VIDEODRAW: A VIDEO INTERFACE FOR COLLABORATIVE DRAWING

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ABSTRACT

This paper describes VideoDraw, a shared drawing tool, and the process by which it is being designed and developed. VideoDraw is a prototype, video-based, tool that provides a shared "virtual sketchbook" among two or more collaborators. It not only allows the collaborators to see each others' drawings, but also conveys the accompanying hand gestures and the process of creating and using those drawings. Its design stems from studying how people collaborate using shared drawing spaces. Design implications raised by those studies were embodied in a prototype, which was in turn observed in use situations. Continued research studying the use of VideoDraw (in comparison with other collaborative media) will lead to a better understanding of collaborative drawing activity and inform the continued technical development of VideoDraw.

KEYWORDS: collaborative systems, design process, work practice analysis, gesture, video, user interface

INTRODUCTION

As new technology is developed to support collaborative work, it is important to understand how that technology can best be applied to help people accomplish their work. Over the past several years, an interdisciplinary working group, known as the Designer Interaction Analysis Laboratory (DIAL)[1], has been studying collaborative work activity. The aims of this research are both to understand collaborative activity and to build tools to support that activity. Studying actual work activity leads to an understanding of how the participants accomplish their work. Based on that understanding, design implications for tools to support this activity can be identified and embodied into prototype tools. The use of these tools can in turn be studied, leading to a better understanding of the work activity and further design implications for improving the tool being developed. Tatar [1989] describes the methodology emerging from this research of integrating work practice analysis with tool design.

Recently, DIAL has been focusing on the activity that occurs when two or more people work using a shared drawing surface—what we refer to as shared drawing space activity. Much human collaboration involves a shared drawing surface (e.g., paper sheets, chalkboards, computer screens, cocktail napkins); recent research is exploring computer support for such shared workspaces [Greif, 1988]. DIAL's studies indicate that many computational collaborative tools do not support aspects of shared drawing activity that our focused observation reveals to be important. We have come to view shared drawing space activity as encompassing not only the resulting sketches left on the paper, but also the talking, writing, drawing, and gesturing activity involved in creating and making use of those sketches.

This paper describes VideoDraw and illustrates how studying it in use has led to new insights into shared drawing activity as well as improvements in its design. We begin with some observations about

[1]DIAL is a working group consisting of designers, computer scientists, and anthropologists within the System Sciences Laboratory at Xerox PARC. This paper expresses several insights that have arisen in DIAL meetings. The members of DIAL at the time of this work were: Sara Bly, Francoise Brun-Cottan, Brigitte Jordan, Scott Minneman, Lucy Suchman, John Tang, Deborah Tatar, and Randy Trigg.

shared drawing space activity that have arisen in DIAL's studies. We describe VideoDraw, a prototype shared drawing tool that embodies some of the design implications raised by these observations. It uses video to create a shared "virtual sketchbook" among collaborators. Based on preliminary observations of VideoDraw in use, we discuss some of its features and compare it with other collaborative media.

OBSERVATIONS ON SHARED DRAWING ACTIVITY

The DIAL working group has been studying videotapes of drawing space activity collected from a variety of situations, including sessions of:

- pairs of collaborators specifying designs for a computer system, using a whiteboard [Suchman and Trigg, forthcoming],
- small teams (2-4 people) of designers working on human-machine interface design tasks, using large sheets of paper on a table [Tang, 1989; Bly, 1988] ,
- a small team of researchers planning research programs and papers, using a collaborative software tool in a computer-augmented meeting room (Colab) [Tatar et al., in prep.], and
- a team of architects conceptualizing a futuristic office design working remotely using audio-video links (Media Space) [Stults, 1988].

In the course of these studies, we noted three aspects of drawing space activity that have design implications for tools to support that activity:

- hand gestures are used prominently and productively,
- timing relationships help the participants understand the drawings created, and
- timing relationships and spatial arrangement help the participants negotiate the use of their shared drawing surface.

