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Maria Victoria Ramos
Embry-Riddle Aeronautical University - Daytona Beach

AN ANALYSIS OF REMOTE COMMUNICATION PROCESSES INVOLVED IN VIDEO-MEDIATED, AND TEXT-BASED COMPUTER-MEDIATED COMMUNICATION DURING COLLABORATIVE PROBLEM SOLVING

by

Maria Victoria Ramos

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This thesis research proposal was prepared under the direction of the candidate's thesis committee chair, Christina Frederick, Ph.D., Department of Human Factors & Systems, and has been approved by the members of the thesis committee. It will be submitted to the Department of Human Factors & Systems in partial fulfillment of the requirements for the degree of Masters of Science in Human Factors & Systems.

THESIS COMMITTEE:

Christina Frederick, Ph.D., Chair

John A. Wise, Ph.D., Member

Steven Hall, Ph.D., Member

Arlin J. Cooper, Ph.D., Member

MS HFS Program Coordinator

Department Chair, Department of Human Factors & Systems

ABSTRACT

Author: Maria Victoria Ramos

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The purpose of this study was to explore the impact of current available communication mediums on the process of collaborative problem solving tasks in today's modern society. Seven male-only dyads were asked to complete two tasks, both with a finite and definable solution, by communicating through one of three possible ways: face-to-face (FTF), a synchronous text-based computer system (CMC), and a video-mediated system (VMC). The effectiveness of the medium was evaluated based on time to solution, number of turns and words in relation to a visual search task and a spatial task. Results showed a significant difference in time to solution between dyads communicating through CMC and VMC and FTF mode for the visual search task. For the spatial task, significant time differences were found between all modes of communication, with the computer-mediated group taking the longest time to complete the task. No difference was found between FTF mode and VMC mode in regards to number of words and turns for the visual task, and for the special task no significant difference was found between FTF mode and CMC mode.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Technological advances in communication are having a great impact on today's societal progression. Innovations in computer technology, such as chat groups, e-mail, conferencing, and the internet provide individuals with easy access to all types of information and provide a global connectivity that is revolutionizing the way people relate. As these technologies continue to rapidly evolve new concepts such as telehealth, telemedicine, distance learning and remote teleconferencing are reshaping societal norms, and bringing together a diverse groups of individuals who will create a new international society (Jerome, DeLeon, James, Folen, Earles, & Gedney, 2000). As a result video-mediated communication (VMC) and computer-mediated communication (CMC) have become important research areas in psychology, with implications for clinical practice, research and learning, human factors, ethics, social development, and the societal impact of these changes.

The effectiveness of these new technologies (VMC and CMC) for important tasks, such as distance learning or teleconferencing is important. Most software or hardware is designed by engineers who do not take into account human constraints, flexibility, or acceptance of new mediums of communication for important tasks. Issues such as experience with new technology, level of understanding of the task, situation, and individual differences or preferences affect the way certain mediums are used. In important situations or tasks, such as telemedical consultations or business conferences, understanding and productivity are important factors that should be addressed in relation to the human and not just to the machine.

In order to successfully develop efficient interactive computerized systems that will allow users in remote areas to communicate, human communication through technological means must be thoroughly understood. People behave or communicate differently depending on the technological constraints set upon them. These constraints can have an impact on the interaction between people, as far as understanding and perception of information and of the person on the other end of the medium. As a result, much research has been conducted on the effectiveness of human communication through different mediums. It is understood that information transmission through natural, face-to-face (FTF) communication is currently the most effective way to present information (Finn et al., 1997). There have been numerous experiments that have attempted to test the efficacy of different mediums of communications, such as computer-mediated communication (CMC), video-mediated communication (VMC), and aural communication. While it seems that for very simple tasks the medium does not greatly affect the outcome, for more difficult tasks there seems to be an advantage to presenting information in person. However, presenting information visually through a medium (e.g., VMC) and presenting it face-to-face also has an impact on the way the information is communicated, because one does not replace the other (Finn et al., 1997).

This study addresses the impact of three communication modes – video-mediated, computer-mediated, and face-to-face – on the effectiveness of collaborative problem solving. Although, these communication modes are used for many different tasks, this experiment will focus only on the collaboration of participants solving a problem with an objective and definite solution.

REVIEW OF THE LITERATURE

The Communication Process and Face to Face Communication

Communication is a process that requires coordination amongst the individuals involved, as conversation is both incremental and interactive (O'Conaill et al., 1993). It is an activity that requires coordination of process and content surrounding the subject matter of conversation. Throughout this interactive process the speakers and listeners build up understanding about the subject matter (Finn et al., 1997). A very important issue that affects this coordination is listener feedback. While the individual speaking delivers information incrementally, the listener provides simultaneous feedback to assess that the conversation is on track, both visually (e.g., head nods, eye gaze) and auditorily (e.g., "uhu"). If the listener provides positive feedback, the speaker knows to continue to talk and build upon the listener's continuous understanding. If the feedback is absent or delayed, the efficiency of the messages that the speaker is producing drops significantly. Through other means of communication where verbal and visual feedback are not present, the speaker has no way of knowing if the listener has understood, which may lead to unnecessary clarification of messages. During FTF communication, if a breakdown in communication does occur, the listener can easily interrupt the speaker and ask for clarification, leading to further coordination and interaction amongst the individuals.

In general, FTF communication flows smoothly, and listener interruptions tend to be non-disruptive to the overall flow of the conversation. Turn taking is a key issue in the process of communication (O'Conaill et al, 1993). Both, the speaker and the listener, use certain devices to indicate when they wish to stop speaking or when they wish to speak. The speaker uses a combination of intonational, syntactic, pragmatic, and non-verbal cues to signify that he is ready to conclude his turn. The listener picks up on these cues before the speaker is done speaking, which causes very short speaking-switching pauses (from about 620 msec to 770 msec) or even no pauses at all. In fact, less than 5% of conversation is delivered in overlap. On the other hand, the listener tends to use non-verbal cues, such as leaning forward or achieving mutual gaze, to show that he/she would like to speak. However, when these cues are not present in other mediums of communication, the turns are not as smooth, and the speaker tends to take longer turns to over-explain the information (O'Conaill et al., 1993). Therefore, conversations can be characterized in terms of frequency and duration of turns, lengths of pauses and number of interruptions. These characteristics are usually used in experimental studies as a way of assessing the effect of communication or conversational mediums (Sellen, 1995).

There are two types of visual information that affect communication: participant behavior, and environmental information (Finn et al., 1997). Information about the behavior of the participants is given with their eyes (gaze), faces (facial expressions), hands and arms (gestures), and the movements and orientation of their bodies (posture). Environmental information that the participants share can be a set of shared objects or events, and the information of the activities of others.

Gaze is one way that the speaker and the listener obtain information from the environment. It provides several communicative functions, such as turn-taking cues, availability cues, feedback cues, and interpersonal information cues. In fact, participants may evaluate others by their patterns of gaze to subjectively evaluate their interest in the conversation and their level of understanding, as well as their attitude or affect. Most participants spend only 3% to 7% of the conversational time looking at others, and as little as 5% in mutual gaze, which means that they are more focused on their environment (or relevant visible objects) than on each other (Argyle & Graham, 1977). Gestures are dynamic movements by a participant's hands and arms that take place during conversation that may substitute spoken words or phrases. They also provide several communicative functions, such as turn taking cues, availability cues, reference cues, feedback cues and interpersonal information. Facial expressions give information about the participants by the use of their eyes, eyebrows, nose, mouth and forehead. They provide feedback and serve as indicators of the emotional state of the individual, such as interest or puzzlement. Also, mouth movements help the listener to decipher unintelligible speech. The "McGurk effect" demonstrated that visual information had an effect on the perception of speech. When a participant was presented with conflicting information from speech and voice, such as the lips saying "ga" and the voice "ba," the participant would hear "da" (Finn et al., 1997). Posture also provides information during conversation by the inclination of a participant's body, the upper body in particular. The posture of a listener gives the speaker cues about his or her level of interest and understanding, for example, if a listener is leaning forward it signals interest, but if the head is lowered or supported by one hand it signals boredom (Finn et al., 1997).

During face-to-face communication, participants also interact in the same physical environment and share visual information about physical objects, events and people, which enables the participants to make inferences about the shared objects or events. This helps to minimize ambiguity in the messages, and can aid the participants in making judgments about the availability of the other participant, which helps in the process of initiating and terminating conversations. For some tasks, having a shared environment is very important. For example, if the participants have to handle or modify complex objects a shared environment can help them to better coordinate the content of the conversation (Finn et al., 1997).

Many studies have demonstrated that non-verbal cues or visual cues that occur during face-to face communication serve a great number of functions. For example, eye contact has been shown to be a cue for dominance, for friendliness, for approval, and for speech synchronization. However, in media-based experimental research, the impact of non-verbal communication on transmission of information has been shown to make only a subtle difference on the efficiency of the message being communicated (Chapanis, Ochsman, Parrish & Weeks, 1972). It appears that having a visual channel is only overtly useful for tasks where the social factors are a central component, such as negotiation and bargaining tasks. Several explanations have been provided to explain those findings (Williams, 1977). One explanation claims that the impact of non-verbal cues on communication has been greatly exaggerated, and compared to verbal communication those cues serve only a minimal purpose. Another hypothesis says that non-verbal cues have functions that are momentary and specific, and that their absence has different impacts on different people. In other words, when looking at the whole communication process, non-verbal communication is only a small part of the whole process and its impact may be difficult to detect. Another explanation for the lack of significant effects of non-verbal communication states that non-verbal communication is highly redundant.

Therefore, the non-verbal cues only help to reinforce the message and are not a critical part of the whole interaction. Yet another hypothesis is that non-verbal cues are usually used in substitution of verbal cues, which again does not make them a necessity (Williams, 1977).

Video-Mediated Communication (VMC)

However, as face-to-face communication seems to be the most effective way to share information, the emerging technology of video-mediated communication (VMC) has been a topic of much experimental research. There are three hypothesis on how video might improve information sharing: (1) video supports non-verbal cues (visible behaviors) that facilitate understanding; (2) video gives the participants visual information about the environment and helps them assess the availability of the other person, therefore facilitating turn-taking; (3) video supports dynamic visual information which greatly aids participants when conducting collaborate tasks. These hypotheses have been tested in different communication modalities that have attempted to assess how human-to-human communication is affected when it is supported by a system. For example, Chapanis et al. (1972) studied different communication modalities and their effect on problem solving and linguistic behavior, Williams (1977) studied human communication through different modes and its effect on behavior and task performance, O'Conaill et al. (1993) looked at the effects of the properties of ISDN versus LIVE-NET on communication, Sellen (1995) investigated three different videoconferencing systems with respect to their support for gaze and listening, and their effect on remote conversations.

Chapanis and colleagues (Chapanis et al., 1972, 1977; Ochsman & Chapanis, 1974) conducted several experiments to understand the impact of interactive computer systems on human communication. They compared the effectiveness of different communication mediums – handwriting, typewriting, voice, natural communication, and video communication – on cognitive cooperative problem-solving tasks. The problem solving tasks were chosen on several criteria: (1) they had to sample different psychological functions, (2) they had to be representative of tasks for which these modes of communication are used, (3) they had to have definite, recognizable solutions, (4) they required no special skill or knowledge from the participants, and (5) they required two participants to work together as a team. The two problem-solving tasks used were a geographic orientation task and an equipment assembly task. In the first one, two participants had enough information to solve a problem together, but not alone. One participant (the source) was given one page from a telephone directory with physicians' listing and the other participant (the seeker) was given an index of streets and a gridded street map, and a card with a home address. The seeker's job was to find the office of a physician closest to the home address on the card. The equipment assembly task required the seeker to assemble a common household item, while the source, who was given the instructions, had to help him assemble it.

When Chapanis et al. (1976) compared audio-only communication, high quality video/audio, they found that adding visual information did not increase the efficiency of problem solving. In fact, they concluded that speech was the main component of interpersonal communication, and while natural, unrestricted communication (or FTF) was more efficient when it came to the time it took to reach the solution to the problem, the quality of the solution was equivalent regardless of the medium.

