Video Support for Shared Work-Space Interaction – An Empirical Study

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ABSTRACT

A study has been carried out to identify the effects of different human-to-human communication modes on dyadic computer supported group work. A pilot study evaluated an available shared work-space software system, supplemented by face-to-face, telephone-based, and text-based communication modes between the two users. The findings from this study were then used to design an extensive experiment to explore the relative impact of face-to-face, full motion video, slow motion video, and audio only communication modes when used in conjunction with this type of CSCW system. This paper describes the experiments, and examines the findings of this empirical study with the aim of establishing the importance of co-presence[1] in CSCW, and the effectiveness of these various communication modes in achieving it.

KEYWORDS

computer supported cooperative work (CSCW), group communication, group work, communication mode, video conferencing.

INTRODUCTION

A growing number of tasks in our work environment are carried out by groups of people. Members of cooperative work groups require some means of communication and coordination. The communication mode between group members can range from highly

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[1] The term co-presence is used in this paper to describe the situation where, ideally, users are physically located "... in the same surroundings and can readily see and hear what each other is doing and looking at" (Clark and Brennan, 1991). It is recognised that users located at a distance from one another may be able to achieve the effect of co-presence through video or other communication links.

interactive face-to-face meetings to less interactive text-based forms.

In recent years a large amount of effort and resources have gone into recreating face-to-face meeting environments by using audio, video, and computer links between distributed individuals. Although a number of software packages now exist which provide for a shared work-space between physically distributed individuals (Group Technologies, 1990; McGuffin and Olson, 1992; Greenberg *et al.*, 1992) little research has been carried out to establish the significance of creating co-presence, and the relative effectiveness of various, often costly, communication techniques in achieving this co-presence. Designers have often assumed that audio-visual communication is sufficient improvement over audio to justify the order-of-magnitude cost difference (Williams, 1977). However, these assumptions have not usually been backed up by any evidence originating from research on the effects of various media on human-to-human communication. Establishing the relative significance of these communication modes is an important step in designing useful Computer Supported Cooperative Work (CSCW) technology.

Most of the literature on human communication relevant to CSCW comes from the research in the area of social psychology. Unfortunately, as Short *et al.* (1976) have pointed out, a large number of these studies have serious limitations in that their variations in the medium of communication have been very crude (for example, communication versus no communication).

However, there were a series of studies carried out during 1970s by a number of different researchers that produced some interesting results. One such study was carried out by Ochsman and Chapanis (Ochsman and Chapanis, 1974; Chapanis, 1975; Chapanis, 1971; Chapanis *et al.*, 1972). This investigated a wide range of communication media (from text-based communication to face-to-face) in the context of non-computer-supported cooperative problem solving. The problems that were used had only one correct solution and they were formulated in a way that solving them required the subjects to work together.

The most interesting result of Chapanis and Ochsman's work was that they identified the presence of an audio channel to be the single most important factor in a cooperative problem solving environment. This research clearly showed that there wasn't any significant difference in the time taken between the face-to-face ('communication rich' mode) and the audio-only communication mode.

Since a large percentage of the currently available papers on human communication (including Chapanis and Ochsman's work) are the results of research carried out in the absence of advanced computer technology, their results cannot be directly used in CSCW. It

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is therefore necessary to repeat some of the work done by social psychologists to investigate their findings in the context of computer supported collaborative work.

An initial pilot study suggested that performance with an available shared work-space system was affected by the extent to which it was supplemented by direct human-to-human communication. However, it was necessary to understand whether various telecommunication media, such as video, could be used effectively to replace face-to-face meetings without detrimental consequences (Williams, 1977). Therefore, an extensive experiment was designed to establish the differences in effect when a shared work-space software is used in conjunction with face-to-face, full motion video, slow motion video, and voice-based communication modes.

This paper describes both the pilot study and the main experiment, and discusses some of the results gained from this study. Although further analysis of the data is yet to be completed, the results so far indicate no significant differences between the four communication modes used in this context.

IMPORTANCE OF EMPIRICAL STUDIES

As Olson *et al.* (1993) have noted, because of the similarities between HCI and CSCW, the development stages of the field of HCI could be used to identify the stages that CSCW will need to go through to get to where HCI is today. Card (1991) has identified the growth stages of HCI to be:

Stage 1: Design and implementation of illustrative point systems.

Stage 2: Evaluation, comparison, and review of existing systems to understand the dimensions that affect success or failure of a system.

Stage 3: Analysing the dimensions to characterise the relationship between them.