We observed that much of the group's collaborative activity involved hand gestures, and that these gestures accomplish substantive work: to act out a sequence of events; to refer to a locus of attention; or to mediate their interaction (e.g., raising a hand to take a turn of talk). Furthermore, we noticed that these gestures are often conducted in relation to a sketch or object in the drawing space (e.g., acting out a behavior over a sketch, pointing to a drawing). These observations indicate that it is important to convey hand gestures among collaborators, and to do so in a way that maintains the relationship between the gestures and their referents in the drawing space. We also observed that the significance of shared drawing activity extends beyond the resulting marks made in the drawing space. These marks often do not make much sense when viewed by themselves afterwards. It is through the process in time of creating and referring to those marks that the group comes to understand what the marks mean. The coordination in time among drawing, gesturing, and the explanatory talk is also an important resource for interpreting the marks. The value of these timing relationships is further indicated by interactional difficulties observed in work settings where the timing was disrupted, as will be discussed later.

In face-to-face interaction, negotiating the use of a shared drawing surface also involves intricate relations in time (e.g., timing when to add a drawing to get the group's attention) and space (e.g., coordinating hand motions to avoid collisions over the drawing surface). Often more than one collaborator is active in the drawing space at the same time, yet their ability to smoothly negotiate this activity in time and space avoids any confusion. Collaborators rely on a familiar sense of time and space to negotiate sharing a drawing surface.

The spatial arrangement between the collaborators and the drawing surface is another factor that influences negotiating the use of a shared drawing surface. For example, when using a wall-mounted chalkboard, the participants usually have to leave their seat and walk up to the chalkboard to work at it. Alternatively, if the collaborators are working around a table with large paper sheets in their midst, everyone can easily reach the drawing surface. However, some drawings may appear upside down or at odd orientations to some participants, a problem that does not occur when viewing a chalkboard. As will be discussed later, VideoDraw offers a different sense of spatial arrangement between the participants and the drawing surface.

VIDEODRAW: A COLLABORATIVE DRAWING TOOL

VideoDraw is a tool to support collaborative drawing activity that embodies design implications based on observations from DIAL's studies. We designed and implemented a 2-person VideoDraw prototype and studied how people used it in actual collaborative activity.

The Design of VideoDraw

A schematic diagram of VideoDraw is shown in Figure 1. In this configuration, VideoDraw allows two people to share a drawing surface. It consists of video cameras aimed at the display screens of video monitors, interconnected as shown. The participants use whiteboard markers (dry erase ink markers) to draw directly on the surface of the display screen.

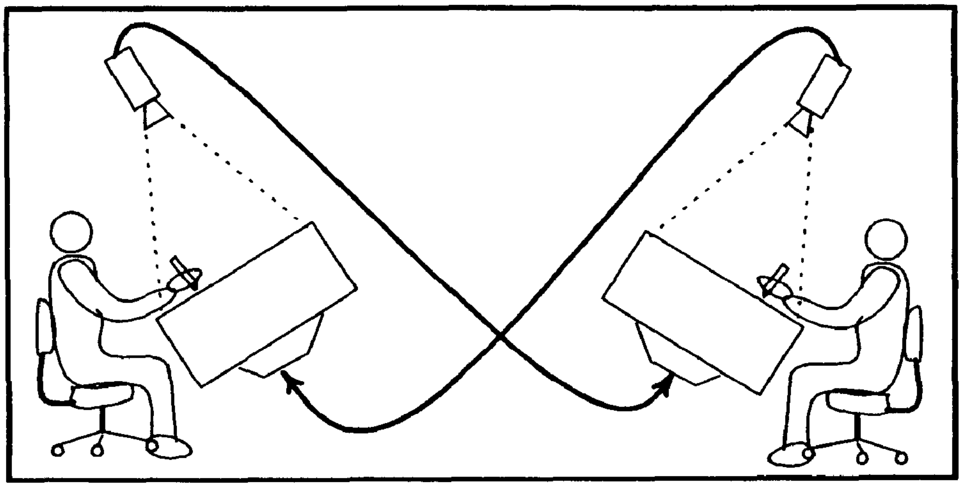

Figure 1: Schematic diagram of 2-person VideoDraw

As each collaborator draws on the screen, the video camera transmits those marks *and* the accompanying hand gestures to the other collaborator. Each collaborator can add to a sketch that appears on the display screen, and those additional marks and gestures are transmitted back to the other collaborator. At all times, a complete image consisting of real and "video" marks is visible on all the collaborators' screens. The collaborators can draw, erase, and gesture over the VideoDraw screens much as if they were sharing a pad of paper.

