

Figure 3-2 presents a mockup of the user's workstation for cases in which no video was transmitted.

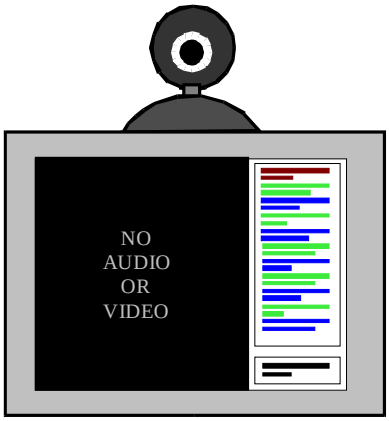

Figure 3-2. Workstation configuration for text-only communications.

Figure 3-3 presents a mockup of the user's workstation for cases in which video was transmitted but not received.

Figure 3-3. Workstation configuration for sending video and receiving text.

Figure 3-4 presents a mockup of the user's workstation for cases in which video was both transmitted and received (the video feed was in color).

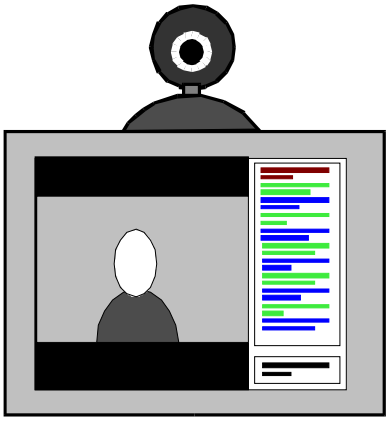

Figure 3-4. Workstation configuration for receiving video.

3.4.5 Data Logging Software Requirements

In order to perform a detailed analysis of misunderstandings in communication and the use of gestures in sessions with video, it was necessary to record an overall view of each conversation. The recording software chosen was Morae, one of the emerging standards for usability testing. Although Morae could not be made to combine multiple simultaneous recordings, it was used to record a combined view of the active media used for each task. This combined view presented the active video and audio feeds used for each task as well as a view of the text chat.

3.5 Tasks

This section outlines the tasks used in this experiment. Refer to Table 2-1 for a review of prior experiment designs including detailed information on the tasks participants were required to perform during each experiment.

3.5.1 Practice Tasks

The selected practice tasks introduced the participants to each other and familiarized them with the experimental hardware. Participants were asked to complete two simple assembly tasks in which one participant has a set of tangrams, and the other has a picture of the pattern the tangrams must be arranged to match (Hancock & Dunham, 2001). This task was selected because it was simple enough to be performed quickly, and because it was different from both the low equivocality and high equivocality tasks.

For both tasks, participants used the same communications media as each other, first sending and receiving text, and then sending and receiving video. See Appendix C for the complete instructions given to each participant for this task.

3.5.2 Low Equivocality Tasks

The low equivocality task scenario required users to select an item from a catalog based on a set of criteria. The catalog used for these problems was based loosely on the Edmund Optics Catalog (Edmund Optics, 2004), which is used as a resource in industry, education, research, and any other setting requiring lenses, lasers, and other optical equipment.

To be useful in an experimental setting, a low equivocality task must have clearly right and clearly wrong answers, and typically involves the manipulation of quantitative data. Previous studies (see Table 2-1) used low equivocality tasks that were not closely related to actual job tasks (sample SAT questions, etc.). Since the hope is to apply the results of this research to a work setting, the low equivocality tasks created for this study were an extension of inspection tasks, which have been used in previous research regarding teleoperation (Thepvongs, 1998) and augmented reality (Chung, 2002).

Inspection tasks involve establishing criteria that distinguish a usable component from an unusable component. These criteria are typically expressed in quantitative terms (length, hardness, etc.). Typically, inspection tasks involve physical manipulation of an object. Since this study was primarily concerned with how information is exchanged among conversants rather than the speed with which an object can be measured and the rate of measurement error, the inspection problems used in this study idealized the problem by providing the participants with the quantities that might otherwise be measured (diameter, etc.). These quantities were expressed in the same units as the criteria, reducing the potential for error.

Because this study requires participants to coordinate using CMC, the task goals and the information required to solve the task goals were divided between dyad members. Each participant was provided with the same list of objects to be examined, but each participant was provided with a subset of the overall list of criteria that an object must meet. In order to determine if the given object met the criteria, dyad members were required to exchange information and agree on a single definitive answer. The full text of these idealized inspection tasks can be found in Appendix C.

3.5.3 High Equivocality Tasks

In direct contrast with low equivocality tasks, high equivocality tasks provide less clear cues as to the criteria that must be met for a successful outcome, or the degree to which a selected course of action meets those criteria.

Previous studies (see Table 2-1) provided a number of high equivocality tasks stated in terms of work activities. The problems created for this study were hiring tasks, which have been used in prior studies of social presence (Daly-Jones et al., 1998; Dennis & Kinney, 1998; Dennis et al., 1999; Kinney & Dennis, 1992, 1994). These tasks were adapted in part from listings of applicant requirements posted on the Virginia Tech Personnel Services web site (*Virginia Tech Personnel Services Employment Web Site*, 2004).

In the low equivocality tasks, the information given was completely objective and could be directly compared with the criteria for success. The information given to the participants in the high equivocality task was subjective, stated imprecisely, and there were no clear terms for success. Portions of the information provided could also be interpreted as conflicting with other information given.

Participants were provided with shared information in the form of a handful of resumes. Participants exchanged information and discussed the choices presented. They then select what they felt was the best option. The full text of these applicant selection tasks is detailed in Appendix C.

3.6 Procedures

3.6.1 Pretesting

Prior to the start of the study proper, five rounds of pretesting took place. These were used to help refine the sample tasks and data collection methods. Each round of pretesting involved a single pair of participants. Participants used for pretesting were friends and colleagues of the researcher familiar with instant messaging, and who met the screening criteria used for the main experiment. Pretest participants were informed that their data would be recorded, and that it would not be retained beyond the pretesting period. Pretest participants were not compensated.

Each pair of pretest participants completed a subset of the main experiment consisting of both practice tasks and one each of the high and low equivocality tasks under only the mixed-richness communication environment. This subset allowed for participants to experience all types of tasks and communications media, but did not require the same amount of time as the full experiment.

For all tasks (including sample tasks), the audio and video presented at both user workstations was recorded. This data was retained for long enough to ensure that the audio and data streams from both participants could be timestamped, synchronized and reliably analyzed for time-to-complete and communication breakdown frequency.

Pretest participants also completed a post-task questionnaire. The results of this post-task questionnaire were analyzed. The sample tasks were refined between each round of pretesting to increase the perceived distinction between the high equivocality and low

equivocality tasks. Pretest participants were encouraged to leave subjective feedback, which was used to refine experimental procedures, including problems with the task instructions. The subjective feedback acquired during pretesting was also used to identify distracting or frustrating aspects of the hardware and software (glitches, control issues, etc.) that were not directly relevant to the study.

Pretesting continued until one complete pretest trial was completed in which there were no critical issues outstanding.

3.6.2 Participant Recruitment and Screening

The study was advertised via electronic mailing lists. All advertisements indicated that the study involves CMC and videoconferencing, and detailed the requirements for participating in the study and the hourly compensation rate. The advertisements did not mention the experimental goals of the study.

Participants who responded to the advertisement were asked to complete a screening survey that provided their demographic information and indicated their schedule. Participants were scheduled for their session based on eligibility, availability and gender (see section 3.2). Two participants were scheduled for each session. Where possible, participants were greeted individually and set to work on their informed consent and prescreening measures in separate areas.

During the experimental sessions, participants first completed and informed consent form (see Appendix A). After completing the form, participants were asked to complete a typing test. All participants met the typing requirements, and were considered eligible for participation in the study.

There were several cases in which one participant did not attend their scheduled session. The other participant was compensated for their time and was given the opportunity to participate in a later dyad at their discretion.

3.6.3 Instructions for Participants

After the participants were seated in their areas, they were given instructions as to the configuration of their workstation, the use of headphones, and the location of the volume controls.

3.6.4 Sample Tasks

Each dyad completed two sample tasks intended to familiarize the participants with each other and the equipment. Prior to each of the sample tasks, both participants were given a moment to review the printed instructions for the task. Both participants were asked to complete one sample task using text chat, and another using video. This helps participants become familiar with the operation of both the text chat and the video feed. The video-based practice task ensures that participants whose first experimental tasks were conducted using text only were not confused as to the gender of their partner, as it has been suggested that participant awareness of gender in text-only CMC changes the perception of and response to the other party in negotiation tasks (Matheson, 1991). A post-task questionnaire was not completed following the sample tasks.

3.6.5 Experimental Tasks

The remaining eight tasks were presented in the randomized order detailed previously in Table 3-4. The full text of all task scenarios and the related instructions can be found in Appendix C. Prior to each task, the researcher provided the instructions for the individual task to each participant. When providing the instructions, the researcher reminded the participant of the communications medium they would be using for the next trial and instructed them to put on their headphones if necessary.

While the participants reviewed the instructions, the researcher configured each workstation for the appropriate media configuration. In media configurations in which a user was not transmitting audio and video, the user's microphone and camera were disabled, and a blank image was displayed to their partner in place of the video feed. In all media configurations, the remote user's video (or a view of a black screen) was displayed in a window filling the left side of the screen. The text chat window was displayed on the right side of the screen.

When the workstations were configured and the recording software was ready, participants were asked if they were ready to proceed. The conferencing equipment, recording equipment, and timer were then activated and the participants were instructed to begin work on the sample task.

While the participants performed the task, the researcher remained out of sight, monitoring the recording equipment and waiting for participants to indicate that they had completed the task. The researcher was able to see both viewing conditions to ensure that the appropriate media configuration was preserved and that there were no equipment problems.

The participants were instructed to indicate to the researcher when they feel they have completed the task by typing "done" in the text chat window. When this signal was received by the researcher, the recording equipment and conferencing equipment was deactivated and post-task questionnaires were distributed.

3.6.6 Post-task Questionnaire

Participants completed a post-task questionnaire designed to measure perceived task complexity, perceived task ambiguity, and perceived social presence. Social presence was measured in terms of the semantic differential terms (personal-impersonal, warm-cold, sensitive-insensitive, social-unsocial, and passive-active) used in the majority of social presence research. See Appendix D for the full text of the post-task questionnaire.

While the participants completed the post-task questionnaire, the researcher reconfigured the workstations for the next task. This was accomplished from the researcher's station using the remote-control software called VNC (RealVNC, 2004). The researcher then collected the post-task questionnaire from each participant.

3.6.7 Participant Debriefing

When all tasks were complete, participants were paid for their participation and signed a form indicating receipt of their compensation. Before leaving, participants were reminded of the researcher's contact information, and reminded that they should get in touch if they change their mind about allowing their data to be used in the study.

Chapter 4 - Results

4.1 Analysis

As stated in section 1.10, this experiment was designed to address the following research hypotheses and sub-hypotheses:

1. Task performance is affected by the interaction between communication medium and task equivocality:
    a. For high equivocality tasks, time-to-complete is lower for mixed-richness environments than for text-only environments.
    b. For high equivocality tasks, time-to-complete is higher for mixed-richness environments than for video-only environments.
    c. For low equivocality tasks, time-to-complete is higher for mixed-richness environments than for text-only environments.
    d. For low equivocality tasks, time-to-complete is lower for mixed-richness environments than for video-only environments.
2. Communication quality is affected by the interaction between communication medium and task equivocality:
    a. For high equivocality tasks, communication breakdown frequency is lower for mixed-richness environments than for text-only environments.
    b. For high equivocality tasks, communication breakdown frequency is higher for mixed-richness environments than for video-only environments.
    c. For low equivocality tasks, communication breakdown frequency is higher for mixed-richness environments than for text-only environments.
    d. For low equivocality tasks, communication breakdown frequency is lower for mixed-richness environments than for video-only environments.
3. The sense of social presence reported in mixed-richness environments differs from the sense of social presence reported in same-richness environments:
    a. A higher sense of social presence is reported in mixed-richness environments than in text-only environments.
    b. A lower sense of social presence is reported in mixed-richness environments than in video-only environments.

This section outlines how the data collected during the experiment was analyzed and the results of the analysis performed.

4.1.1 Notation

When comparing conditions in equations, the notation described in Table 4-1 is used in the subscripts attached to a variable. When a pair of media is joined by the plus symbol (+), the medium on the left is the medium sent, and the medium on the right is the

medium received. In this section, the term "video" is used to refer to the combination of audio and video media used in this experiment.

Table 4-1. Notation used in equations

Notation	Description
T + T	**Participant sent and received text**
T + V	**Participant sent text and received video**
V + T	**Participant sent video and received text**
Mixed	**Either of the conditions in which participants used different media from one another. When referring to values, "mixed" is the combined value of V+T and T+V divided by two**
V + V	**Participant sent and received video**
HE	**High equivocality task**
LE	**Low equivocality task**

As mentioned in previous sections, there were eight total treatments, and each of the eight groups participated in all eight treatments, for a total of 64 cells. Table 4-2 outlines the treatments conditions using the notation outlined previously in Table 4-1.

Table 4-2. Treatment Conditions and Associated Variables

Treatment	Task Equivocality (T)	Communication Medium (M)	Notation (Medium, Task)
1	**Low**	**Both participants sent and received text.**	**A: T+T, LE1** **B: T+T, LE1**
2	**Low**	**Participant A sends video and received text.** **Participant B sends text and received video.**	**A: V+T,LE2** **B: T+V,LE2**
3	**Low**	**Both participants sent and received video.**	**A: V+V, LE3** **B: V+V, LE3**
4	**Low**	**Participant A sends video and received text.** **Participant B sends text and received video.**	**A: T+V,LE4** **B: V+T,LE4**
5	**High**	**Both participants sent and received text.**	**A: T+T, HE1** **B: T+T, HE1**
6	**High**	**Participant A sends video and received text.** **Participant B sends text and received video.**	**A: V+T,HE2** **B: T+V,HE2**
7	**High**	**Both participants sent and received video.**	**A: V+V, LE3** **B: V+V, LE3**
8	**High**	**Participant A sends video and received text.** **Participant B sends text and received video.**	**A: T+V,LE4** **B: V+T,LE4**

Time-to-complete and communication breakdown frequency can only be meaningfully measured at the dyadic level (Dennis & Kinney, 1998; Dennis et al., 1999; Kinney & Dennis, 1992, 1994), for a total of 64 data points for those variables. For perceived social presence, each dyad member enters their response separately, for a total of 128 data points for that variable.

4.2 Hypothesis 1: Task Performance and the Task-Media Fit

As mentioned in previous sections, task-media fitness theory suggests that that task performance is affected by the interaction between communication medium and task equivocality. Task performance in this case was measured in terms of the time in seconds from the announced start of the task until both participants indicate that they have completed the task.

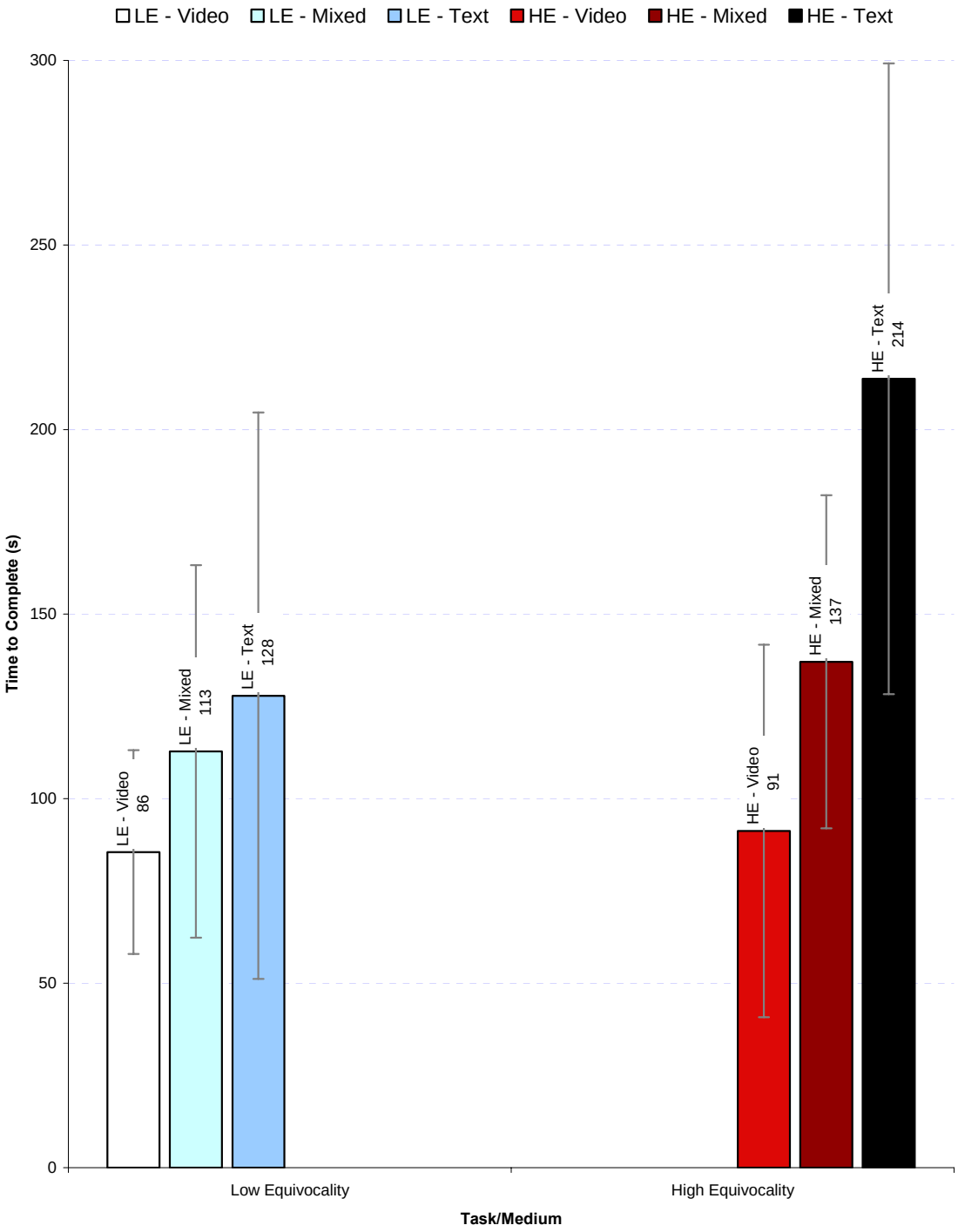

Figure 4-1. Time to complete by task and medium.

Figure 4-1 displays time to complete by task and medium. Low equivocality tasks are displayed in shades of white and blue and high equivocality tasks are displayed in shades

of red and black. The trend for both types of task is clear. Both types of task were completed most quickly using video-only communications, followed by mixed-richness communications, with text-only communications requiring the most time to complete both types of task. The trend observed for high equivocality tasks matches that predicted by task-media fitness theory. The trend observed for low equivocality tasks does not match that predicted by task-media fitness theory.

4.2.1 Time-to-complete, Text-only vs. Mixed-richness, High Equivocality Tasks

Hypothesis 1A: ***For high equivocality tasks, time-to-complete is lower for mixed-richness environments than for text-only environments.***

To compare time-to-complete with regard to the task-media fit, a series of orthogonal comparisons was used. In this comparison, the average time to complete high-equivocality tasks using the text-only medium was compared to the average time to complete high equivocality tasks using the two mixed-richness media.

Hypothesis 1A: *For high equivocality tasks, time-to-complete is lower for mixed-richness environments than for text-only environments.*

H_0: $\mu_{T+T,HE} = \frac{1}{2}\mu_{V+T,HE} + \frac{1}{2}\mu_{T+V,HE}$

H_A: $\mu_{T+T,HE} > \frac{1}{2}\mu_{V+T,HE} + \frac{1}{2}\mu_{T+V,HE}$

Test Statistic: Planned F-Test

Decision Rule: I will reject H_0 if $\mu_{T+T,HE} > \frac{1}{2}\mu_{V+T,HE} + \frac{1}{2}\mu_{T+V,HE}$ and $F_{observed} > F_{(1,7)}$, α=.05

Figure 4-2. Analysis of time-to-complete in text-only versus mixed-richness environments

As indicated in Figure 4-2, time to complete high equivocality tasks was lower for mixed-richness environments than for text-only environments, which supports the hypothesis. The planned comparison of average time to complete for high equivocality tasks completed using text-only versus mixed media indicated that the difference was significant (p=0.0059).

4.2.2 Time-to-complete, Video-only vs. Mixed-richness, High Equivocality Tasks

Hypothesis 1B: ***For high equivocality tasks, time-to-complete is higher for mixed-richness environments than for video-only environments.***

To compare time-to-complete with regard to the task-media fit, a series of orthogonal comparisons was used. In this comparison, time-to-complete for high-equivocality tasks in the video-only communication condition was compared to the average time-to-complete for high equivocality tasks in the two mixed-richness communication conditions.

Hypothesis 1B: *For high equivocality tasks, time-to-complete is higher for mixed-richness environments than for video-only environments.*

H_0: $\mu_{V+V,HE} = \frac{1}{2}\mu_{V+T,HE} + \frac{1}{2}\mu_{T+V,HE}$

H_A: $\mu_{V+V,HE} < \frac{1}{2}\mu_{V+T,HE} + \frac{1}{2}\mu_{T+V,HE}$

Test Statistic: Planned F-Test

Decision Rule: I will reject H_0 if $\mu_{V+V,HE} < \frac{1}{2}\mu_{V+T,HE} + \frac{1}{2}\mu_{T+V,HE}$ and $F_{observed} > F_{(1,7)}$, α=.05

Figure 4-3. Analysis of time-to-complete high equivocality tasks in video-only versus mixed-richness environments

As indicated in Figure 4-3, time to complete high equivocality tasks was higher for mixed-richness environments than for video-only environments, which supports the hypothesis. However, the planned comparison of average time to complete for high equivocality tasks completed using video versus mixed media indicated that the difference was not quite significant (p=0.0861).

4.2.3 Time-to-complete, Text-only vs. Mixed-richness, Low Equivocality Tasks

Hypothesis 1C: ***For low equivocality tasks, time-to-complete is higher for mixed-richness environments than for text-only environments.***

To compare time-to-complete with regard to the task-media fit, a series of orthogonal comparisons was used. In this comparison, time-to-complete for low equivocality tasks in the text-only communication condition was compared to the average time-to-complete for low equivocality tasks in the two mixed-richness communication conditions.

Hypothesis 1C: *For low equivocality tasks, time-to-complete is higher for mixed-richness environments than for text-only environments.*

H_0: $\mu_{T+T,LE} = \frac{1}{2}\mu_{V+T,LE} + \frac{1}{2}\mu_{T+V,LE}$

H_A: $\mu_{T+T,LE} > \frac{1}{2}\mu_{V+T,LE} + \frac{1}{2}\mu_{T+V,LE}$

Test Statistic: Planned F-Test

Decision Rule: I will reject H_0 if $\mu_{T+T,LE} > \frac{1}{2}\mu_{V+T,LE} + \frac{1}{2}\mu_{T+V,LE}$ and $F_{observed} > F_{(1,7)}$, α=.05

Figure 4-4. Analysis of time-to-complete in text-only versus mixed-richness environments

As indicated in Figure 4-4, time to complete low equivocality tasks was not lower for mixed-richness environments than for text-only environments, which does not support the hypothesis. In addition, the planned comparison of average time to complete for high equivocality tasks completed using text-only versus mixed media indicated the difference was not significant (F=8.86, p=0.5329).

4.2.4 Time-to-complete, Video-only vs. Mixed-richness, Low Equivocality Tasks

Hypothesis 1D: ***For low equivocality tasks, time-to-complete is lower for mixed-richness environments than for video-only environments***

To compare time-to-complete with regard to the task-media fit, a series of orthogonal comparisons was used. In this comparison, time-to-complete for low equivocality tasks in the video-only communication condition was compared to the average time-to-complete for low equivocality tasks in the two mixed-richness communication conditions.

Hypothesis 1D: *For low equivocality tasks, time-to-complete is lower for mixed-richness environments than for video-only environments.*

H_0: $\mu_{V+V,LE} = \frac{1}{2}\mu_{V+T,LE} + \frac{1}{2}\mu_{T+V,LE}$

H_A: $\mu_{V+V,LE} < \frac{1}{2}\mu_{V+T,LE} + \frac{1}{2}\mu_{T+V,LE}$

Test Statistic: Planned F-Test

Decision Rule: I will reject H_0 if $\mu_{V+V,LE} < \frac{1}{2}\mu_{V+T,LE} + \frac{1}{2}\mu_{T+V,LE}$ and $F_{observed} > F_{(1,7)}$, α=.05

Figure 4-5. Analysis of time-to-complete in video-only versus mixed-richness environments

As indicated in Figure 4-5, time to complete low equivocality tasks was not lower for mixed-richness environments than for video-only environments. In addition, the planned comparison of average time to complete for low equivocality tasks completed using video and mixed media indicated that the difference was not significant, $F(1,7)=1.31$, $p=0.2619$.

4.2.5 Overall Analysis of Time-to-complete

None of the planned comparisons conducted for the time to complete variable confirmed the task-media fitness theory. This was in keeping with the conflicted nature of the results of previous studies of task-media fitness theory, as expressed most directly in the 1994 paper by Kinney and Dennis.

An overall ANOVA for time to complete was conducted as outlined in Table G-2. The results for the time to complete variable are presented in Table G-3. As with the analysis of social presence, medium had a significant effect, $F(3,21)=4.86$, $p=0.0101$. Task approaches significance, but was not significant at the specified alpha of .05, $F(3,21)=2.08$, $p=0.133$. A post-hoc analysis of the effect of medium was performed using Tukey's HSD, as presented in Table G-4.

The results indicate a significant difference between the text-only medium and each of the other media. There was also a significant difference between the video-only medium and each of the three other media. The results indicate that mixed media are not significantly different from one another, or from the text-only or video-only media.