In a later experiment, O'Conaill et al. (1993) found that compared to FTF meetings, the communication process with a low quality VMC system is poor and disruptive. The study compared two Integrated Services Digital Network (ISDN) lines to LIVE-NET, which is the London Interactive Video Education Network. ISDN operated on a 56kb/sec digital network had an available bandwidth of 112 kb/sec, 16 kb/sec of which were used for audio, so the available amount for video transmission was about 90 kb/sec. This system had a propagation delay, and the lag between an individual on one site speaking and the information arriving at the other site varied between 410 msec and 78 msec. The audio channel was half duplex, which means that only the voice of one person could be transmitted at one time. In addition, transmission problems would occur occasionally, disrupting the audio channel and the video picture. The participants using this system had control over their local camera, and could also switch between close-up shots of the speaker. The LIVE-NET system was connected through a pair of optical fibers for each site, each pair containing four full bandwidth video channels, with sound on a 6-MHz sub carrier. The system required no video or audio processing, which means the time lag was the propagation time at the speed of light. The audio system was full duplex, and the system provided a full motion picture with no frozen picture motion. The participants in this group could control the image they received, and had an overhead camera for the display of documents.

The effectiveness of the VMC system was assessed by measuring backchannels, interruptions, overlapping speech, explicit handovers, turn size, and turn distribution. Backchannels were described as auditory feedback utterances by the listener that indicated attention, support, or acceptance. Interruptions were instances of simultaneous speech caused by the speech of a second speaker who does not have the floor. Overlaps were instances of simultaneous speech that occur after the first speaker has indicated that he is relinquishing the floor. Explicit handovers occurred when the speaker indicated through verbal cues that he was about to relinquish the floor. Turns were described as any attempt by the next speaker to gain the conversational floor. They found that backchannels were reduced in ISDN compared to FTF meetings because of the half duplex audio channel, but when they did occur, the conversation floor of the speaker was disrupted. Backchannels were also significantly reduced in LIVE-NET compared to FTF meetings, but occurred more frequently then in ISDN. Interruptions were also significantly lower in ISDN then in FTF meetings. Although interruptions in LIVE-NET were also significantly different than FTF meetings, they were less frequent then in ISDN communication.

In addition, interruptions caused more problems in communication, such as requests for repetition of information or technical problems, in ISDN then in LIVE-NET and no problems in FTF communication. Overlapping speech occurred more in FTF and LIVE-NET communication then in ISDN, probably because listeners avoided them in ISDN due to the combination of the half-duplex line and the time lags, however, overlaps were statistically significant at all levels. Explicit or formal handovers occurred more in ISDN, less in LIVE-NET, and even less in FTF meetings, but again explicit handovers were significant for all levels. In regard to turn size, it was found that ISDN meetings were characterized by fewer turns of greater length per participant. Again, the numbers of turns and turn size in ISDN were significantly different from FTF and form LIVE-NET, as well as FTF from LIVE-NET. Last, although it was hypothesized that the different mediums would lead to unequal distribution of turns among individuals, there was no overall difference in percentage of turns for the three conditions.

As a whole, the results showed that compared to FTF meetings, ISDN differed in several manners, including: (1) listeners were less likely to anticipate turn endings; (2) speakers formally handed the floor using a question or naming the speaker, and were less redundant in their messages; (3) interaction amongst participants was formal lecture style, with long turns, and very formal handovers. LIVE-NET also differed from FTF meetings in several ways, including; (1) the participants gave less backchannels, although they interrupted almost as frequently as in FTF; (2) speakers were likely to formally hand over the floor, and less likely to give redundant information. These results show that although LIVE-NET, a high quality system, closely mimics FTF communication in several ways, many of the conversational characteristics are similar to ISDN, a low quality system. This suggests that there are other factors involved in communicating through an interactive communication system that affect the way individuals interact and that the mediated communication process is highly affected by the properties of the communication channels.

In several experiments, Anderson et al. (1994) explored the effects of VMC on task outcome and on the process of communication. They tested two cooperative tasks that would produce objective measures of task success: the Map Task and the Travel Game. In the Map Task, participants had to cooperate to develop an accurate map route. In the Travel Game the participants had to plan an itinerary for travel around the United States, trying to visit as many places as possible taking into account the availability of flights. The tasks were performed using VMC (high and low bandwidth), audio link only or face-to-face. The dialogues were analyzed for length of turns and words, as well as for the management of turn-taking process. Boyle, Anderson & Newlands (1994) had first conducted a similar experiment using the Map Task and found that in FTF communication speakers used 28% less turns and 20% less words then those speakers communicating through audio only, but the level of task performance was equal for both mediums of communication.

In one study, Anderson et al. (1994) compared VMC where participants could use eye contact, VMC where they could not make eye contact and audio only. They chose to replace the FTF condition with the high-resolution video link, which allowed direct eye contact and included full duplex audio. They found that there was no difference in levels of task performance across conditions. However, they did find that VMC with eye contact did not replicate FTF communication, as it was significantly less efficient. In addition, the discussions through VMC with eye contact contained 11% more turns and 10 % more words than the other two conditions. In comparison to VMC, audio only participants checked to see if the other person had understood what was said, and in this respect VMC is comparable to FTF. Another interesting finding was that during VMC participants produced significantly longer dialogues, especially in the eye contact condition. They attempted to explain this behavior by suggesting that gaze might interfere with cognitive processing and speech planning. The speaker becomes distracted by the other person's face and has to use more messages to accomplish the task successfully. Overall, this study showed that VMC cannot replicate FTF communication, perhaps because of the technical limitations of the medium or because it does not seem as natural and effortless as FTF communication to the participants.

Anderson et al. (1994) also investigated the effects of audio delay and lip synchronization, which is caused by bandwidth limitations. For example, in the telephone network in the United States the transmission delay is about 20 msec to 30 msec, in ISDN it is about 10 msec, and a T1 connection has a delay in the single digits. However, a satellite link is much slower and causes a propagation delay of about 260 msec for a single satellite jump. In addition, video image compression causes a delay in the video because video compression techniques require time to process (200 msec to 400 msec). If there is a misalignment between the audio delay and the video delay, and the audio delay is 200 msec to 400 msec faster, the user communication will be impaired (Finn et al., 1997). Anderson compared task performance and communication with high or low bandwidth. In the video/audio delay condition (low bandwidth) there was a delay of approximately 500 msec. The results showed a decrement in task performance of about 40% when the delay was present. Also, the delay affected turn taking, as over 50% of a speaker' turns were interrupted by the listener. This shows that signal delay is a detrimental factor in VMC.

Looking at the data it appears that although VMC elicits some of the advantages of FTF communication, it does not mimic or replace FTF conversational behavior. Sellen (1995) conducted a study to examine the properties of conversation in different situations: face-to-face, with audio link only, and with three types of multiparty videoconferencing systems. Sellen examined the effects of videoconferencing (VDC) technology and pointed out that a conventional VDC consists of a single camera and monitor for each participant, which limits the visual cues available. Another important issue is that the principal of reciprocity does not always hold in VMC (i.e., "If I can see you, you can see me"). This becomes important when one participant believes that he/she is making eye contact, but the other participant does not perceive it as such because of the separation of camera and monitor. VMC also differs from FTF in the sharing of physical space, as participants cannot determine the physical distance between them during remote conversations and, therefore, do not share the same physical space. In addition, the speakers have no idea how the listeners perceive their voice.

In her experiment, Sellen found that VMC had no discernable effects on the number of turns compared to FTF communication. These results differed from previous studies, such as Cohen's (1982), that found longer and fewer turns in VMC. She attributed the results to the 705-msc audio transmission delay that Cohen introduced to simulate round-trip satellite conditions. However, Sellen's study also showed no significant difference in the distribution of turns, which showed that participants did not have any difficulty managing the conversational floor. A significant difference across conditions was found in the amount of simultaneous speech that occurred when speakers switched, supporting previous findings that showed overlapping speech occurred more in FTF communication than in VMC. In addition, Sellen found that in VMC participants were more likely to formally hand over the floor, a result she attributed to the participant's feeling disconnected from the situation and thinking that non-verbal cues would not be as effective as in FTF.

Computer-Mediated Communication (CMC)

Electronic, synchronous text-based communication, where individuals can communicate by typing messages to each other, has also been an important development in today's technology. The effects of this type of communication on information sharing has been researched in regards to the social impact and interpersonal perceptions of individuals, as well as the impact on the efficiency of cooperative tasks and conflictful tasks (Williams, 1977). The social context in electronic communication creates or leads to feelings of anonymity in participants, which in turn reduces their inhibitions when communicating. Studies, such as that of Straus (1996), have found that during group discussions with CMC all members participate more equally in discussions then in FTF discussions. However, some of these results could also be attributed to the system's hardware and software rather then to the social psychological process of the individuals, because as Straus points out, typing requires effort which may suppress communication from all the participants and thereby create a floor effect. It has also been found that compared to FTF communication, participants communicating through CMC take about twice as long to complete a task. In addition, participants sharing information through CMC tend to be less satisfied with the process than those communicating FTF Although, the levels of satisfaction do appear to be related to the type of task, for tasks that require little coordination, participants communicating through CMC tend to be more satisfied than those communicating FTF. However, social context cues seem to have little impact on the accuracy of the outcome of a cooperative task, even if the time to completion is higher than that of FTF participants.

Computer-Mediated Communication and Task Type

Straus and McGrath (1994) decided to perform a study to test the effectiveness of CMC for three types of tasks: generating ideas, solving problems with correct answers, and making decisions. They operated on a modification of McGrath's (1984) theoretical framework which suggests that that tasks can be classified into four categories: generate, choose, negotiate, and execute tasks. These categories are related to the task types they contain within a two dimensional space that has the attributes of a circumplex, with the horizontal dimension showing cognitive versus behavioral requirements, and the vertical dimensions the degree and form of interdependence among group members. He defined a three-level specification of interdependence: collaboration, coordination, and conflict resolution. During collaborative tasks, found at the top of the circumplex, each member can contribute ideas, but there is little need for coordination or consensus among members. Social context cues should have a relatively small impact on group performance for this type of task, reducing the impact of the communication medium. Next are coordination tasks, which include intellective and judgment tasks. These tasks involve solving problems that have correct answers, so group consensus is required at the conclusion of the task, and the communication medium should be of more importance for these types of tasks. Social context cues should be relatively unimportant here. Judgment tasks require coordination and timing among group members, and include the expression and perception of emotions. They are conflict resolution tasks and do not have a correct answer, so it requires the participants to reach a consensus of facts, values, beliefs, and attitudes. Studies show that the communication medium has much impact on conflict resolution tasks (Strauss & McGrath, 1994).

In their study, Strauss and McGrath (1994) tested an idea generation task, where participants had to generate ideas to improve the quality of a physical environment; an intellective task, where groups worked on a complex logic problem; and a judgment task, where groups had to determine disciplinary actions for a fictitious case. The dependent measure was task performance, which included overall task performance (quantity and quality), average quality (to control for speed), and productivity. They found that indeed

CMC is less productive then FTF communication, as participants in CMC completed less of a given task in a fixed time period. In addition, they found that CMC had a negative effect for tasks that require consensus on the solution, in particular if the process includes discussing values and beliefs. However, there was no significant difference between CMC groups and FTF communication groups for the idea generation task, even though FTF groups generated more ideas during the given period of time. For this task, groups for both conditions were equally satisfied. Also, there was no significant effect found for the overall effectiveness scores for the intellective task or cognitive-cooperative task. However, here, productivity was lower for CMC groups, and participants reported low levels of satisfaction. For the judgment task, CMC had the most pronounced negative impact on communication. CMC groups were much less productive, and reported a very low level of satisfaction with the communication medium. In general, although it has been proposed that CMC helps concentration and comprehension because it provides a written record of the discussion, CMC groups had less in-depth discussions because of time pressure and the physical demands of typing. In addition, CMC participants reported a lower level of comprehension during the discussion. Strauss and McGrath also found that CMC participants committed more errors in recording the groups' solution, probably because the participant chose to ignore the other participants' preferences.

In another study, in order to test the negative and positive aspects of CMC, Graetz, Boyle, Kimble, Thomson, & Garloch (1998) designed an experiment to test a group of participants performing an information-sharing task (with a correct answer) either through CMC, FTF, or telephone. They operated on the assumptions that text-based CMC may have several limitations. To begin with it tends to have relatively low bandwidth, which restricts the rate of communication. Also, since there is no verbal or visual communication, users tend to not provide feedback (or backchannels) to the message being received. Therefore, the user sending the message cannot assess the understanding, agreement or attention of the other user, which may cause the sender to send redundant messages. Also, unlike oral communication, CMC allows users to send or type information at the same time, which could lead to "attention blocking." This means that users do not attend to the messages they are receiving because they are focused on the message they are typing, which could lead to problems with the coordination and integration of information. These limitations can have a negative impact on users trying to perform a collaborative task because it may cause an elevation in cognitive workload and increase the likelihood of committing decision-making errors.