Video feedback between the two camera/display pairs is controlled by polarizing filters on the camera lenses and nearly orthogonal polarizing sheets covering the surface of each display screen. Pictures of a 2-person VideoDraw configuration and a view of a VideoDraw screen as seen by the participant are shown in Figures 2 and 3. If the stations are located in remote locations, additional communication links (e.g., audio, visual) between the collaborators may be desired. Although the utility of VideoDraw is most clearly demonstrated in the context of supporting the shared drawing activity of people in physically remote locations, the insights emerging from studying its use have implications for collaborative work in general.

Studying the Use of the Prototype

A prototype version of a 2-person VideoDraw has been operational for several months. During that period, we have videotaped several informal uses and one extended use of the system. In the observed informal uses, VideoDraw was set up within one room, as in Figure 2, and pairs of colleagues were invited to experience using it. The participants typically worked on a small problem of their own choosing for 5-10 minutes.

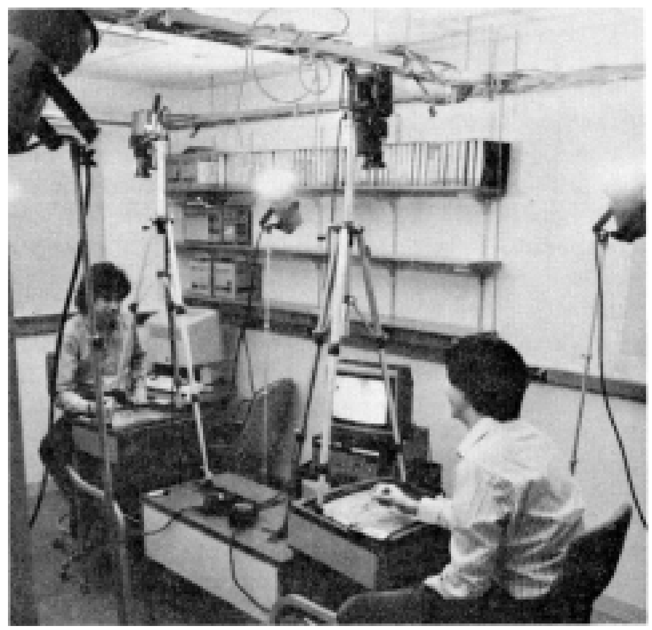

Figure 2: Prototype setup of a 2-person VideoDraw

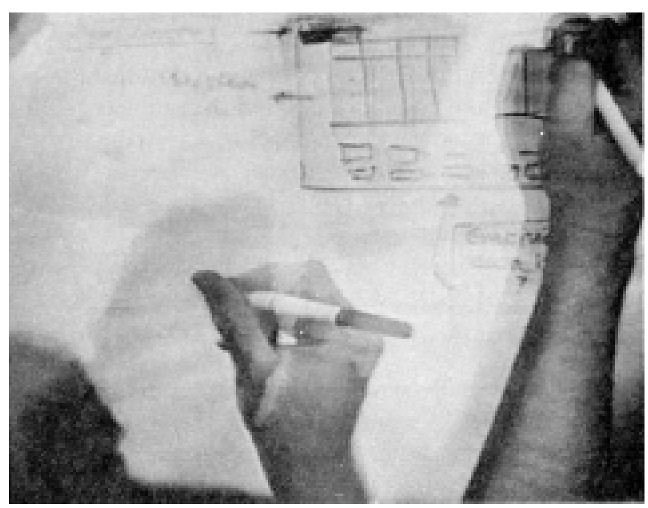

Figure 3: Participant's view of a VideoDraw screen

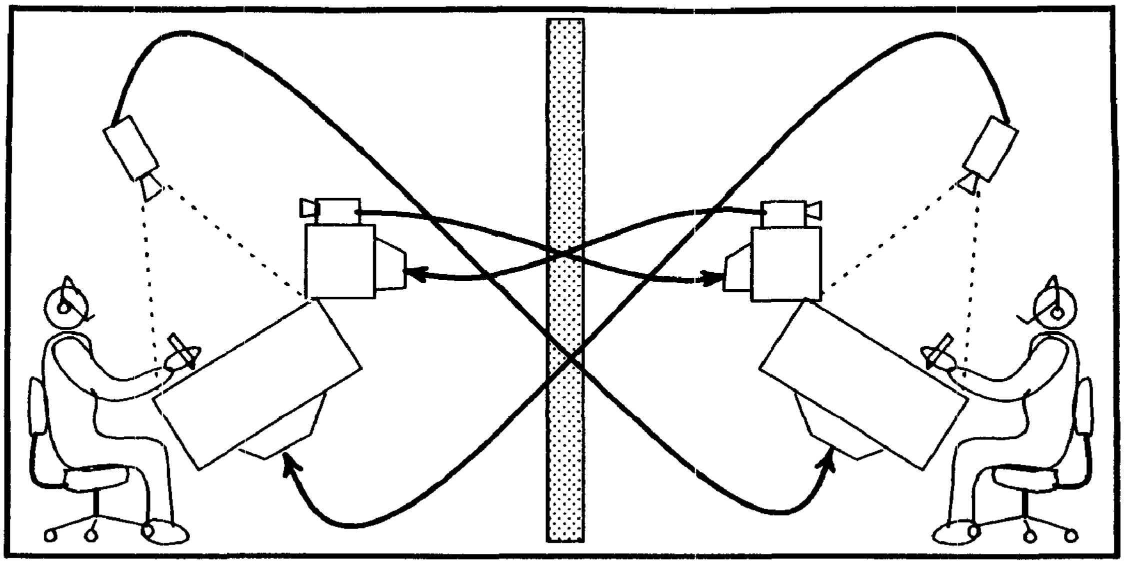

Figure 4: Schematic diagram of VideoDraw connecting remote locations

In the extended use of VideoDraw, the stations were placed in separate rooms and connected by an audio-video (Media Space) link. Each participant not only had a VideoDraw station, but also a video camera and monitor conveying a frontal view of the collaborator's face and upper body. Telephone headsets provided a full-duplex audio connection. A schematic diagram of this setup is shown in Figure 4. The participants worked on a user interface design task of their own choosing for approximately 1-1/2 hours, and the session was recorded on videotape.

FEATURES OF THE USE OF VIDEODRAW

Based on DIAL's studies of shared drawing activity and our preliminary observation of VideoDraw in use, we have identified some distinctive features of how VideoDraw is used as a collaborative drawing tool. We have observed that VideoDraw:

- conveys hand gestures among the participants,
- does not introduce problematic time delays into the interaction,
- affords a novel sense of spatial relationship among the collaborators and drawing space, and
- allows multiple participants to have concurrent access to the drawing space.

These features are discussed individually and illustrated with examples from our observed uses of VideoDraw.

Conveying Hand Gestures

Although there is a long history of studying gesture [Kendon, 1986], we focused on the use of hand gestures in relation to drawing and other activity in the drawing space. DIAL's studies of drawing space activity indicated the importance of conveying hand gestures and their relationship to the drawing space. Hand gestures are often enacted with respect to sketches on the drawing surface to convey information. Figure 5 shows how these hand gestures are conveyed in VideoDraw; one participant is gesturing to indicate an operation on an object in a proposed user interface. The effectiveness of gestures of this type depends on maintaining the relationship between the hands and the sketches on the screen. A sequence of actions can be enacted with respect to a drawing on the screen or specific locations on the screen can be pointed at, and those gestures and their referents are communicated to the other collaborators.

