

# ADDING AUDIO AND VIDEO TO AN OFFICE ENVIRONMENT

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## *ABSTRACT*

The aim of the VISION project was to determine the value added to an office system by incorporating audio and video. The performance, feelings and perceptions of work groups were measured while they carried out cooperative tasks in a controlled environment using an experimental video communication system. The results showed no significant differences in the quality of the output, or the time taken to complete the tasks, under three conditions: data sharing; data sharing plus audio; data sharing plus audio and video. The results suggest that high bandwidth communication is particularly effective for social, informal, communication.

## **1.0 Introduction**

When AT&T introduced the PicturePhone at the 1964 World's Fair the product was met with popular acclaim. Attendees at the fair stood in long lines to try it out. AT&T claimed that the PicturePhone was going to change the face of telecommunications. Commercially, however, the PicturePhone was unsuccessful. It became the proverbial solution looking for a problem. Indeed, when introducing new technologies, many vendors - including AT&T - go out of their way to claim "This is NOT another PicturePhone!"

However, technology has come a long way since 1964 and there have been a number of developments recently which could make this marketplace a reality. Firstly, the availability of ISDN via a public switched network will dramatically reduce the cost of communications. Secondly, the development of high powered, high resolution personal computers makes desktop video conferencing possible. And thirdly, advances in video compression technology has greatly reduced the amount of bandwidth required to transmit full motion video.

Yet, to be able to effectively develop and market a product one must understand the effects that such a product has on its users.

## **2.0 Experimental Design**

The aim of this current study was to determine the value added to an office system by incorporating visual communication. The following experiments attempted to identify the effects that visual communication has upon users when performing tasks in an integrated office environment.

Direct comparisons of visual communication with other forms of communication traditionally found in the office, e.g. electronic mail, telephone, face-to-face, are difficult because of the number of variables involved. For example, face-to-face communication and the telephone are synchronous, whereas electronic mail is asynchronous. The results from any experiment which compares these media, could be as much to do with the asynchronous/synchronous nature of the media, as the with the media itself. Indeed, if a mixture of asynchronous and synchronous media were to be used then it might be argued that different tasks should be used. This would then give rise to another possible variable which could affect the results.

The approach taken with these experiments was to use a data sharing condition as the base condition, then to add an audio channel and attempt to measure the enhancements to workgroup communication, and then to add a video channel and attempt to measure any further improvements.

- (a) *'Data sharing only' condition*  
The only form of communication between the individuals in the group is via an arrangement which allows multiple users to simultaneously draw and type on the same workspace. The arrangement, referred to as a "shared whiteboard", has been implemented on a computer network and updates are performed in real time (within 10 milliseconds) thus allowing synchronous communication.
- (b) *'Data sharing plus audio' condition*  
In addition to the shared whiteboard, each workstation has a headset microphone for the transmission of audio and the incoming audio channels are mixed and output through a single speaker. The audio system is of high, near broadcast, quality.
- (c) *'Data sharing plus audio plus video' condition*  
Each workstation has a CCD camera which transmits a picture of the user. The incoming video can be displayed on one of three 6 inch monitors placed along the top of the computer monitor (a pilot study determined that this was the preferred configuration), thus allowing a 4 person meeting. In both cases the audio and video channels are transmitted using cable TV technology.

## 2.1 Tasks

Three tasks were used in these experiments, chosen to represent the diverse nature of office work.