4.3 Hypothesis 2: Communication Quality and the Task-Media Fit

As mentioned in previous sections, it was expected that communication quality would be affected by the interaction between communication medium and task equivocality. Communication quality was measured in terms of communication breakdown frequency, or the number of communication breakdowns per minute (see Appendix E for definitions and classifications of communication breakdowns used in this study).

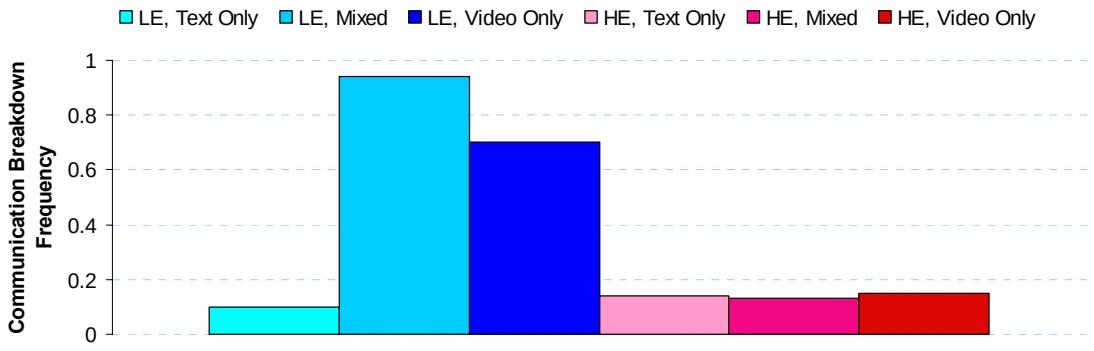

Figure 4-6. Communication Breakdown Frequency by Task and Medium.

Figure 4-6 presents a comparison of the mean communication breakdown frequencies observed. Low equivocality tasks are displayed in shades of blue and high equivocality tasks are displayed in shades of red. Communication breakdown frequency for low equivocality tasks was highest for mixed-richness media, followed by video-only. A large gap was observed between mixed and text-only media. Communication breakdown frequency for high equivocality tasks was similar for all three media.

4.3.1 Communication Breakdown Frequency, Text-only vs. Mixed-richness, High Equivocality Tasks

Hypothesis 2A: ***For high equivocality tasks, communication breakdown frequency is lower for mixed-richness environments than for text-only environments.***

To compare communication breakdown frequency with regard to the task-media fit, a series of orthogonal comparisons was used. In this comparison, communication breakdown frequency for high-equivocality tasks in the text-only communication condition was compared to the average communication breakdown frequency for high equivocality tasks in the two mixed-richness communication conditions. See Table G-5 for the complete results of all comparisons conducted for communication breakdown frequency.

Hypothesis 2A: *For high equivocality tasks, communication breakdown frequency is lower for mixed-richness environments than for text-only environments.*

H_0: $\mu_{T+T,HE} = \frac{1}{2}\mu_{V+T,HE} + \frac{1}{2}\mu_{T+V,HE}$

H_A: $\mu_{T+T,HE} > \frac{1}{2}\mu_{V+T,HE} + \frac{1}{2}\mu_{T+V,HE}$

Test Statistic: Planned F-Test

Decision Rule: I will reject H_0 if $\mu_{T+T,HE} > \frac{1}{2}\mu_{V+T,HE} + \frac{1}{2}\mu_{T+V,HE}$ and $F_{observed} > F_{(1,7)}$, α=.05

Figure 4-7. Analysis of communication breakdown frequency in text-only versus mixed-richness environments for high equivocality tasks

As indicated in Figure 4-7, communication breakdown frequency for high equivocality tasks was lower for mixed-richness environments than for text-only environments. However, The planned comparison of communication breakdown frequency for high equivocality tasks completed using text-only and mixed media indicated that the difference was not significant, $F(1,7)=0.83$, $p=0.3697$.

4.3.2 Communication Breakdown Frequency, Video-only vs. Mixed-richness, High Equivocality Tasks

Hypothesis 2B: ***For high equivocality tasks, communication breakdown frequency is higher for mixed-richness environments than for video-only environments.***

To compare communication breakdown frequency with regard to the task-media fit, a series of orthogonal comparisons was used. In this comparison, communication breakdown frequency for high-equivocality tasks in the video-only communication condition was compared to the average communication breakdown frequency for high equivocality tasks in the two mixed-richness communication conditions.

Hypothesis 2B: *For high equivocality tasks, communication breakdown frequency is higher for mixed-richness environments than for video-only environments.*

H_0: $\mu_{V+V,HE} = \frac{1}{2}\mu_{V+T,HE} + \frac{1}{2}\mu_{T+V,HE}$

H_A: $\mu_{V+V,HE} < \frac{1}{2}\mu_{V+T,HE} + \frac{1}{2}\mu_{T+V,HE}$

Test Statistic: Planned F-Test

Decision Rule: I will reject H_0 if $\mu_{V+V,HE} < \frac{1}{2}\mu_{V+T,HE} + \frac{1}{2}\mu_{T+V,HE}$ and $F_{observed} > F_{(1,7)}$, α=.05

Figure 4-8. Analysis of communication breakdown frequency in video-only versus mixed-richness environments for high equivocality tasks

As indicated in Figure 4-8, communication breakdown frequency for high equivocality tasks was not lower for mixed-richness environments than for video-only environments. In addition, the planned comparison of communication breakdown frequency for high equivocality tasks completed using video and mixed media indicated that the difference was not significant, $F(1,7)=0.83$, $p=0.3924$.

4.3.3 Communication Breakdown Frequency, Text-only vs. Mixed-richness, Low Equivocality Tasks

Hypothesis 2C: ***For low equivocality tasks, communication breakdown frequency is higher for mixed-richness environments than for text-only environments.***

To compare communication breakdown frequency with regard to the task-media fit, a series of orthogonal comparisons was used. In this comparison, communication breakdown frequency for low equivocality tasks in the text-only communication condition was compared to the average communication breakdown frequency for low equivocality tasks in the two mixed-richness communication conditions.

Hypothesis 2C: *For low equivocality tasks, communication breakdown frequency is higher for mixed-richness environments than for text-only environments.*

H_0: $\mu_{T+T,LE} = \frac{1}{2}\mu_{V+T,LE} + \frac{1}{2}\mu_{T+V,LE}$

H_A: $\mu_{T+T,LE} > \frac{1}{2}\mu_{V+T,LE} + \frac{1}{2}\mu_{T+V,LE}$

Test Statistic: Planned F-Test

Decision Rule: I will reject H_0 if $\mu_{T+T,LE} > \frac{1}{2}\mu_{V+T,LE} + \frac{1}{2}\mu_{T+V,LE}$ and $F_{observed} > F_{(1,7)}$, $\alpha=.05$

Figure 4-9. Analysis of communication breakdown frequency in text-only versus mixed-richness environments for low equivocality tasks

As indicated in Figure 4-9, communication breakdown frequency for low equivocality tasks was higher for mixed-richness environments than for text-only environments. However, The planned comparison of communication breakdown frequency for low equivocality tasks completed using text-only versus mixed media indicated that the difference was not significant, $F(1,7)=3.13$, $p=0.0878$.

4.3.4 Communication Breakdown Frequency, Video-only vs. Mixed-richness, Low Equivocality Tasks

Hypothesis 2D: ***For low equivocality tasks, communication breakdown frequency is lower for mixed-richness environments than for video-only environments.***

To compare communication breakdown frequency with regard to the task-media fit, a series of orthogonal comparisons was used. In this comparison, communication breakdown frequency for low equivocality tasks in the video-only communication condition was compared to the average communication breakdown frequency for low equivocality tasks in the two mixed-richness communication conditions.

Hypothesis 2D: *For low equivocality tasks, communication breakdown frequency is lower for mixed-richness environments than for video-only environments.*

H_0: $\mu_{V+V,LE} = \frac{1}{2}\mu_{V+T,LE} + \frac{1}{2}\mu_{T+V,LE}$

H_A: $\mu_{V+V,LE} < \frac{1}{2}\mu_{V+T,LE} + \frac{1}{2}\mu_{T+V,LE}$

Test Statistic: Planned F-Test

Decision Rule: I will reject H_0 if $\mu_{V+V,LE} < \frac{1}{2}\mu_{V+T,LE} + \frac{1}{2}\mu_{T+V,LE}$ and $F_{observed} > F_{(1,7)}$, α=.05

Figure 4-10. Analysis of communication breakdown frequency in video-only versus mixed-richness environments for low equivocality tasks

As indicated in Figure 4-10, communication breakdown frequency for low equivocality tasks was not lower for mixed-richness environments than for video-only environments. In addition, the planned comparison of communication breakdown frequency for low equivocality tasks completed using video versus mixed media indicated that the difference was not significant, $F(1,7)=0.77$, $p= 0.3880$.

4.3.5 Overall Analysis of Communication Breakdown Frequency

None of the planned comparisons conducted for the time to complete variable confirmed the task-media fitness theory. This was in keeping with the conflicted nature of the results of previous studies of task-media fitness theory, as expressed most directly in the 1994 paper by Kinney and Dennis.

An overall ANOVA for time to complete was conducted as outlined in Table G-2. The results are presented in Table G-6. There were no significant effects observed for communication breakdown frequency.

4.4 Hypothesis 3: Social Presence in Mixed versus Same-richness Environments

As mentioned in previous sections, the expectation before running this experiment was that social presence in mixed-richness environments would differ from social presence in same-richness environments. For both types of tasks, a post-task questionnaire (see Appendix D) was administered. The post-task questionnaire contains the classic semantic differential scales that are used to measure social presence. The responses entered by the participants were scored by positioning a ruler on the center of the mark made by the participant, and recording the point on the scale rounded to the nearest quarter of a point. As Social presence is subjective in nature, responses were collected and analyzed at the individual rather than the dyad level.

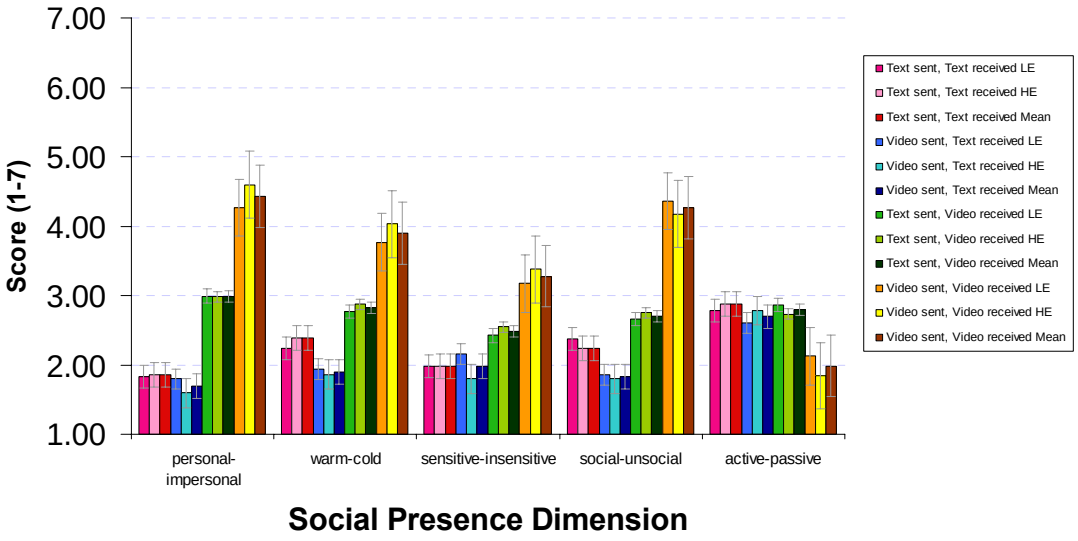

Figure 4-11. Social Presence by Medium and Task.

Figure 4-11 presents an overall view of social presence by medium and task. With the exception of the active-passive criteria, each of the scales follows the same rough trend.

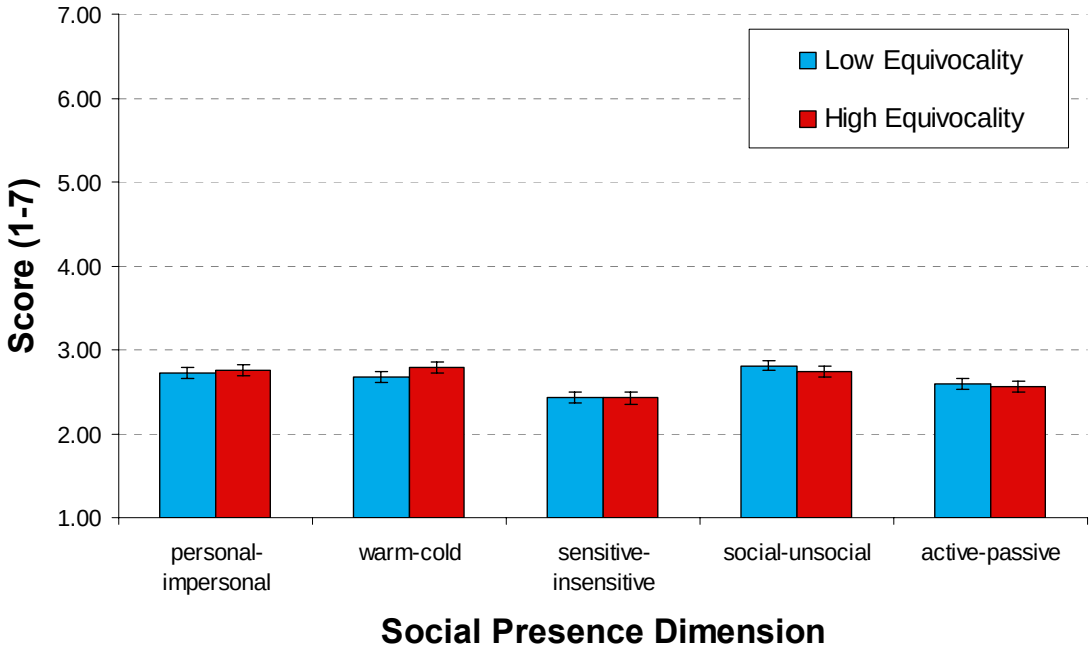

Figure 4-12. Social Presence by Task.

Figure 4-12 presents a comparison of social presence scales by task. Social presence reported for all scales was roughly even for the different task types.

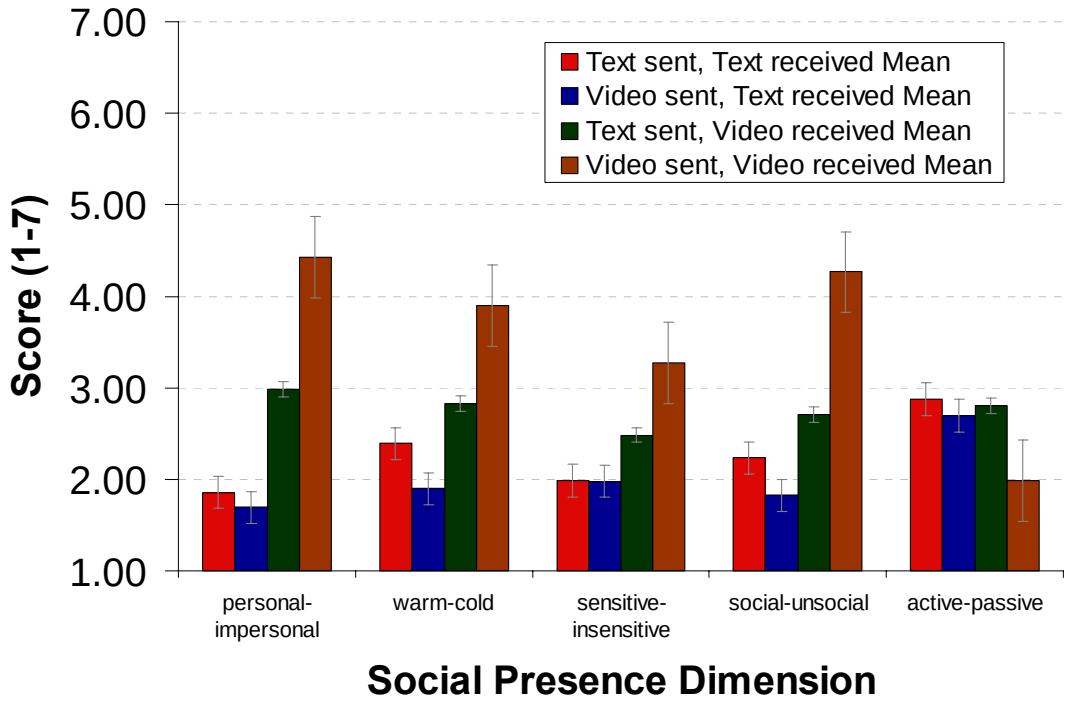

Figure 4-13. Social Presence by Medium.

Figure 4-13 presents a view of social presence by medium. As with Figure 4-11, all scales but active-passive follow the same rough trend, which is easier to perceive when looking at the averages across all tasks.

For the personal-impersonal, warm-cold, and social-unsocial scales, sending video and receiving text has the lowest reported social presence. One participant summarized this by saying "[using text only] seemed less impersonal than the voice/text one". Another participant repeatedly commented that sending video and receiving text was "like talking to a machine". Another participant sending video and receiving text commented that there was a long delay while waiting for their partner to type a response. Another participant sending video and receiving text reported feeling as though they "dominated" the conversation.

For all scales, the video-only medium has the highest reported social presence. The average of both mixed-media conditions falls somewhere between the text-only and video-only conditions, but the condition in which video was sent and text received had the lowest reported social presence for all scales except for the active-passive scale.

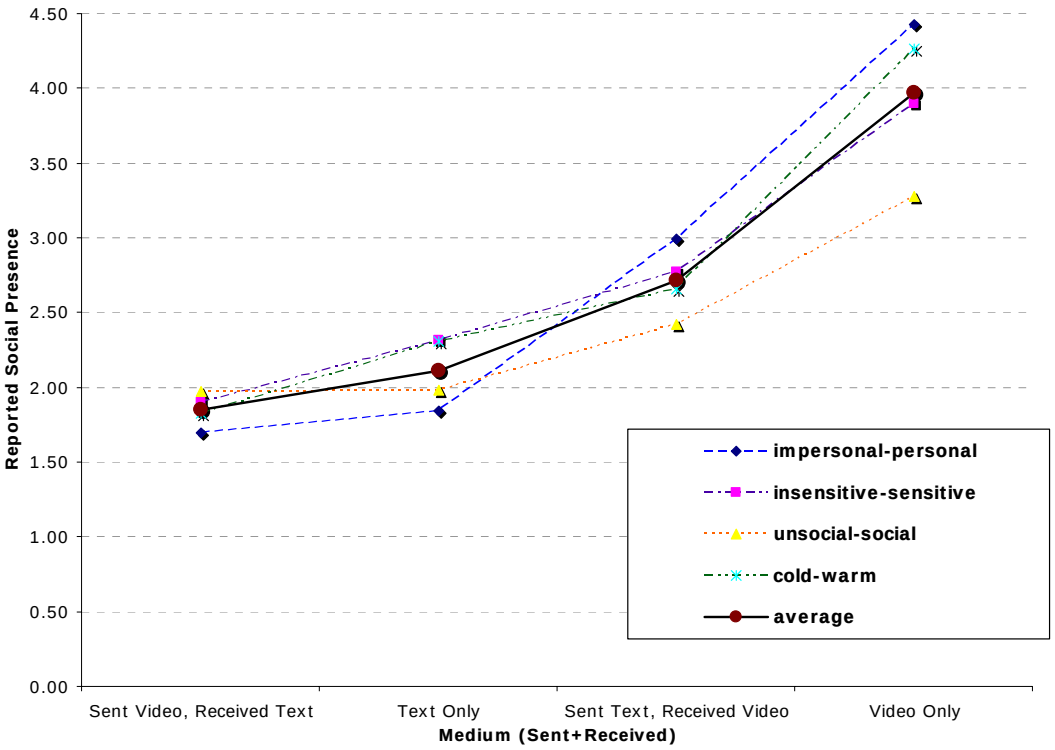

Figure 4-14. Social Presence Scales by Medium.

Figure 4-14 displays social presence scales by medium. Based on the results observed in Figure 4-13, this chart was arranged from lowest perceived social presence to highest. Comparing Figure 4-14 (social presence by medium), to Figure 4-12 (social presence by task), we begin to see that the combined effect of task and medium is more clearly a result of the medium than the task, which is confirmed by the results observed in section 4.5.

4.4.1 Social Presence, Text-only vs. Mixed-richness

Hypothesis 3A: ***A higher sense of social presence is observed in mixed-richness environments than in text-only environments.***

To compare social presence for text-only conditions versus social presence for mixed-richness conditions, an orthogonal comparison was used. In this comparison, the text-only communication condition was compared to the average of the two mixed-richness communication conditions.

Hypothesis 3A: *A higher sense of social presence is observed in mixed-richness environments than in text-only environments.*

H_0: $\mu_{T+T} = \frac{1}{2}\mu_{V+T} + \frac{1}{2}\mu_{T+V}$

H_A: $\mu_{T+T} < \frac{1}{2}\mu_{V+T} + \frac{1}{2}\mu_{T+V}$

Test Statistic: Planned F-Test

Decision Rule: I will reject H_0 if $\mu_{T+T} < \frac{1}{2}\mu_{V+T} + \frac{1}{2}\mu_{T+V}$ and $F_{observed} > F_{(1,7)}$, α=.05

Figure 4-15. Analysis of social presence in text-only versus mixed-richness environments

Only the personal-impersonal scale showed significant results, and only when comparison text-only media to sending text and receiving video, $F(1,7)=12.93$, $p=0.0005$. The consistent notch seen in Figure 4-13 regarding sending video and receiving text was not determined to be significant for any scale. The complete results of all comparisons and all scales can found in Table G-7.

4.4.2 Social Presence, Video-only vs. Mixed-richness

Hypothesis 3B: ***A higher sense of social presence is observed in video-only environments than in mixed-richness environments.***

To compare social presence for text-only conditions versus social presence for mixed-richness conditions, an orthogonal comparison was used. In this comparison, the video-only communication condition was compared to the average of the two mixed-richness communication conditions.

Hypothesis 3B: *A higher sense of social presence is observed in video-only environments than in mixed-richness environments.*

H_0: $\mu_{V+V} = \frac{1}{2}\mu_{V+T} + \frac{1}{2}\mu_{T+V}$

H_A: $\mu_{V+V} > \frac{1}{2}\mu_{V+T} + \frac{1}{2}\mu_{T+V}$

Test Statistic: Planned F-Test

Decision Rule: I will reject H_0 if $\mu_{V+V} > \frac{1}{2}\mu_{V+T} + \frac{1}{2}\mu_{T+V}$ and $F_{observed} > F_{(1,7)}$, α=.05

Figure 4-16. Analysis of social presence in video-only versus mixed-richness environments

There was a significant difference between the social presence reported for the video-only condition and the social presence reported for each of the mixed conditions. There was also a significant difference between the social presence reported for the video-only condition and the average social presence reported for both mixed conditions. See Table G-8 for the complete results for all scales including F-values and probabilities.

The user comments reported further illustrate the preference for sending and receiving video:

> "[I] prefer this style of communication especially with someone I don't know."
>
> "I definitely prefer verbal communication."
>
> "The video/video seemed very warm & friendly. It was also easier to communicate."
>
> "Just like talking face to face."

4.5 Overall Analysis of Social Presence

Social presence must be measured at the individual level. For this analysis, the experiment was considered as a factorial design in which group is an added between subject variable. A standard ANOVA was performed as outlined in Table G-9. The alpha level used was .05.

In addition to indicating main effects and interactions for the independent variables task and medium, this analysis indicates whether the dyad to which an individual was assigned had an effect on their perception of social presence. The remaining portions of this section review the results for each of the individual scales that make up the social presence questionnaire.

4.5.1 Personal-Impersonal Scale

The personal-impersonal scale was one of the five semantic differentials used by Short and Christie. Table G-10 outlines the results derived for this scale.

The results suggest that although the dyad had an effect on this scale, the effect was not quite significant, $F(7,8)=3.43$, $p=0.0525$. As with the remaining scales, only medium had a significant effect, $F(3,24)=26.03$, $p=<.0001$. A post-hoc analysis of the effect of medium was performed using Tukey's HSD, see Table G-11 for full details.

Sending video and receiving text was reported as the least personal medium. The post-hoc analysis indicates that the difference was significant between sending video and receiving text and all other media tested. Sending and receiving text was perceived as significantly more impersonal than sending text and receiving video. Sending and receiving video at the same time was reported as the most personal medium. The post-hoc analysis indicates that the difference was significant between sending and receiving video and all other media. No other differences were significant for this scale. These results are summarized in Table 4-3.

Table 4-3. Summary of Tukey's HSD for personal-impersonal scale.

Medium (Sent + Received)	Video+Text	Text+Text	Text+Video	Video+Video
Video+Text	-	Not Significant	Significant	Significant
Text+Text	Not significant	-	Not Significant	Significant
Text+Video	Significant	Not Significant	-	Significant
Video+Video	Significant	Significant	Significant	-

The user comments reported further illustrate the preference for sending text and receiving video versus sending video and receiving text:

> "I liked this set up better than the last one [sending video and receiving text]. I prefer being able to see/hear the other participant, even if I can only type, to the other way around."
>
> "That was easier than when I could see/hear her if I had to do the talking."

4.5.2 Warm-Cold Scale

The warm-cold scale is one of the five semantic differentials used by Short and Christie. Table G-12 outlines the results derived for this scale. As with the remaining scales, only medium has a significant effect, $F(3,24)=19.83$, $p=<.0001$. A post-hoc analysis of the effect of medium was performed using Tukey's HSD, as presented in Table G-13. Sending and receiving video was perceived as significantly warmer than all other media. No other differences were significant for this scale. These results are summarized in Table 4-4.

Table 4-4. Summary of Post-hoc Analysis Results for warm-cold Scale.