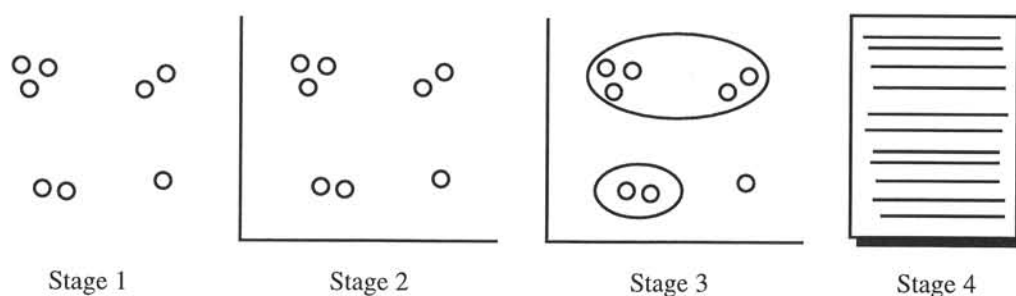**Stage 4**: Articulation of laws that govern the behaviour of systems.

Figure 1: Development Stages of HCI (from Olson et al.)

Currently CSCW is in the first stage of development. A large number of groupware systems

have been and are being built by researchers and commercial companies. In comparison to the number of systems being built there has been little empirical research into the use of such systems in real group work.

From observations in the field of HCI, advancing from the first stage to the third stage is not possible without evaluation of built systems and the study of the factors and dimensions that affect the success or failure of these systems. CSCW must go through a similar phase to get to its third stage of development. Research is needed into the fundamentals of group work and human-to-human interaction, so that those aspects of cooperation and communication that must be supported by groupware to make them useful tools for facilitating cooperative work can be identified.

PILOT STUDY

There are a large number of factors that affect group communication and cooperative work. However, some of these factors are more important than the others and they play a critical role in the way group members interact with each other (Isaacs and Tang, 1993; Rutter *et al.*, 1981; Short *et al.*, 1976; Argyle and Cook, 1976). To examine the effects of all the factors is a very complex task and perhaps the best that can be done is to identify the most important factors first and then study their effects.

The primary purpose of the pilot study was to identify the effect of co-presence in the use of shared work-space computer groupware, and to establish the extent to which audio and keyboard communication could create an element of co-presence. It was intended that this pilot study would lead to a more focused experiment.

For the pilot study groups of two students were required to work cooperatively in one of five different settings solving a common design problem[2]. Four of these settings centred on a shared work-space groupware application, Aspects™ (Group Technologies, 1990), which provides shared drawing, painting and writing, and a simple text-based communication facility (Chat Box). The fifth group carried out the same task on paper, without any computer facility.

Figure 2 shows the five different settings of the pilot study in terms of their communication mode and the type of work-space used to support the group activity. Four of the five different settings (**A** to **D**) were selected to cover a full spectrum of "presence" from true co-presence to interactive typewriter-like exchanges. These settings were: (**A**) working remotely with

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[2] The task that each group performed was to cooperatively design a user interface for a credit card petrol pump. This design problem, which has previously been used by Minneman and Bly (1991) for testing a multi-user drawing tool, was chosen becuase its solutions would contain a mixture of text and graphics.

Aspects and Chat Box, **(B)** working remotely with Aspects and telephone, **(C)** working face-to-face with Aspects, and **(D)** working side-by-side with Aspects. The fifth setting, **(E)** working face-to-face with pen and paper only, was included so that the effects of the Aspects software could be tested.
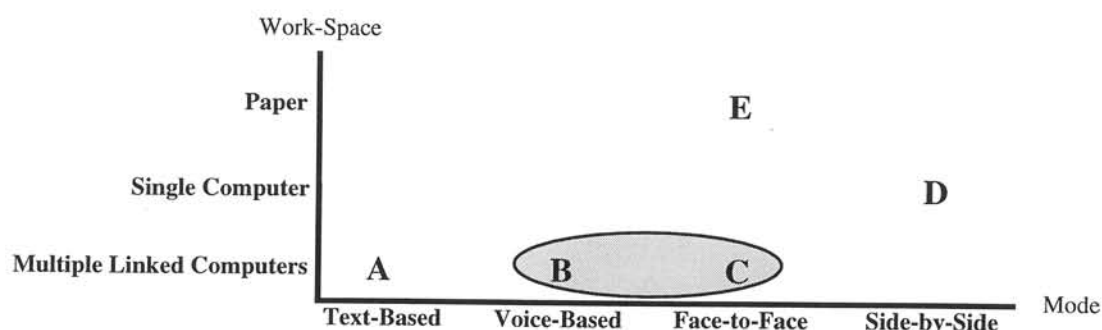
Figure 2: Relative Position of the Five Settings of the Pilot Study

Although the productivity of the groups in terms of the completion of their solution and the time taken to achieve it was very similar, the study showed an increase in satisfaction from the use of the Chat Box as the communication medium moved towards the use of telephone, or the face-to-face meeting. There was also an increase in the time spent in discussion and planning from the group who used the Chat Box to the group who used the paper. A similar point was noted by Muller *et al.* (1993), who suggest that in a collaborative environment group members spend their time on three different tasks, either successively or simultaneously. These are: transcribing, critiquing, and changing the design; communicating with each other; and managing the medium. It follows that the more time group members spend managing the medium, the less they are going to communicate or do critical design. The reason that the group using the Chat Box communicated less than the others was that their communication took more effort (since they had to stop working so that they could communicate, whereas the others communicated while working). This is also why the group who worked on paper communicated more than the others (simply because they spent less time managing their less complicated medium).