- (a) Task One: *Information dissemination*  
In this task all group members have access to the same information and they have to negotiate the presentation of that information. The information is contained in a set of details of five houses. The details for each house are brief and contained on two sides of an A4 sheet. The subjects are also supplied with the house requirements of a would-be purchaser. The task is for the group to produce a slide which identifies the two most appropriate properties for this particular purchaser. However, the material has been selected so that two properties do not completely fulfil the requirements, thus requiring the group to discuss and negotiate a group view.
- (b) Task two: *Creative cooperative work*  
This task differs from task one in that each member of the group has different information and experiences to contribute, as well as having different skills. The element of negotiation involved in task one remains, but in this case it involves more persuasion and communication of ideas, rather than just the agreement of a group view of the same information. In contrast to the previous task, users were given a one line statement such as: "The most desirable characteristics of a project manager are ....".
- (c) Task Three: *Meeting scheduling*  
The aim of this task is for the group to arrange a two hour meeting in the only available meeting room. Each member is given a timetable which is his/her diary for the coming week. Timetables are known only to the individuals to which they refer and to nobody else. In addition, one person in the group, who has been chosen at random, is given a timetable for the meeting room. Each timetable has two types of meetings marked on it, those that can be re-arranged, and those that cannot. The timetables have been arranged such that the group members cannot fix a two hour meeting without significantly altering their own timetable, so the group members have to negotiate between themselves certain changes to their timetables. Attendance at only part of a meeting is not allowed.

## 2.2 Method

The tasks were run over a three week period, each task taking a week. During each week, each task was performed five times under the three conditions, a different variation of the task was used each time. A group consisted of four individuals who have been randomly assigned to that group from a pool of twelve. All subjects were software engineers working in the laboratory.

At the beginning of each week, the subjects were asked to complete a questionnaire which attempted to measure the subjects' expectations of the equipment. Before the first questionnaire was administered each group was given a demonstration and explanation of the workstations. This ensured that the subjects had something on which to base their expectations.

The group was briefed on the purpose of the experiment and what they had to do. They were told that the purpose of the trial is to produce a slide which represents the group recommendation and the reasons behind it. Each of the subjects is taken to a separate room where there is a workstation with the appropriately configured communications media. The groups were given no guidance about how to solve the problem, how they should communicate with one another, or how to use the media. They were given a maximum of 30 minutes to solve the problem. When group consensus was reached, or at the end of the 30 minute period, the members of the group stood up and left the room. At this point the current state of the shared whiteboard was saved and the experiment stopped.

### 3.0 Results

#### 3.1 The Group Slide

The output of each session was a slide, or in the case of task three a timetable, which represented the view of the group. Assessing the quality of each slide was difficult because in these tasks there were no right and wrong answers (this was particularly true for the creative task two). In an attempt to assess objectively the quality of the slides they were marked by two independent judges on a number of scales: clarity, coherence, and agreement with original task description. However, the judges felt that the content of the slides were so similar that it was impossible to distinguish between them. All groups managed to complete the tasks in the allotted time.

#### 3.2 Completion Times

There were 15 trials for each of the three tasks and the time taken to complete each of the 45 trials was recorded. The times for each task are shown in Figure 1.

##### *Variance due to differences in trial number*

In all three tasks there were no significant differences between the times taken to complete the task on the different trial numbers ( $P > 0.05$ ). Therefore, this data does not support the hypotheses that there are significant differences due to learning effects. However, it is possible that learning effects are present, but are being confounded by other variables, e.g. a 'novelty' effect, which increase the amount of time taken to complete the task over time, thus compensating for any learning effects. A number of studies have found the presence of a 'novelty' effect in this type of study. (Cook and Lalljee, 1968).

Condition Trial	Whiteboard	Whiteboard, and Audio	Whiteboard, Audio, Video	Condition Trial	Whiteboard	Whiteboard, and Audio	Whiteboard, Audio, Video	Condition Trial	Whiteboard	Whiteboard, and Audio	Whiteboard, Audio, Video
1	1560	900	960	1	1273	2635	1738	1	754	359	439
2	1680	1140	1680	2	1326	1198	931	2	681	169	361
3	1320	1380	960	3	1045	1235	1235	3	450	360	226
4	1254	1157	784	4	839	777	883	4	253	199	307
5	601	1099	1125	5	1222	861	1150	5	856	492	312
Mean	1283	1135	1101	Mean	1141	1341	1187	Mean	598	315	329

Task 1

Task 2

Task 3

Figure 1: Completion times (in seconds) for the three tasks

##### *Variances due to different conditions*

In task one and task two, a two way analysis of variance showed that the differences in completion times under the three conditions were not significant ( $P > 0.05$ ). In task three, however, there were significant differences ( $P < 0.05$ ) in the completion times between the three conditions. In this task the 'shared whiteboard only' condition was the slowest and the 'shared whiteboard plus audio' condition the fastest. In the previous two tasks the difference in average completion times between the different conditions was approximately 10%. In task three the difference between the slowest and the second slowest condition

amounted to 82%; the 'shared whiteboard only' (slowest) condition had an average completion time almost double that of the 'shared whiteboard plus audio' (fastest) condition.