In addition, when participants collaborate through CMC in order to share information (e.g. brainstorm) and reach a solution to a new problem, a phenomenon known as the "common knowledge effect" occurs (Siegel, Dubrovsky, Kiesler, & McGuire, 1986). The participants tend to focus on information that all participants already know and unique information known to only one or a few participants is left out or just briefly discussed, which leads to inferior solutions to the problem. An explanation to this effect is that individual participants attach more importance to information known to all participants, and dismiss unique information as irrelevant. Also, participants may be reluctant to share unique information because of self-presentational concerns. However, some researchers have found no significant differences in the decision-making quality of CMC and FTF communication (Siegel, Dubrovsky, Kiesler, & McGuire, 1986).

On the other hand, text-based CMC may have some advantages over FTF communication. For example, text-based messages are usually composed and edited more carefully and received faster then spoken conversation, thus increasing the quantity and quality of information. Also, because messages can be entered simultaneously, cognitive interference (e.g. the generating counter arguments or participants' forgetting what they wanted to say while waiting for their turn to speak) can be reduced. Of course, CMC also reduces social anxiety due to a lower level of social presence, so individuals experience less apprehension when contributing their ideas. Numerous studies have shown that participants communicating through CMC tend to be more uninhibited and to use more emotionally charged language than during FTF encounters.

Graetz et al. (1998) hypothesized that the limitations imposed by the text-based CMC would have a negative impact on the processes necessary to solve the problem, because users would experience more cognitive or mental workload. They tested proposal ranking of final proposal (task) outcome, time to decision (15 minute limit), subjective mental workload (utilizing NASA Task Load Index), impressions of the participants within group, and recorded discussions where experimenters reviewed the discussions and evaluated them on certain criteria. The participants were to review three proposals in relation to the request for proposals (RFP) and to rank them in order of accuracy (which one met the most criteria from the RFP); a task that could only be achieved by the sharing of unique information.

Results showed that proposal ranking was significant between groups in FTF and CMC, as participants in CMC were less accurate in ranking the proposals correctly, with 81% of the total number of groups ranking them correctly. They also found that participants in CMC took significantly more time to reach a decision. For subjective mental workload, participants in CMC seemed to experience higher mental workload levels. As far as individual satisfaction with the group, participants communicating FTF reported higher levels of task motivation, however all the participants for all conditions reported that they agreed with the group's final decision. They also found that 92% of the groups across conditions evaluated the proposals in a rational and consistent manner, but groups in CMC had a harder time solving the task. The results supported their hypothesis that CMC has a negative impact on this type of information-sharing task.

Chapanis et. al (1972) compared the effects of typewriting (text-based CMC), handwriting, voice, and natural, unrestricted (FTF) communication, on cooperative problem-solving. They tested the effectiveness of the medium for the two tasks previously mentioned: the geographic orientation problem, and equipment assembly problem. Forty high school boys between the ages of 14 and 18 were used for the experiment, and they were told that accuracy of the solution was more important then the time required to reach it. The groups of two were divided into a seeker (the participant who was to solve the problem) and a source (the participant who had pertinent information and had to help solve the problem). It was the seeker's responsibility to decide when the problem was solved. The participants communicating through CMC were divided into inexperienced typists and experienced typists. Chapanis and colleagues tested the participants for the time they took to reach the solution. They also recorded 15 behaviors to understand the activities undertaken by the participants communicating through the different mediums. The behaviors were: time spent sending only, sending pause, receiving only, searching only, handling parts, making notes, waiting, other, sending and searching, sending and handling, sending and making notes, receiving and handling, receiving and making notes, and searching and making notes.

The results showed that participants using CMC took longer to solve the problem than participants using other modes. In addition, inexperienced typists took almost one-and-a-half times as long to solve the problems than did subjects communicating FTF. Average times to solution were as follows: 29.0 minutes for FTF, 33.0 for voice, 53.3 for handwriting, 66.2 for typewriting (experienced), and 69.0 for typewriting (inexperience) mode. They also found that the time spent in "all sending" in the typewriting mode was more then twice that of the FTF mode. The same was true for "all sending," except for the experienced typists. However, the proportion of time spent "all sending" was almost constant across all communication modes, the more deviant being that for the inexperienced typists. One of the key finding in the study was that participants in the FTF mode did not use non-verbal communication very much, which is why the time spent "all receiving" and "all sending" were almost equal for this mode. On the other hand, in the typewriting mode, a participant could do other things while the next massage was being typed remotely, so the "all receiving" and "all sending" categories were disproportional to each other.

The two problems were statistically significant in several categories. For "sending and searching," "all receiving," "receiving and searching," "searching only," and "searching and making notes," more time was spent during the solution for the geographic orientation problem then during the equipment assembly task. Of course, the geographic orientation task is more of a search problem, and the equipment assembly problem is a construction task and searching was reduced for the FTF mode, because the source could visually tell if the seeker was assembling correctly. Also, subjects did more "waiting" in the equipment assembly problem. For the CMC mode, experienced source typists spent the greatest amount of time of all modes waiting, because typing and sending instructions took less time then executing them, so they waited while the seeker tried to assemble the parts.

In the linguistic evaluation of the communication modes, Chapanis et al. (1977) found that spoken words are not directly comparable to written or typewritten words. For example, typed words or messages had a tendency to run together, especially for inexperienced typists, such as "goaheaddoyouknowhowto put this together." Also, during oral communication there are variations in pronunciation, as in "I'm" or "you," which were pronounced "Ahm" or 'yuh." On the other hand, in typewriting mode participants used abbreviations, such as Dr., +, and %, that cannot be accounted for in oral mode. However, the experimenters chose seven dependent variables: messages (began when a subject began to talk, write or type, and ended when control was relinquished to the other participant), interruptions, sentences, words, characters, communication rates (words communicated per minute), pauses (indicated by commas or dots in the typing mode). They found that the mean number of messages, number of sentences, and number of words communicated per minute in the FTF mode were 6 to 19 times the corresponding values in the writing and typing modes. In other words, the FTF mode is extremely verbose, even though it is very fast. It took participants in FTF mode about one-half the time to solve the problem then in the typewriting and writing modes. Also, participants FTF talked at a rate of 183 words per minute, but typed about 18 words per minute in the typing mode.

Gender Differences in Communication

It is the general consensus that women and men communicate differently and have different abilities in conventional or FTF communication. Much research has been conducted in the area of gender interaction, but the results appear to conflict in several areas, such as number and length of turns in mixed-gender and same gender interaction, as well as the number and influence of interruptions. In a well know study conducted by Edelsky (1981) the difference in communication between genders was examined in relation to "floor" type, where the floor is "the acknowledged what's-going-on within a psychological time/space" (Edelsky, 1981). The floors were divided into two types: collaborative floors and singly developed floors. The latter was highly task-oriented and characterized by monologues, single party control and hierarchical interaction, where participants spoke one at a time. Collaborative floors were described as more informal and cooperative, where participants talked with each other, produced massages with similar meaning and tried to develop an idea. She found that in singly developed floors participants took longer, but fewer turns regardless of gender. However, women took more turns (participated more) in collaborative floors, and men took longer turns (but not more of them) in singly developed floors. She concluded that when the participants were "on the same wavelength" the females could take more of an anonymous role and participate more fully in the conversation. Therefore, males and females seemed to interact as equals in collaborative floors, while females would feel more intimidated in a singly developed role and give in to societal norms by letting the men speak more.

James & Drakich (1993) conducted an extensive review of the literature dealing with gender differences in amount of talk, and while most of their review dealt with mixed-sex interactions, some same-sex interaction results were cited. They found that the large majority of the research conducted between 1951 and 1991 indicated that overall men talk more than women, with the measures being total number of words, total seconds spent talking, number of turns taken and average length of turns. In studies dealing with mixed-gender interaction, twenty-four of fifty-six studies have found men to talk more then women, ten found males only talk more in certain situations, sixteen found no difference, and only 2 found females talk more. Of seventeen studies dealing with same-gender interaction, thirteen found no gender difference and three found females talk more then males.

However, these differences also differed in relation to types of interaction. The review further divided interaction into three types: formal task oriented, non-task oriented, and informal task oriented (which lie in the middle of the other two types). Of interest in this paper are the results for formal tasks, where a dyad or a group had to solve a problem and produce a single, correct answer. Results for mixed-gender interaction for formal tasks showed that men talk more then women overall (thirteen out of twenty-four studies), and five studies found no difference between genders. The authors explain these results through Status Characteristic Theory, which states, "individuals who have high status with regard to some status characteristic (gender, race, organizational rank) will be viewed both by themselves and by others as more intellectually competent, and will therefore perform better" (James & Drakich, 1992). In addition, studies by Bilous and Krauss (1988) and Mulac (1989) comparing same-gender and mixed-gender interaction for a formal task found that women talked more during same-gender interaction then during mixed-gender interaction. Also, Yamada, Tjosvold, and Draguns (1983) and

Lockheed (1976) found no significant difference between females and males in same-gender interaction, yet males contributed more in mixed-gender interactions.

It seems that women are more reliant on non-verbal communication then men are, and can send messages more clearly if they can use non-verbal cues (Dennis, Kinney & Hung, 1999). In addition, women appear to focus more on the social aspects of communication, whereas as men tend to be more task-oriented. In other words, women communicate in a manner that attempts to facilitate comfortable relationships and intimacy by expressing agreement and acknowledging the speaker's message through verbal and non-verbal cues. Men, on the other hand, do not attempt to make the other person comfortable by facilitating conversation, instead, they try to express dominance (Tannen, 1990). Denis and colleagues (1999) performed a study to assess the impact of media richness (FTF communication is the richest) and task equivocacy or vagueness on gender. They hypothesized that women would be more affected by the lack of non-verbal cues associated with text-based CMC, especially for less equivocal tasks (or problem-solving tasks with a finite answer). They found that indeed all-female dyads took significantly longer to arrive at a decision in CMC for all tasks as compared to mixed gender dyads and all-male dyads. However, all three gender-mix conditions took a significantly longer time to complete the less equivocal task in CMC than in FTF communication. Although, the type of task did not make a significant difference for all-male and mixed gender dyads, all-female dyads took five times longer to perform the equivocal task in CMC. For the less equivocal task, there was no-significant difference between all the gender-mixed dyads. In summary, Denis et al.'s (1999) hypothesis was supported for decision time, but not for task type.

Although there seems to be communication differences in CMC as well as in FTF communication between males and females, most of the differences appear when social interaction and independent ideas are necessary. For example, Herring (1993) found that gender inequalities are not removed in CMC when both men and women are involved using asynchronous communication (an electronic message board). Women tended to be more personal in their messages, while men were more informative, and men dominated the conversation and took longer and more turns then women. In addition, female ideas and opinions were acknowledged less often then male opinions.

In another study pertaining to synchronous CMC communication between gender, Savicki, Kelley & Oesterreich (1998) found that mixed gender teams took more time to arrive at a consensus in CMC then did single gender teams, pressumably because the teams had to figure out which language norms to use (female or male). They also suggested that text-based CMC may not constrain or eliminate differences in gender communication, and in fact, males and females may make an effort to emotionally assess themselves through the written word.

Savicki, Kelley & Lingenfelter (1996) conducted a study that isolated specific tasks to determine their effect on asynchronous CMC between female only (FO), male only (MO), and mixed (MIX) groups. Their hypothesis were based on previous research that stated males had a higher preference for science oriented tasks and outdoor activities than women, and used McGrath's (1984) circumplex model to divide tasks into an intellective or problem solving task and a decision-making task requiring agreement to a problem with no correct answer. Therefore, the tasks were divided into a feminine-content, decision making task (with no correct verifiable answer) and a masculinecontent, intellective task. They found no significant difference for the number of messages sent due to group composition or task type. However, they did find that FO groups sent a significantly higher number of words during both tasks than MO and MIX groups. They also found that regardless of task type, FO groups were more satisfied with the whole process. However, Savicki, Kelley & Lingenfelter (1996) conducted a similar experiment using only a task that had no correct verifiable answer, where the participants had to solve a moral dilemma and obtained different results. In this study, they did find a significant difference between groups in the total number of messages sent, but no difference in the length of the messages. Mixed groups sent significantly more messages then both FO and MO groups, and again FO groups were the most satisfied with the process.

THE PRESENT STUDY

The present study revisits Chapanis' communication experiments with advances in technology. Since the experiments were conducted in the 1970's there has been much progress in the area of computer technology. As seen in the review of the literature, current research has shown the impact of evolving technology on the way people communicate, as the use of computers is now a part of many individuals everyday life. People have adapted to the use of personal computers as principal communication tools, and so expectations of technology have changed. We now have access to high-quality teleconferencing systems that offer the simultaneous use of real time video/audio, whiteboards, overhead projectors, etc.