The pilot study indicated a clear advantage of the voice link (**B, C, D** over **A** in Figure 2), entirely consistent with earlier studies (Ochsman and Chapanis, 1974; Chapanis, 1975; Chapanis, 1971; Chapanis *et al.*, 1972). It also showed that there were differences between shared work-spaces supported by multiple linked computers (**A, B, C**) and other types of work-spaces (**D, E**).

However, it was less clear whether there was a significant gain in moving from an audio-only mode to a much richer face-to-face communication mode when working on a computer supported shared work-space. In other words, is there any significant difference between

points **B** and **C** in Figure 2? The variations from **B** to **C** can be regarded as the extent to which co-presence is achieved.

This study had not assessed the use of a video link between physically separated co-workers. There are at least two other modes of communication coming somewhere between telephone-based and face-to-face meetings that could be provided using video technology. These are: meetings supported by slow motion video link, and meetings supported by full motion video link. The slow motion video could either be a video link that allowed fewer frames per second than a full motion video link, or a video link with reduced picture quality.

MAIN EXPERIMENT

Based on the observations made in the pilot study, a more substantial experiment was planned to study in more detail the effects of different human-to-human communication modes in a shared work-space computer supported cooperative work environment (the shaded region in Figure 2 shows the focus of this experiment). For this study four different modes of meeting were selected, each utilising the same software (Aspects, as used in the pilot study). These modes were: face-to-face meetings, meetings supported by audio link, meetings supported by full motion video link, and meetings supported by slow motion (5 frames per second) video link.

In this experiment it was assumed that the face-to-face meeting environment would provide the highest human-to-human communication bandwidth (and hence the greatest degree of co-presence), and the voiced-based meeting environment the lowest. The video-based meeting environments would be somewhere in the middle since they supported visual as well as audio communication, with the slow motion video link offering less bandwidth than the full motion video. The face-to-face meeting environment was used as a benchmark against which the other environments could be compared. The predicted ranking of these environments is shown in Figure 3.
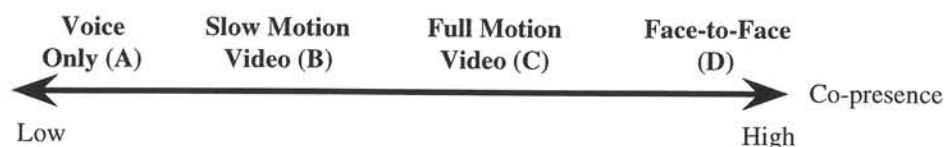

Figure 3: Communication Bandwidth of the Four Environments

Aim Of The Experiment

The primary objective of this experiment was to compare face-to-face, audio, slow motion, and full motion video communication links when they are used in conjunction with a computer-based shared work-space to provide a collaborative work environment. The

experiment aimed at finding the answers to the following questions:

- When used to support this type of shared work-space groupware, how effective is a voice-only link in creating the co-presence of a face-to-face meeting? (i.e. How far apart are the two extremes, **A** and **D**, in Figure 3?)

- To what extent does a full motion video link help in coming closer to the co-presence of a face-to-face situation? (i.e. How close is **C** to **D** in Figure 3?)

- Does slow motion video come closer to creating the face-to-face situation than just a voice link? (i.e. Is **B** closer to **D** than **A** in Figure 3?)

Environments

All of the four environments in this experiment utilised a computer-based shared work-space system, provided by using the Aspects conferencing software and pairs of linked Macintosh computers. Aspects software allowed the subjects to work interactively on shared drawing documents.

Aspects, like other software of this type, has a number of shortcomings. These were identified through the pilot study by comparing the sessions that used Aspects to provide a shared work-space and the session that used paper. Some of the problems of Aspects such as its speed were minimised by using it in a point-to-point mode, and so avoiding unnecessary network delays. Also, because Aspects was used in all of the four settings, any remaining effects that it may have had on the communication between the subjects were eliminated.

What follows is a more detailed description of each of the four environments.

Face-to-Face meeting environment

In this environment the two subjects sat in front of their computers on the opposite sides of a table facing each other. The subjects were able to see each other's upper-body area.