Despite the large amount of variance within the conditions, there are significant differences between the conditions. However, it was the 'shared whiteboard plus audio' condition that was the fastest and not the 'shared whiteboard plus audio and video'. This means that the presence of the video channel has affected the performance of the group, although in this particular instance the overall effect was to increase the amount of time taken to complete the task. This is an important finding; using different media to communicate has, in this particular instance, had a significant effect on the time taken to complete the task. However, the effect is a complex one and these results emphasise that we cannot simply conclude that increasing the communication bandwidth reduces the completion time.

### 3.3 Dimensions of Social Interaction

The questionnaires provide approximate scores for key process dimensions which, on the basis of previous research (Christie, 1973; Christie, 1974; Short, Williams and Christie, 1976), are expected to be especially sensitive to differences between the variations of the workstation; these dimensions are: Social Presence, Task Focussing, Aesthetic Dimension and Team Working.

A number of studies (Champness, 1972a; Synder and Wiggins, 1970; Christie, 1973; Champness 1972b) have applied a semantic differential technique to social interaction when using different communication media. Subsequent factor analysis of the data has revealed a number of underlying factors, the exact number and nature of which differ from study to study. However, certain factors repeatedly appear; Social Presence and Aesthetic Appeal, are two such factors. In addition to these factors, Task Focussing, and Team Working were identified as possible factors that were of additional interest in this study.

Five questions that related to each dimension are grouped together on one page of the questionnaire, since research suggests this should raise the correlation between the different scales within a group (Oppenheim, 1966). Positive items were mixed with negative items in order to reduce any simple response biases.

#### *Social Presence*

Initial expectations were substantially lower than later expectations; as users gained more experience with the system their expectations increased. Even so, at the beginning of the final week, after two weeks using the system, users' expectations were still significantly below what they report after having used the system.

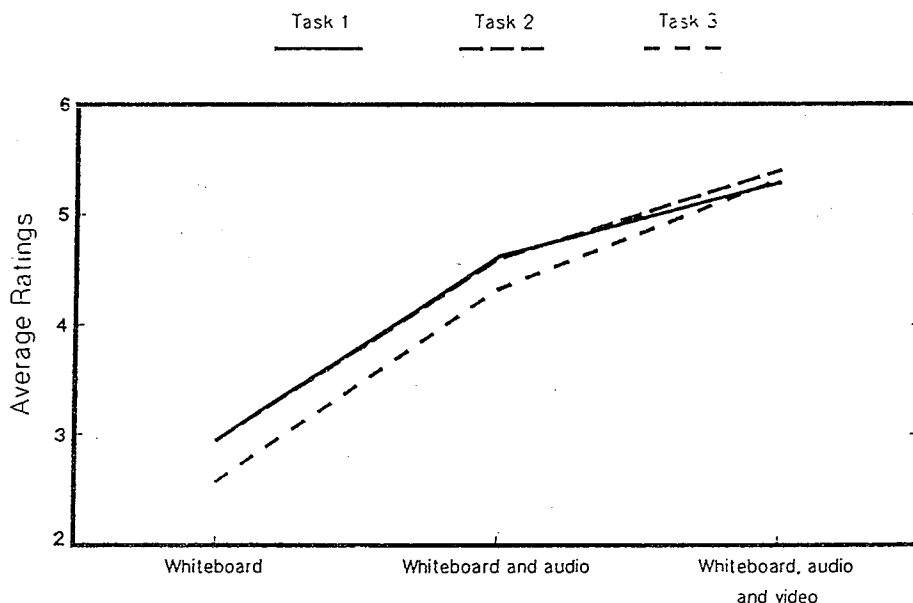


Figure 2: Ratings for Social Presence of the three different media

As the bandwidth of the communication media increased, so did the feeling of 'Social Presence'; the highest score was obtained under the 'shared whiteboard plus audio and video' condition, and the lowest under the 'shared whiteboard only' condition.