When Oshman & Chapanis (1974) conducted their communication modes experiments, the available technology was limited in quality. For example, the participants communicating through typewriting mode had to actively push buttons to enable the system to send a message or to receive a message, therefore, messages from the two different participants could not be sent or received simultaneously from one station to another. Consequently, a participant could only be in either receiving mode or in sending mode at any given time. In addition, the video system consisted of a television monitor, with a camera placed on top, and the voice system required headsets that were connected to a switching relay that was wired into a control box network. The participants could control their voice transmission, however, when a participant was sending a message the other one simultaneously lost the capacity to send a message. With today's technology and the availability of full duplex audio channels, instantaneous electronic message systems, high-quality full motion video, and moveable desktop cameras, the technical quality of the communication process has improved.

In this experiment, the effects of commercially available video-mediated communication, text-based computer-mediated communication, and face-to-face communication will be tested on two different problem-solving tasks that have a finite solution. The effectiveness of the communication mode will be based on the time required to solve the problem. In addition, the communication process will be evaluated on the number and length of turns that were necessary to solve the problem. Although some studies have found that there is no significant difference in solution time when using high-quality video/audio system, it is expected that in this study a significant difference will occur because of user expectation of current available technology and because of present video/audio delay. While an attempt was made to create a high-quality video/audio communication system, the equipment that will be used in this experiment does have significant audio/video delay (greater than 500 msec.), which has been shown to decrease performance by 40%, and a few, but disruptive audio lapses. In addition, following each experimental session a questionnaire will be administered to each participant to assess the subjective impact of the medium. The questionnaire will collect information on the participant's perspective on task difficulty in relation to medium, as well as the perceived impact of non-verbal communication, and perceived participant availability. Demographical communication will also be collected, to provide additional insight into the participants' experience with current computer communication media.[1]

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[1] Regrettably, due to circumstances outside the experimenter's control this data was lost and was unable to be reported

Hypothesis 1. Participants will take longer to solve the problem when communicating through the text-based computer-mediated mode than in the video-mediated mode, and the least amount of time in the FTF mode.

Hypothesis 2: Fewer but longer turns will be taken by the CMC team, followed by the VMC team, and then the FTF team.

Hypothesis 3: Due to the nature of the task, the assembly task will take longer then the geographic orientation task.

METHOD

Participants

A power analysis was conducted prior to the collection of data to assess the number of participants necessary for the experiment (see Appendix A). The computations revealed a need for a total of 42 participants (seven groups of two in each condition). All the participants were male due to the interaction effects of gender. By factoring out gender as a variable, a more homogeneous population could be created and error due to subject variability would be minimized. The participants consisted of undergraduate and graduate students pursuing a degree at Embry-Riddle Aeronautical University. Participation was voluntary and the students were not monetarily compensated, but some did obtain class credit at the instructor's discretion. The participants were randomly divided into male-only groups of two, and each group was exposed to one communication mode and to both tasks.

Tasks

The tasks used in the current study were similar to the problem solving tasks in Chapanis and colleagues' experiment: the geographic orientation task and the assembly task. Both represented real world problems and had to meet certain criteria (1) they sampled different psychological functions, (2) they were representative of tasks for which these modes of communication are used, (3) they had recognizable and practical importance in everyday life (4) they had solutions that could be reached within a practical amount of time, (5) they required no special skill or knowledge from the participants, and (6) they required two participants to work together as a team.

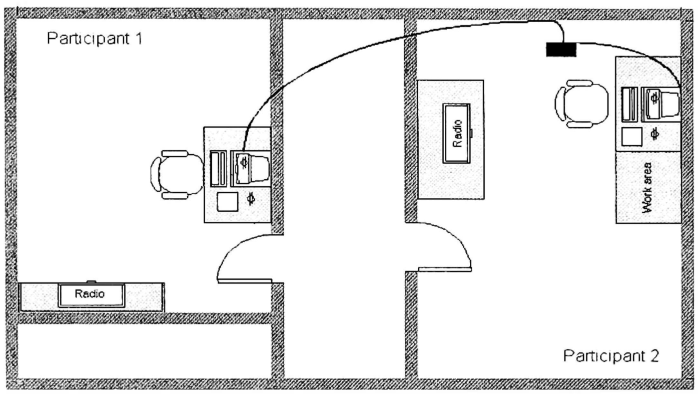
In the geographical orientation problem, two participants had enough information to solve a problem together, but not alone. This task was more logical and verbally oriented and required a visual search. One participant (participant 1) was given one page from a telephone directory with physicians' listings, where the names of the physicians appeared alphabetically. The other participant (participant 2) was given an index of streets, a gridded street map, and a piece of paper with a home address. The participants' job was to find the office of the physician closest to the home address. The time required to solve this task in the FTF mode was estimated to be about 15 minutes.

The equipment assembly or building task was a spatial task and required participant 2 to assemble an item (a swing set), while the other participant, who was given a picture of the finished item, helped him assemble it. For this problem a classic rod and connector toy was used.

Apparatus

The study was conducted in the Embry-Riddle Aeronautical University (ERAU) Human Factors department. The two participants of the group worked at two different workstations in adjoining rooms (see Figure 1). The workstations were connected through an Ethernet Local Area Network (LAN). It used CAT 5 cable connecting through a six-port hub into two 100Mbps Ethernet cards. The workstations were 850 MHz Dell Pentium III PCs, with standard QWERTY keyboards and 17-inch color monitors. The participants used NetMeeting video chat software. The software included document sharing and text-based chat windows, audio, video, and motion JPEG video code for high quality video over LANs. The hardware also include an Intel Deluxe PC Camera with a live video capture of up to 30 frames per sec at 352x288 resolution and up to 15 frames per sec at 640x480 resolution, and a focusable lens of 75 mm to infinity. To receive audio, the participants had speakers, and a noise-canceling microphone. There was a minimal video/adio delay due to the availability of the existing technology. In addition, a radio playing 100% white noise was placed in each room to minimize the chance of the participants hearing each other through the door.

Figure 1. Layout of research area



Experimental Design

The experiment was a completely randomized, mixed 3x2 factorial design. The participants were randomly divided into groups of two. The groups consisted of male-only (MO) dyads. No female-only or mixed-gender dyads were studied due to time constraints and to a limited availability of participants. Groups were randomly assigned to each communication mode, so each group was exposed to one communication mode and to both tasks. The tasks were countered-balanced across groups to account for learning effects and familiarization with the mode. Participants in the computer-mediated mode were not required to have formalized typing training, but were asked to estimate their typing speed. The independent variables were (1) communication mode and (2) task type. The dependent variables were (1) time to solution in minutes (2) number of turns (or messages) (3) length of turns (or messages).

A turn was defined as an attempt by a participant to gain the conversational floor, and began when a subject started to talk or to type, and ended when control was relinquished to the partner, or when the speaker was interrupted. The length of the turns was difficult to score, because a spoken word is not directly comparable to a typewritten word (e.g., abbreviations, symbols). Therefore, as in Chapanis et al. (1972) there was a set of rules to define how words would be scored:

1.) Mispronounced words in oral mode and misspelled typewritten words are counted as words.

2.) Partial and incomplete words are counted as words.

3.) Slang words, such as "yup" and "nope" are counted as words.

4.) Contractions are counted as one word.

5.) In typing mode combined numerals are counted as one word, and in oral mode the same number is counted in words. For example, "405" in text mode would count as one word, but as three in oral mode, "four-ooh-five."

6.) Interjections are counted as words

7.) Hyphenated words in text mode are counted as single words.

8.) Special symbols, such as "%" are counted as an individual word.

Procedure

After the participants were randomly assigned into groups of two, they were randomly assigned to a communication mode. Then, again, when the group arrived at the lab, the participants were introduced, and randomly assigned to be either participant 1 or participant 2. The experimenter provided them with written instructions. They were also assured confidentiality of the results, and asked to sign a consent form. Since each group was to perform both tasks, after the first one had been completed, both participants were again given the opportunity to read through the set of instructions. The participants had to be told that the tasks had a discernable solution, and that the time taken to arrive at the solution did not matter as much as the quality of the solution. In addition, the participants were told that it was the responsibility of both to decide when the task was complete and to notify the experimenter when they decided they were finished. The instructions also include an explanation of the hardware and software, and the participants were given a chance to play around and become comfortable with the equipment before they began the experiment. Participants in the CMC and VMC modes were in their prospective workstations in different rooms, where a video tape recorder recorded spoken messages throughout the VMC and FTF modes. When the participants had finished the first task, they were given instructions on the second task and then returned to find a solution to the given problem. At the conclusion of both tasks, the participants were asked to complete a questionnaire and were told that final results of the experiment could be sent to them at the conclusion of the study, and then they were thanked for their participation.

RESULTS

Six Univariate ANOVAs were performed in order to assess the relationship between the time it took to complete each task, as well as the number of words and turns that were associated with the completion of the task. Originally, it was intended that a Mixed ANOVA would be performed, where the tasks would be set up as within subject variables within each medium (the between subject variables). However, after studying the data, it was concluded that the two tasks were not equally related and could, therefore, not be compared against one another. In other words, there were no theoretical or practical bases that showed these tasks to be equal in difficulty and, consequently, a comparison of the two would not have been appropriate. The options were to either form a composite score of the two tasks for the dependent variables or to separate the two tasks and analyze them independently; the latter option was chosen.

In addition, one of the objectives of this study was to compare the number of words per turn taken by each participant during each task-to-task performance, however, an inferential analysis of this data was not practical, as certain assumptions were not met. An ANOVA assumes normality of the data, as well as homogeneity of variance within each group and the data for the number of turns met none of these assumptions. In addition, the words per turn were so largely distributed that comparing the mean for each group would not have shown a fair assessment of the actual results. The data for this variable is summarized in Appendix B. It was decided, instead, to analyze the difference in the total number of words per group.

While exploring the data, correlation coefficients were computed to study the relationships amongst the variables in order to better assess the meaning of the total data. Table 1 shows the correlations amongst the dependent variables for both tasks.

Table 1.

Correlations between dependent variables including both tasks

	1	2	3	4	5	6
1. T1Time	--					
2. T2Time	.602*	--				
3. T1Words	.162	-.642*	--			
4. T2Words	.197	.117	.153	--		
5. T1Turns	.241	.578*	.933*	.142	--	
6. T2Turns	.217	.286	.056	.846*	-.060	--

* Correlation is significant at the 0.01 level

The correlation table shows a clear relationship between Task 1 Turns and Task 1 Words and Task 2 Words and Task 2 Turns, making the dependent variables not independent of each other as is necessary for an ANOVA. The implication of this is that the variances of the two dependent variables will overlap and, therefore, a proportion of the variance (SSs) will be counted more than once (in the ANOVA table is shown by η^2, which gives an index of how much variance is accounted for by each variable). In other words, in the analysis of variance for each of those variables, the amount of variance explained by the variable taken into consideration may be reported as greater than it actually is.

The analysis of variance for task 1 showed a main effect for the variable time to completion of the task, $F(2, 18) = 7.742$, $p = .004$. However, the assumption of homogeneity of variance was not met, as SPSS Levene's Test of Equality of Variance, which tests the null hypothesis that the error variance of the dependent variable is equal across groups, was significant. This signifies a probable increase in Type I error, which means that differences may have been found were there were indeed none. However, since the significance level was $p = .004$, it is still likely that a significant difference between the groups does exist. It is important to note that time can be considered a logarithmic variable, meaning that the difference between 10 minutes and 12 minutes is not the same as the difference between 15 minutes and 17 minutes. As such, an attempt was made to normalize the data by taking the natural log and the $\log_{10}$ of the time variables for both tasks, however, no significant change occurred. In either case, ANOVA tends to be fairly robust to violations of the normality assumption. Table 2 shows a summary of the three ANOVAs for task 1.

Table 2.

Analysis of Variance for Task 1 Time, Words and Turns

Source	df	F	η^2	p
Medium (time)	2	7.742**	.462	.004
Error	18	(258856.095)		
Total	21			
Medium (words)	2	7.804**	.462	.004
Error	18	(140529.397)		

Total	21			
Medium (turns)	2	6.301**	412	.008
Error	18	(56577.429)		
Total	21			

Note. Values enclosed in parentheses represent mean square errors.
** $p < .01$

The analysis of variance also showed a main effect for number of words $F(2, 18) = 7.804$, $p = .004$, and for turns, $F(2, 18) = 6.301$, $p = .008$. However, the assumption for homogeneity of variance across groups was also violated for both cases.