There were four video cameras present in the meeting room which recorded each session for analysis purposes. Two of these cameras recorded the upper-body area of each of the subjects and the other two recorded the screen area of the two computers. This was done so that during the subsequent analysis, it would be possible to observe the view that each subject had of the other, and the view that each subject had of their own work-space. The four video signals, and the spoken dialogue between the subjects, were recorded on a single video tape using a four-quadrant video mixer.
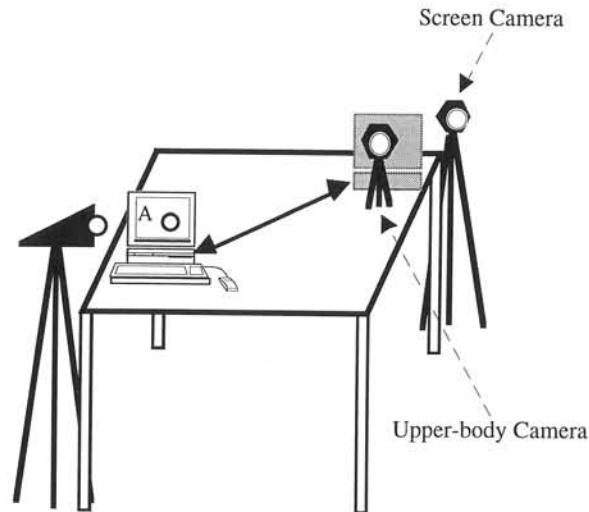
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Figure 4: Face-to-Face Meeting Environment

Slow and Full Motion Video meeting environments

The physical set-up of the slow motion video and the full motion video environments were identical, with the subjects in separate rooms. As with the face-to-face environment, the subjects worked on two linked computers on which the Aspects software was running. In addition, each subject was provided with a video image of the upper body area of the other on a separate monitor, and an audio link to the other via a headset. In both of these environments, video cameras captured the images of the upper-body area of each subject for transmission to the other. In the full motion video environment the real-time images of each room were shown on the monitor in the other room, but in the slow motion video environment the video images on the monitors were shown at about a fifth of the normal frame rate (5 frames per second, commonly used by many video conferencing systems).
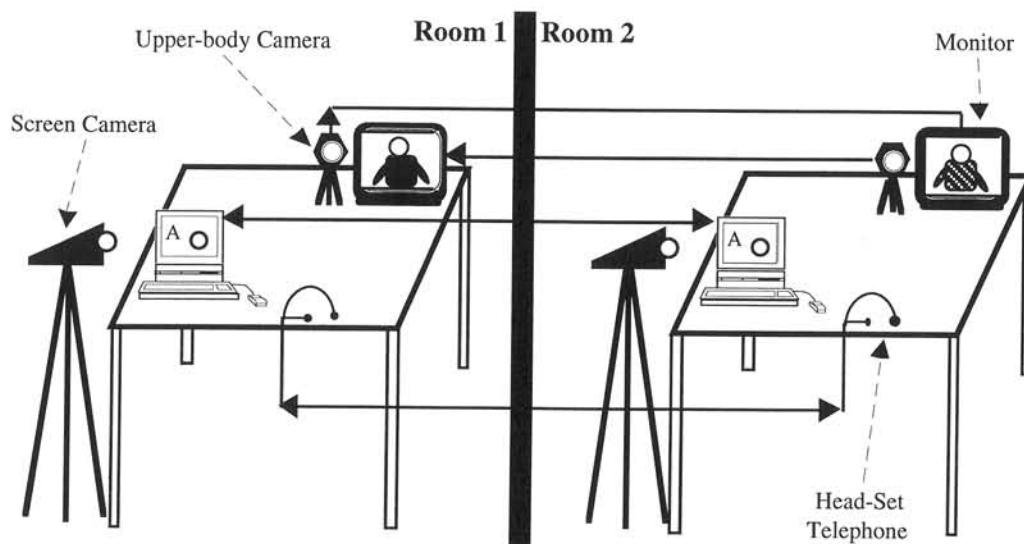

Figure 5: Slow and Full Motion Video Meeting Environments

In these cases also, four video signals (the screens and the two upper body images) and the audio exchanges were recorded on a single video tape for later analysis.

