VIDEOWHITEBOARD: VIDEO SHADOWS TO SUPPORT REMOTE COLLABORATION

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ABSTRACT
VideoWhiteboard is a prototype tool to support remote shared drawing activity. It provides a whiteboard-sized shared drawing space for collaborators who are located in remote sites. It allows each user to see the drawings and a shadow of the gestures of collaborators at the remote site. The development of VideoWhiteboard is based on empirical studies of collaborative drawing activity, including experiences in using the VideoDraw shared drawing prototype. VideoWhiteboard enables remote collaborators to work together much as if they were sharing a whiteboard, and in some ways allows them to work together even more closely than if they were in the same room.

KEYWORDS: collaborative systems, shared drawing, gesture, video, user interface, design process.

INTRODUCTION
Over two thousand years ago, Chinese artisans began entertaining the imperial court with shadow plays [March, 1938]. This form of drama uses brightly colored flat puppets that are pressed against the rear surface of a backlit screen, casting shadows that can be seen by the audience in front of the screen. The puppets project distinct shadows onto the screen while the shadows of the rods that are used to manipulate the puppets are barely perceptible to the audience. An Indonesian variety of this art form, *wayang kulit*, is shown in Figure 1. VideoWhiteboard uses a similar shadowy effect to help remote collaborators work together.

Figure 1: Scene from a shadow play performance

Sharing a common drawing space is an important resource needed for interactive graphical communication between collaborators who are physically remote from each other. This need for a shared drawing space was noted in a study of collaborators in a software design project that was distributed between two remote sites [Olson & Bly, in press].

Over the last decade, several systems have been developed that partially address this need. O'Boyle et al. [1979] reported on the development of an electronic blackboard for teleconferencing. Many current video teleconferencing facilities include overhead cameras or video copy stands for presenting images of drawings to remote collaborators. Collaborators who are separated by geographical distance tell tales of sending faxes back and forth while talking on the phone in order to have timely interaction over graphical information. Shared window systems that enable people to interact over a common view of text and

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graphics through a computer network have also become available (see [Lauwers & Lantz, 1990] for a review). These approaches, however, are often clumsy or limited in their ability to support fluent interaction over drawings in a way that people are familiar with from face-to-face collaboration.

VideoWhiteboard is one of a series of prototype tools that support collaborative drawing activity in a natural and familiar way. It uses video technology to connect whiteboard-sized drawing surfaces between remote locations. It provides a shared "virtual whiteboard" that allows collaborators to interactively create marks and see shadows of each others' gestures in relation to those marks. Remote collaborators can draw on, erase, and gesture at the VideoWhiteboard screens much as if they were interacting around a shared whiteboard. The development of VideoWhiteboard is based on our empirical studies of collaborative drawing activity [Tatar, 1989] and is closely related to the VideoDraw prototype [Tang & Minneman, 1990].

This paper describes VideoWhiteboard and the process by which it is being developed. We begin with a review of VideoDraw and describe how our experiences with VideoDraw led to the development of VideoWhiteboard. Then we describe what Video-Whiteboard is and report on early observations of people using it. Finally, we discuss some issues raised in these preliminary observations of the use of VideoWhiteboard, both about the design of the prototype and about collaborative drawing activity in general.

EXPERIENCES WITH VIDEODRAW

VideoDraw [Tang & Minneman, 1990] is a prototype tool that enables collaborators to share a video sketchpad. A schematic diagram of a 2-person VideoDraw is shown in Figure 2. It consists of an interconnection of cameras aimed at video display screens. Users draw on the video display screen (using dry erase whiteboard markers) and those marks and accompanying hand gestures are imaged by the camera and displayed on the other screen. This arrangement creates a composite shared drawing surface where the collaborators can see each other's marks and the hand gestures that are made in relation to those marks. Figure 3 shows a typical view of a VideoDraw screen.