Medium (Sent + Received)	Video+Text	Text+Text	Text+Video	Video+Video
Video+Text	-	Not Significant	Not Significant	Significant
Text+Text	Not significant	-	Not Significant	Significant
Text+Video	Not Significant	Not Significant	-	Significant
Video+Video	Significant	Significant	Significant	-

4.5.3 Sensitive-Insensitive Scale

The sensitive-insensitive scale is one of the five semantic differentials used by Short and Christie. Table G-14 outlines the results derived for this scale. As with the remaining scales, only medium had a significant effect, $F(3,24)=8.63$, $p=0.0005$. A post-hoc analysis of the effect of medium was performed using Tukey's HSD, as presented in Table G-15. Sending and receiving video was reported to be significantly more sensitive than all other media. No other significant differences were reported for this scale. These results are summarized in Table 4-5.

Table 4-5. Summary of Post-hoc Analysis Results for Sensitive-insensitive Scale.

Medium (Sent + Received)	Video+Text	Text+Text	Text+Video	Video+Video
Video+Text	-	Not Significant	Not Significant	Significant
Text+Text	Not significant	-	Not Significant	Significant
Text+Video	Not Significant	Not Significant	-	Significant
Video+Video	Significant	Significant	Significant	-

4.5.4 Social-Unsocial Scale

The social-unsocial scale is one of the five semantic differentials used by Short and Christie. Table G-16 outlines the results derived for this scale. As with the remaining scales, only medium had a significant effect, $F(3,24)=18.58$, $p=<.0001$. A post-hoc analysis of the effect of medium was performed using Tukey's HSD, as presented in Table G-17. Sending and receiving video was reported to be significantly more social

than all other media. No other significant differences were reported for this scale. These results are summarized in Table 4-6.

Table 4-6. Summary of Post-hoc Analysis Results for Social-unsocial Scale.

Medium (Sent + Received)	Video+Text	Text+Text	Text+Video	Video+Video
Video+Text	-	Not Significant	Not Significant	Significant
Text+Text	Not significant	-	Not Significant	Significant
Text+Video	Not Significant	Not Significant	-	Significant
Video+Video	Significant	Significant	Significant	-

4.5.5 Passive-Active Scale

The passive-active scale is one of the five semantic differentials used by Short and Christie. Table G-18 outlines the results derived for this scale. As with the remaining scales, only medium had a significant effect, $F(3,24)=3.16$, $p=0.043$. A post-hoc analysis of the effect of medium was performed using Tukey's HSD, as presented in Table G-19. Although a significant effect of medium was reported for the active-passive scale, Tukey's HSD did not reveal a significant difference between any of the media tested. The difference between sending and receiving video and sending text and receiving video comes closest to significance, with an observed difference of 0.8828. These results are summarized in Table 4-7.

Table 4-7. Summary of Post-hoc Analysis Results for Passive-active Scale.

Medium (Sent + Received)	Video+Text	Text+Text	Text+Video	Video+Video
Video+Text	-	Not Significant	Not Significant	Not Significant
Text+Text	Not significant	-	Not Significant	Not Significant
Text+Video	Not Significant	Not Significant	-	Not Significant
Video+Video	Not Significant	Not Significant	Not Significant	-

4.5.6 Summary, Social Presence

A combined summary of the post-hoc analysis results for all scales is presented in Table 4-8, which displays the scales for which a significant difference was found for each combination of media.

Table 4-8. Combined Summary of Post-hoc Analyses for All Social Presence Scales.

Medium (Sent + Received)	Video+Text	Text+Text	Text+Video	Video+Video
Video+Text	-		personal-impersonal	personal-impersonal warm-cold sensitive-insensitive social-unsocial
Text+Text		-		personal-impersonal warm-cold sensitive-insensitive social-unsocial
Text+Video	personal-impersonal		-	personal-impersonal warm-cold sensitive-insensitive social-unsocial
Video+Video	personal-impersonal warm-cold sensitive-insensitive social-unsocial	personal-impersonal warm-cold sensitive-insensitive social-unsocial	personal-impersonal warm-cold sensitive-insensitive social-unsocial	-

4.6 Confounding Variables

In addition to the semantic differential used to measure social presence, the post-task questionnaire (see Appendix D) instructs the user to mark a Likert-type scale to indicate how strongly they agree or disagree with a series of statements. Participants were asked to circle the words most closely corresponding to their response. This data was scored from one to five, with 1 corresponding to "Strongly Disagree", 2 corresponding to "Disagree", 3 corresponding to "Neutral", 4 corresponding to "Agree", and 5 corresponding to "Strongly Agree". As the questions were arranged into oppositely worded pairs, the scale was inverted for one question in each pair, and the results averaged between pairs. The results for each dyad were compiled as the average of the individual responses made by each of the two participants.

4.6.1 Perceived Equivocality of Experimental Tasks

The paired statements used in the post-task questionnaire were designed to confirm the validity of the tasks selected for the experiment, in that they directly inquire about task complexity and ambiguity. Scoring was inverted for statements that are preceded by **(NEG)**:

1. **(NEG)** This task was simple.
5. This task was complex.

2. More than one reasonable solution exists for the problems faced in this task.
6. **(NEG)** There was a single reasonable solution for the problems faced in this task.

3. **(NEG)** The goals outlined for this task were clearly defined.
7. The goals outlined for this task were ambiguous

4. **(NEG)** The information provided to solve this task was clearly defined.
8. The information provided to solve this task was ambiguous.

Responses entered for pairs of oppositely worded questions were averaged for each participant. Responses entered by each member of a dyad were averaged to arrive at a response score for each pair of questions for each dyad.

During pretesting, the response scores were examined on a case-by-case basis to refine the sample tasks.

During the experiment, the same information was collected to confirm the subjective validity of the experimental tasks.

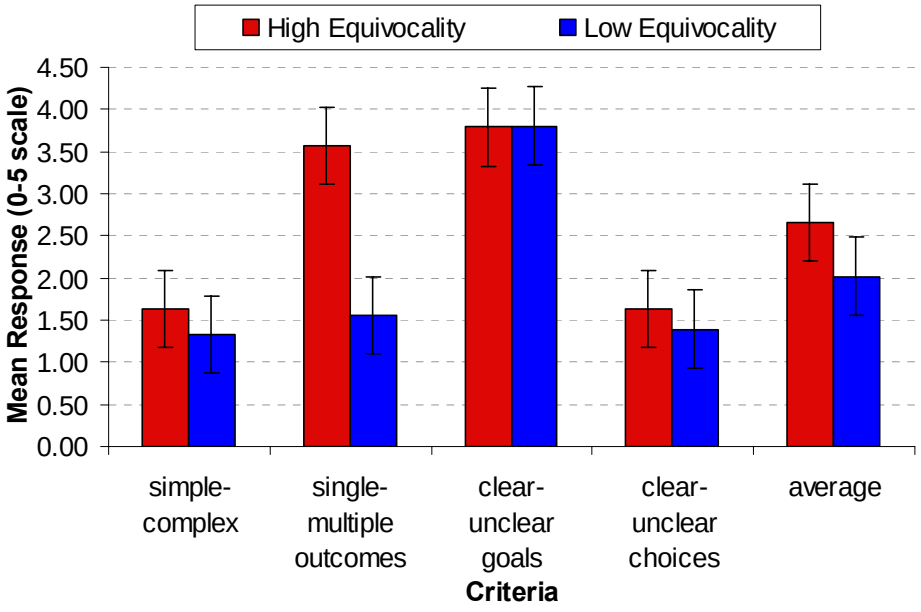

Figure 4-17. Perceived Equivocality by Task Type and Criteria.

Figure 4-17 illustrates that high Equivocality tasks were perceived as being more complex, having a greater number of successful outcomes, and having less clear choices. The goals were perceived as equally unclear for both types of task. The average perceived equivocality was higher for high equivocality tasks.

Comments about the low equivocality tasks highlighted that they were “simple” and “easy”. Comments about the high equivocality tasks suggested that they were “more difficult”, “not as simple”, and that “the task was a bit difficult seeing as there was no true correct answer”.

4.6.2 Gender

As social presence is an individual variable, it is possible to provide descriptive statistics comparing social presence responses by gender (see Figure 4-18).

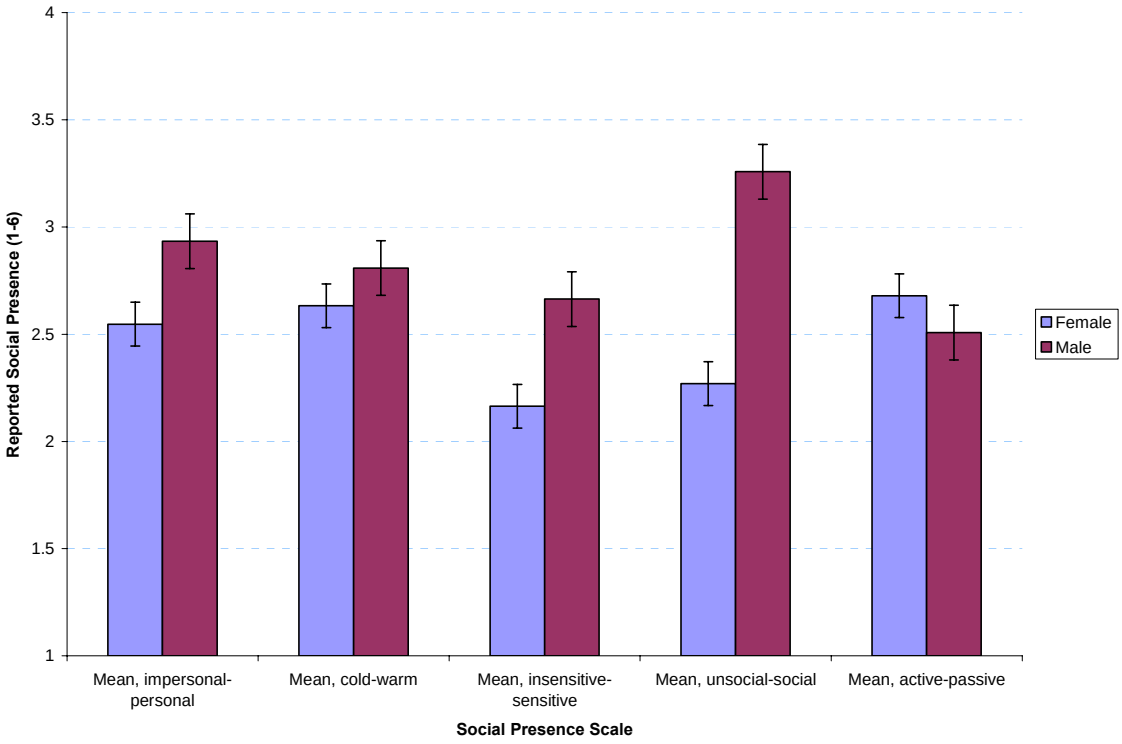

Figure 4-18. Social Presence by Gender.

Females indicated that communication conditions were less personal, colder, less sensitive, less social, and more passive than males. For all scales except social-unsocial, the difference was a half point or less (a half point is 8% of the total scale). For the social-unsocial scale, the difference was around a point (17% of the total scale). With the exception of the personal-impersonal scale, the same rough trend was observed for both males and females. This effect is in opposition to that reported in previous research (De Greef & IJsselsteijn, 2001). De Greef and Ijsselsteijn found that females were more sensitive to social presence than males.

4.6.3 Typing Speed

Each dyad completed six experimental tasks in which one or both participants made use of a text chat to communicate with their partner. When designed the experiment, there was a concern that typing speed would unduly influence the overall time to complete.

This potential effect was expected to be controlled by disallowing any participants who scored below 30WPM (none did). Each participant was also given a typing test so that the time to complete could be compared to the average typing speed of a dyad. Figure 4-19 shows the average time to complete for media conditions involving text, arranged by the average typing speed of the group in question. The linear trend is indicated by the heavy black line.

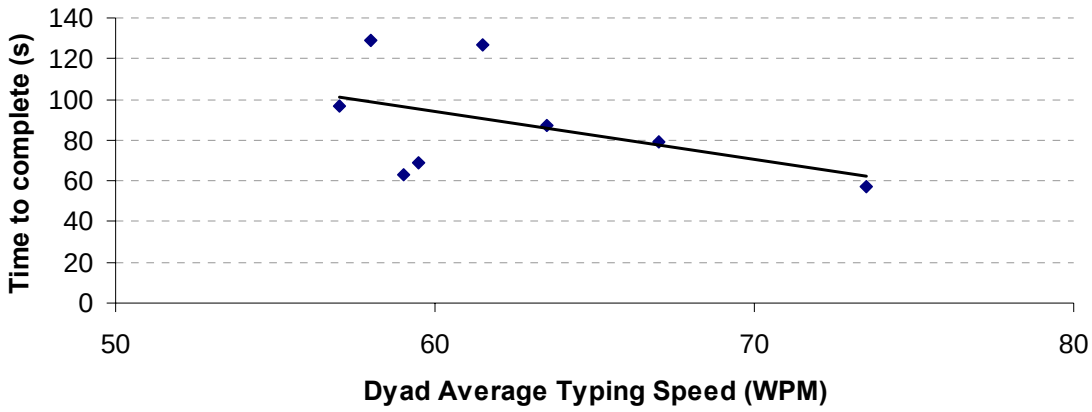

Figure 4-19. Time to complete IM tasks by Dyad Average Typing Speed.

The concern was that faster typists would perform better in tasks involving instant messaging. A slight trend in this direction was observed.

4.7 Participant Comments

At the end of each post-task questionnaire was an area reserved for free form comments, with instructions asking each participant to provide their feedback on the communication medium used or on the task itself. During pretesting, the text of these comments was reviewed to ensure that the sample tasks were appropriate and that the survey was appropriately and clearly worded.

Out of 128 surveys completed, users left 46 comments. These comments were transcribed, and are presented in full in Appendix F. Where appropriate, comments have been referenced throughout the results and discussion sections of this document.

4.8 Results Summary

4.8.1 Time to complete

Hypothesis 1A: For high equivocality tasks, time-to-complete is lower for mixed-richness environments than for text-only environments.

Hypothesis 1B: For high equivocality tasks, time-to-complete is higher for mixed-richness environments than for video-only environments.

Hypothesis 1C: For low equivocality tasks, time-to-complete is higher for mixed-richness environments than for text-only environments.

Hypothesis 1D: For low equivocality tasks, time-to-complete is lower for mixed-richness environments than for video-only environments.

Only one of the hypotheses supporting the task-media fitness theory was confirmed for the time to complete variable. The results confirmed only that high equivocality tasks took longer to complete sending and receiving text than using mixed-richness media.

Medium was found to have had a significant effect on time to complete. Task did not have a significant effect on time to complete, nor did the interaction between task and medium.

In examining the significant effect of medium, sending and receiving text was found to be significantly slower than all other tested media combinations. Sending and receiving video was found to be significantly faster than all other tested media combinations.

4.8.2 Communication Breakdown Frequency

Hypothesis 2A: For high equivocality tasks, communication breakdown frequency is lower for mixed-richness environments than for text-only environments.

Hypothesis 2B: For high equivocality tasks, communication breakdown frequency is higher for mixed-richness environments than for video-only environments.

Hypothesis 2C: For low equivocality tasks, communication breakdown frequency is higher for mixed-richness environments than for text-only environments.

Hypothesis 2D: For low equivocality tasks, communication breakdown frequency is lower for mixed-richness environments than for video-only environments.

None of the hypotheses supporting the task-media fitness theory was confirmed for communication breakdown frequency. There were no significant main effects or interactions discovered in the overall analysis of Communication Breakdown Frequency.

4.8.3 Social Presence

Hypothesis 3A: A higher sense of social presence is reported in mixed-richness environments than in text-only environments.

Hypothesis 3B: A lower sense of social presence is reported in mixed-richness environments than in video-only environments.

A significantly higher sense of social presence was observed for sending text and receiving video versus sending text and receiving text, but only for the personal-impersonal scale. A significantly higher sense of social presence was observed for sending video and receiving video versus any other combination of media. This comparison was significant for all scales.

In the overall analysis of social presence, medium was found to have had a significant effect for all social presence scales. The specific Dyad to which a participant was assigned did not have a significant effect on reported social presence, nor did task or any of the interactions between task, dyad, and medium.

In examining the significant effect of medium, a significant difference was found between sending and receiving video and all other media for all scales except active-passive. Sending and receiving video was perceived as more personal, warmer, more sensitive and more social. For the personal-impersonal scale, a significant difference was found between sending text and receiving video and sending text and receiving text as well as sending video and receiving text. Sending text and receiving video was perceived as more personal than sending video and receiving text or sending text and receiving text.

Chapter 5 – Discussion

5.1 Time to Complete

5.1.1 Task-Media Fitness and Time to Complete

Hypothesis 1A: For high equivocality tasks, time-to-complete is lower for mixed-richness environments than for text-only environments.

Hypothesis 1B: For high equivocality tasks, time-to-complete is higher for mixed-richness environments than for video-only environments.

Hypothesis 1C: For low equivocality tasks, time-to-complete is higher for mixed-richness environments than for text-only environments.

Hypothesis 1D: For low equivocality tasks, time-to-complete is lower for mixed-richness environments than for video-only environments.

All of the four hypotheses for time-to-complete were formulated to test task-media fitness. Of these, only hypothesis 1A was confirmed by the observed results. The results for the remaining hypotheses did not support task-media-fitness theory with significance, and the overall trend for low equivocality tasks was in the opposite direction of that predicted by task-media fitness theory. Task media fitness has previously been confirmed for high equivocality tasks more often than for low equivocality tasks (Tan et al., 1999). These results were confirmed in part by the results of this experiment, as one of the hypotheses regarding high equivocality tasks was confirmed. The lack of results for low equivocality tasks is in keeping with previous studies.

In comparison to the observed results, there is anecdotal evidence to support task-media fitness found in the user comments recorded:

> "For this particular exercise [a low equivocality catalog selection task], "chatting" on the computer was just as effective for conveying the necessary information."
>
> "It may have been more accurate to type all the requirements, but [it's] faster to just talk."

When the second comment refers to text as "accurate", it may be that the transcript is perceived as a more accurate reference than memory of a spoken conversation. Time to complete was lower for video communications than for IM, but there were a lot of requests for repeats of requirements observed when using video to complete low equivocality tasks. See section 5.4 for more discussion about the appropriateness of continuing to use task-media fitness theory.

5.1.2 Overall Effects on Time to Complete

Medium was found to have had a significant effect on time to complete. Using Tukey's HSD to examine the significant effect of medium, a significant difference was found between sending and receiving text and all other tested media combinations. Time to complete was highest when sending and receiving text regardless of task type. As with the results of the previous section, the results observed do not correspond to the results predicted by task-media fitness theory. See section 5.4 for more discussion about the appropriateness of continuing to use task-media fitness theory.

A significant difference was not found between the two types of mixed-richness media, which is not surprising, since time to complete was measured at the dyadic level, and should not be affected by differences between the two types of mixed-richness media.

The results observed suggest that if it is appropriate to use audio/video to facilitate communication related to a task, it provides a significant reduction in time to complete for all types of task versus any other communication media tested. If video is not appropriate for both ends of the conversation for technical or practical reasons, mixed-richness communications still offer a significant performance benefit versus text-only media. Text-only media require significantly longer time to complete tasks than any other combination of media tested. See section 5.6 for design implications derived from this observation.

5.2 Communication Breakdown Frequency

5.2.1 Task-Media Fitness and Communication Breakdown Frequency

Hypothesis 2A: For high equivocality tasks, communication breakdown frequency is lower for mixed-richness environments than for text-only environments.

Hypothesis 2B: For high equivocality tasks, communication breakdown frequency is higher for mixed-richness environments than for video-only environments.

Hypothesis 2C: For low equivocality tasks, communication breakdown frequency is higher for mixed-richness environments than for text-only environments.

Hypothesis 2D: For low equivocality tasks, communication breakdown frequency is lower for mixed-richness environments than for video-only environments.

All four hypotheses for communication breakdown frequency were formulated to test task-media fitness. The results did not support task-media-fitness theory with significance. See section 5.4 for more discussion about the appropriateness of continuing to use task-media fitness theory.

5.2.2 Overall Effects on Communication Breakdown Frequency

No significant effect on communication breakdown frequency was found for either task or medium. During pretesting, the data collected could be easily analyzed in terms of communication breakdown frequency, and trends emerged for the different combinations of medium and task. During the experiment itself, communication breakdowns were not observed at all for many combinations of task and medium. This may be in part because the operational definitions outlined in Kies' research were intended primarily for use in analyzing audio and video media, and did not lend themselves to analyzing text-only media or combinations of audio/video and text media.

An attempt was made to correct for this by identifying additional types of communication breakdowns requiring correction and/or introducing delays. A few unique to text-only media and combinations of text and audio/video media were identified. For example, there were a number of cases in which participants sending video and receiving text failed to attend to their partner because they were looking at their keyboard or paper handouts. However, because there was no objective recording of participants, it was not possible to screen for this new type of communication breakdown for participants sending text and receiving video.

The higher communication breakdown frequency observed during pretesting may also have to do with the populations tested. During pretesting, participants were 5-15 years older than the undergraduates tested during the experiment itself. It may be that there are generational differences in using communications media, such that younger participants experience fewer breakdowns in general than older participants.

It may be that communication breakdown frequency could still be a useful criterion in evaluating mixed-richness conditions. However, groundwork would have to be laid for analyzing communication breakdowns in text media. A wider range of breakdowns specific to text-only and mixed richness media would have to be observed, documented, and operationalized. It would also be necessary to have an objective video recording of all participants in a conversation to be able to identify problems with shifts in gaze, et cetera.

5.3 Social Presence

Hypothesis 3A: A higher sense of social presence is reported in mixed-richness environments than in text-only environments.

Hypothesis 3B: A lower sense of social presence is reported in mixed-richness environments than in video-only environments.

The results observed confirmed hypothesis 3A, but only for the personal-impersonal scale, and only when comparing text-only communications to sending text and receiving video. The results observed confirm hypothesis 3B for all scales.

5.3.1 Overall Effects on Social Presence

Using an ANOVA, medium was found to have had a significant effect for all social presence scales. A significant difference was found between sending and receiving video and all other media for all scales except active-passive. Sending and receiving video was perceived as more personal, warmer, more sensitive and more social. For the personal-impersonal scale, an additional significant difference was found between sending text and receiving video and sending video and receiving video. Sending text and receiving video was perceived as more personal.

These results suggest that mixed-richness media do not offer a clear improvement in perceived social presence versus text-only media. The results also suggest that sending and receiving video offers a clear improvement in perceived social presence versus mixed-richness media.

The results observed suggest that sending and receiving audio and video provides significant gains in perceived social presence versus mixed richness media, where sending and receiving text does not significantly degrade social presence versus mixed-richness media. This may provide justification for using audio and video only when it is available at both ends of the conversation, and using text chat otherwise. See section 5.6 for design implications derived from this observation.

5.4 Overall Concerns about Task-Media Fitness Theory

Task-media fitness is a measure that is not without its critics (most notably Alan Dennis and Susan Kinney). A number of studies have been unable to confirm task-media fitness.

This may be because the theory itself is unsound, or may be because the equivocality of tasks used in various experiments is not varied enough.

If there is a continued interest in exploring task-media fitness as a model for performing tasks with appropriate media, operational definitions for high and low equivocality tasks are needed. This study attempted to make use of an informal means of separating high equivocality tasks from low equivocality tasks, which was to ask questions about perceived equivocality. It may be that checking the perceived equivocality of idealized tasks may not be a useful method for validating experimental tasks. A better approach might be to poll workers for the types of tasks they complete using communications media, and to ask them to rate each task using criteria similar that used in the post-task questionnaire administered for this study. The experimental researcher would then attempt to construct tasks in a laboratory setting that are rated similarly to real-world tasks.

5.5 Additional Observations

When recording communication breakdown frequency and time to complete, the researcher watched each of the task recordings at least twice. During these viewings, a number of things were observed.

First, very few people made use of the video feed to make gestures. This may have been in part because people commonly held their instruction sheets in their hands while working on the experimental tasks.

Participants who received video while working on low equivocality tasks frequently asked their partner to repeat requirements. In some cases, request for repeats were made more than once while completing the same task. In some low equivocality trials, a partner transmitting video deliberately made use of the text chat to transmit their preferences as a means of providing a more permanent record. In other low equivocality trials, the partner using text transmitted the requirements their partner had spoken, which mean that the transcript contained all requirements for use as a reference. The text transcript that participants referred to when completing the low equivocality task is not a part of its richness using Daft and Lengle's definitions, but it made the text chat better suited for the low equivocality task used, at least in terms of user preferences.

5.6 Research Applications Revisited

This research is intended to apply to a range of work settings. See section 1.3 for a range of specific examples.

Work applications where this research is more directly applicable:

- **One-on-one communications between colleagues in private spaces and colleagues in public spaces.**
  Examples: Users working from areas with public internet access.
- **One-on-one professional consultations conducted at a distance.**
  Examples: doctors, lawyers, realtors, accountants, tutors
- **One-on-one interviews conducted remotely.**
- **One-on-one communications with colleagues that can receive rich media but cannot send because of technical or practical limitations.**
  Examples: laptop users, PDA users.
- **One-on-one communications with colleagues that can send rich media but cannot receive because of technical or practical limitations.**
  Examples: Truck drivers, cab drivers, delivery personnel
- **One-on-one communications with colleagues that have special needs that prohibit the use of specific media.**
  Examples: Users who can hear but not speak. Users who can speak and hear but who cannot type.

Work applications where this research is less directly applicable:

- **Communications involving groups of more than two persons in any of the contexts mentioned above.**
- **Cases in which one person presents content to a large number of users.**
  Examples: Distance learning, streaming of conference presentations to remote attendees.

5.6.1 Design Guidelines

This section outlines design guidelines for the communication aspects of work systems in the areas mentioned above and in section 1.3.

Design guidelines derived from the significant results of this experiment:

- **When the speed of communication is important, it is preferable to both send and receive video.**
  Text media and mixtures of text and video should be used primarily when other concerns are paramount, such as:
  - the desire not to interrupt
  - privacy concerns
  - noisy environments

- hardware limitations
- cost
- bandwidth limitations
- workers with special needs
- the need to refer to a text transcript

- **When it is important to control the emotional sense of the other party, sending and receiving video provides the best emotional sense.**
  If sending and receiving video is not feasible, including video on one end of the conversation provides a better emotional sense of the other party than using text chat only.