Audio Only meeting environment

The physical set-up of this environment was almost identical to the video environments, except that images of the upper-body area of each subject were not shown to the other subject. However, these images were recorded for analysis purposes.
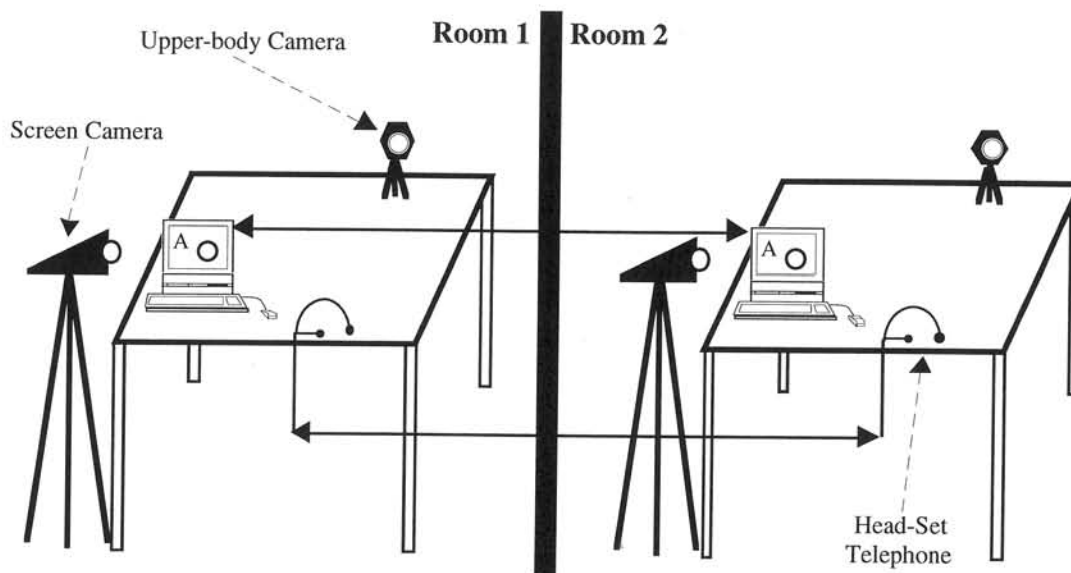

Figure 6: Audio Only Meeting Environment

Sessions

To study the relative significance of the four different communication modes without affecting the results of the experiment by the order in which groups worked in different environments, it would be necessary to consider 24 (4!) different orderings of the four environments. However, because of the large amount of data collected during each session and the time and resources required to analyse the data, not all 24 of these combinations were used (for instance, each session took about 30 minutes meaning that 48 (24*4*1/2) hours of recorded sessions would need to be analysed). It was contended that the order of the first two environments in which a group worked would be most significant from a learning point of view; by the time they were in their third or fourth session, subjects would know enough about the software for further learning effects to make little difference to their performance. Based on this assumption, all the combinations of the first two environments were considered and the next two environments were randomly assigned. This meant that the number of sessions was reduced from 96 to 48, and the resources required to carry out the experiment were halved. In fact since the type of task performed by the groups in each of the sessions

remained the same (see next section) the learning effect related only to the software. Experience showed that the subjects became fully familiar with the software by the end of the first session. Therefore the assumption that the compromise had no effect beyond the first two sessions was justified, and the results were not significantly affected by this reduction.

Figure 7 shows the ordering of the environments that was used for the twelve groups. Numbers 1 to 4 (in bold style) show the order in which the groups worked in different environments. Each of these numbers also identifies a task on which the given group worked in that environment.

Tasks

Finding a suitable set of tasks for an experiment of this type is critical, because the nature of the tasks used ultimately determines the real work environments to which the results can be applied. In selecting suitable tasks it was important to consider issues such as the type of the tasks (design, problem solving, etc.), their difficulty level, the time taken to solve them, possible ways of evaluating their results, and the type of knowledge that the subject would require to be able to perform them.

Mode / Group	Face-to-Face	Full Motion	Slow Motion	Audio Only
1	1	2	3	4
2	1	4	2	3
3	1	3	4	2
4	2	1	4	3
5	4	1	2	3
6	4	1	3	2
7	2	3	1	4
8	3	2	1	4
9	3	4	1	2
10	2	4	3	1
11	4	2	3	1
12	3	4	2	1

Figure 7: Ordering of the Environments

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Among all of these factors perhaps the most important one that needs to be looked at before selecting a task is its type. McGrath (1984) has identified eight different group task types in total. As Figure 8 shows McGrath has categorised these task types along two orthogonal axes. The first dimension shows whether a task is conceptual or behavioural. The second dimension shows if a task requires cooperation or conflict resolution between the group members. This dimension differentiates between the tasks that have to be 'solved' and the tasks that have to be 'resolved' (this may be resolving conflict of view-points or conflict of interests between the group members). McGrath further divides group task types into four different quadrants of generate, choose, negotiate, and execute.

Any of the eight group task types could be used in an experiment designed to study the human communication process. However, to study the effects of different communication media in a computer supported cooperative work environment it seems reasonable to select a task that requires cooperation between the people who are working together. Still further, out of the four cooperative task types only three of them (planning, creativity, intellective) are suitable for a computer supported shared work-space environment.