While the design of VideoDraw was informed by studies of collaborative drawing activity, studying VideoDraw in use also contributed to a better understanding of that activity and the development

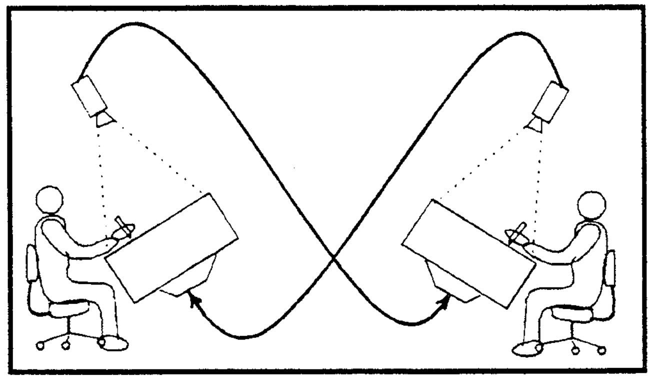

Figure 2: Schematic of 2-person VideoDraw

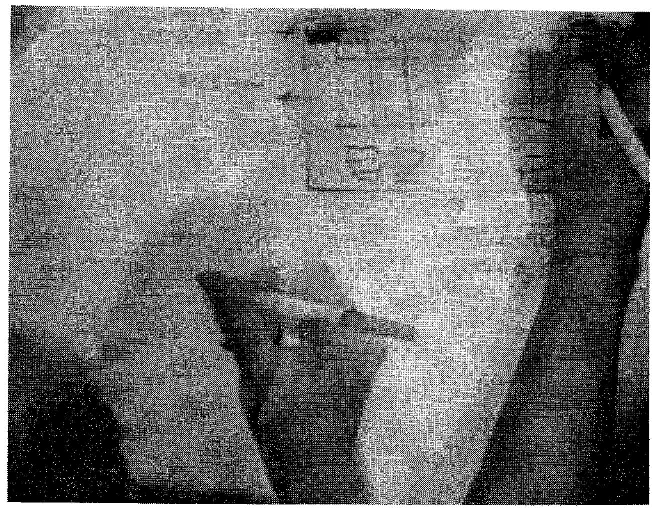

Figure 3: User's view of a VideoDraw screen

of other collaborative drawing prototypes. An idealized representation of this development process is shown in Figure 4. An interdisciplinary working group of anthropologists, computer scientists, and designers applied interaction analysis methods to study videotape records of face-to-face collaborative work [Tang et al., 1990]. The analysis focused on drawing activity, and a subset of the observations from this analysis led to the design of VideoDraw. Observing how people used VideoDraw and comparing it to how people work face-to-face led to the development of VideoWhiteboard. Although this idealization implies a linear sequence of steps, the actual process involved alternating between looking at various kinds of collaborative work (face-to-face, using VideoDraw, using other shared drawing tools) and modifying the designs of VideoDraw and VideoWhiteboard.

Our observations of people using VideoDraw confirmed that they often used hand gestures to enact simulations or mediate their interaction, and that these gestures were often made with respect to a referent sketch in the drawing space. Using

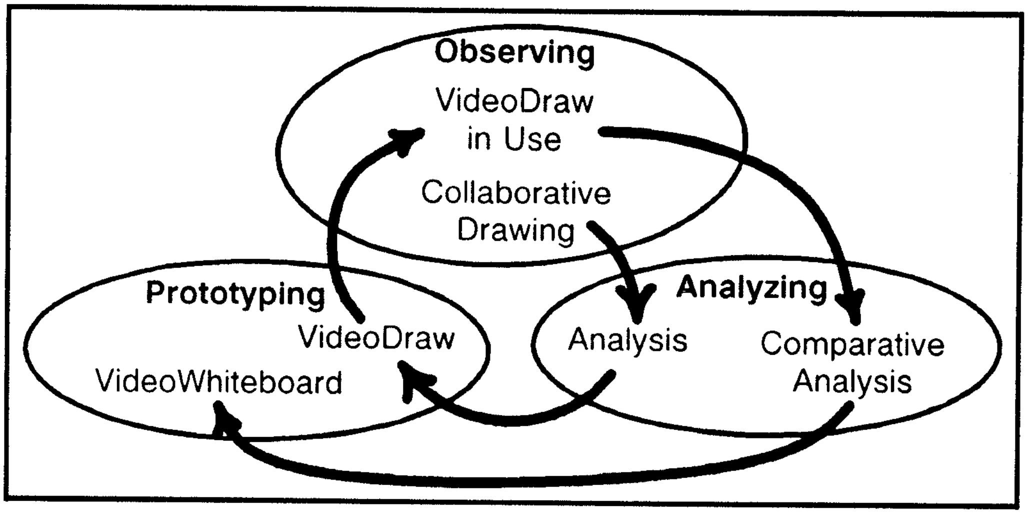

Figure 4: Iterative development of tools to support collaborative drawing through observing work practice, analyzing that activity, and building prototypes

VideoDraw, remote collaborators were able to see the process of creating and referring to drawings (rather than just seeing the resulting drawings), which is an important resource in shared drawing activity. Collaborators even occasionally used VideoDraw to be drawing in the same place at the same time, an interaction which cannot be accomplished when working together over a single drawing surface. Furthermore, VideoDraw helped us explore new ways of providing a sense of co-presence among remote collaborators. The video image of the users' hands working together over the drawing surface provides a different sense of presence than, for example, cursors interacting in a computational sketchpad.