This factor was the most defined of the four factors under investigation. These findings agree well with previous work on other communication media (Christie, 1973; Christie, 1974; Champness, 1972b) which show that 'Social Presence' increases with the communication bandwidth. Factor analysis, performed in these studies, has shown this factor to be the second highest loaded, after 'Aesthetic Qualities'.

The other factors (aesthetic qualities, task focussing and team working), however, failed to show any significant trends. It seems likely that the questions relating to each factor are, in fact, not tapping a single underlying factor. By using factor analysis it might be possible to identify a number of factors that underlie the questions, but this is an area of research outside the scope of this current study.

### 3.4 Productivity

At the end of each week, the subjects were asked to fill in a questionnaire which attempted to assess productivity, on an individual, as well as a group level. The subjects were asked to assess productivity under two conditions: (1) if only the department in which they were working had the system, and (2) if the whole site had the system. Subjects were asked to estimate the percentage improvement due to the use of the shared whiteboard, the shared whiteboard plus audio, or the shared whiteboard plus audio and video.

#### *If only the department in which they were working had the system*

Generally speaking, the estimated productivity improvements decreased as the users gained experience with the system. This may be because over time they developed a better understanding of the system, and as a consequence gave a more accurate estimation of productivity, or it may be because of a "boredom" factor, as the weeks progressed on users got more disinterested in the system. It is impossible to identify the exact cause of this trend.

There was little difference between the estimations of their own productivity and that of the group. In both cases the estimation increases as the bandwidth increases, the major difference seems to be between the audio and non-audio media. Also it is worth noting that all the estimations are positive; no minus percentages were obtained on any of the questionnaires, although a number of 0%'s were encountered.

#### *If the whole site had the system.*

The estimations of productivity improvements were more extreme when it was assumed that the whole site had the system and the differences between audio and non-audio media become more clear. Also the estimations of improvements obtained from the questionnaires administered after task three were much lower than those obtained from the two previous tasks, much more so than those estimations obtained when assuming only the department had the system.

### 3.5 Time Saving

The subjects were asked to assess the amount of time they would save in a typical week under two conditions: (1) if only the department in which they were working had the system, and (2) if the whole site had the system. The subjects were asked for both the minimum and maximum amount of time they expected the system to save them in a typical week. Figures 3a and 3b show the results from these questions.

#### *If only the department in which they were working had the system*

From Figure 3a it can be seen that the minimum amount of "saved time" remained reasonably constant, between -16 minutes and -22 minutes. It is interesting to note that a negative estimation was achieved although all the estimations of productivity improvements were positive. A negative estimate of time saving indicates that users believe there was some overhead in using the system, i.e. the system may distract them, thus increasing the amount of time taken to complete certain tasks. The maximum estimated amount of time saved using the system increases with the bandwidth, again the main difference was between audio and non-audio media.

There may be factors, other than just time saving, involved in the estimated productivity improvements outlined in the previous section. Some of the productivity gains may be due, for example, to a more social or informal media, rather than to any direct result of time saving.