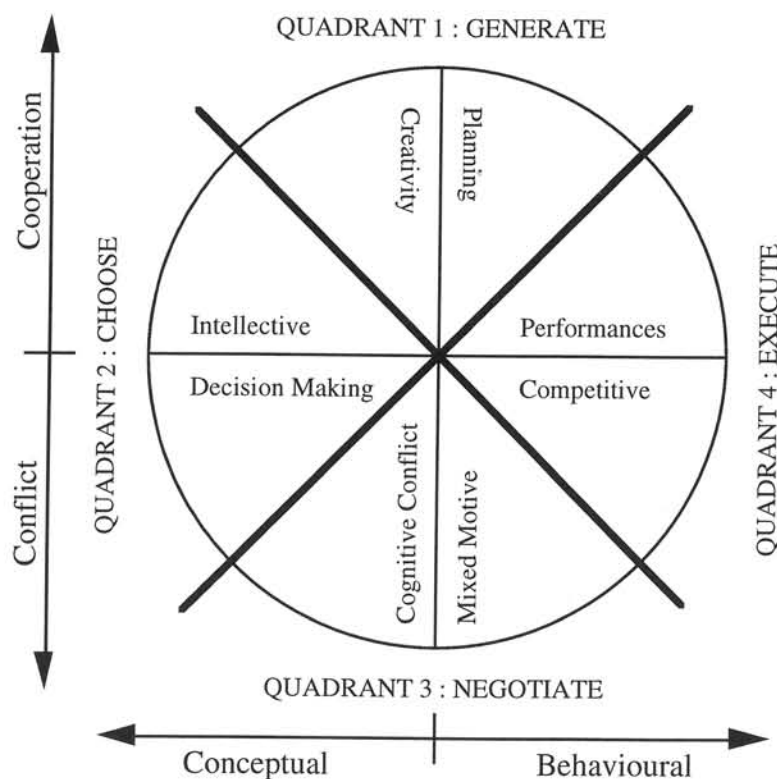Figure 8: The Group Task Circumplex (from McGrath)

Although all three of the planning, creativity, and intellective task types were suitable for this experiment, to keep the task type the same across the four environments, it was necessary to choose only one of them. The intellective task type was selected simply because this type of task has a single reachable solution that can be easily evaluated.

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After considering these issues and carrying out a small pilot study, a set of simple problem solving (intellective) tasks was proposed. Jigsaw puzzles were chosen, because solving them does not require any pre-knowledge of the task area, four different puzzles of the same difficulty level could be used as four different tasks, shortcomings of the software could be largely ignored since the subjects didn't need to use it as a creative tool, the learning effect of the software was minimised, and the subjects could not prepare themselves before coming to the sessions.

Subjects

Twenty-four native English speaking people, both males and females, volunteered to take part in this experiment. The fifteen males and nine females were randomly divided into five male only, two female only, and five mixed sex groups of two people each. All of the subjects had good computer skills and they were either Computer Science or Information Systems students. Fifteen of the subjects were postgraduate and nine of them were third-year undergraduate students.

1.1- How satisfied do you think you will be with this communication Mode?	(1) Very Dissatisfied to (7) Very Satisfied
1.2- How easy do think it will be to communicate in this environment?	(1) Very Difficult to (7) Very Easy
1.3- How efficiently do you think you can work in this environment?	(1) Not Very Efficiently to (7) Very Efficiently
1.4- How enjoyable think it will be to work in this environment?	(1) Not Very Enjoyable to (7) Very Enjoyable
1.5- Indicate your expectations about working in this environment?	
1.5A	(1) Very Impersonal to (7) Very Friendly
1.5B	(1) Very Frustrating to (7) Not Very Frustrating
1.5C	(1) Very Time Wasting to (7) Very Time Saving
1.5D	(1) Very Unproductive to (7) Very Productive
2.1- How satisfied are you with this communication Mode?	(1) Very Dissatisfied to (7) Very Satisfied
2.2- How much did you enjoy working on this task?	(1) Very Little to (7) Very Much
2.3- How efficient was the group work?	(1) Not Very Efficient to (7) Very Efficient
2.4- How easy was it to control the communication?	(1) Very Difficult to (7) Very Easy
2.5- How satisfied are you with the group work?	(1) Very Dissatisfied to (7) Very Satisfied
2.6- How easy was it to understand your partner's ideas?	(1) Very Difficult to (7) Very Easy
2.7- How easy was it to get your own ideas across?	(1) Very Difficult to (7) Very Easy
2.8- How much did the other participant contribute to this group work?	(1) Very Little to (7) Very Much
2.9- How much did you contribute to this group work?	(1) Very Little to (7) Very Much

Table 1: Summary of the Expectations and Reactions Questionnaires

Data Collection

As outcomes from this type of experiment are very dependent on the available data, it was decided to record as much data as possible during the experiment, and then utilise this as appropriate during analysis. Overall, three sets of data were collected. These were obtained by:

- Videotaping the work-space of each of the subjects (their computer screen).