We also observed several limitations in the use of VideoDraw. The relatively small video display screens (20" diagonal) restricted the amount of text and graphics that could be drawn before effectively filling the screen. Parallax sometimes made it difficult to align marks made by the users because of the glass thickness between the phosphor layer of the display (where others' marks appeared) and the glass surface of the display (where a user's marks were drawn). Users could only erase the marks made on their own screen and sometimes needed to request others to erase their marks. Straddling an upward facing CRT display while at the same time avoiding blocking the overhead camera with one's head is uncomfortable and compounded the parallax viewing problem. In addition to suggesting modifications to the design of VideoDraw, these observations informed the design of Video-Whiteboard.

VIDEOWHITEBOARD: A TOOL FOR SHARED DRAWING

VideoWhiteboard is a video-based prototype tool that provides a large area shared drawing space between remote sites. A schematic of a Video-Whiteboard system between two sites is shown in Figure 5.

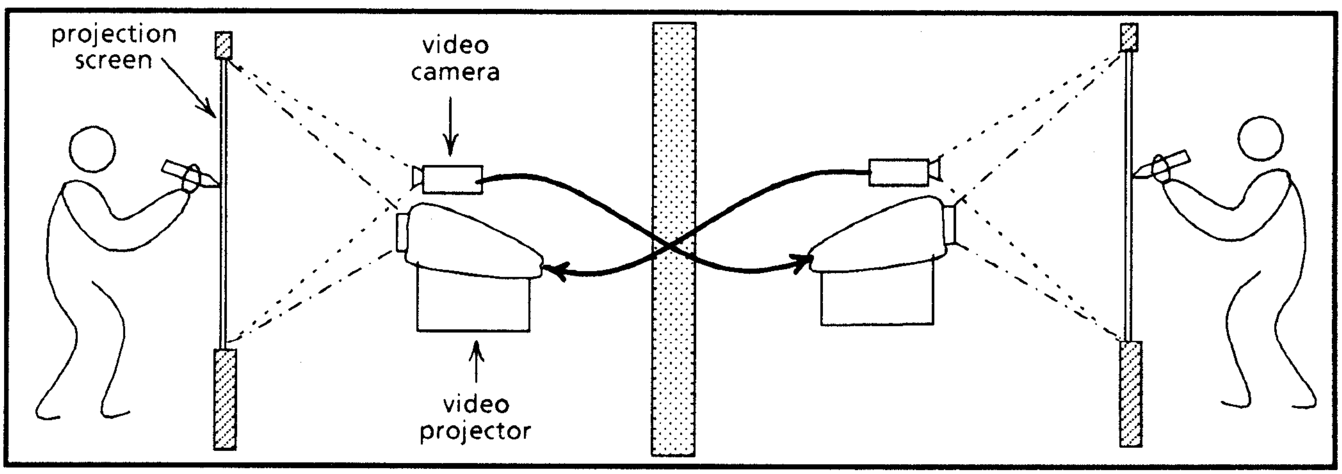

Figure 5: Schematic of VideoWhiteboard system between two sites

Each site is equipped with a wall-mounted rear projection screen (approximately 4.5' x 6'), a video camera, a video projector, and appropriate audio equipment. Users draw on the smooth front surface of the screen using standard dry erase whiteboard markers. The video camera, located on the opposite side of the screen from the user, captures an image of the entire screen and sends it to the video projector at the other site, which presents the image on that screen. As each user draws on the screen, those marks are imaged by the camera and projected onto the screen at the other site. Along with an image of the marks, the camera also transmits a shadow of the collaborator to the screen at the remote site. The collaborators see a composite image of real and "video" marks, as well as shadows of their remote collaborators' gestures and actions. An audio connection also enables the collaborators to talk with each other. Users can write, draw, erase, and gesture at the VideoWhiteboard screens much as if they were working together at a shared whiteboard. Figure 6 shows a user interacting with a remote collaborator through a VideoWhiteboard.