A series of Post hoc pair wise comparisons were performed to identify where the significant differences occurred. The Bonferroni approach was chosen in this case because it is more conservative, meaning it has a smaller chance of rejecting the null hypothesis, correctly or incorrectly. This decision was made based on the previous observation of the data, which showed that not all the dependent variables were independently distributed (e.g. non-orthogonal), thereby violating another assumption of an analysis of variance. For the dependent variable time in task 1, a significant difference was found between FTF (M = 941.86, SD = 305.89) communication and CMC (M = 2012.0, SD = 571.17), no other differences were found among the other mediums. Figure 2 shows the differences amongst means for task 1 time in seconds.

For the dependent variable words in task 1, a significant difference was found between FTF (M = 1058.43, SD = 383.24) communication and CMC (M = 400.43, SD = 161.87), and between VMC (M = 1110.57, SD = 498.5141) and CMC, but not between FTF and VMC. Figure 3 shows the differences amongst means for task 1 words.

Figure 2. Task 1 Time

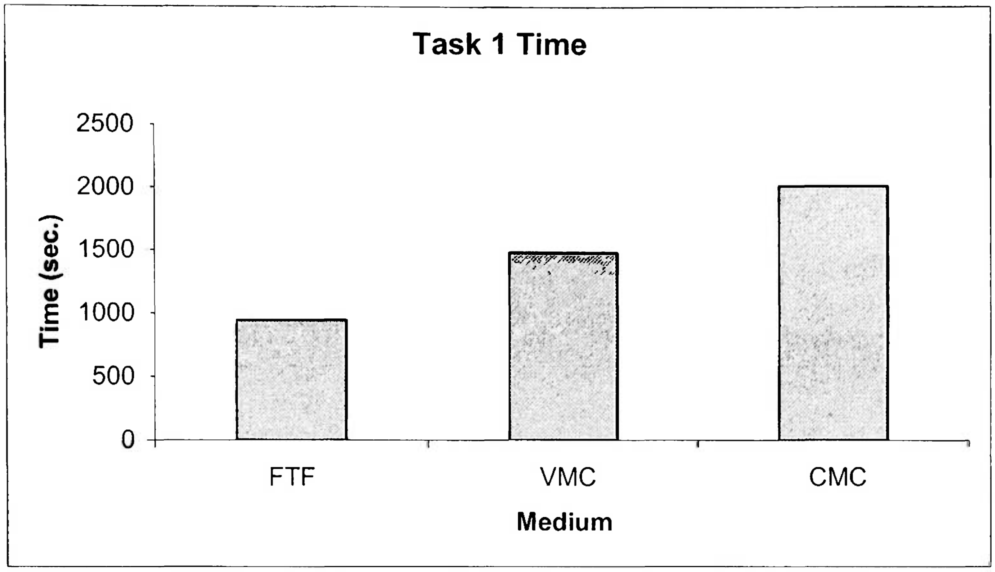
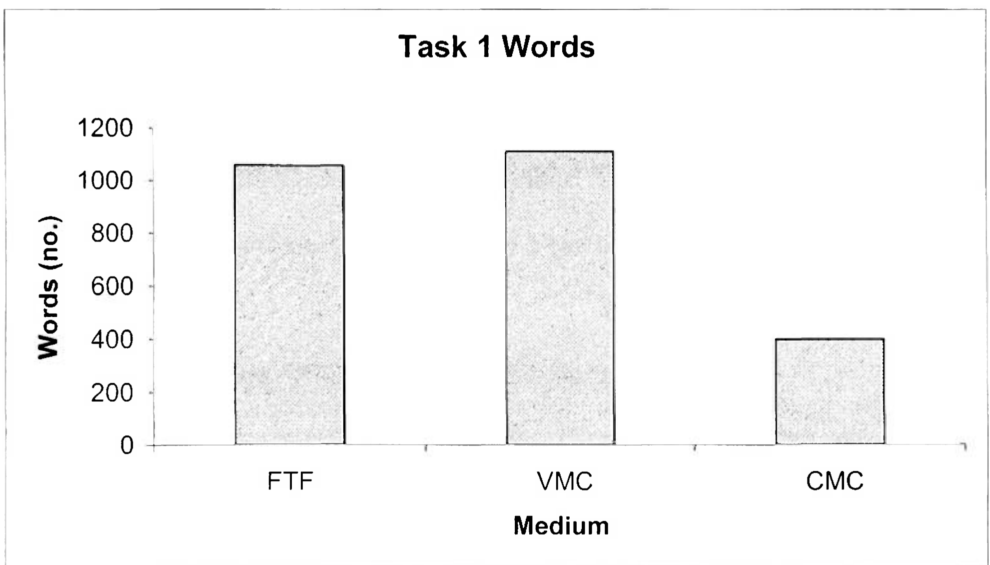
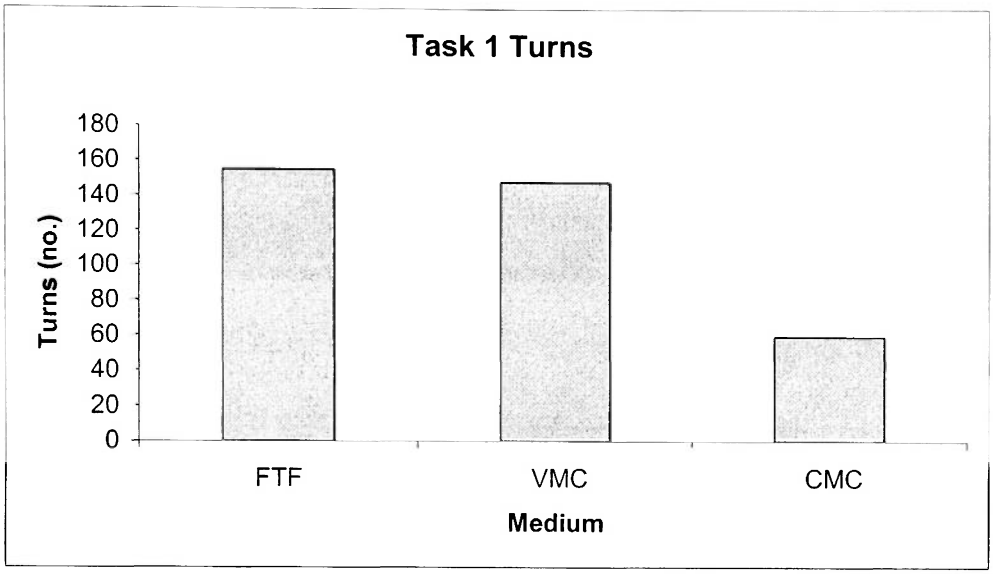


Figure 3. Task 1 Words



For the dependent variable turns in task 1, again, a significant difference was found between FTF (M = 154.86, SD = 68.28) communication and CMC (M = 59.43, SD = 18.30), and between VMC (M = 147.86, SD = 66.57) and CMC, but not between FTF and VMC. Figure 4 shows the differences amongst means for task 1 turns.

Figure 4. Task 1 Turns



The analysis of variance for task 2 time showed a main effect for the variable time to completion of the task, F (2, 18) = 36.418, p = .000. However, here again, the assumption of homogeneity of variance was not met, yet the p value was so low and R squared so large that even though the Type 1 error is increased, it is likely that the there is a significant main effect. Table 4 shows a summary of the three ANOVAs for task 2.

Table 3.

Analysis of Variance for Task 2 Time, Words and Turns

Source	df	F	η^2	p
Medium (time)	2	36.418**	.802	.000
Error	18	(96070.175)		
Total	21			
Medium (words)	2	14.676**	.620	.000
Error	18	(41872.381)		
Total	21			

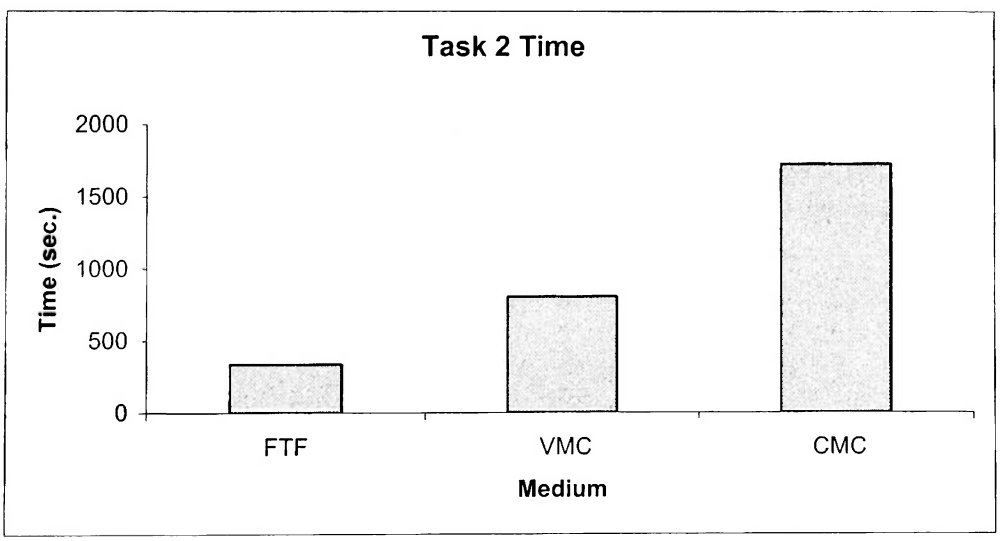
Medium (turns)	2	7.665**	.460	.004
Error	18	(1069.111)		
Total	21			

Note. Values enclosed in parentheses represent mean square errors.
** p < .01

There was also a significant main effect for Task 2 words, F (2, 18) = 14.676, p = .000 and for task 2 turns F (2, 18) = 7.665, p = .004. Here, again, the homogeneity of variance assumption was violated for words, but not for turns.

Post hoc pairwise comparisons were performed to identify where significant differences occurred. The Bonferroni approach was again used for task 2. For the dependent variable time in task 2, a significant difference was found between FTF (M = 337.15, SD = 139.71) communication and VMC (M = 806.29, SD = 221.49), between FTF and CMC (M = 1726.76, SD = 468.65), and between VMC and CMC (see Figure 5).

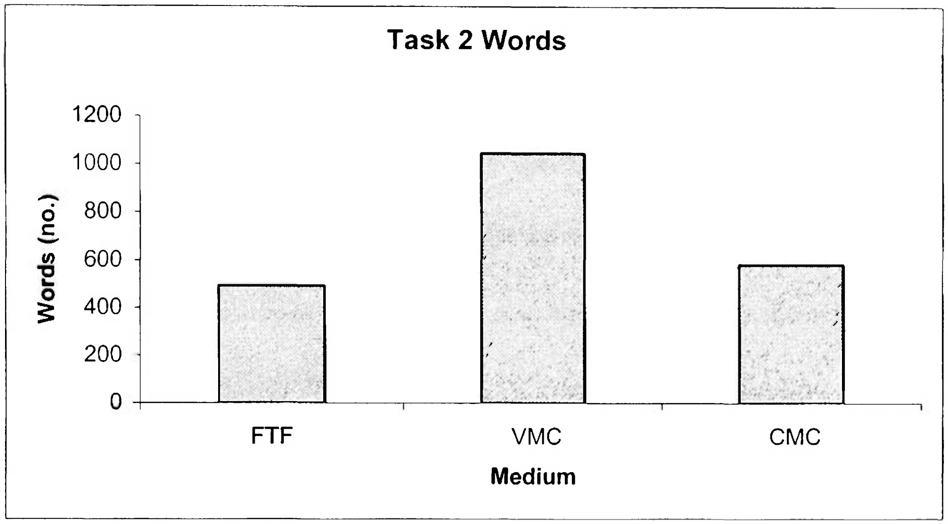
Figure 5. Task 2 Time



For the dependent variable words in task 2, a significant difference was found between FTF (M = 492.57, SD = 149.56) communication and VMC (M = 1045.43, SD =

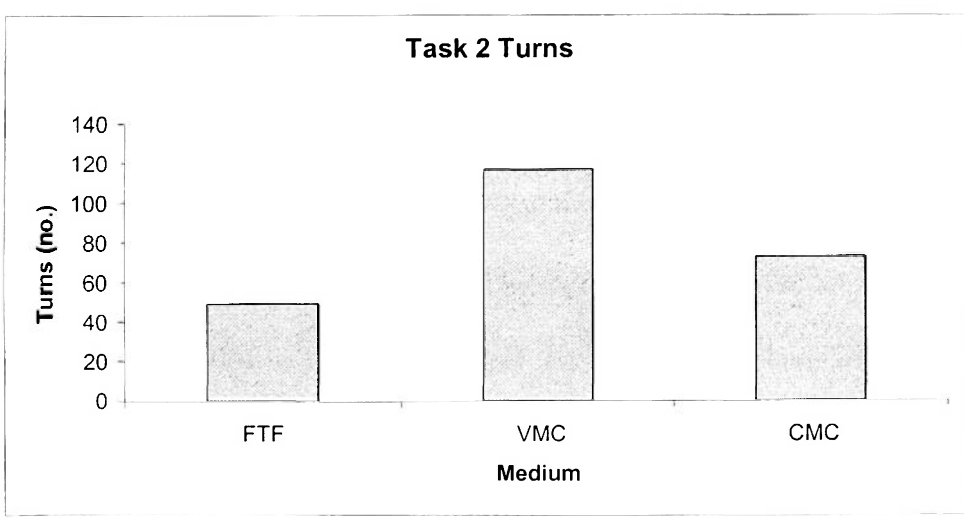
295.27), and between VMC (M = 1045.43, SD = 295.27) and CMC (M = 707.4286, SD = 126.75), but not between FTF and CMC. Figure 6 shows the differences amongst means for task 2 turns.