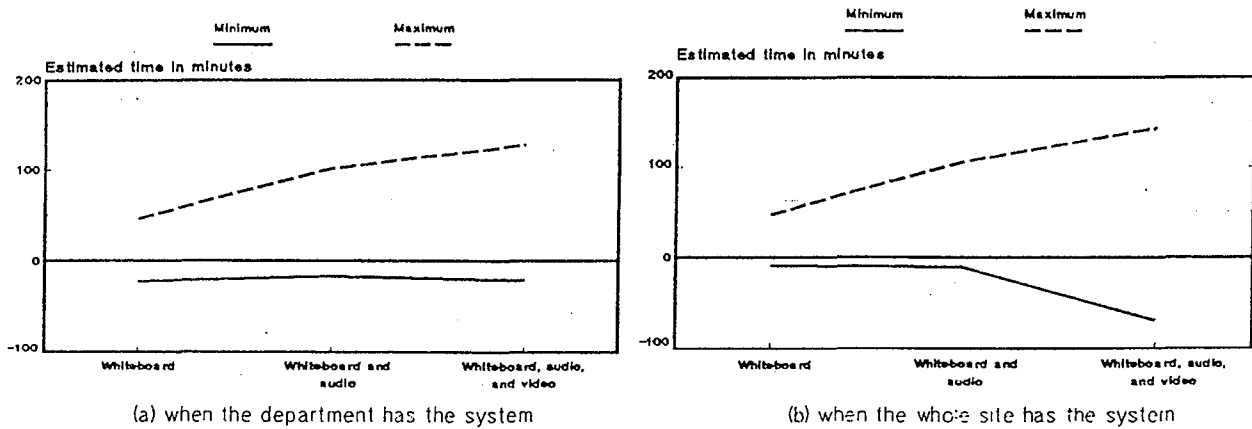


Figure 3: Estimated time savings (in minutes)

*If the whole site had the system.*

The maximum estimated time savings were approximately the same as when only the department has the system. However, the minimum estimates show some interesting results; the estimated time savings in the 'shared whiteboard, audio and video' condition show a large drop. One of the possible reasons for this is that as the system gets exposed to more people (a whole site rather than just a department) the opportunities to have informal, non work related, discussions grow. This may distract from the amount of time saved, and in fact, may cause people to spend more time to do the same amount of work.

These results are based on the expectations of the users who took part in the experiments. They were asked, from their relatively brief use of the system, to predict the productivity improvements they would expect as a consequence of using the system. It is difficult to know how accurate users' predictions are in these cases and these results might be no more than a good indication of how users felt about the system, rather than a real indication of productivity improvements.

3.6 Uses of the different media

It is important to assess the uses that were made of each of the different communication media. An attempt was made to assess the use of each of the three elements; the shared whiteboard, the audio channel and the video channel.

Two methods were used to assess the uses of each of these elements;

- (i) Subjects were asked two open ended questions, one related to when that communication medium appeared strong, and one related to when the medium appeared weak.
- (ii) Subjects were asked to rate the relative uses of each of the three elements on three seven point scales. For each element the three scales were;
  - (a) How much "data" was transmitted via this medium? "Data" was defined as information that actually appeared, or was proposed to appear, in the item the group was asked to produce.
  - (b) How much information about the data was transmitted via this medium? Information about the "data" was defined as information that was used to elaborate or explain the "data".
  - (c) How much "communication control" was transmitted via this medium? "Communication control" was defined as communication that controlled the flow of information between group members.

Condition Type of communication		Whiteboard, audio and video	Whiteboard and audio	Whiteboard
Data	W	6.12	5.90	6.17
	A	4.93	4.65	
	V	1.58		
Information about data	W	2.90	2.48	4.88
	A	6.55	6.10	
	V	1.75		
Communication control	W	1.62	1.67	4.55
	A	6.33	6.17	
	V	2.98		

Figure 4: Ratings for the uses of the three different media

#### *Uses of the Shared Whiteboard*

The results from the three rating scales show that the shared whiteboard was used mainly for the communication of data, that is, the transfer of data that appeared, or was proposed to appear, in the slide that the group was asked to produce. The only occasions when the shared whiteboard was used to communicate "information about the data" or "control information" was when no other media was available. Thus, it is not surprising that most of the responses to the questions about the strengths of the shared whiteboard related to problems encountered when attempting to present data.

The largest number of responses (20%) related to producing the final slide. 18% of the responses related to "Discussing/brainstorming", these responses, however, were only generated under the 'shared whiteboard only' condition; under this condition all the communication was via the shared whiteboard. The remainder of the responses related to the actual process of producing the slide. The shared whiteboard was seen as being useful when "Summarising/Collating information" (16%) and when "Structuring information" (13%). Groups produced lists of possible items and then structured them into a meaningful slide. A process by which the group shared information, "Sharing information" accounted for 11% of the responses.

"Independent writing" (15%) related to all the members of the group being able to type simultaneously. This feature was seen as being particularly attractive when combined with partitioned working. Partitioned working was a technique invented by many of the groups and involved splitting the shared whiteboard into quarters, one quarter for each member of the group. This allowed users to write simultaneously in their own area without disrupting other users.