Design guidelines derived from user comments and researcher observations:

- **Systems that use text chat should include configurable visual and auditory notification of incoming messages.**
  Participants were often slow to respond to messages sent while their attention was directed away from the screen. Visual and auditory notifications help to minimize this, and are a common feature for two-person chats, but are not as common for multi-user chats, which could benefit from this feature.

- **Systems that use text chat should give an indication that a remote partner is composing a message.**
  Participants often transmitted multiple text utterances before their partner had a chance to finish responding. Participants receiving text and sending video also complained about the delay and about not knowing the status of their partner. A visual indication that a remote party is composing a reply would address both issues. This is another common feature for two-person chats, but is not as common for multi-user chats, which could benefit from this feature.

- **A text transcript of spoken content is a needed improvement for audio communications involving detailed information.**
  Participants commonly asked their partner to repeat detailed information transmitted using audio. Some spent time taking notes regarding what their partner had said. As speaker-independent text-to-speech capabilities improve, it would be useful for text transcripts to be produced as a reference. Text transcripts produced in real time would also offer exciting possibilities for hearing impaired users wishing to participate in audioconferences.
  If speaker-independent speech recognition continues to be elusive, it might be useful to buffer incoming conversations to disk as a reference during and after the conversation. Users with digital video recorders are already accustomed to pausing and skipping back through live broadcasts, similar functionality for videoconferencing might be of interest.

Chapter 6 – Future Research

By design, this study focused on a subset of the range of issues involved in mixed-mode communications. It is hoped that the very general questions addressed in this experiment lay the groundwork for more specialized experiments exploring the full range of issues.

Based on the experience of conducting this experiment, I would not recommend that future researchers interested in mixed media communication use Task-Media Fitness as a model. Using task-media fitness adds complexity to an experimental design that could be better used to isolate effects in another area (such as gender, age, or ethnicity).

I would recommend that future researchers continue to use time to complete when studying mixed-media communications, it was sensitive and easy to administer. I would also recommend using Social Presence as an individual measure, it made it possible to isolate the perception of combination of media experienced by the individual, which could be useful when studying more complex combinations.

I would not recommend that future researchers use Communication Breakdown Frequency to study communications involving text. If operational definitions are expanded to include text, it may be appropriate to use Communication Breakdown Frequency for synchronous communications, but it should not be used when studying asynchronous communications conducted using text chats.

I would recommend collecting enough samples to isolate gender effects. This study focused on the effect of using mixed-media communications rather than the effect of gender. Thus, the experiment controlled for gender by only running one possible gender combination for all dyads. Given the focus on the media itself, the study did not record enough observations to make any definite conclusions about the role of gender. Future studies could include a range of gender combinations. Alternately, future studies could replicate this study with a larger number of participants so that gender could be analyzed. If enough studies can demonstrate whether gender has a significant effect on mixed-richness communications, future researchers not concerned with gender will have a better idea whether it is appropriate to run only mixed-gender groups to simplify communication-related experiments.

I would recommend recruiting a wider range of participants in terms of age and ethnicity, so that future results can be fairly applied to systems used by a wider range of working individuals. Toward this end, I would recommend continuing to collect data regarding the reported age of participants, and collecting data regarding ethnicity. This would allow future experiments to look for effects of age and ethnicity, and would pave the way for metaanalyses looking across experiments with regards to age and ethnicity.

This study specifically addresses two communications media (videoconferencing and text chat) and combinations of the two. Future studies could expand the range of communications media to include more communications media and a wider set of mixed-mode combinations. A key area of exploration lies in separating the combined audio/video feed used in this experiment into separate concerns. The significant effects of the audio/video medium on social presence and time to complete could be broken down further to examine whether audio by itself has a similar effect on time to complete

and social presence. It would also be of use to examine whether time to complete and social presence are significantly different between audio only and audio/video media.

This study specifically involved mixed mode communications between a user conducting their portion of the conversation using text chat and a user conducting their portion of the conversation using videoconferencing. This distinction between media was important to isolate the differences between media. Having established a difference between video communications and other combinations of communications media, future studies could look at whether technological affordances could erase the distinction between video and other media. For example, studies could explore whether having automated speech recognition generate a transcript of spoken content would provide a benefit in mixed-mode communications involving audio content.

This study focused on mixing the most commonly used communications media, and on using media available commonly in the workplace today. Future studies could also look at mixed-mode communications in the context of virtual environments. Virtual environments are especially dependent on the availability of specialized hardware. Thus, it would be appropriate to study how collaborations conducted in virtual environments could be made to include collaborators without access to specialized hardware. For example, collaborative workgroups that meet in a virtual environment might include participants whose view of the collaborative environment is two-dimensional and whose conversation in presented as text within the virtual environment.

This study was concerned with the effect of using mixed-media communications. Including a shared workspace would make it difficult to isolate the effects of the communications media independently of the shared workspace. Future studies could look at mixed-mode communications that also include shared workspaces or other features of group and decision support systems.

This study was intended to compare media conditions to one another directly. With groups of two people and three media conditions, there were four combinations of medium sent and medium received possible. For groups of larger than two people, the combinations possible would increase exponentially. Addressing the new and basic questions posed by mixed-mode communications was best accomplished by limiting the communications to dyads. Future studies could include larger groups, making it possible to construct mixed-richness combinations that include face-to-face conditions. Future studies could also look at one-to-many/many-to-one communications such as those used in distance learning settings.

This study limited itself to decision-making tasks, as this type of task has most commonly been used in studies involving equivocality. Future studies not concerned with equivocality or task-media fitness could examine the effect of mixed-mode communications on other types of tasks. One class of tasks not covered by this study is inspection/repair tasks conducted by a novice who is advised by an expert. Future studies could look at an expert receiving a video feed from one or more novices, and study how the choice of outgoing medium from the expert to the novice affects task performance.

This study focused on the effect of using mixed-media communications rather than the effect of power relationships on communications. Thus, this study was limited to

conversations between peers. Future studies could look at mixed-mode conversations between users who have varying amounts of power within the same organization.

This study was designed to monitor communication breakdowns that were the result of technological and psychological limitations rather than cultural misunderstandings or physiological limitations. Thus, this study was limited to conversations between two English speakers with normal hearing and speech. Future studies could look at the additional issues involved in mixed-mode conversations between users with normal hearing and speech and users with hearing or speech difficulties as facilitated by either an operator assisted or automated text relay service.

Future studies could also look at conversations between speakers of different languages that are facilitated by a translator. For example, a study could be conducted comparing the medium received by the translator to their performance. Alternately, a study could be conducted comparing the medium sent by the translator, to see if sending text provides performance benefits or an improved sense of the original speaker versus sending audio, which obscures the original speaker's voice.

Finally, but importantly, future research should look at conversations involving users with special needs. Studies of these users can indicate how they choose to use communication technologies, and how communication technologies can be improved to meet their needs. For example, users with speech impairments may be able to benefit from the use of text-to-speech in conjunction with text chat, this could be studied experimentally and ethnographically.

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Appendix A. Informed Consent Form and IRB Approval

A.1. Informed Consent Form

Purpose of This Experiment

If you agree to participate in this study, you will use a computer to communicate with a partner while completing a series of simple tasks. At the end of each task, you will be asked to complete two questionnaires.

During this session, all communications between you and your partner will be recorded. This will include video and audio recordings as well as the capturing of text chat (IM) transcripts.

Risks

The risks associated with this study are minimal, and are comparable those encountered during short periods of light office work.

Benefits of this Research

Your participation in this study will add to the body of knowledge regarding computer-mediated communications. No specific benefits to you are expected.

Compensation

You will not receive any money for participating in this study. If you are enrolled in a course whose instructor offers course credit for participating in research, please inform the researcher so that your instructor can be notified and course credit given where appropriate.

Your Rights as a Research Participant

1. You may leave the study at any time without penalty.
    a. You may choose to leave the experiment at any time prior to the completion of your session.
    b. If you decide after participating in the session that you do not wish for your data to be used, you may contact the researcher and have your data withdrawn.
2. Your personal information will be held in strict confidence.
    a. Your name will not be directly associated with any data recorded or results reported in this study.
    b. You will be introduced briefly to your partner prior to beginning work on the tasks. If you wish not to be identified by name to your partner, please check the appropriate box on the next page.
    c. All video and audio information will be used only by the researchers for this study and for publications derived from this study. All raw video and audio data will be deleted no later than one year after the completion of the study. Your likeness and voice will not be used in any publication or presentation.
    d. Portions of audio and video in which your face has been blurred and your voice obscured may be used in publications or presentations. If you do not wish to for your audio and video to be used in this way, please check the appropriate box below.
    e. Text transcripts of the audio and chat portions of your sessions may be retained to assist the researchers in constructing future experiments. If you do not wish for your transcripts to be retained, please check the appropriate box below.

f. Text transcripts of the audio and chat portions of your sessions may be published, but your name will not be identified in relation to the study, nor will any personal identifiers (names, etc.) used in your conversation be published. If you do not wish for any portion of your transcripts to be published or used in presentations, please check the appropriate box below.

Your Responsibilities as a Research Participant

1. After the end of your session, you should not discuss your experiences with any other individual for two months. This will help ensure that all future participants come into the experiment without an unfair understanding of the experiment.

Privacy Options

Please indicate any limitations you wish to place on the use of recorded data from your session (check all that apply):

☐ I do not wish to be identified by name to my partner.

☐ I do not wish for my text transcripts to be retained.

☐ I do not wish for anonymized versions of my text transcripts to be published or used in presentations.

☐ I do not wish for anonymized versions of my audio and video content to be published or used in presentations.

Please take a moment to ask any questions you may have.

When you are satisfied that your questions have been answered, please sign below to indicate that you have been informed of your rights and responsibilities.

If you are not comfortable with the terms and conditions presented here, you may end your participation now or at any time before the end of the session.

Permission

I acknowledge the above and give my consent for participation in this experiment. I understand that I may withdraw at any time without penalty.

_____ _____

print your name date

_____

signature

If I have any questions about this research or its conduct, I may contact:

Dr. Brian M. Kleiner	Investigator	231-4926
Anthony Atkins	Co-Investigator	230-5482
Dr. David Moore	Chair, IRB Research Division	231-4991

A.2. IRB Approval Letter

Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

Institutional Review Board

Dr. David M. Moore
IRB (Human Subjects) Chair
Assistant Vice President for Research Compliance
1880 Pratt Drive, Suite 2006(0497), Blacksburg, VA 24061
Office: 540/231-4991; FAX: 540/231-0959
email: moored@vt.edu

DATE: December 28, 2005

MEMORANDUM

TO: Brian M. Kleiner ISE 0118
Anthony Atkins ISE 0118

FROM: David Moore

SUBJECT: **IRB Expedited Approval:** "Mixed Media Richness and Computer-Mediated Communications" IRB # 05-794

This memo is regarding the above-mentioned protocol. The proposed research is eligible for expedited review according to the specifications authorized by 45 CFR 46.110 and 21 CFR 56.110. As Chair of the Virginia Tech Institutional Review Board, I have granted approval to the study for a period of 12 months, effective December 22, 2005.

Virginia Tech has an approved Federal Wide Assurance (FWA00000572, exp. 7/20/07) on file with OHRP, and its IRB Registration Number is IRB00000667.

cc: File
Department Reviewer: Thurmon E. Lockhart
T. Coalson 0118

Appendix B. Demographic Questionnaire

This section presents the complete text of the recruitment survey administered to potential participants prior to scheduling their experimental session. This survey was administered using survey.vt.edu, a service provided by the university.

Recruitment Survey

Thanks for your interest in participating in a study related to instant messaging and videoconferencing. Please take a few moments to complete the following survey indicating your background and availability for test sessions.

General Information

Please provide some basic information about yourself.

Email Address: [ ]

Sex: ○male ○female

Age: [ ]

What country were you born in? [ ]

If you were not born in the US, how may years have you lived in the US? [ ]

Is English your primary language? ○yes ○no

If not, how many years have you studied English? [ ]

Computer Skills

This study involves the use of instant messaging and videoconferencing. Please provide information about your previous experience in these areas.

On average, how much time do you spend using a computer in a single day?
○1 hour or less a day
○Between 1 and 2 hours a day
○Between 2 and 3 hours a day
○3 or more hours a day

Which of the following forms of communication have you used? (check all that apply)
☐Audioconferencing (Voice over IP, conferences conducted via speakerphone, etc.)
☐Videoconferencing (Netmeeting, iChat, conferences conducted via satellite feed, etc.)
☐Email
☐Threaded Discussions (Newsgroups, web-based forums, etc.)
☐Instant Messaging (AIM, ICQ, Jabber, MSN Messenger, Yahoo Messenger, etc.)
☐Internet Relay Chat
Other Chat Software (please specify) [ ]

How often do you use a computer to communicate with others?
○1 hour or less a day
○Between 1 and 2 hours a day
○Between 2 and 3 hours a day
○3 or more hours a day

How often do you use text chat (IRC, IM, etc.) to communicate with others?
○1 hour or less a day
○Between 1 and 2 hours a day
○Between 2 and 3 hours a day
○3 or more hours a day

When you use text chat (IRC, IM, etc.), do you:

Use acronyms (LOL, OMG, BRB, etc.)? ○yes ○no

Use simplified spellings for words ("U" instead of "you", etc.)? ○yes ○no

Use emoticons or "smileys" such as :)? ○yes ○no

Write using incomplete sentences? ○yes ○no

When you use text chat (IRC, IM, etc.), are you able to understand people who:

Use acronyms (LOL, OMG, BRB, etc.)? ○yes ○no

Use simplified spellings for words ("U" instead of "you", etc.)? ○yes ○no

Use emoticons or "smileys" such as :)? ○yes ○no

Write using incomplete sentences? ○yes ○no

Availability

To participate in this study, you must be able to attend one of the two hour sessions listed below. Please check all of the times you are available, again, only one session is actually needed. Use the "Notes" field below if you wish to indicate a preference for a particular date and time.

January 21st - January 22nd

- ☐ Saturday, January 21st, 10:00 AM - 12:00 PM
- ☐ Saturday, January 21st, 1:00 PM - 3:00 PM
- ☐ Saturday, January 21st, 4:00 PM - 6:00 PM
- ☐ Sunday, January 22nd, 10:00 AM - 12:00 PM
- ☐ Sunday, January 22nd, 1:00 PM - 3:00 PM
- ☐ Sunday, January 22nd, 4:00 PM - 6:00 PM

January 23rd - January 29th

- ☐ Monday, January 23rd, 6:00 PM - 8:00 PM
- ☐ Tuesday, January 24th, 6:00 PM - 8:00 PM
- ☐ Wednesday, January 25th, 6:00 PM - 8:00 PM
- ☐ Thursday, January 26th, 6:00 PM - 8:00 PM
- ☐ Friday, January 27th, 6:00 PM - 8:00 PM
- ☐ Saturday, January 28th, 10:00 AM - 12:00 PM
- ☐ Saturday, January 28th, 1:00 PM - 3:00 PM
- ☐ Saturday, January 28th, 4:00 PM - 6:00 PM
- ☐ Sunday, January 29th, 10:00 AM - 12:00 PM
- ☐ Sunday, January 29th, 1:00 PM - 3:00 PM
- ☐ Sunday, January 29th, 4:00 PM - 6:00 PM

January 30th - February 2nd

- ☐ Monday, January 30rd, 6:00 PM - 8:00 PM
- ☐ Tuesday, January 31st, 6:00 PM - 8:00 PM
- ☐ Wednesday, February 1st, 6:00 PM - 8:00 PM
- ☐ Thursday, February 2nd, 6:00 PM - 8:00 PM

Notes:
Please enter any special instructions or preferences you have regarding the date and time of your session.

Thanks for taking the time to complete this form. To finish entering your data, click the submit button.

Submit

All information collected on this form is confidential. If you have questions or concerns about this form, please contact anthony.atkins@vt.edu.

Appendix C. Task Scenarios and Instructions.

Practice Tasks

CMC Practice Task

Participant A Instruction Sheet

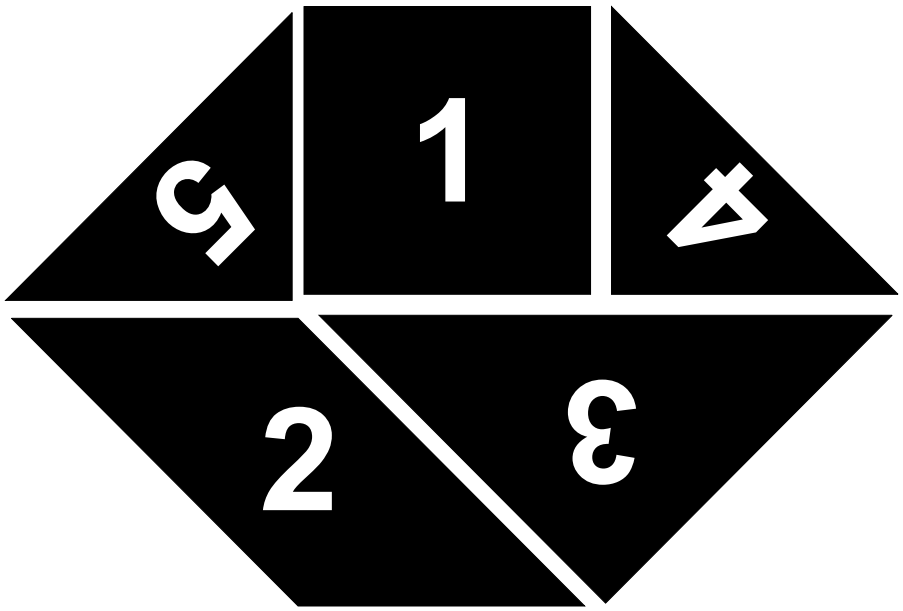
You and your partner must work together to arrange a set of numbered blocks to match a pattern.

You have been given a pattern indicating the placement of each of the numbered blocks. Your partner has been given the numbered blocks.

You will use the text messaging system to communicate with your partner. Below is a picture of the pattern.

When you have read the instructions and are ready to begin, signal the researcher by typing "ready" in the chat window.

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.



When you and your partner feel that you have assembled the blocks to match the pattern, signal the researcher by typing “done” in the chat window.

CMC Practice Task

Participant B Instruction Sheet

You and your partner must work together to arrange a set of numbered blocks to match a pattern.

You have been given the numbered blocks.

Your partner has been given a pattern indicating the placement of each of the numbered blocks. You will use the text messaging system to communicate with your partner.

When you have read the instructions and are ready to begin, signal the researcher by typing "ready" in the chat window.

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

When you and your partner feel that you have assembled the blocks to match the pattern, signal the researcher by typing “done” in the chat window.

Video Practice Task

Participant A Instruction Sheet

You and your partner must work together to arrange a set of numbered blocks to match a pattern.

You have been given the numbered blocks. Your partner has been given a pattern indicating the placement of each of the numbered blocks.

Use the text videoconferencing equipment to communicate with your partner. You may not display the state of the blocks to your partner.

When you have read the instructions and are ready to begin, signal the researcher by saying "ready".

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

When you and your partner feel that you have assembled the blocks to match the pattern, signal the researcher by saying “done”.

Video Practice Task

Participant B Instruction Sheet

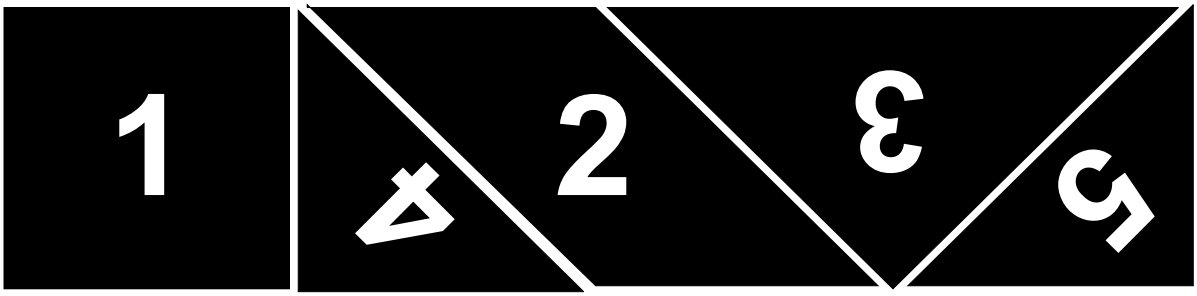
You and your partner must work together to arrange a set of numbered blocks to match a pattern.

You have been given a pattern indicating the placement of each of the numbered blocks. Your partner has been given the numbered blocks.

Use the videoconferencing system to communicate with your partner. Below is a picture of the pattern. You may not show the pattern to your partner.

When you have read the instructions and are ready to begin, signal the researcher by saying "ready".

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.



When you and your partner feel that you have assembled the blocks to match the pattern, signal the researcher by saying “done”.

Low Equivocality Tasks

Low Equivocality Task 1

Participant A Instruction Sheet

You and your partner must work together to select a lens from a catalog. You must select the lens that matches a list of requirements.

You have been given the appropriate page of the catalog and two of the four requirements. Your partner has been given the same page of the catalog and an additional list of requirements.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

When you have read the instructions and are ready to begin, signal the researcher by saying "ready" or typing "ready" in the chat window.

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

Part #	Focal Length	Diameter	Thickness	Price
LENS-10-06-02	10 mm	6 mm	2 mm	$20
LENS-10-06-04	10 mm	6 mm	4 mm	$24
LENS-10-06-06	10 mm	6 mm	6 mm	$28
LENS-10-09-03	10 mm	9 mm	3 mm	$28
LENS-10-09-05	10 mm	9 mm	5 mm	$32
LENS-10-09-07	10 mm	9 mm	7 mm	$36
LENS-10-12-04	10 mm	12 mm	4 mm	$36
LENS-10-12-06	10 mm	12 mm	6 mm	$40
LENS-10-12-08	10 mm	12 mm	8 mm	$44
LENS-10-15-05	10 mm	15 mm	5 mm	$44
LENS-10-15-07	10 mm	15 mm	7 mm	$48
LENS-10-15-09	10 mm	15 mm	9 mm	$52
LENS-10-18-06	10 mm	18 mm	6 mm	$52
LENS-10-18-08	10 mm	18 mm	8 mm	$56
LENS-10-18-10	10 mm	18 mm	10 mm	$60
LENS-15-09-03	15 mm	9 mm	3 mm	$30
LENS-15-09-05	15 mm	9 mm	5 mm	$34
LENS-15-09-07	15 mm	9 mm	7 mm	$38
LENS-15-12-04	15 mm	12 mm	4 mm	$38
LENS-15-12-06	15 mm	12 mm	6 mm	$42
LENS-15-12-08	15 mm	12 mm	8 mm	$46
LENS-15-15-05	15 mm	15 mm	5 mm	$46
LENS-15-15-07	15 mm	15 mm	7 mm	$50
LENS-15-15-09	15 mm	15 mm	9 mm	$54
LENS-15-18-06	15 mm	18 mm	6 mm	$54
LENS-15-18-08	15 mm	18 mm	8 mm	$58
LENS-15-18-10	15 mm	18 mm	10 mm	$62
LENS-15-21-07	15 mm	21 mm	7 mm	$62
LENS-15-21-09	15 mm	21 mm	9 mm	$66
LENS-15-21-11	15 mm	21 mm	11 mm	$70
LENS-20-12-04	20 mm	12 mm	4 mm	$40
LENS-20-12-06	20 mm	12 mm	6 mm	$44
LENS-20-12-08	20 mm	12 mm	8 mm	$48
LENS-20-15-05	20 mm	15 mm	5 mm	$48
LENS-20-15-07	20 mm	15 mm	7 mm	$52
LENS-20-15-09	20 mm	15 mm	9 mm	$56
LENS-20-18-06	20 mm	18 mm	6 mm	$56
LENS-20-18-08	20 mm	18 mm	8 mm	$60
LENS-20-18-10	20 mm	18 mm	10 mm	$64
LENS-20-21-07	20 mm	21 mm	7 mm	$64
LENS-20-21-09	20 mm	21 mm	9 mm	$68
LENS-20-21-11	20 mm	21 mm	11 mm	$72
LENS-20-24-08	20 mm	24 mm	8 mm	$72
LENS-20-24-10	20 mm	24 mm	10 mm	$76
LENS-20-24-12	20 mm	24 mm	12 mm	$80

Requirements

1. The lens must cost no more than $67.

2. The lens must have Focal Length between 15 and 20 millimeters.

When you and your partner feel that you have selected the product that best matches the requirements, record the part number of the selected lens below.

Part # _____

When you have recorded the part number of the selected lens, signal the researcher by saying "done" or typing "done" in the chat window.

Low Equivocality Task 1

Participant B Instruction Sheet

You and your partner must work together to select a lens from a catalog. You must select the lens that matches a list of requirements.

You have been given the appropriate page of the catalog and two of the four requirements. Your partner has been given the same page of the catalog and an additional list of requirements.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

When you have read the instructions and are ready to begin, signal the researcher by saying "ready" or typing "ready" in the chat window.