Figure 6. Task 2 Words



Post hoc analysis for number of turns showed a significant difference between FTF (M = 49.29, SD = 25.42) and VMC (M = 116.57, SD = 46.88), and no other significant differences amongst the other independent variables. Figure 7 shows the differences amongst means for task 2 words.

Figure 7. Task 2 Turns



DISCUSSION

The statistical analyses showed that there was a significant difference in the amount of time taken to complete the task between FTF dyads and CMC dyads for the geographic task, but no significant difference between FTF and VMC dyads, thereby not supporting Hypothesis 1, which stated that participants would take longer to solve the problem when communicating through the text-based computer-mediated mode than in the video-mediated mode, and the least amount of time in the FTF mode. However, for the building task a significant difference was found amongst all three mediums. This could imply that depending on the type of task the quality of the VMC can have a larger impact on the process of the interaction. However, because of the heterogeneity of variance within groups for both tasks, the differences could have also been attributed to the range of abilities, motivations and personalities of the participants.

The analysis of variance also showed that for the geographic task there was a significant difference in the number of turns taken to complete the task between FTF and CMC dyads, and between VMC and CMC dyads. Here again Hypothesis 2, which stated that fewer (but longer turns) would be taken by the CMC team, followed by the VMC team, and then the FTF team, was not completely supported, however, the CMC dyads did take the least amount of turns to complete the task, most likely due to the time it takes to type in the instructions, and to the fact that participants did not provide as much feedback to the other person while a task was being performed. During FTF and VMC most participants continuously verbally reinforced the other person as they were completing the task and perhaps made jokes or comments about what was taking place. The number of words taken to complete the task supports this interpretation, as there was a significant difference between FTF and CMC modes, and between VMC and FTF modes, but not between FTF and VMC modes.

The length of the turns, which is characterized by the number of words in each turn, is summarized in Appendix B. Examining the data, it seems that for the geographic task, FTF dyads experienced turns of 1 to 5 words 57.8% of the time, turns of 6 to 10 words 22.9% of the time, turns of 11 to 15 words 9.4% of the time, turns of 16 to 20 words 5% of the time, and turns of grater length only took place 4.9% of the time, with the longest turn consisting of 90 words (.001%), and the shortest turn consisting of 1 word (18%). The VMC dyads took turns of 1 to 5 words 48.9 % of the time, turns of 6 to 10 words 27.4% of the time, turns of 11 to 15 words turns 12% of the time, 16 to 20 words 5.7 % of the time, and turns of grater length only took place 6% of the time, with the longest turn consisting of 58 words (.001%), and the shortest turn consisting of 1 word (22.8%). In addition, although CMC dyads took the least amount of words to complete the task, the spread of the length of the turns does not appear to be much different. The dyads took turns of 1 to 5 words 61.2 % of the time, turns of 6 to 10 words 21.4% of the time, turns of 11 to 15 words 7.7% of the time, turns of 16 to 20 words 4.8% of the time, and turns of grater length only took place 4.9% of the time, with the longest turn consisting of 52 words (.001%), and the shortest turn consisting of 1 word (18.8%). While grouping the data in this manner loses much interpretation, it appears that for the three conditions turns consisting of one or two words comprised the largest percentage of the total number of turns. This is surprising considering that most research has shown that, as a whole, in CMC, dyads tended to use much longer turns because they were typing. However, due to the nature of the task, which consisted of one participant visually searching for a place on a map while the other provided directions, it makes sense that the participant doing the searching used less words and provided short turns consisting of reassuring feedback. Perhaps, if the data were to be studied in relation to the role of the participants in each dyad the results would differ. On the other hand, the percentage of longer turns for the CMC group was not greater than for the VMC or FTF groups. Nevertheless, no concrete assessment can be made about the difference in length of turns between mediums without further statistical analysis.

Conversely, for the building task, FTF and VMC groups significantly differed in the number of turns that were taken during the participant interaction, but the CMC group did not significantly differ from the other mediums. In fact, the mean amount of turns for CMC was 72.14 (SD = 19.06) and for FTF it was 49.28 (SD = 25.42). Now, the spread was also fairly large for each group, however, the VMC dyads had a mean number of turns of 116.57 (SD = 46.89). The results of this analysis do not support the hypothesis stating that participants would use less turns to solve the problem when communicating through the text-based computer-mediated mode than in the video-mediated mode, and the least amount of time in the FTF mode, and perhaps has implications as to the impact of the audio/video for such a task. Perhaps, because objects (the toy parts) did have to be moved around by the participants in a table adjacent to the location of the camera, the interaction between the participants became awkward, as they might have felt obligated to remain in view of the camera while at the same time putting the object together. This may have caused the participants to verbally communicate more often with each other to reinforce that they were in fact still present and conducting the task. This is supported by the results of the amount of words taken to complete the building task, as VMC significantly differed from both the FTF and CMC conditions. Again, it took a greater number of words to complete the tasks through the VMC condition then it did through the other two conditions.

The spread of the length of the turns for the building is also reported in Appendix B. The data showed that for the FTF group 51% of the total turns contained 1 to 5 words, 23.4% contained 6 to 10 words, 9.5% contained 11 to 15 words, and 6.4% contained 16 to 20 words, with the highest number of words for one turn being 83 (.003%), and the least number of words being 1 (19.8%). For the VMC group 46.5% of the total turns contained 1 to 5 words, 22.5% contained 6 to 10 words, 14.4% contained 11 to 15 words, and 7.8% contained 16 to 20 words, with the highest number of words for one turn being 79 (.003%), and the least number of words being 1 (24.1%). Once again, for the building task, although the CMC group did not differ from the other two groups in the number of turns, the spread of the number of words per turn seem fairly similar to that of the other groups, as 51.9% of the total turns contained 1 to 5 words, 21.1% contained 6 to 10 words, 12.5% contained 11 to 15 words, and 6.6% contained 16 to 20 words, with the highest number of words for one turn being 71 (.002%), and the least number of words being one (27.1%). In the case of this task also, it does not seem that the CMC dyads used much longer turns then the other two groups.

The heterogeneity of variance in this study can very likely be attributed to sampling error. It appears that the differences in performance on the tasks were due more to individual differences and factors amongst the participants than to the impact of the medium. For example, it seemed that those with higher ability or training in spatial tasks (perhaps those with engineering aptitude) performed faster in the building task then those who were not as highly skilled in these types of tasks, regardless of the medium. In addition, the motivation of the participant to perform the task in an optimal manner may have affected how much attention was given to the task at hand. Those who did not give the task much importance may have taken longer to perform the task because they were not as concerned with what strategies could be used to more effectively complete the task correctly. Although the effectiveness of the medium was not measured in this case, it seems it would be of interest not only to look at the process, but also at the outcome and effectiveness of the task in relation to the medium. For example, the effectiveness of the medium could be measured by taking into account, not only how much time it took to perform the task, but also whether the task was performed correctly or incorrectly.

Unfortunately, the data obtained from this study could not be used to measure the effectiveness of the tasks in the different mediums, because the participants were not asked to continue the experiment until the task was performed correctly, they were only asked to continue the experiment until they agreed the task was complete. Therefore, no connection could be made between the time it took to complete the task and the correctness or quality of the task. In fact, of the seven dyads in the FTF condition, six completed the map task correctly and one completed it incorrectly as occurred with the building task; of the seven dyads in the VMC condition five completed the map task correctly and six completed the building task correctly; and in the CMC condition, four dyads completed the map task correctly and five completed the building task correctly. The number of steps taken to complete the building task were also documented, however, the data could not be analyzed because only the data from those dyads that performed the task correctly would be applicable. On the other hand, if the participants had been asked to continue to build the task until it was correct, the steps taken to build the object could have been compared. For informational purposes only, the mean number of steps taken to complete the building task in FTF mode was 32.71 (SD = 6.16), in VMC the mean was 43.427 (SD = 6.11), and in CMC the mean was 37.00 (SD = 4.69). Examining this data, it seems that the number of steps taken to complete the task for each medium were not drastically different from each other, and it is also interesting to note that, overall, it took the CMC dyads less steps to complete the task then the VMC dyads (the spread of the scores was also relatively normal). This could mean that by chance the participants in the CMC mode were more motivated to complete the task or were just generally better at spatial tasks or perhaps for such a task it is just as easy to read the instructions from the screen as it is to hear it in person. It was noted, while looking at the videotape recordings, that participants (the ones assembling the object) communicating through VMC for the building task kept moving the camera around trying to figure out what the best way to position the camera was and before they found what worked best for them they had already taken a number of steps in an attempt to put the figure together. The positioning of the camera was not restricted to one view, and participants were free to move it at will. This may have caused some confusion on behalf of the participants that could have been minimized by restricting the movement of the camera to a certain position. In any case, no concrete conclusions can be made about the impact of the CMC condition on this type of task based on the number of steps to complete it without further research. Yet, these observations also correspond to the results seen in the analysis of variance for turns and words, as more words and turns were taken in the VMC modes.

Overall, it appears that it took less time to complete the tasks in FTF mode, followed by VMC mode, and CMC mode. However, differences between VMV and FTF modes were only found for the building task. In addition, results from the building task in number of words and turns were unexpected and can perhaps be better explained through uncontrolled factors than through the actual impact of the communication mode. It would be of interest to conduct a similar study that would actually test the effectiveness of the mode for a particular task instead of the process. It seems of importance that the tasks be completed correctly and with as much ease as possible without focusing as much on the actual process. In order to better assess the effectiveness of the mediums for a particular task, a measurement would have to be produced that would take into account the quality of the task as well as the amount of time and steps taken to complete it (e.g. the quantity).

This type of research is of particular importance in today's society where the majority of the communication takes place through computers. E-mail and messaging systems are used by a large number of the population, and as we move further into this computer information age it is important to understand how communication is affected by these technological factors. Particularly, if this technology is to be used in the work place, at schools for learning purposes, in military operations, and perhaps even for medical consultations. In addition, as people continue to use this technology on an everyday basis the impact of the medium might not be as relevant as it was a few years ago, when this technology was fairly new. Future research should include studies that investigate the impact of the medium for specific tasks, such as certain especial military operations and medical consultations, as it does not appear that all collaborative tasks are affected by the communication medium in the same manner. In addition, research should include expert novice interaction, such as a mechanic trying to explain to a regular person how to fix something in a car in an emergency situation. Also, since this technology is of great importance in distance learning situations, the effectiveness of this learning method should be further explored. Another factor that affects the communication process is gender. This issue should be studied in more depth in relation to these new and evolving communication mediums.

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APPENDIX A

PRELIMINARY POWER ANALYSIS

A preliminary power analysis was conducted to obtain an estimate of sample size. According to Keppel (1991), although there is no set minimum power for the behavioral sciences, a power of around .80 is a reasonable value. Power is determined by the significance level of alpha, which in this case is set at .05, the magnitude of the treatment effect, and sample size *n*. Therefore, to begin with, the power analysis will help to determine the sample size necessary to obtain a reasonable level of power.

The analysis was performed using the results obtained in a methodological and conceptually similar study documented in the literature (Graetz et al., 1998). The study provided information regarding the magnitude of *F* for the dependent variable *time to decision*. However, it is important that it be understood that the estimate of sample size is only an educated guess, and the effect size achieved by the study, which impacts the power, may not directly translate to that of the present study. Effect size is directly impacted by the amount of error in the study (as error increases, effect size will decreases), which in this case may differ from the amount of error in the current study.