Interestingly enough, when we look at instances when the shared whiteboard was perceived as being weak we find that the largest number of responses (37%) relate to problems caused by having multiple writers. Most of the problems arose when the workspace was un-partitioned and the different members of the group ended up writing on top of one another. However, even when the work was partitioned some problems were still encountered, such as one member of the group erasing the whole workspace accidentally when trying to determine how the erase function worked. There was no difference in the number of responses in this category between the three conditions, in other words, the addition of audio and video to the communication medium did not significantly help overcome problems caused by multiple writers.

11% of the responses related to the size of the display which was not large enough to display all of the data used throughout the task, so users had to erase parts of the display at different times. This, combined with a lack of a co-ordinated deletion function, caused many problems.

### *Uses of the Audio channel*

From the results of the rating scales it can be seen that the audio channel was perceived to be used for all three types of communication, although the audio channel was used more for the transmission of control information and information about the data, than for the transmission of the data itself.

The majority of responses, 46%, indicated that the audio channel was particularly effective for discussing the task. A further 32% of the responses indicated that the audio was used for planning how the group would tackle the problem. The planning phase is an important part of the problem solving process, since deciding on the right strategy can have a critical influence on the outcome. A large proportion of the time taken to complete the tasks was concerned with the planning phase of problem solving.

A relatively small fraction of the responses (4%) suggested that the audio channel was used to actually solve the problem. Other uses of the audio channel were helping the other members of the group overcome problems when their PC crashed (4%), or correcting mistakes that had been made (2%), or detecting the moods of the other members (4%).

29% of the responses indicated that the audio channel was weak when trying to assess the readiness of the other members of the group, particularly at the beginning and end of the sessions. Interestingly though, none of the responses in this category were generated when a video channel was present. This was only perceived to be a problem in the 'shared whiteboard plus audio' condition. One might conclude from this that the video channel is being used to assess the readiness of the other members of the group. "Collating information" accounted for 11% of the responses. Problems were encountered when the group attempted to maintain a long list of items via the audio channel, as the recall of such lists relies on the collective memory of the group.

A problem was encountered during some of the sessions when technical difficulties led to one member of the group being at a reduced volume. This caused difficulties in trying to hear all the members of the group. This led to 11% of the responses relating to "one contributor at reduced volume".

### *The Uses of the Video channel*

If we look at the results of the rating scales with respect to the use of video it will be seen that the use of video in the experiments was seemingly very limited. On the rating scales a score of 7 indicates extensive usage, a score of 1 indicates no usage and a score of 4 is half way between the two extremes. On these scales the use of the video channel never exceeded the mid point. The highest score was for the transmission of communication control, but even this did not exceed a score of three.

Despite the low ratings for the use of the video channel, the video tapes of the users during the experiments show that the video channel was used throughout the tasks. However, these ratings demonstrate that this use was not perceived by the subjects. This could be due to the fact that the use of the video channel was intuitive and transparent to the communication process.

The video channel was seen as being particularly effective when assessing the attention of the other members of the group (64%). Typically this involved seeing if people were sat down ready to start, if they were paying attention to what was being said, or if they had stood up and left the room. This seems like a trivial use of such a high bandwidth channel, but it was one which made a dramatic difference to the interaction process. Knowing when to start and stop was a critical part of the group interaction.

11% of the responses related to the transmission of data which was solely confined to task 3. In this task members of the group had to organise their individual timetables so they could hold a group meeting. On a number of occasions members of the group held up their timetables to the camera so that the other members of the group could see it.

Interestingly, only 14% of the responses indicated that the video channel was seen as being effective for "discussions" and a "more personal medium".



61% of the responses stated that the use of video was poor "while working". The tasks being performed required the subjects to read material, both on and off the screen. During these activities the subjects' eyes were diverted away from the video monitors and towards what they were working on.