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

Part #	Focal Length	Diameter	Thickness	Price
LENS-10-06-02	10 mm	6 mm	2 mm	$20
LENS-10-06-04	10 mm	6 mm	4 mm	$24
LENS-10-06-06	10 mm	6 mm	6 mm	$28
LENS-10-09-03	10 mm	9 mm	3 mm	$28
LENS-10-09-05	10 mm	9 mm	5 mm	$32
LENS-10-09-07	10 mm	9 mm	7 mm	$36
LENS-10-12-04	10 mm	12 mm	4 mm	$36
LENS-10-12-06	10 mm	12 mm	6 mm	$40
LENS-10-12-08	10 mm	12 mm	8 mm	$44
LENS-10-15-05	10 mm	15 mm	5 mm	$44
LENS-10-15-07	10 mm	15 mm	7 mm	$48
LENS-10-15-09	10 mm	15 mm	9 mm	$52
LENS-10-18-06	10 mm	18 mm	6 mm	$52
LENS-10-18-08	10 mm	18 mm	8 mm	$56
LENS-10-18-10	10 mm	18 mm	10 mm	$60
LENS-15-09-03	15 mm	9 mm	3 mm	$30
LENS-15-09-05	15 mm	9 mm	5 mm	$34
LENS-15-09-07	15 mm	9 mm	7 mm	$38
LENS-15-12-04	15 mm	12 mm	4 mm	$38
LENS-15-12-06	15 mm	12 mm	6 mm	$42
LENS-15-12-08	15 mm	12 mm	8 mm	$46
LENS-15-15-05	15 mm	15 mm	5 mm	$46
LENS-15-15-07	15 mm	15 mm	7 mm	$50
LENS-15-15-09	15 mm	15 mm	9 mm	$54
LENS-15-18-06	15 mm	18 mm	6 mm	$54
LENS-15-18-08	15 mm	18 mm	8 mm	$58
LENS-15-18-10	15 mm	18 mm	10 mm	$62
LENS-15-21-07	15 mm	21 mm	7 mm	$62
LENS-15-21-09	15 mm	21 mm	9 mm	$66
LENS-15-21-11	15 mm	21 mm	11 mm	$70
LENS-20-12-04	20 mm	12 mm	4 mm	$40
LENS-20-12-06	20 mm	12 mm	6 mm	$44
LENS-20-12-08	20 mm	12 mm	8 mm	$48
LENS-20-15-05	20 mm	15 mm	5 mm	$48
LENS-20-15-07	20 mm	15 mm	7 mm	$52
LENS-20-15-09	20 mm	15 mm	9 mm	$56
LENS-20-18-06	20 mm	18 mm	6 mm	$56
LENS-20-18-08	20 mm	18 mm	8 mm	$60
LENS-20-18-10	20 mm	18 mm	10 mm	$64
LENS-20-21-07	20 mm	21 mm	7 mm	$64
LENS-20-21-09	20 mm	21 mm	9 mm	$68
LENS-20-21-11	20 mm	21 mm	11 mm	$72
LENS-20-24-08	20 mm	24 mm	8 mm	$72
LENS-20-24-10	20 mm	24 mm	10 mm	$76
LENS-20-24-12	20 mm	24 mm	12 mm	$80

Requirements

1. The lens must be 21 millimeters in diameter.
2. The lens must be between 9 and 11 millimeters thick.

When you and your partner feel that you have selected the product that best matches the requirements, record the part number of the selected lens below.

Part # _____

When you have recorded the part number of the selected lens, signal the researcher by saying "done" or typing "done" in the chat window.

Low Equivocality Task 1

Answer Key

Only part # LENS-15-21-09 meets all of the selected criteria.

Low Equivocality Task 2

Participant A Instruction Sheet

You and your partner must work together to select a lens from a catalog. You must select the lens that matches a list of requirements.

You have been given the appropriate page of the catalog and two of the four requirements. Your partner has been given the same page of the catalog and an additional list of requirements.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

When you have read the instructions and are ready to begin, signal the researcher by saying "ready" or typing "ready" in the chat window.

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

Part #	Focal Length	Diameter	Thickness	Price
LENS-10-06-02	10 mm	6 mm	2 mm	$20
LENS-10-06-04	10 mm	6 mm	4 mm	$24
LENS-10-06-06	10 mm	6 mm	6 mm	$28
LENS-10-09-03	10 mm	9 mm	3 mm	$28
LENS-10-09-05	10 mm	9 mm	5 mm	$32
LENS-10-09-07	10 mm	9 mm	7 mm	$36
LENS-10-12-04	10 mm	12 mm	4 mm	$36
LENS-10-12-06	10 mm	12 mm	6 mm	$40
LENS-10-12-08	10 mm	12 mm	8 mm	$44
LENS-10-15-05	10 mm	15 mm	5 mm	$44
LENS-10-15-07	10 mm	15 mm	7 mm	$48
LENS-10-15-09	10 mm	15 mm	9 mm	$52
LENS-10-18-06	10 mm	18 mm	6 mm	$52
LENS-10-18-08	10 mm	18 mm	8 mm	$56
LENS-10-18-10	10 mm	18 mm	10 mm	$60
LENS-15-09-03	15 mm	9 mm	3 mm	$30
LENS-15-09-05	15 mm	9 mm	5 mm	$34
LENS-15-09-07	15 mm	9 mm	7 mm	$38
LENS-15-12-04	15 mm	12 mm	4 mm	$38
LENS-15-12-06	15 mm	12 mm	6 mm	$42
LENS-15-12-08	15 mm	12 mm	8 mm	$46
LENS-15-15-05	15 mm	15 mm	5 mm	$46
LENS-15-15-07	15 mm	15 mm	7 mm	$50
LENS-15-15-09	15 mm	15 mm	9 mm	$54
LENS-15-18-06	15 mm	18 mm	6 mm	$54
LENS-15-18-08	15 mm	18 mm	8 mm	$58
LENS-15-18-10	15 mm	18 mm	10 mm	$62
LENS-15-21-07	15 mm	21 mm	7 mm	$62
LENS-15-21-09	15 mm	21 mm	9 mm	$66
LENS-15-21-11	15 mm	21 mm	11 mm	$70
LENS-20-12-04	20 mm	12 mm	4 mm	$40
LENS-20-12-06	20 mm	12 mm	6 mm	$44
LENS-20-12-08	20 mm	12 mm	8 mm	$48
LENS-20-15-05	20 mm	15 mm	5 mm	$48
LENS-20-15-07	20 mm	15 mm	7 mm	$52
LENS-20-15-09	20 mm	15 mm	9 mm	$56
LENS-20-18-06	20 mm	18 mm	6 mm	$56
LENS-20-18-08	20 mm	18 mm	8 mm	$60
LENS-20-18-10	20 mm	18 mm	10 mm	$64
LENS-20-21-07	20 mm	21 mm	7 mm	$64
LENS-20-21-09	20 mm	21 mm	9 mm	$68
LENS-20-21-11	20 mm	21 mm	11 mm	$72
LENS-20-24-08	20 mm	24 mm	8 mm	$72
LENS-20-24-10	20 mm	24 mm	10 mm	$76
LENS-20-24-12	20 mm	24 mm	12 mm	$80

Requirements

1. The lens must be 18 millimeters in diameter.
2. The lens must be between 6 and 7 millimeters thick.

When you and your partner feel that you have selected the product that best matches the requirements, record the part number of the selected lens below.

Part # _____

When you have recorded the part number of the selected lens, signal the researcher by saying “done” or typing “done” in the chat window.

Low Equivocality Task 2

Participant B Instruction Sheet

You and your partner must work together to select a lens from a catalog. You must select the lens that matches a list of requirements.

You have been given the appropriate page of the catalog and two of the four requirements Your partner has been given the same page of the catalog and an additional list of requirements.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

When you have read the instructions and are ready to begin, signal the researcher by saying "ready" or typing "ready" in the chat window.

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

Part #	Focal Length	Diameter	Thickness	Price
LENS-10-06-02	10 mm	6 mm	2 mm	$20
LENS-10-06-04	10 mm	6 mm	4 mm	$24
LENS-10-06-06	10 mm	6 mm	6 mm	$28
LENS-10-09-03	10 mm	9 mm	3 mm	$28
LENS-10-09-05	10 mm	9 mm	5 mm	$32
LENS-10-09-07	10 mm	9 mm	7 mm	$36
LENS-10-12-04	10 mm	12 mm	4 mm	$36
LENS-10-12-06	10 mm	12 mm	6 mm	$40
LENS-10-12-08	10 mm	12 mm	8 mm	$44
LENS-10-15-05	10 mm	15 mm	5 mm	$44
LENS-10-15-07	10 mm	15 mm	7 mm	$48
LENS-10-15-09	10 mm	15 mm	9 mm	$52
LENS-10-18-06	10 mm	18 mm	6 mm	$52
LENS-10-18-08	10 mm	18 mm	8 mm	$56
LENS-10-18-10	10 mm	18 mm	10 mm	$60
LENS-15-09-03	15 mm	9 mm	3 mm	$30
LENS-15-09-05	15 mm	9 mm	5 mm	$34
LENS-15-09-07	15 mm	9 mm	7 mm	$38
LENS-15-12-04	15 mm	12 mm	4 mm	$38
LENS-15-12-06	15 mm	12 mm	6 mm	$42
LENS-15-12-08	15 mm	12 mm	8 mm	$46
LENS-15-15-05	15 mm	15 mm	5 mm	$46
LENS-15-15-07	15 mm	15 mm	7 mm	$50
LENS-15-15-09	15 mm	15 mm	9 mm	$54
LENS-15-18-06	15 mm	18 mm	6 mm	$54
LENS-15-18-08	15 mm	18 mm	8 mm	$58
LENS-15-18-10	15 mm	18 mm	10 mm	$62
LENS-15-21-07	15 mm	21 mm	7 mm	$62
LENS-15-21-09	15 mm	21 mm	9 mm	$66
LENS-15-21-11	15 mm	21 mm	11 mm	$70
LENS-20-12-04	20 mm	12 mm	4 mm	$40
LENS-20-12-06	20 mm	12 mm	6 mm	$44
LENS-20-12-08	20 mm	12 mm	8 mm	$48
LENS-20-15-05	20 mm	15 mm	5 mm	$48
LENS-20-15-07	20 mm	15 mm	7 mm	$52
LENS-20-15-09	20 mm	15 mm	9 mm	$56
LENS-20-18-06	20 mm	18 mm	6 mm	$56
LENS-20-18-08	20 mm	18 mm	8 mm	$60
LENS-20-18-10	20 mm	18 mm	10 mm	$64
LENS-20-21-07	20 mm	21 mm	7 mm	$64
LENS-20-21-09	20 mm	21 mm	9 mm	$68
LENS-20-21-11	20 mm	21 mm	11 mm	$72
LENS-20-24-08	20 mm	24 mm	8 mm	$72
LENS-20-24-10	20 mm	24 mm	10 mm	$76
LENS-20-24-12	20 mm	24 mm	12 mm	$80

Requirements

1. The lens must cost no more $53.
2. The lens must have Focal Length between 10 and 15 millimeters.

When you and your partner feel that you have selected the product that best matches the requirements, record the part number of the selected lens below.

Part # _____

When you have recorded the part number of the selected lens, signal the researcher by saying "done" or typing "done" in the chat window.

Low Equivocality Task 2

Answer Key

Only part # LENS-10-18-06 meets all of the selected criteria.

Low Equivocality Task 3

Participant A Instruction Sheet

You and your partner must work together to select a lens from a catalog. You must select the lens that matches a list of requirements.

You have been given the appropriate page of the catalog and two of the four requirements. Your partner has been given the same page of the catalog and an additional list of requirements.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

When you have read the instructions and are ready to begin, signal the researcher by saying "ready" or typing "ready" in the chat window.

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

Part #	Focal Length	Diameter	Thickness	Price
LENS-10-06-02	10 mm	6 mm	2 mm	$10
LENS-10-06-04	10 mm	6 mm	4 mm	$12
LENS-10-06-06	10 mm	6 mm	6 mm	$14
LENS-10-09-03	10 mm	9 mm	3 mm	$14
LENS-10-09-05	10 mm	9 mm	5 mm	$16
LENS-10-09-07	10 mm	9 mm	7 mm	$18
LENS-10-12-04	10 mm	12 mm	4 mm	$18
LENS-10-12-06	10 mm	12 mm	6 mm	$20
LENS-10-12-08	10 mm	12 mm	8 mm	$22
LENS-10-15-05	10 mm	15 mm	5 mm	$22
LENS-10-15-07	10 mm	15 mm	7 mm	$24
LENS-10-15-09	10 mm	15 mm	9 mm	$26
LENS-10-18-06	10 mm	18 mm	6 mm	$26
LENS-10-18-08	10 mm	18 mm	8 mm	$28
LENS-10-18-10	10 mm	18 mm	10 mm	$30
LENS-15-09-03	15 mm	9 mm	3 mm	$15
LENS-15-09-05	15 mm	9 mm	5 mm	$17
LENS-15-09-07	15 mm	9 mm	7 mm	$19
LENS-15-12-04	15 mm	12 mm	4 mm	$19
LENS-15-12-06	15 mm	12 mm	6 mm	$21
LENS-15-12-08	15 mm	12 mm	8 mm	$23
LENS-15-15-05	15 mm	15 mm	5 mm	$23
LENS-15-15-07	15 mm	15 mm	7 mm	$25
LENS-15-15-09	15 mm	15 mm	9 mm	$27
LENS-15-18-06	15 mm	18 mm	6 mm	$27
LENS-15-18-08	15 mm	18 mm	8 mm	$29
LENS-15-18-10	15 mm	18 mm	10 mm	$31
LENS-15-21-07	15 mm	21 mm	7 mm	$31
LENS-15-21-09	15 mm	21 mm	9 mm	$33
LENS-15-21-11	15 mm	21 mm	11 mm	$35
LENS-20-12-04	20 mm	12 mm	4 mm	$20
LENS-20-12-06	20 mm	12 mm	6 mm	$22
LENS-20-12-08	20 mm	12 mm	8 mm	$24
LENS-20-15-05	20 mm	15 mm	5 mm	$24
LENS-20-15-07	20 mm	15 mm	7 mm	$26
LENS-20-15-09	20 mm	15 mm	9 mm	$28
LENS-20-18-06	20 mm	18 mm	6 mm	$28
LENS-20-18-08	20 mm	18 mm	8 mm	$30
LENS-20-18-10	20 mm	18 mm	10 mm	$32
LENS-20-21-07	20 mm	21 mm	7 mm	$32
LENS-20-21-09	20 mm	21 mm	9 mm	$34
LENS-20-21-11	20 mm	21 mm	11 mm	$36
LENS-20-24-08	20 mm	24 mm	8 mm	$36
LENS-20-24-10	20 mm	24 mm	10 mm	$38
LENS-20-24-12	20 mm	24 mm	12 mm	$40

Requirements

1. The lens must cost no more than $24
2. The lens must have Focal Length of 15 millimeters.

When you and your partner feel that you have selected the product that best matches the requirements, record the part number of the selected lens below.

Part # _____

When you have recorded the part number of the selected lens, signal the researcher by saying "done" or typing "done" in the chat window.

Low Equivocality Task 3

Participant B Instruction Sheet

You and your partner must work together to select a lens from a catalog. You must select the lens that matches a list of requirements.

You have been given the appropriate page of the catalog and two of the four requirements. Your partner has been given the same page of the catalog and an additional list of requirements.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

When you have read the instructions and are ready to begin, signal the researcher by saying "ready" or typing "ready" in the chat window.

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

Part #	Focal Length	Diameter	Thickness	Price
LENS-10-06-02	10 mm	6 mm	2 mm	$10
LENS-10-06-04	10 mm	6 mm	4 mm	$12
LENS-10-06-06	10 mm	6 mm	6 mm	$14
LENS-10-09-03	10 mm	9 mm	3 mm	$14
LENS-10-09-05	10 mm	9 mm	5 mm	$16
LENS-10-09-07	10 mm	9 mm	7 mm	$18
LENS-10-12-04	10 mm	12 mm	4 mm	$18
LENS-10-12-06	10 mm	12 mm	6 mm	$20
LENS-10-12-08	10 mm	12 mm	8 mm	$22
LENS-10-15-05	10 mm	15 mm	5 mm	$22
LENS-10-15-07	10 mm	15 mm	7 mm	$24
LENS-10-15-09	10 mm	15 mm	9 mm	$26
LENS-10-18-06	10 mm	18 mm	6 mm	$26
LENS-10-18-08	10 mm	18 mm	8 mm	$28
LENS-10-18-10	10 mm	18 mm	10 mm	$30
LENS-15-09-03	15 mm	9 mm	3 mm	$15
LENS-15-09-05	15 mm	9 mm	5 mm	$17
LENS-15-09-07	15 mm	9 mm	7 mm	$19
LENS-15-12-04	15 mm	12 mm	4 mm	$19
LENS-15-12-06	15 mm	12 mm	6 mm	$21
LENS-15-12-08	15 mm	12 mm	8 mm	$23
LENS-15-15-05	15 mm	15 mm	5 mm	$23
LENS-15-15-07	15 mm	15 mm	7 mm	$25
LENS-15-15-09	15 mm	15 mm	9 mm	$27
LENS-15-18-06	15 mm	18 mm	6 mm	$27
LENS-15-18-08	15 mm	18 mm	8 mm	$29
LENS-15-18-10	15 mm	18 mm	10 mm	$31
LENS-15-21-07	15 mm	21 mm	7 mm	$31
LENS-15-21-09	15 mm	21 mm	9 mm	$33
LENS-15-21-11	15 mm	21 mm	11 mm	$35
LENS-20-12-04	20 mm	12 mm	4 mm	$20
LENS-20-12-06	20 mm	12 mm	6 mm	$22
LENS-20-12-08	20 mm	12 mm	8 mm	$24
LENS-20-15-05	20 mm	15 mm	5 mm	$24
LENS-20-15-07	20 mm	15 mm	7 mm	$26
LENS-20-15-09	20 mm	15 mm	9 mm	$28
LENS-20-18-06	20 mm	18 mm	6 mm	$28
LENS-20-18-08	20 mm	18 mm	8 mm	$30
LENS-20-18-10	20 mm	18 mm	10 mm	$32
LENS-20-21-07	20 mm	21 mm	7 mm	$32
LENS-20-21-09	20 mm	21 mm	9 mm	$34
LENS-20-21-11	20 mm	21 mm	11 mm	$36
LENS-20-24-08	20 mm	24 mm	8 mm	$36
LENS-20-24-10	20 mm	24 mm	10 mm	$38
LENS-20-24-12	20 mm	24 mm	12 mm	$40

Requirements

1. The lens must be between 12 and 15 millimeters in diameter.
2. The lens must be between 7 and 9 millimeters thick.

When you and your partner feel that you have selected the product that best matches the requirements, record the part number of the selected lens below.

Part # _____

When you have recorded the part number of the selected lens, signal the researcher by saying "done" or typing "done" in the chat window.

Low Equivocality Task 3

Answer Key

Only part # LENS-15-12-08 meets all of the selected criteria.

Low Equivocality Task 4

Participant A Instruction Sheet

You and your partner must work together to select a lens from a catalog. You must select the lens that matches a list of requirements.

You have been given the appropriate page of the catalog and two of the four requirements. Your partner has been given the same page of the catalog and an additional list of requirements.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

When you have read the instructions and are ready to begin, signal the researcher by saying "ready" or typing "ready" in the chat window.

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

Part #	Focal Length	Diameter	Thickness	Price
LENS-10-06-02	10 mm	6 mm	2 mm	$10
LENS-10-06-04	10 mm	6 mm	4 mm	$12
LENS-10-06-06	10 mm	6 mm	6 mm	$14
LENS-10-09-03	10 mm	9 mm	3 mm	$14
LENS-10-09-05	10 mm	9 mm	5 mm	$16
LENS-10-09-07	10 mm	9 mm	7 mm	$18
LENS-10-12-04	10 mm	12 mm	4 mm	$18
LENS-10-12-06	10 mm	12 mm	6 mm	$20
LENS-10-12-08	10 mm	12 mm	8 mm	$22
LENS-10-15-05	10 mm	15 mm	5 mm	$22
LENS-10-15-07	10 mm	15 mm	7 mm	$24
LENS-10-15-09	10 mm	15 mm	9 mm	$26
LENS-10-18-06	10 mm	18 mm	6 mm	$26
LENS-10-18-08	10 mm	18 mm	8 mm	$28
LENS-10-18-10	10 mm	18 mm	10 mm	$30
LENS-15-09-03	15 mm	9 mm	3 mm	$15
LENS-15-09-05	15 mm	9 mm	5 mm	$17
LENS-15-09-07	15 mm	9 mm	7 mm	$19
LENS-15-12-04	15 mm	12 mm	4 mm	$19
LENS-15-12-06	15 mm	12 mm	6 mm	$21
LENS-15-12-08	15 mm	12 mm	8 mm	$23
LENS-15-15-05	15 mm	15 mm	5 mm	$23
LENS-15-15-07	15 mm	15 mm	7 mm	$25
LENS-15-15-09	15 mm	15 mm	9 mm	$27
LENS-15-18-06	15 mm	18 mm	6 mm	$27
LENS-15-18-08	15 mm	18 mm	8 mm	$29
LENS-15-18-10	15 mm	18 mm	10 mm	$31
LENS-15-21-07	15 mm	21 mm	7 mm	$31
LENS-15-21-09	15 mm	21 mm	9 mm	$33
LENS-15-21-11	15 mm	21 mm	11 mm	$35
LENS-20-12-04	20 mm	12 mm	4 mm	$20
LENS-20-12-06	20 mm	12 mm	6 mm	$22
LENS-20-12-08	20 mm	12 mm	8 mm	$24
LENS-20-15-05	20 mm	15 mm	5 mm	$24
LENS-20-15-07	20 mm	15 mm	7 mm	$26
LENS-20-15-09	20 mm	15 mm	9 mm	$28
LENS-20-18-06	20 mm	18 mm	6 mm	$28
LENS-20-18-08	20 mm	18 mm	8 mm	$30
LENS-20-18-10	20 mm	18 mm	10 mm	$32
LENS-20-21-07	20 mm	21 mm	7 mm	$32
LENS-20-21-09	20 mm	21 mm	9 mm	$34
LENS-20-21-11	20 mm	21 mm	11 mm	$36
LENS-20-24-08	20 mm	24 mm	8 mm	$36
LENS-20-24-10	20 mm	24 mm	10 mm	$38
LENS-20-24-12	20 mm	24 mm	12 mm	$40

Requirements

1. The lens must be between 15 and 18 millimeters in diameter.
2. The lens must be between 9 and 12 millimeters thick.

When you and your partner feel that you have selected the product that best matches the requirements, record the part number of the selected lens below.

Part # _____

When you have recorded the part number of the selected lens, signal the researcher by saying “done” or typing “done” in the chat window.

Low Equivocality Task 4

Participant B Instruction Sheet

You and your partner must work together to select a lens from a catalog. You must select the lens that matches a list of requirements.

You have been given the appropriate page of the catalog and two of the four requirements. Your partner has been given the same page of the catalog and an additional list of requirements.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

When you have read the instructions and are ready to begin, signal the researcher by saying "ready" or typing "ready" in the chat window.

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

Part #	Focal Length	Diameter	Thickness	Price
LENS-10-06-02	10 mm	6 mm	2 mm	$10
LENS-10-06-04	10 mm	6 mm	4 mm	$12
LENS-10-06-06	10 mm	6 mm	6 mm	$14
LENS-10-09-03	10 mm	9 mm	3 mm	$14
LENS-10-09-05	10 mm	9 mm	5 mm	$16
LENS-10-09-07	10 mm	9 mm	7 mm	$18
LENS-10-12-04	10 mm	12 mm	4 mm	$18
LENS-10-12-06	10 mm	12 mm	6 mm	$20
LENS-10-12-08	10 mm	12 mm	8 mm	$22
LENS-10-15-05	10 mm	15 mm	5 mm	$22
LENS-10-15-07	10 mm	15 mm	7 mm	$24
LENS-10-15-09	10 mm	15 mm	9 mm	$26
LENS-10-18-06	10 mm	18 mm	6 mm	$26
LENS-10-18-08	10 mm	18 mm	8 mm	$28
LENS-10-18-10	10 mm	18 mm	10 mm	$30
LENS-15-09-03	15 mm	9 mm	3 mm	$15
LENS-15-09-05	15 mm	9 mm	5 mm	$17
LENS-15-09-07	15 mm	9 mm	7 mm	$19
LENS-15-12-04	15 mm	12 mm	4 mm	$19
LENS-15-12-06	15 mm	12 mm	6 mm	$21
LENS-15-12-08	15 mm	12 mm	8 mm	$23
LENS-15-15-05	15 mm	15 mm	5 mm	$23
LENS-15-15-07	15 mm	15 mm	7 mm	$25
LENS-15-15-09	15 mm	15 mm	9 mm	$27
LENS-15-18-06	15 mm	18 mm	6 mm	$27
LENS-15-18-08	15 mm	18 mm	8 mm	$29
LENS-15-18-10	15 mm	18 mm	10 mm	$31
LENS-15-21-07	15 mm	21 mm	7 mm	$31
LENS-15-21-09	15 mm	21 mm	9 mm	$33
LENS-15-21-11	15 mm	21 mm	11 mm	$35
LENS-20-12-04	20 mm	12 mm	4 mm	$20
LENS-20-12-06	20 mm	12 mm	6 mm	$22
LENS-20-12-08	20 mm	12 mm	8 mm	$24
LENS-20-15-05	20 mm	15 mm	5 mm	$24
LENS-20-15-07	20 mm	15 mm	7 mm	$26
LENS-20-15-09	20 mm	15 mm	9 mm	$28
LENS-20-18-06	20 mm	18 mm	6 mm	$28
LENS-20-18-08	20 mm	18 mm	8 mm	$30
LENS-20-18-10	20 mm	18 mm	10 mm	$32
LENS-20-21-07	20 mm	21 mm	7 mm	$32
LENS-20-21-09	20 mm	21 mm	9 mm	$34
LENS-20-21-11	20 mm	21 mm	11 mm	$36
LENS-20-24-08	20 mm	24 mm	8 mm	$36
LENS-20-24-10	20 mm	24 mm	10 mm	$38
LENS-20-24-12	20 mm	24 mm	12 mm	$40

Requirements

1. The lens must cost no more than $30.
2. The lens must have a Focal Length of 20 millimeters.

When you and your partner feel that you have selected the product that best matches the requirements, record the part number of the selected lens below.

Part # _____

When you have recorded the part number of the selected lens, signal the researcher by saying "done" or typing "done" in the chat window.

Low Equivocality Task 4

Answer Key

Only part # LENS-20-15-09 meets all of the selected criteria.

Low Equivocality Task 5 (alternate)

Participant A Instruction Sheet

You and your partner must work together to select a lens from a catalog. You must select the lens that matches a list of requirements.