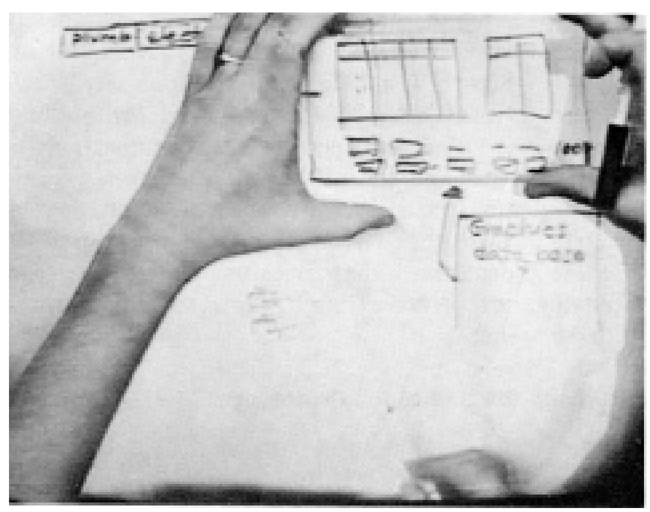

Figure 5: Conveying gestures in VideoDraw

Furthermore, Figure 5 shows that VideoDraw conveys gestures that may involve two hands and/or multiple fingers. It also conveys a sense of 3-dimensional activity. Users can enact gestures in space, or even bring physical objects into the view of the camera, and a 3-dimensional sense of spatial relationship is conveyed to the other participants. We observed several uses of this sense of 3-dimensionality.

Preserving Relationships in Time

DIAL's studies of drawing space activity showed that the collaborators rely on intricate relations in time among various activities. For example, one problem observed in Colab, a computer-based collaborative tool, was that the computer sometimes introduced processing and transmission delays. These delays could disrupt the timing relations between the group's dialog and what was appearing on the computer screens [Tatar et al., in prep.]. In the current implementation of VideoDraw, using full-bandwidth video connection, there are virtually no transmission delays between the two screens. Figure 6 indicates how a collaborator can time a diectic reference with pointing at the object on the screen. The collaborators can coordinate the timing of their activities much as they would be able to in familiar face-to-face settings.

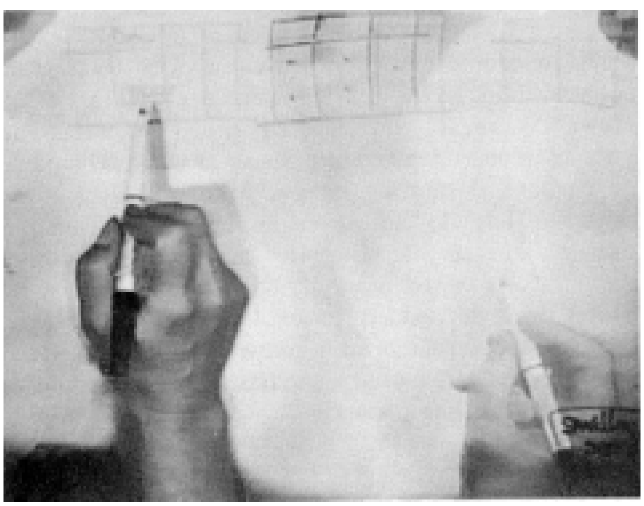

Figure 6: Pointing, coordinated with saying "you've got this already?"

Offering a Novel Sense of Spatial Arrangement

In DIAL, we also observed that shared drawing activity is structured by the spatial relationships among the collaborators and the drawing surface. In VideoDraw, each collaborator can see the drawing surface in a proper orientation, as if looking at a chalkboard together. Anyone can also easily reach in to work on the drawing surface at any time (as if working around a table), since each collaborator is positioned directly in front of a VideoDraw station. VideoDraw allows both a common orientation to the shared drawing surface and easy access to it by multiple collaborators. Figure 7 shows sketches and lists where both participants were involved in creating the marks, taking advantage of this common orientation and easy access.