13% of the responses stated that the video was weak during discussions. A number of these responses mentioned poor eye contact specifically, whereas other users simply stated that it was difficult to talk to the other members of the group directly. This problem is easily solved when there are only two participants - by using a half silvered mirror a camera can be placed directly behind a monitor. However, this solution is not so effective for multiple way conferences, because if eye contact is achieved with one person it is achieved with everybody (because everybody sees the same view). To get around this problem multiple cameras per workstation could be used so that each person receives a different view for each of the speakers. (For more details see Kelly (1983))

Another 13% of the responses related to technical problems encountered during the experiments, mostly due to poor lighting. The experiments took place in a 'normal' office environment and no modifications were made to improve the lighting conditions. The greatest problems were caused when there was a significant amount of lighting behind the subject and little lighting on the subject themselves.

#### 4.0 Discussion

The quality, and the content, of the output of the groups was felt to be so similar that it was pointless to attempt to mark them. As far as the completion times are concerned, with the exception of task three, the differences in the times recorded were non-significant with respect to both the different conditions and the increasing number of trials. However, when the group was asked to assess their productivity it was found that estimated productivity increased as the communications bandwidth increased.

Current models of communication media, including video teleconferencing, rely on an input-output model. Certain things are put into the system and there are certain effects on the output as a consequence. The media themselves are treated as a black box; little attention is paid to what goes on inside and the emphasis is on the inputs and outputs.

Communications media do not comply with this model. Research has shown that, for certain tasks, audio and video telecommunication technologies are no more effective, and sometimes less effective, than audio-only communication (Short, Williams and Christie, 1976; Johansen, Vallee and Spangler, 1979; Pye and Williams, 1977). Short, Williams and Christie (1976) suggest that media affects subtle interpersonal communication, than directly affecting task orientated interaction.

It is noteworthy that generally we do not find media effects at the level of the task outcome, but only at the more subtle level of the person-to-person interaction that precedes task completion. How much of this interaction is directly related to the task, and how much is social, we do not know, but we would hypothesize that many of the media effects observed at this level reflect a greater emphasis on social, as opposed to directly task-orientated interaction over the warmer more sociable media such as face-to-face.

(from Short, J., Williams, E., and Christie, B., 1976; page 87)

The results from this study suggest that by adding audio and video to the communications medium we allow groups to perform more "social" activities. The results from the estimated time savings (see figure 3) show a large drop when the whole site has a system with shared whiteboard, audio and video. When subjects were asked for the reasons behind these low estimations they stated that they felt they would spend time chatting to their colleagues and not getting on with their work. The social presence ratings increase as the communications bandwidth is increased.

A possible reason for the lack of difference in the quality of the output of the groups is that the tasks used in this study were not sensitive to social factors. If, for instance, we had used team building type tasks the outcome might have been very much different.

Team work is at the heart of nearly every industry. Yet working in teams is essentially a social process, a process which relies on frequent, informal communication which is both high quality and has a low initiation overhead. Kraut and Egido (1988) show how frequent, informal communication plays a critical role in the collaborative relationships formed between researchers. However, despite its enormous potential impact, this is an area hardly touched upon by office systems. The growth in recent years of the personal computer has put increasing emphasis on the individual, and it is only now, with the emergence of CSCW, that this balance is beginning to be reassessed.

Although, the potential benefits of such a system are great, so too are the potential pitfalls and side effects. Designing systems that are intended to directly impact social structures and team working is an issue which should not be taken lightly. Successful design will rely on careful and comprehensive evaluation of the effects of such systems on their users. Such evaluation marks a change of emphasis, away from human-computer interaction and towards an approach which analyses human-human interaction and considers the technology merely as a mediator. This causes problems for traditional HCI methodologies, such as video taping users as they interact with their computers, or performing keystroke analysis. These are not effective ways to studying how groups work together.

As the emphasis moves towards human-human interaction we find ourselves dealing with interaction which is highly dependent on social factors. This makes direct comparisons between laboratory experiments, and the real work situations very difficult. Not only this, but there is also a large set of individual differences at work. As we study social interaction we need to take social skills into account, as well as considering how the different skills of the group members interact with one another. Also social issues can tend to be more long term, taking possibly months to come to the surface, and consequently they are not going to be revealed in a one hour experiment.

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