You have been given the appropriate page of the catalog and two of the four requirements. Your partner has been given the same page of the catalog and an additional list of requirements.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

When you have read the instructions and are ready to begin, signal the researcher by saying "ready" or typing "ready" in the chat window.

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

Part #	Focal Length	Diameter	Thickness	Price
LENS-10-06-02	10 mm	6 mm	2 mm	$15
LENS-10-06-04	10 mm	6 mm	4 mm	$18
LENS-10-06-06	10 mm	6 mm	6 mm	$21
LENS-10-09-03	10 mm	9 mm	3 mm	$21
LENS-10-09-05	10 mm	9 mm	5 mm	$24
LENS-10-09-07	10 mm	9 mm	7 mm	$27
LENS-10-12-04	10 mm	12 mm	4 mm	$27
LENS-10-12-06	10 mm	12 mm	6 mm	$30
LENS-10-12-08	10 mm	12 mm	8 mm	$33
LENS-10-15-05	10 mm	15 mm	5 mm	$33
LENS-10-15-07	10 mm	15 mm	7 mm	$36
LENS-10-15-09	10 mm	15 mm	9 mm	$39
LENS-10-18-06	10 mm	18 mm	6 mm	$39
LENS-10-18-08	10 mm	18 mm	8 mm	$42
LENS-10-18-10	10 mm	18 mm	10 mm	$45
LENS-15-09-03	15 mm	9 mm	3 mm	$23
LENS-15-09-05	15 mm	9 mm	5 mm	$26
LENS-15-09-07	15 mm	9 mm	7 mm	$29
LENS-15-12-04	15 mm	12 mm	4 mm	$29
LENS-15-12-06	15 mm	12 mm	6 mm	$32
LENS-15-12-08	15 mm	12 mm	8 mm	$35
LENS-15-15-05	15 mm	15 mm	5 mm	$35
LENS-15-15-07	15 mm	15 mm	7 mm	$38
LENS-15-15-09	15 mm	15 mm	9 mm	$41
LENS-15-18-06	15 mm	18 mm	6 mm	$41
LENS-15-18-08	15 mm	18 mm	8 mm	$44
LENS-15-18-10	15 mm	18 mm	10 mm	$47
LENS-15-21-07	15 mm	21 mm	7 mm	$47
LENS-15-21-09	15 mm	21 mm	9 mm	$50
LENS-15-21-11	15 mm	21 mm	11 mm	$53
LENS-20-12-04	20 mm	12 mm	4 mm	$30
LENS-20-12-06	20 mm	12 mm	6 mm	$33
LENS-20-12-08	20 mm	12 mm	8 mm	$36
LENS-20-15-05	20 mm	15 mm	5 mm	$36
LENS-20-15-07	20 mm	15 mm	7 mm	$39
LENS-20-15-09	20 mm	15 mm	9 mm	$42
LENS-20-18-06	20 mm	18 mm	6 mm	$42
LENS-20-18-08	20 mm	18 mm	8 mm	$45
LENS-20-18-10	20 mm	18 mm	10 mm	$48
LENS-20-21-07	20 mm	21 mm	7 mm	$48
LENS-20-21-09	20 mm	21 mm	9 mm	$51
LENS-20-21-11	20 mm	21 mm	11 mm	$54
LENS-20-24-08	20 mm	24 mm	8 mm	$54
LENS-20-24-10	20 mm	24 mm	10 mm	$57
LENS-20-24-12	20 mm	24 mm	12 mm	$60

Requirements

1. The lens must be between 18 and 21 millimeters in diameter.
2. The lens must be between 5 and 8 millimeters thick.

When you and your partner feel that you have selected the product that best matches the requirements, record the part number of the selected lens below.

Part # _____

When you have recorded the part number of the selected lens, signal the researcher by saying “done” or typing “done” in the chat window.

Low Equivocality Task 5 (alternate)

Participant B Instruction Sheet

You and your partner must work together to select a lens from a catalog. You must select the lens that matches a list of requirements.

You have been given the appropriate page of the catalog and two of the four requirements. Your partner has been given the same page of the catalog and an additional list of requirements.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

When you have read the instructions and are ready to begin, signal the researcher by saying "ready" or typing "ready" in the chat window.

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

Part #	Focal Length	Diameter	Thickness	Price
LENS-10-06-02	10 mm	6 mm	2 mm	$15
LENS-10-06-04	10 mm	6 mm	4 mm	$18
LENS-10-06-06	10 mm	6 mm	6 mm	$21
LENS-10-09-03	10 mm	9 mm	3 mm	$21
LENS-10-09-05	10 mm	9 mm	5 mm	$24
LENS-10-09-07	10 mm	9 mm	7 mm	$27
LENS-10-12-04	10 mm	12 mm	4 mm	$27
LENS-10-12-06	10 mm	12 mm	6 mm	$30
LENS-10-12-08	10 mm	12 mm	8 mm	$33
LENS-10-15-05	10 mm	15 mm	5 mm	$33
LENS-10-15-07	10 mm	15 mm	7 mm	$36
LENS-10-15-09	10 mm	15 mm	9 mm	$39
LENS-10-18-06	10 mm	18 mm	6 mm	$39
LENS-10-18-08	10 mm	18 mm	8 mm	$42
LENS-10-18-10	10 mm	18 mm	10 mm	$45
LENS-15-09-03	15 mm	9 mm	3 mm	$23
LENS-15-09-05	15 mm	9 mm	5 mm	$26
LENS-15-09-07	15 mm	9 mm	7 mm	$29
LENS-15-12-04	15 mm	12 mm	4 mm	$29
LENS-15-12-06	15 mm	12 mm	6 mm	$32
LENS-15-12-08	15 mm	12 mm	8 mm	$35
LENS-15-15-05	15 mm	15 mm	5 mm	$35
LENS-15-15-07	15 mm	15 mm	7 mm	$38
LENS-15-15-09	15 mm	15 mm	9 mm	$41
LENS-15-18-06	15 mm	18 mm	6 mm	$41
LENS-15-18-08	15 mm	18 mm	8 mm	$44
LENS-15-18-10	15 mm	18 mm	10 mm	$47
LENS-15-21-07	15 mm	21 mm	7 mm	$47
LENS-15-21-09	15 mm	21 mm	9 mm	$50
LENS-15-21-11	15 mm	21 mm	11 mm	$53
LENS-20-12-04	20 mm	12 mm	4 mm	$30
LENS-20-12-06	20 mm	12 mm	6 mm	$33
LENS-20-12-08	20 mm	12 mm	8 mm	$36
LENS-20-15-05	20 mm	15 mm	5 mm	$36
LENS-20-15-07	20 mm	15 mm	7 mm	$39
LENS-20-15-09	20 mm	15 mm	9 mm	$42
LENS-20-18-06	20 mm	18 mm	6 mm	$42
LENS-20-18-08	20 mm	18 mm	8 mm	$45
LENS-20-18-10	20 mm	18 mm	10 mm	$48
LENS-20-21-07	20 mm	21 mm	7 mm	$48
LENS-20-21-09	20 mm	21 mm	9 mm	$51
LENS-20-21-11	20 mm	21 mm	11 mm	$54
LENS-20-24-08	20 mm	24 mm	8 mm	$54
LENS-20-24-10	20 mm	24 mm	10 mm	$57
LENS-20-24-12	20 mm	24 mm	12 mm	$60

Requirements

1. The lens must cost no more than $43.
2. The lens must have a Focal Length of 20 millimeters.

When you and your partner feel that you have selected the product that best matches the requirements, record the part number of the selected lens below.

Part # _____

When you have recorded the part number of the selected lens, signal the researcher by saying "done" or typing "done" in the chat window.

Low Equivocality Task 5 (alternate)

Answer Key

Only part # LENS-20-18-06 meets all of the selected criteria.

High Equivocality Tasks

High Equivocality Task 1

Participant Instruction Sheet

You and your partner must work together to rank three applicants applying for a given job in order of hiring preference (the candidate ranked #1 would be your first choice in hiring, etc.).

You have been given a list of job requirements and short descriptions of each applicant. Your partner has been given the same information.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

When you have finished reading these instructions, please continue to the next page.

Please review the job description and applicant information below. You will be given five minutes to review this information before the task begins. Feel free to take notes as needed.

Job Title / Description

Lab Specialist

Performs and supports experiments in a molecular biology lab. Manages isotope use, orders research supplies, and assists with maintenance of the lab.

Job Requirements

Required Qualifications

- **BS degree or higher in Animal Science, Biology, or Biochemistry**
- **Experience working in a lab**
- **Computer experience with a variety of software such as word processing and spreadsheet software**

Preferred Qualifications

- **Experience with molecular biology techniques such as DNA/RNA extraction, PCR, cloning, sequencing, and tissue culture**
- **Experience working with lab animals and/or farm animals**

Applicant A

Education

PhD, Animal Science

Experience

2 years

Qualifications

- **Moderate lab experience**
- **Extensive computer experience**
- **experience working with lab animals**

Applicant B

Education

Masters, Biology

Experience

4 years

Qualifications

- **Extensive lab experience**
- **Moderate computer experience**
- **Experience with DNA/RNA extraction, PCR, cloning, sequencing, and tissue culture**

Applicant C

Education

Bachelor of Sciences, Biochemistry

Experience

6 years

Qualifications

- **Extensive lab experience**
- **Extensive computer experience**
- **Extensive experience working with farm animals**

Applicant D

Education

PhD, Biology

Experience

4 years

Qualifications

- **Moderate lab experience**
- **Moderate computer experience**
- **Extensive experience working with lab animals**

When the researcher signals "go ahead" in the chat window, please turn to the next page and begin working with your partner to complete the task.

Based on the information provided on the previous two pages, please rank the job applicants in order of hiring preference. You may refer to the previous pages as needed.
As you and your partner agree on the desired ranking for each applicant, record their rank in the table below

Applicant	Rank
A	
B	
C	
D	

When you and your partner have ranked all applicants, signal the researcher by saying “done” or typing “done” in the chat window.

High Equivocality Task 2

Participant Instruction Sheet

You and your partner must work together to rank three applicants applying for a given job in order of hiring preference (the candidate ranked #1 would be your first choice in hiring, etc.).

You have been given a list of job requirements and short descriptions of each applicant. Your partner has been given the same information.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

Please signal the researcher when you have finished reading these instructions. Do not turn the page until you are told to do so by the researcher.

Job Title / Description	Job Requirements
Administrative Assistant **Assists with general receptionist duties and office duties to include travel, purchasing office supplies and faculty support.**	Required Qualifications - **Experience working in a professional office environment** - **Experience with word processing, spreadsheets, data entry, and general office duties** - **Good communication, interpersonal, and organizational skills** Preferred Qualifications - **Experience working with Word and Excel** - **Knowledge of University policy and procedures.**

Applicant A	Applicant B	Applicant C
Education **Associates in Applied Science, Administrative Support Technology** Experience **2 years** Qualifications - **strong experience with Word** - **limited experience with Excel**	Education **High School Diploma** Experience **10 years** Qualifications - **strong experience with Word** - **some experience with Excel**	Education **Bachelor of Arts, English** Experience **5 years** Qualifications - **limited experience with Word** - **limited experience with Excel** - **working knowledge of University policy and procedures**

As you and your partner agree on the desired ranking for each applicant, record their rank in the table below

Applicant	Rank
A	
B	
C	

When you and your partner have ranked all applicants, signal the researcher by saying “done” or typing “done” in the chat window.

High Equivocality Task 3

Participant Instruction Sheet

You and your partner must work together to rank three applicants applying for a given job in order of hiring preference (the candidate ranked #1 would be your first choice in hiring, etc.).

You have been given a list of job requirements and short descriptions of each applicant. Your partner has been given the same information.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

Please signal the researcher when you have finished reading these instructions. Do not turn the page until you are told to do so by the researcher.

Job Title / Description	Job Requirements
Field Coordinator **Acts as field coordinator, monitors red-cockaded woodpecker populations and carries out research on their biology and management.**	Required Qualifications - **Bachelor of Science or higher degree in biology, zoology, fisheries and wildlife or related field** - **Demonstrated relevant research experience** Preferred Qualifications - **Master's degree in biology, zoology, fisheries and wildlife or related field** - **Previous supervisory experience** - **Previous experience with red-cockaded woodpeckers**

Applicant A	Applicant B	Applicant C
Education **PhD, Biology** Experience **4 years total field research** Qualifications - **2 years supervisory experience** - **no experience with woodpeckers**	Education **Master of Science degree, Fisheries and Wildlife** Experience **5 years total field research** Qualifications - **familiar with other species of woodpeckers** - **1 year supervisory experience**	Education **Bachelor of Science degree, Zoology** Experience **7 years total field research** Qualifications - **familiar with red-cockaded woodpeckers** - **no supervisory experience**

As you and your partner agree on the desired ranking for each applicant, record their rank in the table below

Applicant	Rank
A	
B	
C	

When you and your partner have ranked all applicants, signal the researcher by saying “done” or typing “done” in the chat window.

High Equivocality Task 4

Participant Instruction Sheet

You and your partner must work together to rank three applicants applying for a given job in order of hiring preference (the candidate ranked #1 would be your first choice in hiring, etc.).

You have been given a list of job requirements and short descriptions of each applicant. Your partner has been given the same information.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

Please signal the researcher when you have finished reading these instructions. Do not turn the page until you are told to do so by the researcher.

Job Title / Description	Job Requirements
Internet/GIS Programmer **Duties include converting geospatial natural resources data for web applications; and performing web/GIS interface programming.**	Required Qualifications - **Bachelor of Science degree in Computer Science, Natural Resources or related field or equivalent training and experience** - **Knowledge of web application programming** - **Knowledge of entry and manipulation of geospatial data** Preferred Qualifications - **Graduate degree with course work in geographic information systems** - **experience programming client/server distributed database processing systems in Windows operating environments** - **experience in natural resources, working with end users, and computer software project planning**

Applicant A	Applicant B	Applicant C
Education **PhD, Computer Science** Experience **4 years** Qualifications - **some coursework related to GIS** - **experience programming client/server systems in a UNIX environment**	Education **Master of Science degree, Natural Resources** Experience **5 years** Qualifications - **no coursework related to GIS** - **Experience planning software projects in a natural resources environment**	Education **Bachelor of Science degree, Computer Science** Experience **3 years** Qualifications - **extensive coursework related to GIS** - **experience programming client/server systems in a Windows environment**

As you and your partner agree on the desired ranking for each applicant, record their rank in the table below

Applicant	Rank
A	
B	
C	

When you and your partner have ranked all applicants, signal the researcher by saying “done” or typing “done” in the chat window.

High Equivocality Task 5 (alternate)

Participant Instruction Sheet

You and your partner must work together to rank three applicants applying for a given job in order of hiring preference (the candidate ranked #1 would be your first choice in hiring, etc.).

You have been given a list of job requirements and short descriptions of each applicant. Your partner has been given the same information.

Use the available communication technology (video, audio, and/or text) to communicate with your partner.

Please signal the researcher when you have finished reading these instructions. Do not turn the page until you are told to do so by the researcher.

Job Title / Description

Multimedia Producer/Director

Responsible for researching, writing, creating, producing, directing and coordinating the development, design, authoring and delivery of multimedia video programs to serve the needs of the University.

Job Requirements

Required Qualifications

- **Comprehensive expertise in development, production, and editing of multimedia and video programs**
- **Working knowledge of and experience with multimedia authoring from interactive CD-ROM through interactive DVD and streaming media**
- **Expert working knowledge of high level media production techniques and television equipment technical operations from traditional broadcast through webcast**
- **Bachelor of Science degree in Communication with emphasis on media production or the equivalent in experience**

Preferred Qualifications

- **At least 2 years experience in development, production, and editing of multimedia and video programs**
- **At least 2 years experience in media production as a producer/director**
- **Website development experience helpful**

Applicant A

Education

Master of Arts degree, Communication

Experience

3 years

Qualifications

- **1 year experience in development, production, and editing of multimedia and video programs**
- **1 year experience in media production as a producer/director**
- **Website development experience**

Applicant B

Education

Bachelor of Arts degree, Communication

Experience

5 years

Qualifications

- **3 years experience in development, production, and editing of multimedia and video programs**
- **1 years experience in media production as a producer/director**

Applicant C

Education

Bachelor of Arts degree, Communication

Experience

6 years

Qualifications

- **4 years experience in development, production, and editing of multimedia and video programs**
- **2 years experience in media production as a producer/director**

As you and your partner agree on the desired ranking for each applicant, record their rank in the table below

Applicant	Rank
A	
B	
C	

When you and your partner have ranked all applicants, signal the researcher by saying “done” or typing “done” in the chat window.

Appendix D. Post-task Questionnaire

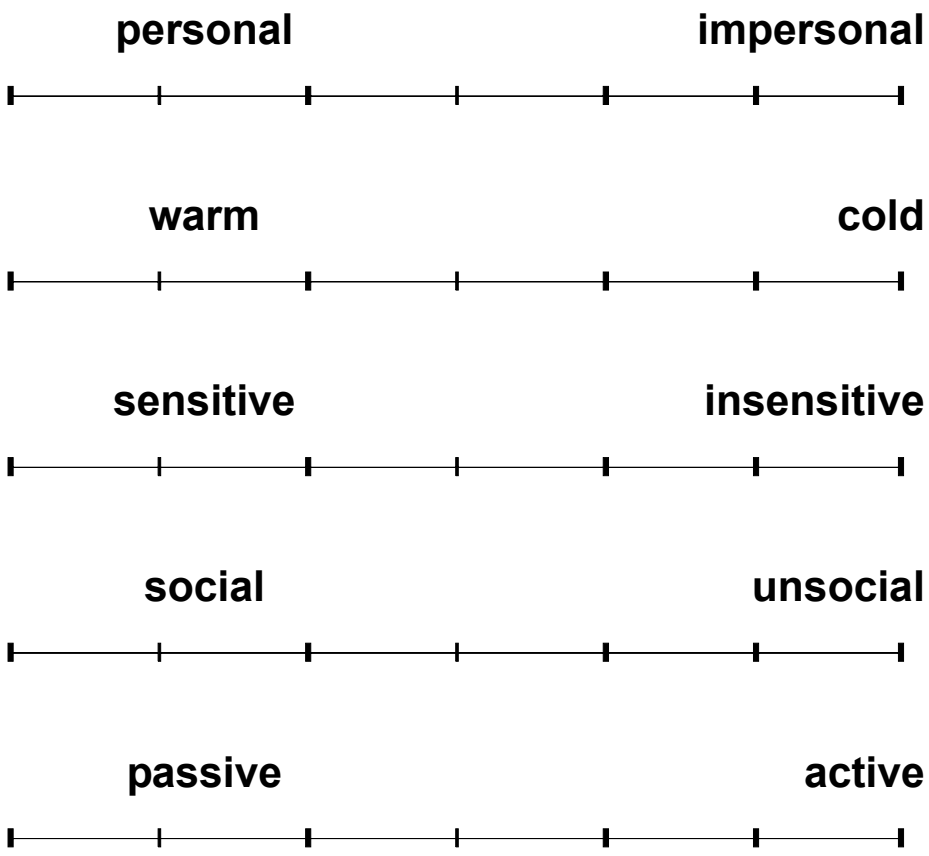
Dyad: _____	Participant: _____	Task:_____
	Medium Sent: _____	Rec'd:_____

this portion to be completed by researcher

Section A

Instructions

Below you see a series of words which are opposite in meaning, positioned on either end of a line. Mark each line to indicate your impression of the communication medium used in the last task.



Section B

Instructions

Please read the following statement about the task you just completed and indicate how strongly you agree or disagree with each statement.

1. This task was simple (circle one).

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

2. There was more than one correct outcome for this task (circle one).

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

3. It was easy to tell when we had reached the stated goal (circle one).

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

4. It was easy to distinguish between the choices presented in this task (circle one).

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

5. This task was complex (circle one).

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

6. There was a single correct outcome for this task (circle one).

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

7. It was difficult to tell when we had reached the stated goal (circle one).

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

8. It was hard to distinguish between the choices presented in this task (circle one).

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Comments

Please write down any comments you have regarding the previous task or the conditions under which it was performed. Feel free to write on the back of this sheet if necessary.

When you have entered a response for all questions and written down your comments, please signal the researcher to come and collect your survey.

Appendix E. Communicative Breakdown Operational Definitions

The criteria used in this study to identify and categorize communication breakdowns were taken directly from an earlier study (Kies, 1997). Kies' operational definitions are detailed in Table E-1.

Table E-1. Communicative Breakdown Operational Definitions (Kies, 1997)

Breakdown Type and Subtype		*Definition*
Verbal Turntaking		**An incident in which two or more participants are talking at the same time. This does not include specific interruptions (i.e. "...Excuse me, but...")**
A	**One stopped, one continued**	**Turntaking breakdown which was resolved by one participant ceasing to speak while the other continues**
B	**Request for other to stop**	**A turntaking breakdown in which a participant asked another to stop talking**
C	**Two continue longer than 3 seconds**	**A turntaking breakdown in which both participants talking simultaneously continue for longer than 3 seconds**
D	**Other**	**Any other example of a turntaking breakdown not described above**
Reference		**An incident in which the sharing of an object (papers, pencil, notes, mouse, etc.) becomes problematic (i.e. two users "battle" for use of the mouse)**
Topic		**An incident in which there is a failure to maintain topical orientation by one or more of the participants**
A	**Request to be updated, result of side conversation**	**A topic breakdown in which one or more participants request to be updated. The breakdown is the result of a side conversation**
B	**Request to be updated, result of other activity**	**A topic breakdown in which one or more participants request to be updated. The result of an activity other than a side conversation**
C	**Other**	**An other topic breakdown not described above**
Visual		**An incident in which visual communication suffers**
A	**Request for shift in seating**	**A visual breakdown evidenced by one participant requesting another to shift seating**
B	**Request for camera movement on participant**	**A visual breakdown evidenced by a request for re-positioning the camera on a participant**
C	**Unable to see a participant**	**A visual breakdown in which a participant is unable to view another participant**
D	**Request for an object to be re-positioned**	**A visual breakdown in which a participant requests that an object of interest be re-positioned in the camera field-of-view**
E	**Request for camera movement on an object**	**A visual breakdown evidenced by a request for re-positioning the camera on an object**
F	**Other**	**Any other visual breakdown not described above**
Audio		**An incident in which a breakdown results due to loudness, feedback, or static difficulties. Requests for repeating due to these problems**
A	**Request for repeat, other repeats**	**An audio breakdown in which one participant asks to repeat a statement and another participant honors the request**
B	**Request for repeat, other does not repeat**	**An audio breakdown in which one participant asks to repeat a statement and no other participant honors the request**
Shared Conversation		**An incident in which a statement or question is directed at an adjacent (or co-located) participant with no attempt to include the rest of the group**
A	**One side conversation**	**A shared conversation breakdown in which only one side conversation occurs**
B	**Two side conversations**	**A shared conversation breakdown in which two side conversations occur**
Criteria not applicable to this study are highlighted in gray.		

In observing the recordings, it became apparent that Kies' definitions did not adequately cover text media or mixtures of text and video. Thus, it was necessary to identify additional breakdowns unique to text media and mixtures of text and video.

Table E-2. Additional Communication Breakdowns Observed

Breakdown Type and Subtype		***Definition***
Text		**Breakdowns observed in text chat communications and communications involving mixtures of text chat and video**
A	Typographical error, corrected by request	**An incident in which one participant transmits a typographical error and transmits a correction after they are requested to clarify.**
B	Typographical error, corrected without request	**An incident in which one participant transmits a typographical error and transmits a correction when they are not requested to clarify.**
C	Text Translation	**An incident in which one or more characters necessary for understanding a message are replaced inappropriately by the text chat client or server.**
D	Request for response	**An incident in which a message is ignored because of inattention (usually looking away from the screen) and a second message asking for a response is sent.**
E	Two messages sent, one response received*	**An incident in which two messages requiring a response are sent but only one is responded to, prompting a request for a response to the remaining message.**
*Can occur in verbal communications as well.		

Appendix F. Results

F.1 Complete Data, Time to Complete

Table F-1. Complete Data for Time to Complete.