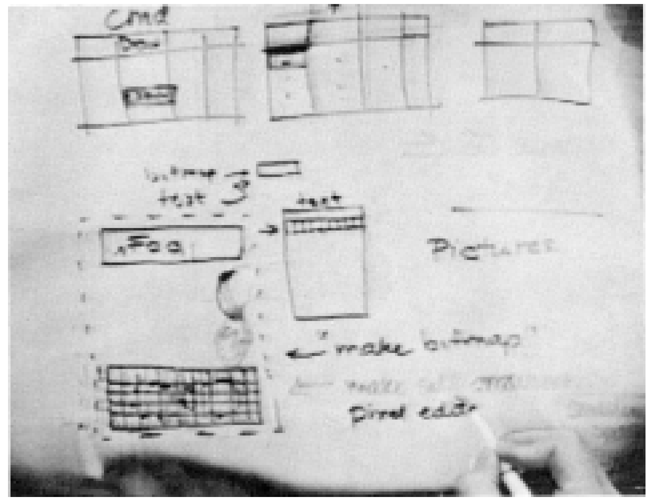

Figure 7: Collaboratively constructed image (lighter marks are from one participant, darker marks are from the other)

Allowing Concurrent Access

DIAL's studies noted that drawing space activity often involves more than one person being active in the drawing space at the same time. While this concurrent activity might be considered to be a source of confusion for the collaborators, we found that being able to access the drawing space at the same time was actually crucial to their ability to smoothly negotiate their collaborative use of it. By analogy to sharing an audio channel, people usually avoid speaking over each other's talk for an extended period of time. However, having concurrent access to the audio channel (including overlapping or interrupting speech) is actually a valuable resource for accomplishing smooth turn-taking in talk [Goodwin and Goodwin, 1987]. The use of this resource is demonstrated by the problems encountered in using half-duplex audio connections, which only transmit one party's talk at a time. In overseas telephone lines and some video teleconferencing facilities, half-duplex connections contribute to making it difficult to achieve smooth turn transitions.

Similarly, concurrent access to the drawing space is an important resource in negotiating the use of a shared drawing surface. Figure 8 shows two participants' hands working over the screen at the same time. It also shows that their hands can actually be closer to each other than if they were physically sharing the same drawing surface. VideoDraw offers even greater concurrent access to the drawing space than is conventionally possible. We have observed instances of the use of concurrent access to help negotiate sharing the drawing surface.

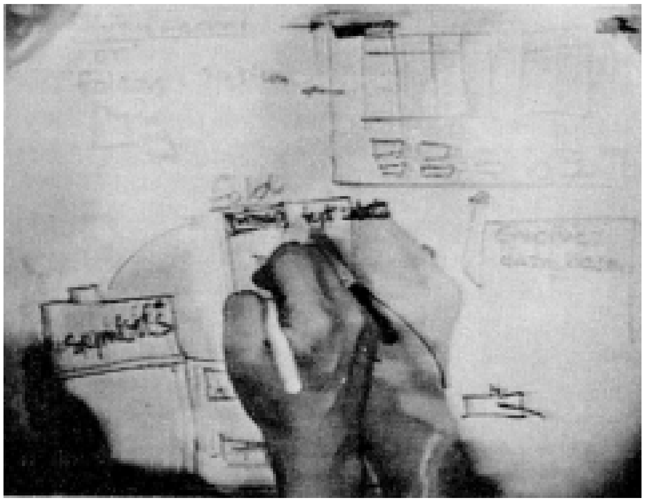

Figure 8: Multiple hands active over a VideoDraw screen

Constraints in Using VideoDraw

The fact that each participant's marks are actually made and presented on different surfaces results in some constraints in the use of VideoDraw. Each participant can only erase marks made on his or her own screen, and cannot edit the marks of the other collaborator. Several incidents where one collaborator requested that the other erase some marks were observed. Also, because of the thickness of the glass screens on the video displays, there is a noticeable amount of parallax between the marks drawn on the surface of the screen and the video image of the other participant's marks appearing on the phosphor of the screen. This parallax sometimes made it difficult to correctly align marks between the participants.

On the other hand, these constraints can be used creatively by the participants. For example, the marks drawn directly on the screen surface and the video marks appearing on the screen are of noticeably different intensity and resolution, as can be seen in Figures 7-8. This dissimilarity sometimes leads to problems in being able to view a collaboratively constructed VideoDraw sketch as a single image. In one of the observed sessions, where the participants were working on an architectural layout, the collaborators used this property to create two distinguishable drawing layers, much like separate sheets of tracing paper. One participant drew the lines representing a first floor plan, while the other added the plans for the second floor directly over the first. They were able to use this constraint as a resource to permit viewing the floor plans superimposed in a single view.