Users at each site share a correct orientation to the display surface—"right" and "left" have appropriate meanings to the collaborators at both sites. Since the camera is on the opposite side of the screen from the user, it actually captures an image that is left-right reversed. This mirror image is corrected by operating the video projector in front projection mode, even though it is actually projecting onto the rear of the screen.

The shadowy effect in VideoWhiteboard is in some ways similar to the computer-generated silhouette image used in VIDEOPLACE [Krueger, 1982]. However, there is a fundamental difference from the user's point of view. In VideoWhiteboard, the input screen for drawing marks and casting shadows is the same as the output screen for projecting the remote collaborators' marks and shadows. Thus, users can add marks and gestures directly over the marks made by their remote collaborators. In the drawing applications of VIDEOPLACE, the input focus (drawing in space) and the output focus (watching a computer monitor) are separated, adding a level of indirection between the remote collaborators' marks and actions.

COMPARING VIDEOWHITEBOARD AND VIDEODRAW

Like VideoDraw, VideoWhiteboard allows each user to share a drawing space and naturally draw, gesture, and interact in that drawing space. Each user has a common view of the drawing space and can make meaningful diectic references (e.g., "this one", "here") to objects or locations in the drawing space. Users can directly augment and interact over sketches created by a collaborator at the remote site. They can gesture over sketches and the remote collaborators can see those gestures in relation to the referent sketch. Users between remote sites

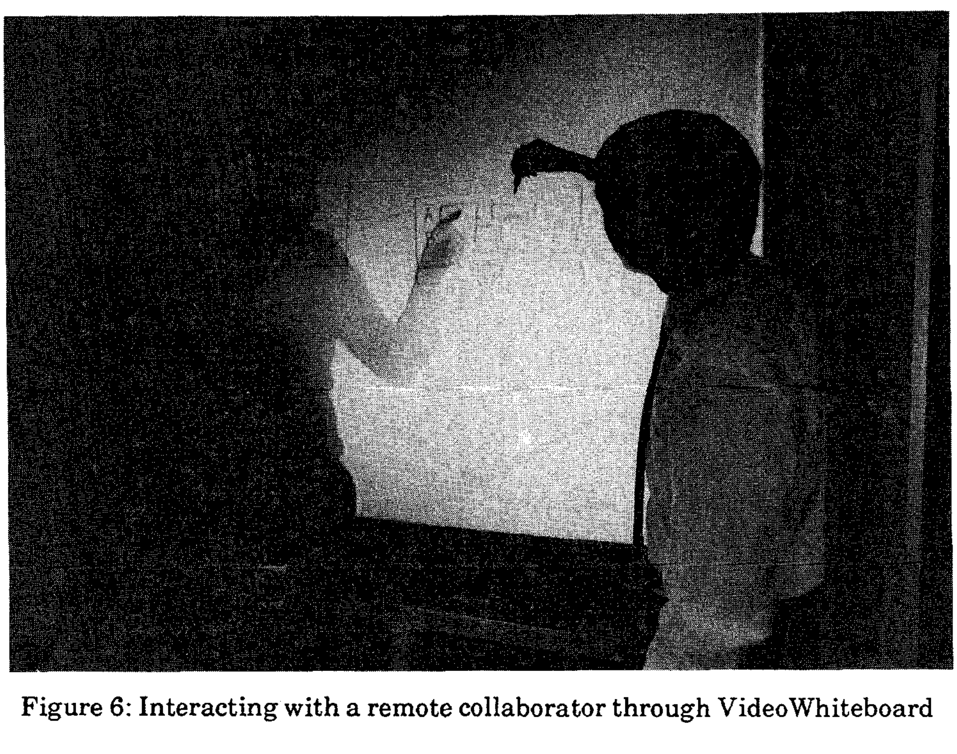

Figure 6: Interacting with a remote collaborator through VideoWhiteboard

being developed at PARC, we observed people using VideoWhiteboard in realistic work activity. VideoWhiteboard was set up connecting two rooms in different sections of the building. A half-duplex audio connection was provided by speakerphones. In addition to several short, informal uses of VideoWhiteboard, we observed two sessions of pairs

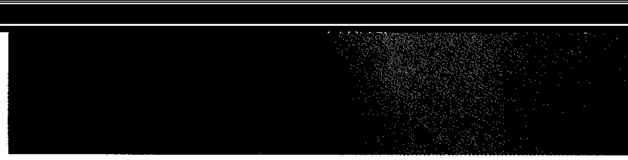

Figure 8: A user directs her ear toward the projection screen as part of a gesture to hear her remote collaborator better

screen), her gesture helped evoke the desired response from her remote collaborator; he enunciated his comment.