- Videotaping the upper-body area of each of the subjects, and recording their speech interactions, during the sessions.

- Using three types of questionnaires: one at the beginning of each session to establish the subjects' expectations of the environment in which they were about to work, one at the end of each session to get the subjects' reaction[3] to the environment in which they had just worked, and a third at the completion of the experiment to obtain an overall ranking of the four environments according to a number of different factors. Table 1 shows a summary of the first two questionnaires. Questions 1.1 to 1.5D were in the expectations questionnaire and questions 2.1 to 2.9 were in the reactions questionnaire. These questionnaires were designed to look at the three important factors of communication mode, group work, and the tasks.

Data Analysis

There are three analyses that are most suited to the nature of data that was collected during this experiment. These are: verbal communication analysis, visual communication analysis, and user satisfaction analysis. Verbal communication can be analysed in terms of its style and content (Kemp and Rutter, 1982; Rutter *et al.*, 1981; Rutter and Robinson, 1981; Morley and Stephenson, 1977). Visual communication on the other hand, can be analysed in terms of the gaze, mutual gaze, hand and head movements, facial expressions, body positioning and so on (Stephenson and Rutter, 1970; Stephenson *et al.*, 1972; Short *et al.*, 1976; Argyle and Cook, 1976). User satisfaction can be analysed by evaluating users' expectations and reactions to each environment (Hiltz and Johnson, 1990).

So far, the style of verbal interaction between the group members, the time taken to complete the tasks in different environments, and the subjects' response to the three questionnaires have been analysed. The results of the user satisfaction analysis have been discussed in Masoodian and Apperley (1995). The results of the other two analyses are discussed below.

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[3] The concepts of user expectations and reactions are discussed in Hiltz and Johnson (1990).

The style of the conversation between the subjects was measured by the use of a number of variables used by Rutter and Stephenson (1977). These are: total speech duration, number of utterances, number of simultaneous speech utterances, total duration of simultaneous speech, total duration of mutual silence, number of floor control changes, and the number of unsuccessful attempts to change floor control. These variables have usually been used to see whether conversation between people in one environment is more spontaneous than conversation between them in another environment. For instance, Rutter and Stephenson have argued that audio conversations are less spontaneous than face-to-face conversations and this is reflected in the number of simultaneous speech utterances being more in the face-to-face mode than the audio mode. Although no predictions were made about the values of these variables in this experiment they were included to see if there was any significant difference between the four environments.

All the variables were scored directly from the recorded video tapes of the sessions by an observer using a computer program specifically written for this purpose. The observer viewed the recorded sessions and indicated whether each participant was talking or not at a given time by pressing or releasing a key on the computer keyboard assigned to that participant. Based on these input values the program generated a series of on/off patterns for both of the group members through the entire session. These generated patterns were then analysed by another program to measure all the variables discussed earlier. This method, which appears simple, is in fact very powerful and allows a large number variables to be measured. For example as Figure 9 shows, if the pattern for both of the participants is on at a given time it indicates a simultaneous speech, or if the pattern is off for both participants it indicates a mutual silence.
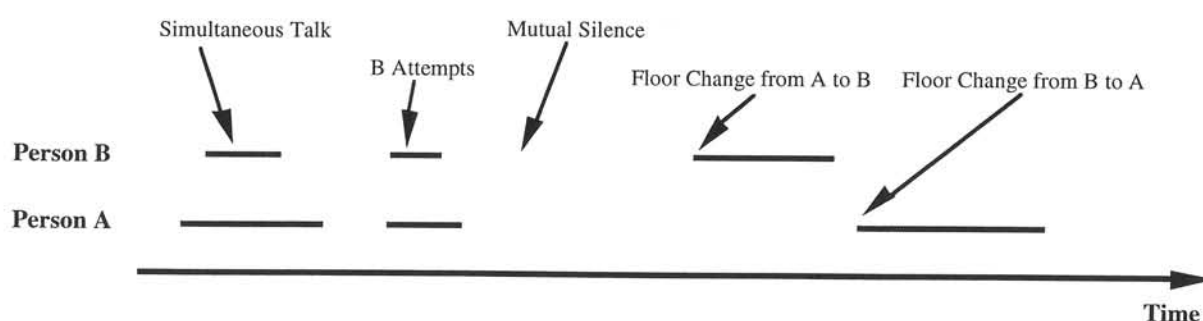

Figure 9: A Sample Speech Pattern Between Two People

RESULTS

A two-way analysis of variance test (Kenkel, 1989) was used to compare the mean value of the measured variables for each of the four environments and twelve groups. A summary of this analysis is shown in Table 2. Note that since the duration of the sessions were not always

the same, time values were normalised to a total of 1800 seconds (this was the average session duration).