Graetz and colleagues (1998) manipulated three different communication conditions: face-to-face, telephone, and electronic. The task conducted by the participants (in groups of 4) was a business problem that had a correct, definable answer, although this particular task may have involved slightly more social interaction then the participants in the present study will experience. While the study tested for several dependent measures, the variable of interest was *time to decision*. An F value of 22.03 was reported. Omega-squared (equation 1) was computed to calculate the relative size of the treatment effect or the variance accounted for by the independent variables in the experiment (Keppel, 1991). The values for omega-squared can range from 0 (no treatment effect) to 1 (strong treatment effect).

$$\omega^2 = \frac{(a-1)(F-1)}{(a-1)(F-1)+(a)(n)} \quad [1]$$

Substituting numbers,

$$\omega^2 = \frac{(a-1)(F-1)}{(a-1)(F-1)+(a)(n)} = \frac{(3-1)(22.03-1)}{(3-1)(22.03-1)+(3)(12)} = .537$$

This value was then converted into Cohen's f statistic using equation 2 (Keppel, 1991).

$$f = \sqrt{\frac{\omega^2}{1-\varpi^2}} \quad [2]$$

Substituting numbers,

$$f = \sqrt{\frac{\omega^2}{1-\varpi^2}} = \sqrt{\frac{.537}{1-.537}} = 1.07$$

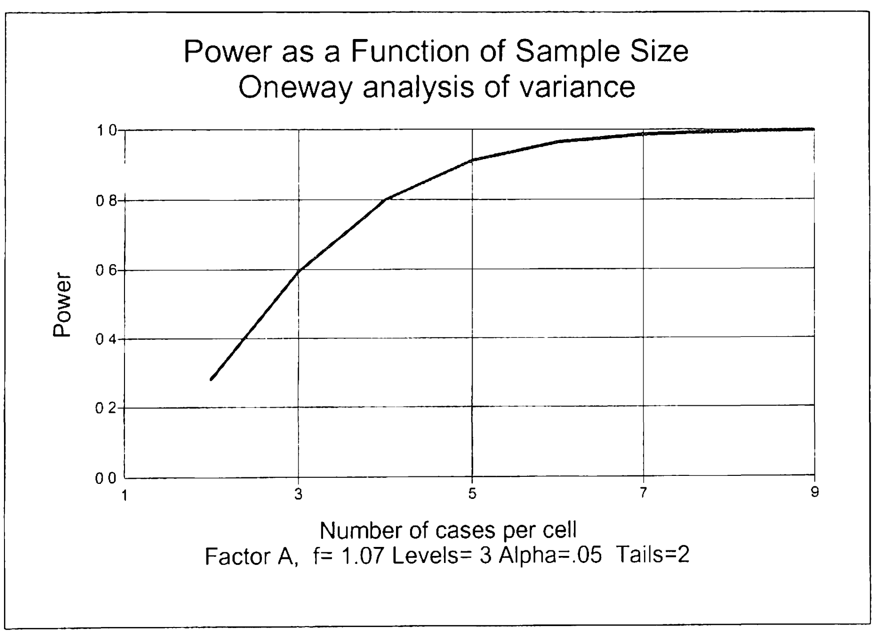
This value of Cohen's f, along with the number of levels and the number of groups in each level, was entered into the SamplePower™ (Revision 1.20, SPSS, Inc., 1997) program in order to compute the power for the study. The computations revealed that the study by Graetz and colleagues (1998) had a very high power of .999. In order to determine the number of participants needed per cell, given the three independent variables, to achieve a power of at least .80, the computer program computed a table of power for different cell sizes (Table 1, Figure 1). According to the table, only 4 groups per cell were necessary to achieve a power of .80 in the analyzed study. However, an ANOVA does not work well unless there is at least 5 or 6 groups per cell. In addition, the current study includes other dependent variables that may require more measurements to identify the differences along the levels of the independent variables. Therefore, taking into consideration the other dependent variables and the possible differences in effect size between the analyzed study and that of the current study, it seems reasonable to include at least 7 groups per cell.

Table 4.

Estimated Power as a Function of Sample Size for the Present Study

N per cell	Power
2	.281
3	.593
4	.801
5	.912
6	.964
7	.986
8	.995
9	.998
10	.999

Figure 8. Estimated Power as a Function of Sample Size for the Present Study



APPENDIX B

SUMMARY OF WORDS PER TURN

Table 5.

Frequencies and percentages of words per turn for FTF Task 1

Number of words	Frequency	Percentage
1.00	198	18.1
2.00	126	11.5
3.00	97	8.9
4.00	106	9.07
5.00	112	10.2
6.00	53	4.8
7.00	76	6.9
8.00	64	5.9
9.00	35	3.2
10.00	23	2.1
11.00	29	2.7
12.00	20	1.8
13.00	21	1.9
14.00	20	1.8
15.00	13	1.2
16.00	13	1.2
17.00	11	1.0
18.00	7	.6
19.00	8	.7
20.00	16	1.5
21.00	3	.3
22.00	5	.5
23.00	2	.2
24.00	2	.2
25.00	3	.3
26.00	6	.5
28.00	2	.2
29.00	3	.3
30.00	6	.5
32.00	2	.2
33.00	1	.1
37.00	2	.2
39.00	1	.1
41.00	2	.2
44.00	1	.1
46.00	1	.1
52.00	1	.1
62.00	1	.1
70.00	1	.1
90.00	1	.1
Total	1094	100.0

Figure 9. Distribution of words per turn for FTF Task 1

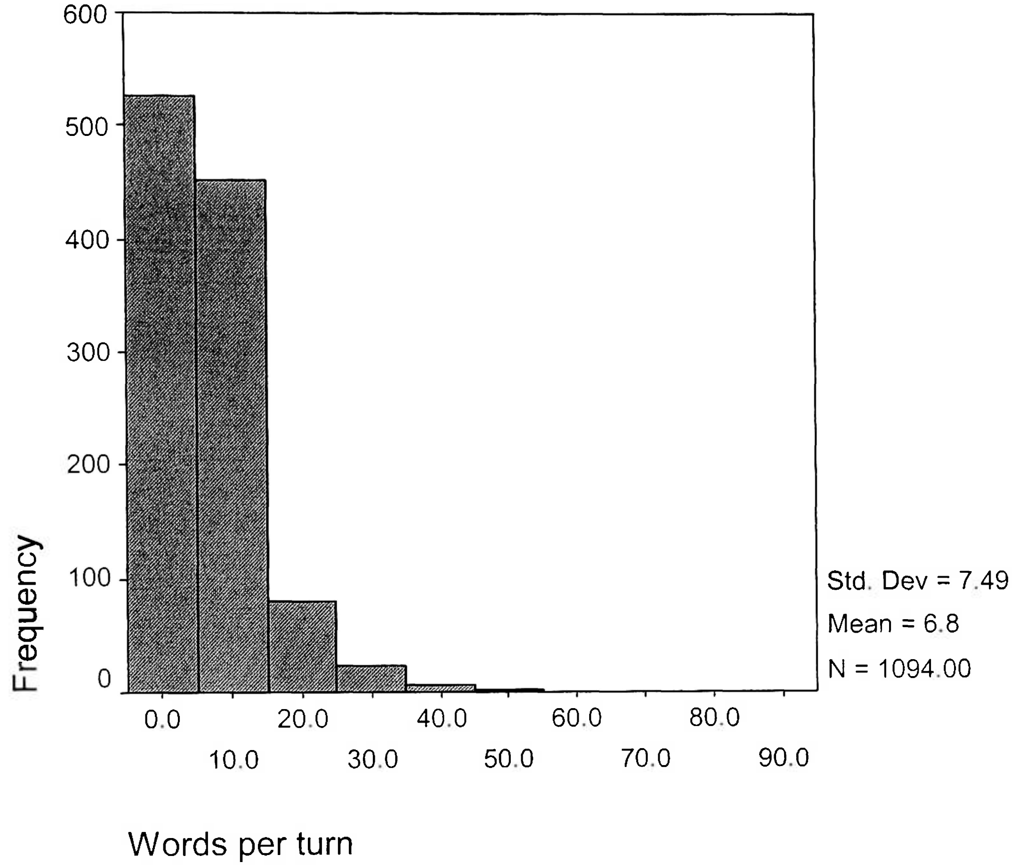


Table 6.

Frequencies and percentages of words per turn for FTF Task 2

Number of words	Frequency	Percentage
1.00	71	19.8
2.00	42	11.7
3.00	31	8.6
4.00	20	5.6
5.00	19	5.3
6.00	25	7.0
7.00	21	5.8
8.00	11	3.1
9.00	12	3.3
10.00	15	4.2
11.00	4	1.1
12.00	6	1.7
13.00	9	2.5
14.00	6	1.7
15.00	9	2.5
16.00	4	1.1
17.00	4	1.1
18.00	6	1.7
19.00	5	1.4
20.00	4	1.1
21.00	2	.6
23.00	1	.3
24.00	1	.3
25.00	1	.3
26.00	1	.3
28.00	1	.3
30.00	2	.6
31.00	2	.6
33.00	1	.3
34.00	2	.6
35.00	1	.3
36.00	2	.6
38.00	1	.3
40.00	1	.3
44.00	1	.3
47.00	2	.6
48.00	2	.6
49.00	1	.3
50.00	1	.3
52.00	1	.3
61.00	2	.6
63.00	1	.3

66.00	1	.3
69.00	1	.3
73.00	1	.3
78.00	1	.3
83.00	1	.3
Total	359	100.0

Figure 10. Distribution of words per turn for FTF Task 2

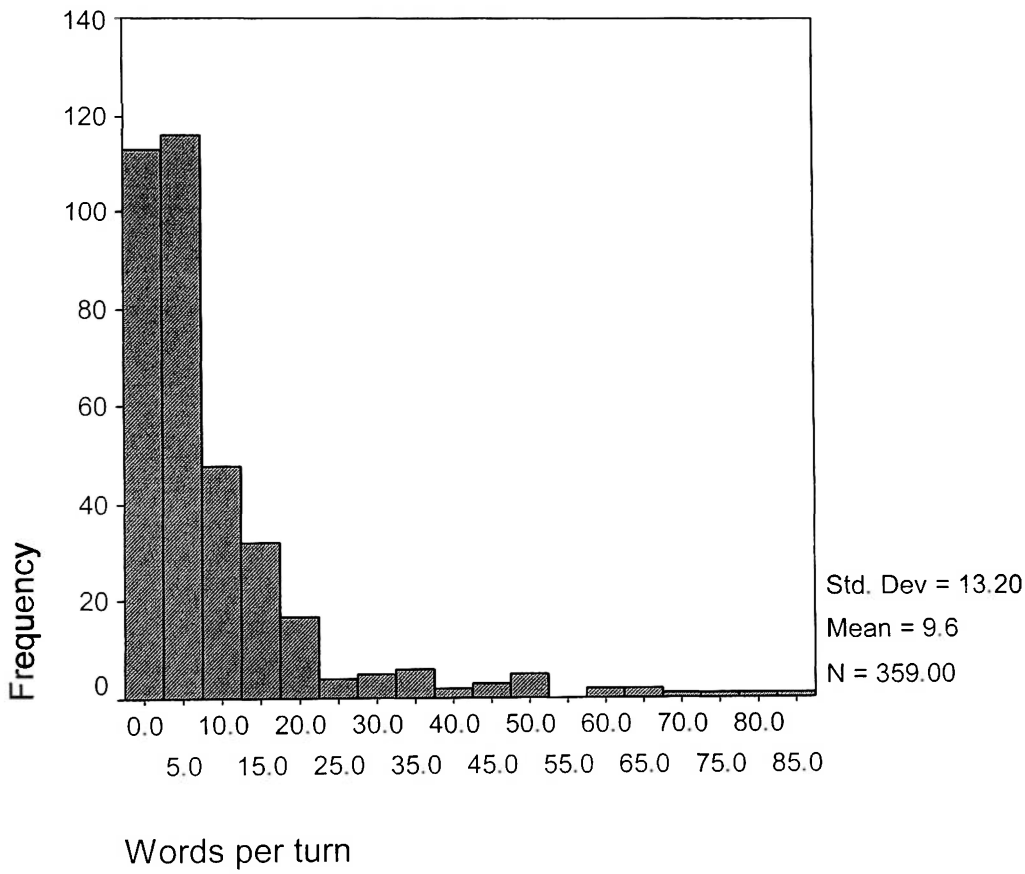


Table 7.