Although this impression of interacting with someone on the opposite side of a translucent screen is false, this illusion seldom disrupts (and may even help) the users' ability to interact with each other in this situation. Even if the users are not operating under that impression, VideoWhiteboard appears to evoke appropriate mechanisms for interacting through it. Users quickly realize that they share a view of the marks on the screen with their remote collaborators, and they can see the shadows that their remote collaborators cast on the screen.

An interesting feature of VideoWhiteboard is that the shadows of the remote collaborators are superimposed directly on the screen image where the marks and sketches are also appearing. This arrangement greatly reduces the division of attention that occurs in other collaborative drawing situations where participants must choose between looking at their collaborator or looking at the drawing surface. In face-to-face interaction around a whiteboard, fellow collaborators are either beside or behind a participant who is facing the whiteboard making a drawing. When using the VideoDraw prototype, collaborators alternated between looking down at the drawing surface and looking up at the other collaborators. VideoWhiteboard aligns the drawing surface and the shadow of the remote collaborators into the same viewing angle, providing a "heads-up display" effect that affords attending to the collaborators' actions and the drawing surface at the same time.

In one sense, VideoWhiteboard goes beyond VideoDraw's ability to convey hand gestures because VideoWhiteboard conveys gestures of the entire upper body. VideoWhiteboard can convey large scale gestures that involve both arms and even some of the body language (e.g., shrugs) that people naturally use in interaction to elicit responses from their collaborators or demonstrate reaction. Figure 9 shows an example where the shadow conveys a gesture of "whatever, it doesn't matter".

Although VideoWhiteboard does not present the same sense of 3-D that the full color image in VideoDraw does, the ambient lighting around the screen can provide differences in shade in the projected shadow depending on how close the object is to the screen. Thus, users get some idea of how close their collaborators or other objects are to the screen in the remote site through the density and sharpness of the projected shadow.

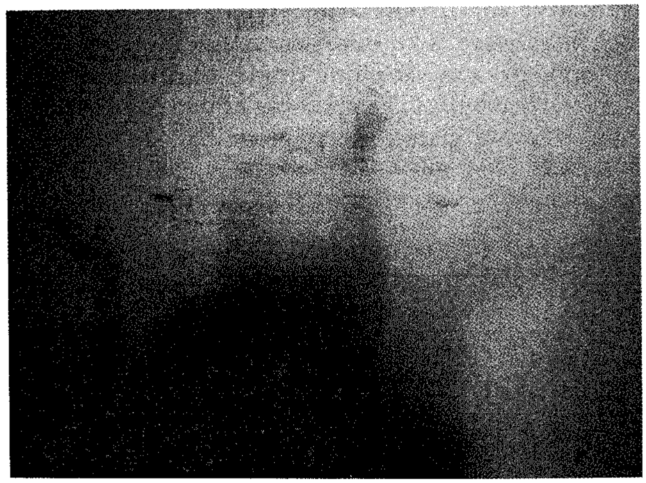

Figure 9: Conveying body language through shadows in VideoWhiteboard

Limitations in Using VideoWhiteboard

Several limitations were also observed in the use of VideoWhiteboard. Although the shadows do seem to effectively communicate a certain amount of gestural information, they are significantly less rich than a full color video image. In particular, the shadows do not afford eye contact between the remote collaborators. It is unclear if seeing only the shadows of a remote collaborator is enough to sustain focused, long-term interaction.

The masking effect of the shadows is especially troublesome when there is more than one collaborator within a site, which occurred in some of the informal uses of VideoWhiteboard. When collaborating with multiple remote collaborators that are visible only by their shadows, it is sometimes difficult to distinguish which shadow corresponds to which collaborator. Some users reported that they felt uncomfortable because they could not easily tell who they were interacting with in those situations. This problem might be eased by using stereo audio to help provide some location cues about which voice belongs to which shadow.

The fundamental asymmetry between what a user actually does and what the remote collaborator can see through the projected shadow can cause some interactional difficulties. Hand gestures that refer to precise locations (e.g., pointing) or subtle gestures that are performed some distance away from the screen (e.g., a head nod) can be difficult to perceive. Similarly, if a user steps far enough away from the screen that she does not cast a perceivable shadow, the remote collaborator may experience a sense of losing contact with her. Unfortunately, users do not get any visible feedback as to what kind of shadow they are projecting to their remote collaborator, since the shadow is largely an artifact of the optics behind the screen. We observed ways in which the users compensated for these potential difficulties (e.g., exaggerated gestures, staying close enough to the screen that they are always visible to each other through their shadows) in order to sustain their interaction through VideoWhiteboard.