OTHER COLLABORATIVE MEDIA

It is instructive to compare VideoDraw with other collaborative media. Computer-augmented meeting rooms [e.g., Stefik et al., 1987; Mantei, 1988] and shared window systems [Lantz, 1986] are computational systems that support collaborative work. These systems make available much of the computing power of personal computer workstations to participants in a collaborative context. However, as mentioned earlier, computers often introduce time delays that can disrupt group interaction. Computers also do not effectively transmit hand gestures (other than a cursor tracking hand motions). Furthermore, computational systems tend to dilute personal distinctions in drawing space activity (e.g., typed input vs. handprinting, non-distinguishable cursors vs. hands), diminishing the identification cues that are available to the collaborators. Smith [1988] explores how to provide some of these cues in a shared virtual world with a system known as SharedARK.

Video teleconferencing systems use video to support collaboration across remote distances [Egido, 1988]. However, most conventional video conferencing systems focus on providing views of the participants or perhaps presenting images from one site to the other. They do not offer an interactively shared drawing surface that both sites can work on, limiting the kind of shared work that can be accomplished. More work is needed to explore how VideoDraw could be constructed with reduced bandwidth video technologies often used in video teleconferencing to transmit over long distances.

VIDEOPLACE [Krueger, 1982] is a novel interactive computer system that was demonstrated in a collaborative configuration at CHI '89. Using a live video image of a participant and converting it in real time to a computationally represented silhouette, it can detect features from the video signal as input to a variety of computational operations. One application enables participants to use their fingers to "draw" in space. VideoDraw differs from VIDEOPLACE in that VideoDraw offers a sense of 3-dimensionality by using the actual video image, not a computational silhouette of the image. In VideoDraw, the drawing surface is overlaid directly on top of the display surface, whereas in the demonstrated version of VIDEOPLACE the input (interacting in space) and output (watching a computer monitor) were separated. VideoDraw offers a different perceptual experience among the collaborators than VIDEOPLACE.

We are not posing VideoDraw as a replacement to these other collaborative systems. Rather, we want to use VideoDraw to examine collaborative activity from a new perspective to identify what elements of shared activity are crucial to the interaction. Our intent is to provide designers of collaborative systems with a clearer sense of the impact of their design decisions on how their systems will be used.

CONCLUSION

VideoDraw is a novel tool to support collaborative drawing activity. Its design incorporates studying collaborative work practice with developing the technology. The design of VideoDraw came as a direct result of noticing some substantial resources being used in collaborative work activity (e.g., hand gesture, timing relationships) that were not being supported by existing computational collaborative tools. Observing VideoDraw in use is helping us further probe collaborative work activity from a new perspective and reveal ways in which VideoDraw can be improved. The development of VideoDraw is itself a demonstration of the value of integrating studies of work practice in the design process.

Based on studies of shared drawing space activity, we constructed a VideoDraw prototype that conveyed hand gestures, did not disrupt timing relationships, offered a new sense of spatial relationships, and allowed concurrent access to the drawing space. Preliminary observations of VideoDraw in use indicate that it provides collaborators with an enhanced sense of interaction not found in conventional computer-supported collaborative tools.

In studying collaborative activity, DIAL has adopted the term "co-presence" to describe a sense of awareness among collaborators that facilitates group interaction. Although we are only beginning to articulate the various dimensions of what this term means, we assert that a sense of co-presence among collaborators who are remotely located is enabled by making available to them resources that are used in face-to-face interaction. Based on our observation of VideoDraw in use, we believe that it affords a heightened sense of co-presence compared to current computer-based collaborative tools. The video image superimposed on the drawing surface appears to provide participants with a greater sense of awareness of their collaborators. Seeing the marks on the drawing surface and the video image transmitting the gestures and sense of space around those marks provides an awareness that helps the collaborators interpret the marks and negotiate using the shared drawing space.

Understanding what aspects of VideoDraw help create this sense of co-presence will require further study. A better definition of what co-presence is and how tools can provide or augment a sense of co-presence among collaborators is needed. By studying co-presence and how to provide it, we hope to understand collaborative activity better and refine the design of VideoDraw to support it more effectively.

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