Dyad	Task	Medium	Total Time (s)
1	HE3	V+V	80
2	HE3	V+V	62
3	HE3	V+V	150
4	HE3	V+V	121
5	HE3	V+V	24
6	HE3	V+V	63
7	HE3	V+V	170
8	HE3	V+V	60
1	HE2	Mixed	86
1	HE4	Mixed	81
2	HE2	Mixed	140
2	HE4	Mixed	128
3	HE2	Mixed	204
3	HE4	Mixed	175
4	HE2	Mixed	104
4	HE4	Mixed	143
5	HE2	Mixed	129
5	HE4	Mixed	129
6	HE2	Mixed	112
6	HE4	Mixed	91
7	HE2	Mixed	80
7	HE4	Mixed	176
8	HE2	Mixed	201
8	HE4	Mixed	214
1	HE1	T+T	102
2	HE1	T+T	304
3	HE1	T+T	187
4	HE1	T+T	141
5	HE1	T+T	360
6	HE1	T+T	249
7	HE1	T+T	184
8	HE1	T+T	183
1	LE3	V+V	77
2	LE3	V+V	77
3	LE3	V+V	108
4	LE3	V+V	54

Dyad	Task	Medium	Total Time (s)
5	LE3	V+V	101
6	LE3	V+V	51
7	LE3	V+V	83
8	LE3	V+V	133
1	LE2	Mixed	104
1	LE4	Mixed	164
2	LE2	Mixed	201
2	LE4	Mixed	99
3	LE2	Mixed	110
3	LE4	Mixed	102
4	LE2	Mixed	67
4	LE4	Mixed	110
5	LE2	Mixed	114
5	LE4	Mixed	132
6	LE2	Mixed	62
6	LE4	Mixed	94
7	LE2	Mixed	92
7	LE4	Mixed	46
8	LE2	Mixed	65
8	LE4	Mixed	243
1	LE1	T+T	240
2	LE1	T+T	110
3	LE1	T+T	83
4	LE1	T+T	82
5	LE1	T+T	260
6	LE1	T+T	73
7	LE1	T+T	103
8	LE1	T+T	72

F.2 Complete Data, Communication Breakdown Frequency

Table F-2. Complete Data for Communication Breakdown Frequency

Dyad	Task	Medium	turn-taking	topic	visual	audio	other	total	time to complete	freq-uency
1	HE1	T+T						0	0:03:03	0.00
1	HE2	Mixed	1					1	0:04:03	0.25
1	HE3	V+V						0	0:03:21	0.00
1	HE4	Mixed						0	0:01:00	0.00
1	LE1	T+T						0	0:03:34	0.00
1	LE2	Mixed						0	0:02:13	0.00
1	LE3	V+V						0	0:01:05	0.00
1	LE4	Mixed						0	0:01:12	0.00
2	HE1	T+T						0	0:03:04	0.00
2	HE2	Mixed						0	0:02:56	0.00
2	HE3	V+V						0	0:01:20	0.00
2	HE4	Mixed			1			1	0:01:23	0.72
2	LE1	T+T						0	0:01:32	0.00
2	LE2	Mixed		1				1	0:02:50	0.35
2	LE3	V+V	2					2	0:01:43	1.17
2	LE4	Mixed					1	1	0:00:46	1.30
3	HE1	T+T						0	0:01:13	0.00
3	HE2	Mixed						0	0:01:31	0.00
3	HE3	V+V						0	0:01:03	0.00
3	HE4	Mixed						0	0:04:09	0.00
3	LE1	T+T						0	0:00:51	0.00
3	LE2	Mixed		3	1			4	0:01:02	3.87
3	LE3	V+V	1	1				2	0:01:52	1.07
3	LE4	Mixed		1	1			2	0:01:34	1.28
4	HE1	T+T						0	0:02:12	0.00
4	HE2	Mixed						0	0:01:41	0.00
4	HE3	V+V	1					1	0:02:09	0.47
4	HE4	Mixed	1					1	0:00:24	2.50
4	LE1	T+T						0	0:04:20	0.00
4	LE2	Mixed						0	0:02:09	0.00
4	LE3	V+V	1					1	0:01:54	0.53
4	LE4	Mixed						0	0:06:00	0.00
5	HE1	T+T	1					1	0:01:50	0.55
5	HE2	Mixed						0	0:02:01	0.00
5	HE3	V+V						0	0:02:23	0.00
5	HE4	Mixed						0	0:01:07	0.00
5	LE1	T+T						0	0:01:22	0.00
5	LE2	Mixed		1				1	0:00:54	1.11
5	LE3	V+V	1					1	0:01:44	0.58
5	LE4	Mixed	1					1	0:02:21	0.43

Dyad	Task	Medium	turn-taking	topic	visual	audio	other	total	time to complete	freq-uency
6	HE1	T+T						0	0:02:55	0.00
6	HE2	Mixed	1					1	0:01:48	0.56
6	HE3	V+V						0	0:02:30	0.00
6	HE4	Mixed					1	1	0:03:24	0.29
6	LE1	T+T						0	0:03:07	0.00
6	LE2	Mixed						0	0:01:50	0.00
6	LE3	V+V	1					1	0:01:23	0.72
6	LE4	Mixed		1				1	0:01:42	0.59
7	HE1	T+T						0	0:05:04	0.00
7	HE2	Mixed						0	0:01:02	0.00
7	HE3	V+V						0	0:03:21	0.00
7	HE4	Mixed			1			1	0:02:20	0.43
7	LE1	T+T	1					1	0:01:17	0.78
7	LE2	Mixed		1	1			2	0:01:50	1.09
7	LE3	V+V	5	1				6	0:02:08	2.81
7	LE4	Mixed			1			1	0:01:39	0.61
8	HE1	T+T	1					1	0:01:42	0.59
8	HE2	Mixed						0	0:01:20	0.00
8	HE3	V+V	1					1	0:01:21	0.74
8	HE4	Mixed	2					2	0:04:00	0.50
8	LE1	T+T						0	0:02:44	0.00
8	LE2	Mixed						0	0:01:17	0.00
8	LE3	V+V	1	1		1		3	0:01:44	1.73
8	LE4	Mixed	1				1	2	0:01:26	1.40

F.3 Complete Data, Social Presence

Social Presence is measured at the individual level, making it possible to consider gender as a factor. The data is coded such that participant A is always female and participant B is always male. The data below is coded such that a lower score corresponds more to the left hand term. For example, a score of 3 for the personal-impersonal scale is considered more personal than a score of 6. The active-passive scale was reversed on the questionnaire. It is presented here with the same orientation as other scales.

Table F-3. Complete Data for Social Presence (All Scales)

Dyad	Part.	Task	Sent	Recvd.	personal-impersonal	warm-cold	sensitive-insensitive	social-unsocial	active-passive
1	1A	HE1	T	T	6	4	7	6	1
1	1B	HE1	T	T	3	4	4	3	2
2	2A	HE1	T	T	6	6	6	6	3
2	2B	HE1	T	T	5	4	5	3	4
3	3A	HE1	T	T	7	6	6	7	3
3	3B	HE1	T	T	4.25	4.75	4	5	2.5
4	4A	HE1	T	T	6	6	6	6	5
4	4B	HE1	T	T	6	6	6	5	3
5	5A	HE1	T	T	5	3	5	4	4
5	5B	HE1	T	T	3	3	4	3	2
6	6A	HE1	T	T	6	4	4	6	3
6	6B	HE1	T	T	5	4	5	4	3
7	7A	HE1	T	T	6.25	5.75	6.25	5	3
7	7B	HE1	T	T	7	5	3	6	3
8	8A	HE1	T	T	3	5	5	4	3
8	8B	HE1	T	T	3.75	3.25	4	3.25	1.5
1	1A	LE1	T	T	5	4	7	5	4
1	1B	LE1	T	T	4	5	4	2	0
2	2A	LE1	T	T	7	7	7	7	1
2	2B	LE1	T	T	6	4	5	5	5
3	3A	LE1	T	T	7	6	6	7	2
3	3B	LE1	T	T	5.75	4	5	6	4.75
4	4A	LE1	T	T	6	6	6	6	5
4	4B	LE1	T	T	6	6	6	5	2
5	5A	LE1	T	T	3	3	3	4	3
5	5B	LE1	T	T	5	5	4	3	3
6	6A	LE1	T	T	6	4	4	5	3
6	6B	LE1	T	T	5	5	5	4	3
7	7A	LE1	T	T	5.25	4.5	5	3.75	1.5
7	7B	LE1	T	T	6	5	7	6	3
8	8A	LE1	T	T	3	5	5	4	2
8	8B	LE1	T	T	2.75	2.75	1.25	1.25	2.25
1	1B	HE2	T	V	7	6	5	5	0

Dyad	Part.	Task	Sent	Recvd.	personal-impersonal	warm-cold	sensitive-insensitive	social-unsocial	active-passive
2	2B	HE2	T	V	2	3	3	2	2
3	3B	HE2	T	V	3	3	4	3.25	1.5
4	4B	HE2	T	V	5	6	6	5	3
5	5B	HE2	T	V	3	3	3	3	4
6	6B	HE2	T	V	4	5	4	3	3
7	7B	HE2	T	V	4	3	6	6	4
8	8B	HE2	T	V	2.5	2.5	3.5	2.5	4.5
1	1A	HE4	T	V	6	4	7	5	1
2	2A	HE4	T	V	4	4	4	4	3
3	3A	HE4	T	V	5	5	5	6	3
4	4A	HE4	T	V	5	6	4	4	5
5	5A	HE4	T	V	3	3	3	4	2
6	6A	HE4	T	V	3	4	4	3	3
7	7A	HE4	T	V	3.75	3.5	5.75	6.25	1.75
8	8A	HE4	T	V	4	5	4	6	3
1	1B	LE2	T	V	6	5	4	2	2
2	2B	LE2	T	V	2	3	6	4	4
3	3B	LE2	T	V	3.25	3.25	3.75	4.75	3
4	4B	LE2	T	V	5	6	6	5	4
5	5B	LE2	T	V	3	3	4	3	4
6	6B	LE2	T	V	4	4	4	5	2
7	7B	LE2	T	V	4	6	6	5	2
8	8B	LE2	T	V	3.5	3.5	3.5	3.75	3
1	1A	LE4	T	V	6	4	7	6	1
2	2A	LE4	T	V	4	4	4	4	3
3	3A	LE4	T	V	4	5	4	5	4
4	4A	LE4	T	V	5	4	5	6	5
5	5A	LE4	T	V	3	3	3	4	3
6	6A	LE4	T	V	2	4	4	3	3
7	7A	LE4	T	V	6.25	6.5	6	5.5	2
8	8A	LE4	T	V	3	5	5	5	3
1	1A	HE2	V	T	6	4	7	6	2
2	2A	HE2	V	T	7	7	7	7	3
3	3A	HE2	V	T	5	4	5	7	0
4	4A	HE2	V	T	5	6	6	6	5
5	5A	HE2	V	T	6	5	4	5	3
6	6A	HE2	V	T	5	4	4	5	3
7	7A	HE2	V	T	7	7	7	7	3.5
8	8A	HE2	V	T	2	3	3	4	2
1	1B	HE4	V	T	5	4	4	3	2
2	2B	HE4	V	T	5	5	4	3	2
3	3B	HE4	V	T	5.25	4.75	5.25	5.75	4.5
4	4B	HE4	V	T	6	7	7	5	2
5	5B	HE4	V	T	4	5	5	4	4

Dyad	Part.	Task	Sent	Recvd.	personal-impersonal	warm-cold	sensitive-insensitive	social-unsocial	active-passive
6	6B	HE4	V	T	6	6	6	6	3
7	7B	HE4	V	T	7	6	5	4	4
8	8B	HE4	V	T	5.25	4.5	4	5.5	1.5
1	1A	LE2	V	T	6	4	7	6	2
2	2A	LE2	V	T	5	6	6	4	6
3	3A	LE2	V	T	6	4	5	7	1
4	4A	LE2	V	T	6	6	6	6	5
5	5A	LE2	V	T	5	5	4	4	2
6	6A	LE2	V	T	5	4	4	5	3
7	7A	LE2	V	T	6.5	6.5	4.5	7	3.75
8	8A	LE2	V	T	4	4	3	5	2
1	1B	LE4	V	T	6	6	5	4	1
2	2B	LE4	V	T	5	4	5	5	2
3	3B	LE4	V	T	3.25	4	4	3.25	2
4	4B	LE4	V	T	6	7	7	6	2
5	5B	LE4	V	T	3	4	4	4	3
6	6B	LE4	V	T	5	5	5	6	3
7	7B	LE4	V	T	7	7	4	6	2
8	8B	LE4	V	T	4.5	4.5	4	4	2
1	1A	HE3	V	V	4	3	7	6	2
1	1B	HE3	V	V	1	4	4	1	0
2	2A	HE3	V	V	1	1	1	1	0
2	2B	HE3	V	V	1	2	4	2	1
3	3A	HE3	V	V	1	3	3	1	0
3	3B	HE3	V	V	4	4	4.75	4.75	3
4	4A	HE3	V	V	2	3	5	2	2
4	4B	HE3	V	V	3	4	3	3	2
5	5A	HE3	V	V	3	4	4	5	2
5	5B	HE3	V	V	3	3	3	3	3
6	6A	HE3	V	V	2	3	4	2	3
6	6B	HE3	V	V	2	2	2	2	1
7	7A	HE3	V	V	3	3	3.75	4	3
7	7B	HE3	V	V	3	3	4	2	3
8	8A	HE3	V	V	4	4	4	5	3
8	8B	HE3	V	V	1.5	1.5	1.5	1.5	1.5
1	1A	LE3	V	V	6	4	7	6	1
1	1B	LE3	V	V	1	3	4	1	0
2	2A	LE3	V	V	2	2	2	2	1
2	2B	LE3	V	V	1	4	4	2	1
3	3A	LE3	V	V	2	4	4	2	1
3	3B	LE3	V	V	5.75	4	4	4	2
4	4A	LE3	V	V	2	2	3	2	1
4	4B	LE3	V	V	3	4	4	3	2
5	5A	LE3	V	V	3	4	4	3	3

Dyad	Part.	Task	Sent	Recvd.	personal-impersonal	warm-cold	sensitive-insensitive	social-unsocial	active-passive
5	5B	LE3	V	V	3	4	4	3	4
6	6A	LE3	V	V	2	3	4	2	3
6	6B	LE3	V	V	2	2	2	2	1
7	7A	LE3	V	V	4	4.75	5.25	3.25	4
7	7B	LE3	V	V	2	2	4	2	3
8	8A	LE3	V	V	3	3	3	3	4
8	8B	LE3	V	V	2	2	3	2	3

F.4 Complete Data, Task Feedback

Table F-4. Complete Data for Task Feedback.

Dyad	Part	Task	simple	complex	multiple outcomes	single outcome	clear goal	unclear goal	clear choices	unclear choices
1	A	HE1	3	4	2	4	2	4	3	3
1	B	HE1	2	5	1	5	2	4	2	5
2	A	HE1	2	4	1	5	3	3	2	4
2	B	HE1	2	4	1	5	2	2	2	5
3	A	HE1	4	2	1	5	4	2	2	4
3	B	HE1	2	2	1	4	3	2	3	2
4	A	HE1	2	4	2	4	4	3	2	4
4	B	HE1	3	3	2	4	2	4	3	3
5	A	HE1	1	4	2	4	1	5	2	4
5	B	HE1	2	4	2	4	4	4	4	4
6	A	HE1	2	3	2	4	2	4	4	2
6	B	HE1	2	4	2	4	1	5	1	5
7	A	HE1	3	4	2	4	2	4	2	4
7	B	HE1	2	4	1	5	2	4	2	4
8	A	HE1	2	4	3	3	3	3	3	3
8	B	HE1	2	4	3	3	2	4	2	4
1	A	HE2	2	4	1	5	2	4	3	3
1	B	HE2	3	2	1	4	4	2	3	5
2	A	HE2	2	4	1	4	3	3	2	4
2	B	HE2	1	4	1	1	1	1	2	4
3	A	HE2	4	2	1	5	4	2	2	4
3	B	HE2								
4	A	HE2	3	4	2	4	2	4	4	4
4	B	HE2	2	4	4	3	2	4	2	4
5	A	HE2	3	4	2	4	1	5	1	5
5	B	HE2	2	2	2	4	3	3	3	2
6	A	HE2	2	4	1	5	2	4	2	4
6	B	HE2	2	4	2	4	1	5	2	4
7	A	HE2	1	5	2	4	2	4	2	4
7	B	HE2	2	4	1	5	1	5	2	4
8	A	HE2	2	4	2	4	4	2	3	2
8	B	HE2	1	5	2	4	2	4	2	4
1	A	HE3	2	4	1	5	1	4	2	4
1	B	HE3	1	4	2	4	2	5	1	5
2	A	HE3	2	4	2	5	2	54	2	4
2	B	HE3	1	5	2	5	1	5	1	4
3	A	HE3	3	3	1	5	2	4	2	4
3	B	HE3	2	2	4	2	2	3	3	4

Dyad	Part	Task	simple	complex	multiple outcomes	single outcome	clear goal	unclear goal	clear choices	unclear choices
4	A	HE3	3	2	2	4	2	5	4	5
4	B	HE3	3	3	2	4	2	4	3	3
5	A	HE3	2	4	2	4	1	5	1	5
5	B	HE3	2	4	4	4	3	4	2	4
6	A	HE3	2	4	2	4	2	4	2	4
6	B	HE3	1	5	4	2	1	5	1	5
7	A	HE3	2	4	2	5	1	5	1	4
7	B	HE3	2	4	2	5	1	5	3	4
8	A	HE3	2	4	3	3	2	4	2	4
8	B	HE3	1	5	2	4	1	5	2	4
1	A	HE4	2	4	2	4	2	4	3	3
1	B	HE4	1	5	4	4	2	5	1	5
2	A	HE4	2	4	2	4	2	4	2	4
2	B	HE4	1	5	1	5	1	4	1	5
3	A	HE4	4	2	1	5	4	2	2	4
3	B	HE4	2	2	2	4	4	3	3	2
4	A	HE4	2	4	2	4	2	4	3	4
4	B	HE4	2	4	3	3	2	4	2	4
5	A	HE4	2	4	2	4	1	5	1	5
5	B	HE4	2	4	2	4	2	4	2	4
6	A	HE4	2	4	3	3	2	4	2	4
6	B	HE4	1	5	2	4	1	5	1	5
7	A	HE4	2	4	2	4	2	4	2	4
7	B	HE4	2	4	1	5	1	5	2	4
8	A	HE4	2	4	2	4	2	4	3	3
8	B	HE4	1	4	2	4	2	4	2	4
1	A	LE1	2	4	3	3	1	5	2	4
1	B	LE1	2	3	4	2	2	5	4	2
2	A	LE1	2	5	4	1	3	3	2	4
2	B	LE1	1	5	5	1	1	1	5	5
3	A	LE1	1	4	5	1	2	5	2	4
3	B	LE1	2	5	5	1	1	4	2	5
4	A	LE1	1	4	1	5	1	5	1	5
4	B	LE1	1	5	4	2	2	4	2	4
5	A	LE1	3	3	4	2	2	4	2	4
5	B	LE1	3	4	5	2	2	4	2	4
6	A	LE1	2	4	4	2	2	4	2	4
6	B	LE1	1	5	5	1	1	5	1	5
7	A	LE1	2	4	5	1	1	4	2	5
7	B	LE1	2	4	5	1	1	5	2	4
8	A	LE1	2	4	2	4	1	5	2	4
8	B	LE1	1	4	4	2	2	4	2	4
1	A	LE2	2	4	4	2	2	4	2	4
1	B	LE2	1	4	4	4	2	5	1	5

Dyad	Part	Task	simple	complex	multiple outcomes	single outcome	clear goal	unclear goal	clear choices	unclear choices
2	A	LE2	2	4	2	4	2	4	2	4
2	B	LE2	1	4	4	2	1	4	2	4
3	A	LE2	3	3	4	2	1	4	3	4
3	B	LE2	3	2	4	1	2	4	2	4
4	A	LE2	1	4	1	4	2	5	2	5
4	B	LE2	2	4	5	2	2	4	2	4
5	A	LE2	3	4	4	2	2	5	2	5
5	B	LE2	3	2	4	2	4	4	3	2
6	A	LE2	2	4	4	2	2	4	2	4
6	B	LE2	1	5	5	1	1	5	1	5
7	A	LE2	2	4	5	1	3	3	1	5
7	B	LE2	2	4	5	1	1	5	3	3
8	A	LE2	2	4	4	2	1	5	2	4
8	B	LE2	1	4	4	2	1	4	2	4
1	A	LE3	2	4	4	2	2	4	2	4
1	B	LE3	1	5	2	5	1	5	1	5
2	A	LE3	1	4	4	2	2	4	2	4
2	B	LE3	1	4	4	1	1	5	1	4
3	A	LE3	2	4	4	2	1	4	3	3
3	B	LE3	1	4	4	2	2	4	2	3
4	A	LE3	1	4	1	4	1	4	1	4
4	B	LE3	2	4	4	2	2	4	2	4
5	A	LE3	2	4	4	2	1	5	1	5
5	B	LE3	3	3	4	2	2	4	3	4
6	A	LE3	2	4	4	2	2	4	2	4
6	B	LE3	1	5	5	1	1	5	1	5
7	A	LE3	1	5	5	1	1	5	1	5
7	B	LE3	1	5	5	1	1	5	2	4
8	A	LE3	2	4	2	2	2	4	2	4
8	B	LE3	1	4	1	4	1	4	3	3
1	A	LE4	1	4	4	2	2	4	2	4
1	B	LE4	2	4	4	2	4	2	2	4
2	A	LE4	1	5	4	2	2	4	2	4
2	B	LE4	1	5	4	2	1	5	1	5
3	A	LE4	2	4	4	2	1	4	2	4
3	B	LE4	3	4	5	1	1	4	2	5
4	A	LE4	2	4	4	2	2	5	2	5
4	B	LE4	2	4	5	1	2	4	2	4
5	A	LE4	2	4	4	2	1	5	1	5
5	B	LE4	3	3	5	1	2	4	3	3
6	A	LE4	2	3	4	2	2	4	2	4
6	B	LE4	1	5	5	1	1	5	1	5
7	A	LE4	1	5	5	1	1	5	1	5
7	B	LE4	1	5	5	1	1	5	1	5

Dyad	Part	Task	simple	complex	multiple outcomes	single outcome	clear goal	unclear goal	clear choices	unclear choices
8	A	LE4	2	4	2	4	3	4	2	3
8	B	LE4	2	4	2	4	3	3	3	4

F.5 Complete Data, Participant Comments

Participant comments are presented in the order in which they were recorded.

Table F-5. Participant Comments.

Order	Dyad	Part.	Medium Sent	Medium Received	Task	Comments
1	1	A	Text	Text	LE1	Interesting task, not terribly difficult to do.
1	1	B	Text	Text	LE1	*no comment*
2	1	A	Video	Video	HE3	*no comment*
2	1	B	Video	Video	HE3	*no comment*
3	1	A	Video	Text	HE2	*no comment*
3	1	B	Text	Video	HE2	*no comment*
4	1	A	Video	Text	LE2	*no comment*
4	1	B	Text	Video	LE2	*no comment*
5	1	A	Text	Video	HE4	*no comment*
5	1	B	Video	Text	HE4	*no comment*
6	1	A	Text	Text	HE1	*no comment*
6	1	B	Text	Text	HE1	*no comment*
7	1	A	Video	Video	LE3	*no comment*
7	1	B	Video	Video	LE3	*no comment*
8	1	A	Text	Video	LE4	*no comment*
8	1	B	Video	Text	LE4	*no comment*
1	2	A	Video	Text	LE2	*no comment*
1	2	B	Text	Video	LE2	*no comment*
2	2	A	Video	Video	LE3	*no comment*
2	2	B	Video	Video	LE3	It may have been more accurate to type all the requirements, but faster to just talk.
3	2	A	Text	Text	LE1	*no comment*
3	2	B	Text	Text	LE1	*no comment*
4	2	A	Text	Text	HE1	*no comment*
4	2	B	Text	Text	HE1	*no comment*
5	2	A	Video	Text	HE2	*no comment*
5	2	B	Text	Video	HE2	*no comment*
6	2	A	Text	Video	LE4	*no comment*
6	2	B	Video	Text	LE4	*no comment*
7	2	A	Text	Video	HE4	*no comment*
7	2	B	Video	Text	HE4	*no comment*
8	2	A	Video	Video	HE3	*no comment*
8	2	B	Video	Video	HE3	*no comment*
1	3	A	Video	Video	LE3	*no comment*
1	3	B	Video	Video	LE3	Good task.

Order	Dyad	Part.	Medium Sent	Medium Received	Task	Comments
2	3	A	Text	Video	LE4	*no comment*
2	3	B	Video	Text	LE4	*no comment*
3	3	A	Video	Text	LE2	*no comment*
3	3	B	Text	Video	LE2	*no comment*
4	3	A	Video	Text	HE2	*no comment*
4	3	B	Text	Video	HE2	*no comment*
5	3	A	Text	Video	HE4	*no comment*
5	3	B	Video	Text	HE4	*no comment*
6	3	A	Text	Text	HE1	*no comment*
6	3	B	Text	Text	HE1	*no comment*
7	3	A	Text	Text	LE1	*no comment*
7	3	B	Text	Text	LE1	*no comment*
8	3	A	Video	Video	HE3	*no comment*
8	3	B	Video	Video	HE3	*no comment*
1	4	A	Text	Video	LE4	I liked it.
1	4	B	Video	Text	LE4	*no comment*
2	4	A	Text	Video	HE4	Not bad; interesting trying to communicate like this… I don't think I like it.
2	4	B	Video	Text	HE4	In a real world environment, I would decline from using this type of communication
3	4	A	Video	Text	LE2	I liked this task, easy, easy easy :)
3	4	B	Text	Video	LE2	*no comment*
4	4	A	Video	Video	HE3	prefer this style of communication especially with someone I don't know
4	4	B	Video	Video	HE3	*no comment*
5	4	A	Text	Text	LE1	*no comment*
5	4	B	Text	Text	LE1	*no comment*
6	4	A	Video	Text	HE2	*no comment*
6	4	B	Text	Video	HE2	*no comment*
7	4	A	Video	Video	LE3	I definitely prefer verbal communication
7	4	B	Video	Video	LE3	*no comment*
8	4	A	Text	Text	HE1	text chat is a really cool way of communication
8	4	B	Text	Text	HE1	*no comment*
1	5	A	Text	Text	HE1	It was easy to come to a conclusion of who should be ranked in what order after communicating w/ the other person of why someone was more qualified than another (& hearing their opinions of why they thought so).
1	5	B	Text	Text	HE1	The task was a bit difficult seeing as there was no true "correct answer", but it was still feasible.
2	5	A	Video	Video	HE3	We both came to the same conclusion, so we didn't really need to discuss anything very long.