Frequencies and percentages of words per turn for VMC Task 1

Number of words	Frequency	Percentage
1.00	238	22.8
2.00	63	6.0
3.00	67	6.4
4.00	67	6.4
5.00	76	7.3
6.00	87	8.3
7.00	64	6.1
8.00	56	5.4
9.00	44	4.2
10.00	36	3.4
11.00	34	3.3
12.00	33	3.2
13.00	27	2.6
14.00	17	1.6
15.00	14	1.3
16.00	16	1.5
17.00	12	1.1
18.00	13	1.2
19.00	11	1.1
20.00	8	.8
21.00	10	1.0
22.00	7	.7
23.00	6	.6
24.00	3	.3
25.00	5	.5
26.00	4	.4
27.00	5	.5
28.00	2	.2
29.00	2	.2
30.00	3	.3
31.00	1	.1
32.00	2	.2
33.00	2	.2
35.00	2	.2
36.00	1	.1
37.00	1	.1
42.00	1	.1
48.00	1	.1
50.00	1	.1
54.00	1	.1
57.00	1	.1

58.00	1	.1
Total	1045	100.0

Figure 11. Distribution of words per turn for VMC Task 1

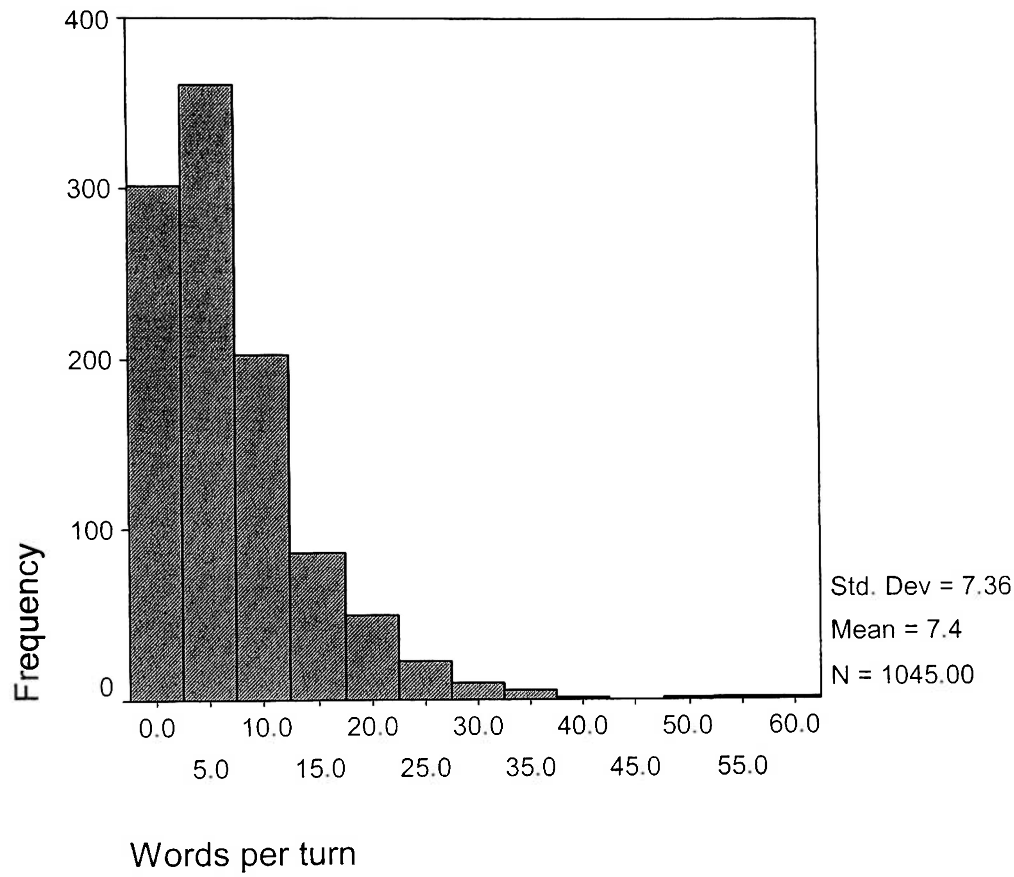


Table 8.

Frequencies and percentages of words per turn for VMC Task 2

Number of words	Frequency	Percentage
1.00	198	24.1
2.00	61	7.4
3.00	46	5.6
4.00	46	5.6
5.00	31	3.8
6.00	43	5.2
7.00	44	5.4
8.00	40	4.9
9.00	31	3.8
10.00	26	3.2
11.00	27	3.3
12.00	23	2.8
13.00	25	3.0
14.00	22	2.7
15.00	21	2.6
16.00	21	2.6
17.00	13	1.6
18.00	9	1.1
19.00	13	1.6
20.00	7	.9
21.00	4	.5
22.00	7	.9
23.00	5	.6
24.00	1	.1
25.00	4	.5
26.00	8	1.0
27.00	4	.5
28.00	4	.5
29.00	6	.7
30.00	2	.4
31.00	3	.4
32.00	1	.1
33.00	1	.1
35.00	6	.7
36.00	1	.1
37.00	2	.2
39.00	1	.1
40.00	3	.4
41.00	1	.1
43.00	1	.1
44.00	1	.1
45.00		

51.00	1	.1
54.00	1	.1
56.00	1	.1
61.00	1	.1
69.00	1	.1
71.00	1	.1
79.00	2	.2
Total	822	100.0

Figure 12. Distribution of words per turn for VMC Task 2

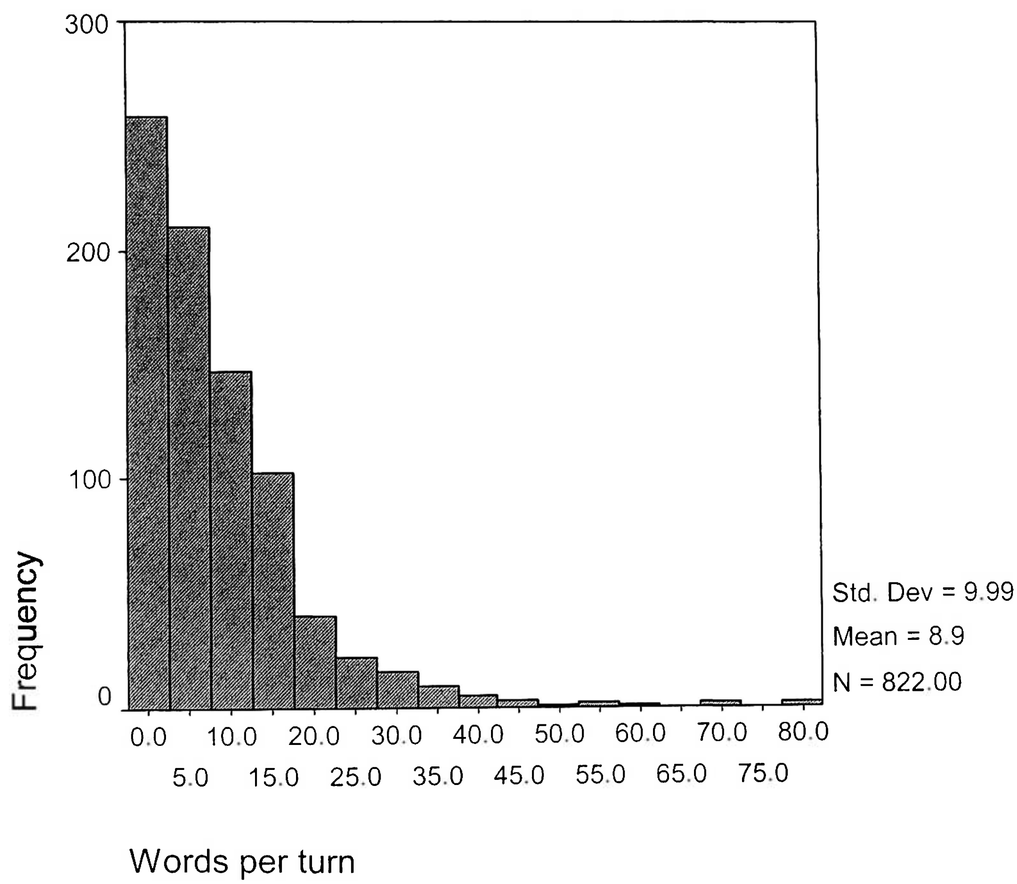


Table 9.

Frequencies and percentages of words per turn for CMC Task 1

Number of words	Frequency	Percentage
1.00	81	18.8
2.00	51	11.9
3.00	54	12.6
4.00	40	9.3
5.00	37	8.6
6.00	24	5.6
7.00	18	4.2
8.00	14	3.3
9.00	23	5.3
10.00	13	3.0
11.00	10	2.3
12.00	3	.7
13.00	9	2.1
14.00	5	1.2
15.00	6	1.4
16.00	6	1.4
17.00	4	.9
18.00	4	.9
19.00	4	.9
20.00	3	.7
21.00	2	.5
22.00	2	.5
23.00	3	.7
25.00	3	.7
26.00	2	.5
28.00	1	.2
29.00	2	.5
30.00	1	.2
31.00	1	.2
38.00	2	.5
42.00	1	.2
52.00	1	.2
Total	430	100.0

Figure 13. Distribution of words per turn for CMC Task 1

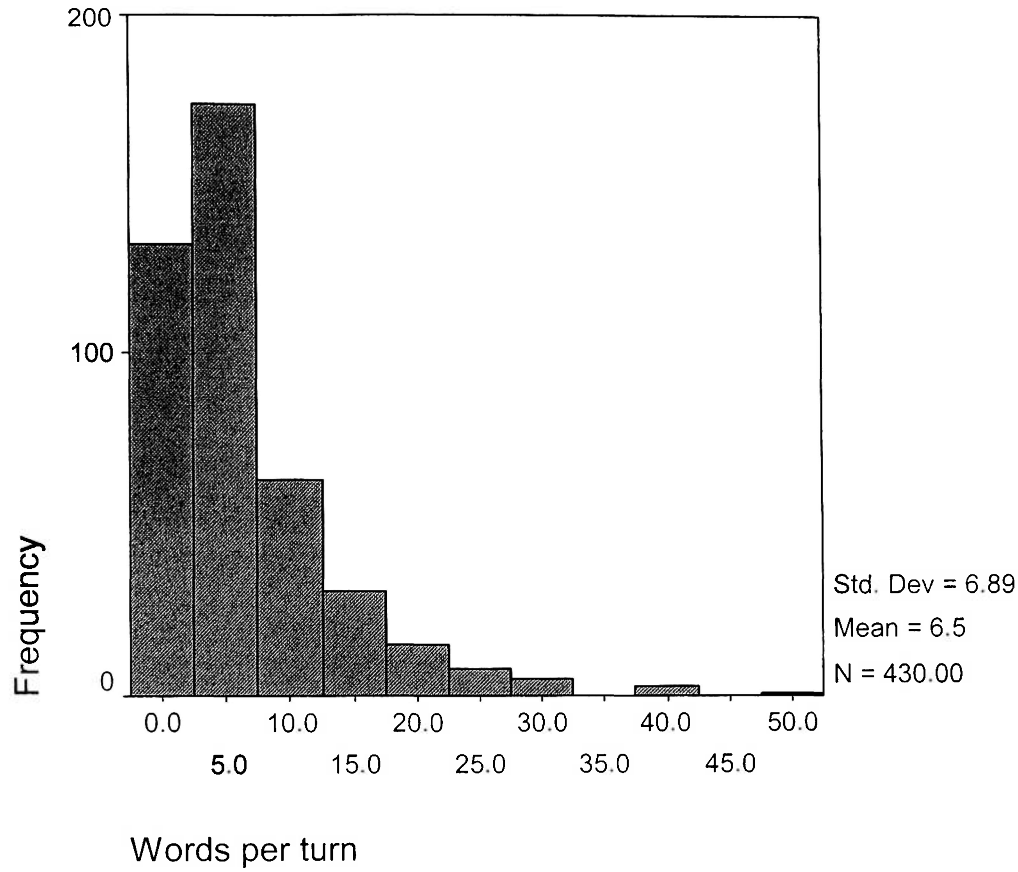


Table 10.

Frequencies and percentages of words per turn for CMC Task 2

Number of words	Frequency	Percentage
1.00	140	27.1
2.00	39	7.6
3.00	29	5.6
4.00	32	6.2
5.00	28	5.4
6.00	30	5.8
7.00	26	5.0
8.00	16	3.1
9.00	16	3.1
10.00	21	4.1
11.00	20	3.9
12.00	16	3.1
13.00	8	1.6
14.00	13	2.5
15.00	7	1.4
16.00	9	1.7
17.00	9	1.7
18.00	5	1.0
19.00	6	1.2
20.00	5	1.0
21.00	3	.6
22.00	4	.8
23.00	3	.6
24.00	3	.6
25.00	3	.6
26.00	2	.4
27.00	2	.4
28.00	1	.2
29.00	4	.8
30.00	3	.6
31.00	2	.4
32.00	1	.2
33.00	1	.2
34.00	1	.2
37.00	1	.2
40.00	1	.2
50.00	1	.2
55.00	1	.2
58.00	1	.2
60.00	2	.4
71.00	1	.2
Total	516	100.0

Figure 14. Distribution of words per turn for CMC Task 2