Despite its large screen area, VideoWhiteboard is limited by the resolution of the particular video technology used (approximately 330 by 240 television lines in our prototype). Consequently, users had to exaggerate their text and graphics slightly to be large enough to be legible. Video projection technology also tends to exhibit a flicker that can be especially bothersome when viewed at such close range (i.e., when drawing on the screen). Constructing a VideoWhiteboard system requires careful optical alignment, since the area imaged by each camera must exactly correspond with the area projected on by each video projector. The optical alignment of the superimposed images is only optimal in the center of the screen and gets progressively worse toward the edges of the screen.

As with VideoDraw, users can only erase marks made on the local VideoWhiteboard screen and cannot erase marks made on remote screens. Also, the users did not have a convenient means for storing, retrieving, or printing the images on the screens, and did not have access to any previous images they created.

CONCLUSION

VideoWhiteboard is useful both as a research vehicle and as a prototype drawing tool. Studying the use of VideoWhiteboard, in comparison withVideoDraw, other prototype shared drawing tools, and face-to-face interaction, is teaching us more about collaborative drawing activity. For example, VideoWhiteboard conveys gestures through shadows while VideoDraw conveys full color video images of gestures. Comparing the two provides an opportunity to understand what interactions require the higher bandwidth full color gestures of VideoDraw and what interactions can be adequately supported by the lower bandwidth gesture shadows of VideoWhiteboard.

VideoWhiteboard is also a useful prototype tool to support remote collaborative drawing. Since it builds upon the familiar model of interacting around a whiteboard, minimal learning is required of the users. Existing video teleconferencing rooms that have rear projection video capability could be readily modified to provide a VideoWhiteboard configuration. Since the video shadows used in VideoWhiteboard place lower demands on video image quality, it might be reasonably robust against video compression or low bandwidth video transmission. A patent application has been filed on the VideoWhiteboard concept.

VideoWhiteboard is a medium for remote collaboration that makes available important interactional resources: gestures, the process of creating and referring to drawings, and concurrent access to the drawing space. It provides a different sense of co-presence from VideoDraw and other prototype tools for shared drawing activity. We plan to continue studying the use of VideoWhiteboard in order to learn more about collaborative activity and how to build shared drawing tools.

ACKNOWLEDGEMENTS

We would like to thank the working group of colleagues who have been involved in the group analysis of videotapes of work activity and Sara Bly, Charles Goodwin, and Marjorie Goodwin for their particular interest in studying the shared drawing prototypes. We also thank our colleagues (especially Kathy Carter and Bob Anderson) who volunteered to use VideoWhiteboard for our analysis purposes.

REFERENCES

Krueger, Myron W., *Artificial Reality*, Reading, MA: Addison-Wesley, 1982.

Lauwers, J. Chris and Keith A. Lantz, "Collaboration Awareness in Support of Collaboration Transparency: Requirements for the Next Generation of Shared Window Systems", *Proc. of the Conference on Computer Human Interaction (CHI) '90*, (Seattle, WA, April 1990), pp. 303-311.

March, Benjamin, *Chinese Shadow-figure Plays and their Making*, Handbook XI, Detroit: Puppetry Imprints, 1938.

O'Boyle, Leonard E., Praful H. Shah, and Gabe P. Torok, "Have blackboard, needn't travel", *Bell Laboratories Record*, (October 1979), pp. 255-258.

Olson, Margrethe H. and Sara A. Bly, "The Portland Experience: A Report on a Distributed Research Group", *International Journal of Man-Machine*

Systems, Special issue on Computer-Supported Cooperative Work and Groupware, in press.

Tang, John C. and Scott L. Minneman, "VideoDraw: A Video Interface for Collaborative Drawing", *Proc. of the Conference on Computer Human Interaction (CHI) '90*, (Seattle, WA, April 1990), pp. 313-320.

Tang, John et al., "Observations on the Use of Shared Drawing Spaces", videotape, Xerox Corporation, Palo Alto Research Center, 1990.

Tatar, Deborah, "Using Video-Based Observation to Shape the Design of a New Technology", *SIGCHI Bulletin*, Vol. 21, No. 2, (October 1989), pp. 108-111.