Order	Dyad	Part.	Medium Sent	Medium Received	Task	Comments
2	5	B	Video	Video	HE3	The task given was slightly easy, and me and my partner were quickly able to provide an acceptable response to the question.
3	5	A	Text	Video	HE4	*no comment*
3	5	B	Video	Text	HE4	The task was fairly simple. The talk function was not utilized though, there was mainly chat.
4	5	A	Video	Text	HE2	I definitely like just using IM (chat room) better than talking/video. It just seems easier to communicate.
4	5	B	Text	Video	HE2	This exercise was not as simple as previous exercises but was feasible
5	5	A	Text	Text	LE1	*no comment*
5	5	B	Text	Text	LE1	The task was a bit difficult but feasible nonetheless.
6	5	A	Video	Video	LE3	*no comment*
6	5	B	Video	Video	LE3	The task was slightly easy but since there was no chat involved there was a bit of difficulty conveying the requirements across.
7	5	A	Video	Text	LE2	It seems to get easier to communicate as we go on - but I still think it's easiest when we're both in the chat room.
7	5	B	Text	Video	LE2	It was slightly difficult to go through all the lens numbers looking for data.
8	5	A	Text	Video	LE4	He didn't talk, even though I could hear him, but we still communicated just fine & reached a goal (decision) just as quickly using the chat room.
8	5	B	Video	Text	LE4	As with other lens exercises it was slightly difficult to brief through the long list of lenses. I had selected a lens but was uncertain and needed my partner's confirmation of whether the lens would work or not.
1	6	A	Video	Text	HE2	It was kind of awkward to not be able to see/hear the other participant knowing that he could see/hear me, but it wasn't that weird. I did feel that I kind of 'dominated', for lack of a better work, the decisions more than he did because it was easier for me to talk than it was for him to type.
1	6	B	Text	Video	HE2	It seemed a bit difficult to type fast enough to keep up with the other participant's voiced comments. I felt like my ideas could not be fully or well explained.
2	6	A	Text	Video	LE4	I liked this set up better than the last one. I prefer being able to see/hear the other participant, even if I can only type, to the other way around.
2	6	B	Video	Text	LE4	This task seemed very cold and impersonal. I felt like I was simply talking to a machine.
3	6	A	Video	Text	LE2	*no comment*
3	6	B	Text	Video	LE2	
4	6	A	Text	Video	HE4	*no comment*
4	6	B	Video	Text	HE4	This task was very impersonal. I felt like I was just talking to a machine.
5	6	A	Text	Text	HE1	I prefer situations in which the other participant and I are using the same communication tools.

Order	Dyad	Part.	Medium Sent	Medium Received	Task	Comments
5	6	B	Text	Text	HE1	This seemed less impersonal than the voice/text one because we were both on text.
6	6	A	Text	Text	LE1	I went kind of fast in this one and would have actually chosen the wrong lens if I had just had all 4 requirements and did it at that speed on my own. Oops.
6	6	B	Text	Text	LE1	*no comment*
7	6	A	Video	Video	LE3	*no comment*
7	6	B	Video	Video	LE3	*no comment*
8	6	A	Video	Video	HE3	*no comment*
8	6	B	Video	Video	HE3	The video/video seemed very warm & friendly. It was also easier to communicate
1	7	A	Video	Video	HE3	It is interesting to communicate w/ a stranger through the use of the audio visual equipment. It's much more awkward than face-to-face contact. I felt a weird need to uphold some sort of conversation while the microphones were on. It's also uncomfortable/weird because you cannot really make eye contact w/ the other person.
1	7	B	Video	Video	HE3	*no comment*
2	7	A	Text	Text	LE1	For this particular exercise, "chatting" on the computer was just as effective for conveying the necessary information.
2	7	B	Text	Text	LE1	*no comment*
3	7	A	Video	Text	LE2	This task was awkward, having delayed feedback as to whether or not my communication was being receiving was rather unsettling.
3	7	B	Text	Video	LE2	*no comment*
4	7	A	Text	Text	HE1	This was more difficult to complete since it involved subjective element in the decision-making process
4	7	B	Text	Text	HE1	*no comment*
5	7	A	Text	Video	HE4	It was strange to have to respond to audio w/ typed messages
5	7	B	Video	Text	HE4	*no comment*
6	7	A	Text	Video	LE4	Same as before - weird to respond to words w/ type
6	7	B	Video	Text	LE4	*no comment*
7	7	A	Video	Video	LE3	The delay between the computers made communication a bit confusing. (This happens to me a lot on my cell phone and it drives me crazy)
7	7	B	Video	Video	LE3	*no comment*
8	7	A	Video	Text	HE2	This was (surprisingly) less awkward than when I could see/hear him but he couldn't see/hear me.
8	7	B	Text	Video	HE2	*no comment*
1	8	A	Text	Video	HE4	*no comment*
1	8	B	Video	Text	HE4	It was easy to communicate despite not being able to hear or see the other person
2	8	A	Video	Text	HE2	*no comment*
2	8	B	Text	Video	HE2	My mind wandered for a second when she was talking about applicant B, and yeah that messed me up some
3	8	A	Text	Video	LE4	*no comment*
3	8	B	Video	Text	LE4	That one was harder

Order	Dyad	Part.	Medium Sent	Medium Received	Task	Comments
4	8	A	Video	Video	LE3	*no comment*
4	8	B	Video	Video	LE3	That one was easier
5	8	A	Video	Video	HE3	*no comment*
5	8	B	Video	Video	HE3	Just like talking face to face
6	8	A	Text	Text	HE1	*no comment*
6	8	B	Text	Text	HE1	*no comment*
7	8	A	Video	Text	LE2	*no comment*
7	8	B	Text	Video	LE2	That was easier than when I could see/hear her if I had to do the talking
8	8	A	Text	Text	LE1	*no comment*
8	8	B	Text	Text	LE1	*no comment*

F.6 Complete Post-Task Questionnaire Results

The 384 pages of post-task questionnaire data compiled in association with this study are available under separate cover. These questionnaire results will be stored in the Virginia Tech Electronic Theses and Dissertation digital library, which can be found at:

http://scholar.lib.vt.edu/theses/

Appendix G. Detailed Analysis Outputs

Table G-1. Combined results of planned comparisons for time to complete.

Equivocality	Contrast	F Value	Pr > F
High	Text-only vs. Mixed	8.87	**0.0059**
High	Video vs. Mixed	3.16	0.0861
Low	Text-only vs. Mixed	0.40	0.5329
Low	Video vs. Mixed	1.31	0.2619

Table G-2. ANOVA Summary Table for Analysis of Dyadic Variables

Source	df			SS	MS	F
Between Subjects						
Subjects (S)	(n – 1)	=	7	$SS_{S/D}$	$MS_{S/D}$	-
Within Subjects						
Task (T)	(t - 1)	=	1	SS_T	MS_T	MS_T / MS_{TxS}
T x S	(t - 1)(n-1)	=	7	SS_{TxS}	MS_{TxS}	
Medium (M)	(m -1)	=	3	SS_M	MS_M	MS_M / MS_{MxS}
M x S	(m -1)(n-1)	=	21	SS_{MxS}	MS_{MxS}	
T x M	(t - 1)(m - 1)	=	3	SS_{TxM}	MS_{TxM}	MS_{TxM} / MS_{TxMxS}
T x M x S	(t - 1)(m - 1)(n-1)	=	21	SS_{TxMxS}	MS_{TxMxS}	
Total	tmn-1	=	63			

Table G-3. ANOVA Summary table for time to complete.

Source	df	SS	MS	F	p
Between Subjects					
Dyad	7	24979.60938	3568.51563	.	.
Within Subjects					
Task	1	19635.01562	19635.01562	5.09	0.0586
Dyad*Task	7	26985.10938	3855.01563	.	.
Medium	3	56762.42188	18920.80729	4.86	0.0101
Dyad*Medium	21	81758.95313	3893.28348	.	.
Medium*Task	3	14975.92187	4991.97396	2.08	0.1330
Dyad*Medium*Task	21	50311.45312	2395.78348	.	.

Table G-4. Post-hoc Analysis of Significant Effect of Medium on time to complete.

Alpha	0.05
Error Degrees of Freedom	21
Error Mean Square	3893.283
Critical Value of Studentized Range	3.94188
Minimum Significant Difference	61.49

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	Medium
	A	170.81	16	Text only
B	A	132.94	16	A sends Text, B sends Video
B	A	116.94	16	A sends Video, B sends Text
B		88.38	16	V+V

Table G-5. Combined results of planned comparisons for communication breakdown frequency.

Equivocality	Contrast	F Value	Pr > F
High	Text-only vs. Mixed	0.83	0.3697
High	Video vs. Mixed	0.75	0.3924
Low	Text-only vs. Mixed	3.13	0.0878
Low	Video vs. Mixed	0.77	0.3880

Table G-6. ANOVA Summary table for communication breakdown frequency.

Source	df	SS	MS	F	p
Between Subjects					
Dyad	**7**	**3.42211875**	**0.48887411**	**.**	**.**
Within Subjects					
Task	**1**	**2.98425625**	**2.98425625**	**3.14**	**0.1197**
Dyad*Task	**7**	**6.65331875**	**0.95047411**	**.**	**.**
Medium	**3**	**2.67838125**	**0.89279375**	**2.26**	**0.1116**
Dyad*Medium	**21**	**8.31074375**	**0.39574970**	**.**	**.**
Medium*Task	**3**	**2.49890625**	**0.83296875**	**2.12**	**0.1276**
Dyad*Medium*Task	**21**	**8.23611875**	**0.39219613**	**.**	**.**

Table G-7. Combined Summary of Comparisons for Social Presence Scales and Media Involving Text

Scale	Medium	F	p
personal-impersonal	Text-only vs. Mixed	3.27	0.0731
personal-impersonal	Text-only vs. Sending Text & Receiving Video	12.93	**0.0005**
personal-impersonal	Text-only vs. Sending Video & Receiving Text	0.22	0.6429
warm-cold	Text-only vs. Mixed	0.01	0.9221
warm-cold	Text-only vs. Sending Text & Receiving Video	2.79	0.0976
warm-cold	Text-only vs. Sending Video & Receiving Text	2.25	0.1363
sensitive-insensitive	Text-only vs. Mixed	0.62	0.4325
sensitive-insensitive	Text-only vs. Sending Text & Receiving Video	1.93	0.1674
sensitive-insensitive	Text-only vs. Sending Video & Receiving Text	0.00	0.9803
social-unsocial	Text-only vs. Mixed	0.05	0.8294
social-unsocial	Text-only vs. Sending Text & Receiving Video	1.11	0.2950
social-unsocial	Text-only vs. Sending Video & Receiving Text	2.03	0.1565
passive-active	Text-only vs. Mixed	0.03	0.8594
passive-active	Text-only vs. Sending Text & Receiving Video	0.02	0.8983
passive-active	Text-only vs. Sending Video & Receiving Text	0.19	0.6639

Table G-8. Combined Summary of Comparisons for Social Presence Scales and Media Involving Video

Scale	Medium	F	p
personal-impersonal	Video vs. Mixed	56.87	**<.0001**
personal-impersonal	Video vs. Sending Text & Receiving Video	20.26	**<.0001**
personal-impersonal	Video vs. Sending Video & Receiving Text	73.29	**<.0001**
warm-cold	Video vs. Mixed	42.70	**<.0001**
warm-cold	Video vs. Sending Text & Receiving Video	16.60	**<.0001**
warm-cold	Video vs. Sending Video & Receiving Text	52.47	**<.0001**
sensitive-insensitive	Video vs. Mixed	15.50	**0.0001**
sensitive-insensitive	Video vs. Sending Text & Receiving Video	7.31	**0.0078**
sensitive-insensitive	Video vs. Sending Video & Receiving Text	16.95	**<.0001**
social-unsocial	Video vs. Mixed	48.85	**<.0001**
social-unsocial	Video vs. Sending Text & Receiving Video	23.18	**<.0001**
social-unsocial	Video vs. Sending Video & Receiving Text	53.16	**<.0001**
passive-active	Video vs. Mixed	9.10	**0.0031**
passive-active	Video vs. Sending Text & Receiving Video	8.38	**0.0045**
passive-active	Video vs. Sending Video & Receiving Text	5.43	**0.0214**

Table G-9. ANOVA Summary Table for Analysis of Individual Variables

Source	df		SS	MS	F
Between Subjects					
Dyad (D)	(d – 1)	= 7	SS_D	MS_D	MS_D / $MS_{S/D}$
Subjects (S/D)	d(n – 1)	= 8	$SS_{S/D}$	$MS_{S/D}$	-
Within Subjects					
Task (T)	(t - 1)	= 1	SS_T	MS_T	MS_T / $MS_{TxS/GD}$
T x D	(t - 1)(d - 1)	= 7	SS_{TxD}	MS_{TxD}	$MS_{TxD}MS_{TxS/GD}$
T x S/D	d(t - 1)(n - 1)	= 8	$SS_{TxS/GD}$	$MS_{TxS/GD}$	-
Medium (M)	(m -1)	= 3	SS_M	MS_M	MS_M / $MS_{MxS/GD}$
M x D	(m - 1)(d – 1)	= 21	SS_{MxD}	MS_{MxD}	MS_{MxD} / $MS_{MxS/GD}$
M x S/D	d(m - 1)(n - 1)	= 24	SS_D	MS_D	-
T x M	(t - 1)(m - 1)	= 3	SS_{TxM}	MS_{TxM}	MS_{TxM} / $MS_{TxMxS/D}$
T x M x D	(t - 1)(m-1)(d-1)	= 21	SS_{TxMxD}	MS_{TxMxD}	MS_{TxMxD} / $MS_{TxMxS/D}$
T x M x S/D	d(t - 1)(m - 1)(n - 1)	= 24	$SS_{TxMxS/GD}$	$MS_{TxMxS/GD}$	-
Total	tdmn-1	= 127			

Table G-10. ANOVA Summary Table for personal-impersonal Scale.

Source	DF	SS	MS	F	p
Between Subjects					
Dyad	7	49.63232422	7.09033203	3.43	0.0525
Subject(Dyad)	8	16.5195313	2.0649414	.	.
Within Subjects					
Task	1	0.03955078	0.03955078	0.15	0.7109
Task*Dyad	7	1.22998047	0.17571150	0.66	0.7044
Task*Subject(Dyad)	8	2.1445313	0.2680664	.	.
Medium	3	154.0249023	51.3416341	26.03	**<.0001**
Medium*Dyad	21	59.0649414	2.8126163	1.43	0.2002
Medium*Subject(Dyad)	24	47.3398438	1.9724935	.	.
Medium*Task	3	1.16162109	0.38720703	0.58	0.6339
Medium*Task*Dyad	21	9.24072266	0.44003441	0.66	0.8312
Medium*Task*Subject(Dyad)	24	16.0273437	0.6678060	.	.

Table G-11. Post-hoc Analysis of Significant Effect of Medium on personal-impersonal scale.

Alpha	**0.05**
Error Degrees of Freedom	**21**
Error Mean Square	**2.812616**
Critical Value of Studentized Range	**3.94188**
Minimum Significant Difference	**1.1686**

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	Medium (Sent+Received)
.	A	5.3047	32	Video+Text
B	A	5.1563	32	Text+Text
B	.	4.0078	32	Text+Video
.	C	2.5703	32	Video+Video

Table G-12. ANOVA Summary Table for warm-cold Scale.

Source	DF	SS	MS	F	p
Between Subjects					
Dyad	7	36.33154297	5.19022042	2.24	0.1400
Subject(Dyad)	8	18.50390625	2.31298828	.	.
Within Subjects					
Task	1	0.59814453	0.59814453	3.82	0.0865
Task*Dyad	7	3.09326172	0.44189453	2.82	0.0849
Task*Subject(Dyad)	8	1.25390625	0.15673828	.	.
Medium	3	71.44287109	23.81429036	19.83	**<.0001**
Medium*Dyad	21	37.31884766	1.77708798	1.48	0.1768
Medium*Subject(Dyad)	24	28.82421875	1.20100911	.	.
Medium*Task	3	0.54052734	0.18017578	0.44	0.7244
Medium*Task*Dyad	21	15.03369141	0.71589007	1.76	0.0914
Medium*Task*Subject(Dyad)	24	9.76171875	0.40673828	.	.

Table G-13. Post-hoc Analysis of Significant Effect of Medium using Tukey's HSD.

Alpha	**0.05**
Error Degrees of Freedom	**21**
Error Mean Square	**1.777088**
Critical Value of Studentized Range	**3.94188**
Minimum Significant Difference	**0.9289**

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	Medium (Sent+Received)
.	A	5.1016	32	Video+Text
.	A	4.6875	32	Text+Text
.	A	4.2266	32	Text+Video
B	.	3.1016	32	Video+Video

Table G-14. ANOVA Summary Table for sensitive-insensitive Scale.

Source	DF	SS	MS	F	p
Between Subjects					
Subject(Dyad)	8	36.64843750	4.58105469	.	.
Dyad	7	63.70312500	9.10044643	1.99	0.1783
Within Subjects					
Task	1	0.01757813	0.01757813	0.04	0.8391
Task*Dyad	7	1.92773437	0.27539062	0.69	0.6814
Task*Subject(Dyad)	8	3.19531250	0.39941406	.	.
Medium	3	35.66796875	11.88932292	8.63	**0.0005**
Medium*Dyad	21	26.90234375	1.28106399	0.93	0.5639
Medium*Subject(Dyad)	24	33.07031250	1.37792969	.	.
Medium*Task	3	1.84570312	0.61523437	0.78	0.5146
Medium*Task*Dyad	21	10.74023437	0.51143973	0.65	0.8375
Medium*Task*Subject(Dyad)	24	18.83593750	0.78483073	.	.

Table G-15. Post-hoc Analysis of Significant Effect of Medium on Sensitive-insensitive Scale.

Alpha	**0.05**
Error Degrees of Freedom	**21**
Error Mean Square	**1.281064**
Critical Value of Studentized Range	**3.94188**
Minimum Significant Difference	**0.7887**

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	Medium (Sent+Received)
.	A	5.0234	32	Video+Text
.	A	5.0156	32	Text+Text
.	A	4.5781	32	Text+Video
B	.	3.7266	32	Video+Video

Table G-16. ANOVA Summary Table for social-unsocial Scale.

Source	DF	SS	MS	F	p
Between Subjects					
Dyad	7	31.48779297	4.49825614	0.60	0.7415
Subject(Dyad)	8	59.8242188	7.4780273	.	.
Within Subjects					
Task	1	0.08251953	0.08251953	0.12	0.7430
Task*Dyad	7	4.33544922	0.61934989	0.86	0.5696
Task*Subject(Dyad)	8	5.7304688	0.7163086	.	.
Medium	3	107.3061523	35.7687174	18.58	**<.0001**
Medium*Dyad	21	41.8227539	1.9915597	1.03	0.4644
Medium*Subject(Dyad)	24	46.1914063	1.9246419	.	.
Medium*Task	3	0.66943359	0.22314453	0.25	0.8578
Medium*Task*Dyad	21	10.49072266	0.49955822	0.57	0.9026
Medium*Task*Subject(Dyad)	24	21.0976563	0.8790690	.	.

Table G-17. Post-hoc Analysis of Significant Effect of Medium on Social-unsocial Scale.

Alpha	**0.05**
Error Degrees of Freedom	**21**
Error Mean Square	**1.99156**
Critical Value of Studentized Range	**3.94188**
Minimum Significant Difference	**0.9834**

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	Medium (Sent+Received)
.	A	5.1719	32	Video+Text
.	A	4.6953	32	Text+Text
.	A	4.3438	32	Text+Video
B	.	2.7344	32	Video+Video

Table G-18. ANOVA Summary Table for Passive-active Scale.

Source	DF	SS	MS	F	p
Between Subjects					
Dyad	7	40.89843750	5.84263393	2.05	0.1674
Subject(Dyad)	8	59.8242188	7.4780273	.	.
Within Subjects					
Task	1	0.15820313	0.15820313	0.60	0.4601
Task*Dyad	7	3.06835938	0.43833705	1.67	0.2440
Task*Subject(Dyad)	8	5.7304688	0.7163086	.	.
Medium	3	16.36328125	5.45442708	3.16	**0.0430**
Medium*Dyad	21	36.30078125	1.72860863	1.00	0.4946
Medium*Subject(Dyad)	24	46.1914063	1.9246419	.	.
Medium*Task	3	1.34570313	0.44856771	0.43	0.7354
Medium*Task*Dyad	21	11.24023438	0.53524926	0.51	0.9386
Medium*Task*Subject(Dyad)	24	21.0976563	0.8790690	.	.

Table G-19. Post-hoc Analysis of Significant Effect of Medium on Passive-active Scale.

Alpha	**0.05**
Error Degrees of Freedom	**21**
Error Mean Square	**1.728609**
Critical Value of Studentized Range	**3.94188**
Minimum Significant Difference	**0.9162**

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Medium (Sent+Received)
. A	5.0156	32	Video+Video
. A	4.3047	32	Video+Text
. A	4.1719	32	Text+Text
. A	4.1328	32	Text+Video

Appendix H. Glossary

Common Ground

The term common ground "refers to the mutual knowledge, beliefs, and assumptions of the participants in a conversation" (McCarthy, Miles, & Monk, 1991)

Computer-Mediated Communication (CMC)

Computer-mediated communication is a term that has been used to refer to text-based computer-based communications. The term can also refer to the entire range of communication media that can be used between one or more users and their computers.

Computer-Supported Cooperative Work (CSCW)

Computer-supported cooperative work is a term that has been used to describe tasks performed by a distributed group using one or more computer-based communications media as a coordinating tool.

Group Decision Support Systems (GDSS)

Group decision support systems are a class of computer-based communication tools intended to help distributed groups collaborate on projects. Such a system typically consists of a combination of communication tools and shared informational spaces. Such a system can be generalized for use in completing a wide range of tasks or tuned for a particular set of tasks.

Emoticons

The term emoticon is short for "emotional icon". Emoticons are textual pictures used to indicate an emotion or to add emphasis to text. Emoticons are one means of inserting explicit emotional content into text media. A very common example is the combination of a colon and a right parenthesis, which appears to be a smiling face when viewed on its side:

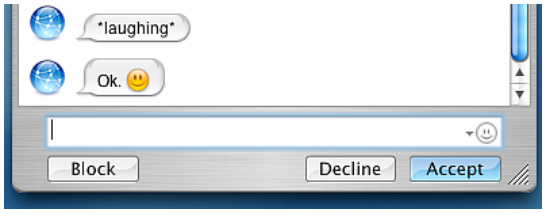


Figure A-1. Sample Emoticon

:)

In western cultures, emoticons are typically represented as lying on one side. Asian users have developed an entirely separate set of emoticons that are meant to be viewed horizontally, and which may include some of the larger set of characters available for multi-byte character sets. As an example, a Japanese emoticon (Takagi, 2002) of a blushing face looks like:

(*^_^*)

Some text chat clients replace emoticons with clearer graphical icons. Figure A-1 presents an example in which the smiley emoticon is replaced with a graphical representation that can be viewed horizontally.

Group Support Systems (GSS)

See ***group decision support systems****.*

Instant Messaging (IM)

The first Instant Messaging (or IM) program, ICQ (a play on "I seek you"), was developed by Mirabilis Ltd. in 1996 (ICQ, 2004). IM resembles but is distinct from other synchronous technologies such as Bulletin Board Systems (BBSes), chat rooms, Internet Relay Chat (IRC), Multiple User Dialogs (MUDs). Like these technologies, it is a means by which two or more users can type their portion of a real-time conversation and can read (usually in context) other users' contributions to the same conversation. A sample screen shot is provided. Instant Messaging can be conducted using a variety of compatible client software, such as the Jabber (see glossary entry) Client PSI (Collins, Germeau, Karneges, & Smith, 2002) depicted in Figure A-2.

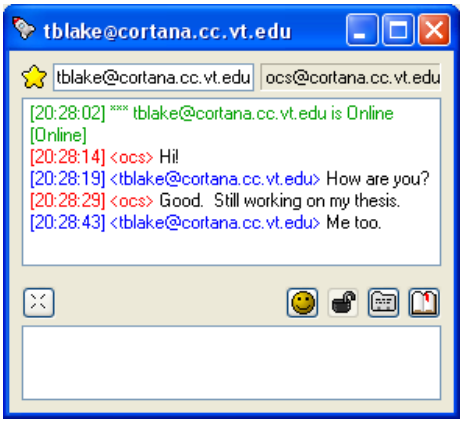


Figure A-2. Screenshot of the IM client PSI

Newer IM clients such as AOL Instant Messenger 5.5 (America Online, 2004), Enigma 2 (Schwarz & Staundinger, 2002), Neos (Novamens, 2004), and Lluna (Wolf, Kaufmann, Bönisch, & Mohammadi, 2004) add support for video and audio for one or more participants in a conversation.

Jabber

Jabber is "a set of streaming XML (see glossary entry) protocols and technologies that enable any two entities on the Internet to exchange messages, presence, and other structured information in close to real time" (Jabber, 2004). Although there are commercial clients developed to work with Jabber, the core technology behind Jabber is "open source", meaning it can be downloaded and modified freely. Like other Instant Messaging clients, a central Jabber server is required to maintain directory information about users who are connected and to facilitate connections between users.

Media Richness

Media richness is the capability of a medium of supporting human communication. Media richness is defined in terms of feedback capability, communication channels utilized, language, and source (Daft & Lengel, 1984).

Situation Awareness

"The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988)

Social Presence

Social Presence is a condition in which a party in a computer-mediated communication is more aware of the person(s) with whom they are interacting than they are aware of the technology that allows them to communicate (Gunawardena, 1995).

Task-Media Fit Hypothesis

This hypothesis states that there should be a correlation between the equivocality of the task and the richness of the medium in which the task is performed (Daft & Lengel, 1984).

In this model, performance is assumed to be higher for high equivocality tasks completed using high richness media than for high equivocality tasks completed using low richness media. Performance is also assumed to be higher for low equivocality tasks completed using low richness media than for low equivocality tasks completed using high richness media.

Voice Over IP (VoIP)

> "VoIP, or Voice over internet protocol, is a method for taking analog audio signals, like the kind you hear when you talk on the phone, and turning them into digital data that can be transmitted over the Internet" (Tyson & Valdes, 2005)

Voice over IP solutions included dedicated hardware solution designed to look and function like a traditional phone as well as pure software solutions such as Skype (*Skype Home Page*, 2005).

XML

XML stands for eXtensible Markup Language. XML is a markup language (like its better-known cousin, HTML). A markup language adds information to control the structure and presentation of blocks of text through the use of tags. Where HTML (HyperText Markup Language) is a rigidly define set of structural and presentational codes used to format web pages, XML is a larger language that can be used to describe many types of data. There are XML document types that can be used to describe print-ready documents, mathematical formulas, music, theses and dissertations, and many other types of data.

The advantage of XML is that it is an open format, it describes data in a way which is easy for computers to process (or "parse"), and which is also more human-readable (at least for human developers and programmers) than closed languages such as those used to encode graphics and other binary formats.

Among other things, XML is used for server-to-server messages in products like Jabber, and is one format in which messages transmitted during a Jabber session can be archived.