Also note that because some of the groups did not complete their task in the maximum allowed time for their task, the session duration for these incomplete sessions could not be measured. To avoid having no real values for the duration of these sessions to use in further calculations, it was necessary to assume that they would have taken a long time to complete. Based on this assumption, it was then possible to compare the average time taken to complete the tasks in different environments by taking a ratio of the maximum allowed time over the actual session duration for each session, therefore making this ratio zero for the incomplete sessions (since the ratio of a number over a large number tends to zero).

	Face-to-Face Mean	Full Motion Mean	Slow Motion Mean	Audio Only Mean	F df = 3, 33
Max. Session Duration/Session Duration	1.35	1.34	1.15	1.07	<1
Speech Duration (s)	929.3	861.3	993.6	1005.3	<1
No. of Utterances	283.3	277.2	316.6	319.6	1.05
No. of Simultaneous Speeches	88.2	88.9	98.5	98.6	<1
Simultaneous Speech Duration (s)	131.9	125.1	138.3	137.3	<1
Mutual Silence Duration (s)	1002.6	1063.8	944.7	931.9	1.04
No. of Floor Changes	174.8	183.3	203.1	197.8	<1
No. of Floor Change Attempts	40.4	41.1	44.6	45.8	<1

Table 2: Summary of the Two-Way Analysis of Variance of Interaction Style and Session Duration

For all the variables shown in Table 2 there was a significant difference between different groups (not shown here). These results were predictable, since it is obvious that some groups would be better at solving puzzles, or would talk more than the others.

However as Table 2 shows, for all the considered variables (averaged across all groups) there is no significant difference between the four environments. The first variable indicates that the time taken to complete the tasks in any of the four environments was the same, showing no significant difference in the efficiency of the group work between the four environments.

The other seven variables are related to the style of interaction between the subjects. These variables show that the style of conversation between the subjects didn't change across the four environments. This implies that the conversation was just as spontaneous in the audio only environment as it was in the video-based or the face-to-face environments. It also clearly

indicates that in this situation the control of conversation was not affected by adding the visual channel. However, previous work (Kemp and Rutter, 1982) has shown that any difference between communication modes would be reflected mainly in the style of interaction between the group members. It is concluded, therefore, that in the context of this experiment, there was little difference between the four modes.

It can also be suggested that if co-presence is affected by the changes in the style of conversation then in a computer supported problem solving situation the sense of co-presence isn't affected by adding a visual channel to an existing audio channel. This leads to the conclusion that the feeling of co-presence is not increased by increasing the communication bandwidth and meetings supported by an audio link create the same sense of co-presence as face-to-face meetings, when shared work-space software is used.

CONCLUSIONS

The results of the data analysis carried out so far quite clearly suggest that little if anything is to be gained by adding video communication when using shared work-space CSCW systems, in the context of this experiment. Further, using just voice communication detracts little from full co-presence. The pilot study did indicate, however, that the voice channel was a very significant factor. These results are entirely consistent with earlier joint problem solving studies carried out in the absence of CSCW support (Ochsman and Chapanis, 1974; Chapanis, 1975).

Although there are many factors that could lead to further experiments, Williams (1977) has identified media and tasks as the two major variables. It is recognised that this experiment has explored only one of the eight group task types identified by McGrath. It is also important to note that as Short *et al.* has pointed out, problem solving tasks do not seem to require a close personal relationship between the co-workers. It might then not be expected that the social aspects of different media would be important for satisfactory completion of the problem solving tasks. Therefore it is necessary to look at the remaining task types, and in particular at creativity and planning, so that an overall image of the relationship between different task types and communication media can be generated.

The other factor that also needs to be considered is the effect of simultaneous cooperative work involving more than two people. Based on the current experiment, further studies are currently being planned to explore these other factors.

The costs associated with providing a video human-to-human communication channel as a part of a CSCW system are not insignificant. If the results can be shown to be more generally

applicable, then they would suggest that current efforts should be concentrated on improving CSCW software and techniques, rather than attempting to integrate video facilities.

As Williams has pointed out, perhaps the future research would allow the domain of face-to-face meetings to be partitioned into two types. Meetings of the first type would be shown to be affected by the use of media providing other than face-to-face communication. If these effects were considered to be important then this type of meetings should be carried out in a face-to-face mode. The second type of meetings, not affected by the type of communication media, could on the other hand be carried out at distance, perhaps using shared work-space software as in this experiment.

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