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Gaze Awareness for Distributed Work Environments

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GAZE AWARENESS FOR DISTRIBUTED WORK ENVIRONMENTS

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ABSTRACT

Recent CSCW related research is exploring new ways to support distributed work settings. Advanced audio- and video-conferencing systems allow workgroups across the globe to collaborate. New developments change the character of meetings and vice versa. Distributed meetings become an increasingly interactive experience offering more flexibilities and functionality than supported by earlier systems. There are two main factors that have both pushed and enabled recent research efforts to explore new distributed meeting concepts and implementations: external, environmental influences and technological advancements. This paper focuses on the concept of gaze awareness for distributed work environments and draws on research done in the areas of virtualization technologies and videoconferencing systems. Companies already have, or may soon develop, have a growing interest in integrating existing virtual (prototyping) environments in the company with collaborative tools based on interaction in these virtual worlds. Until then, videoconferencing systems can be vastly improved to mediate awareness states in innovative ways.

CONTENTS

1. INTRODUCTION

Recent CSCW related research is exploring new ways to support distributed work settings. Advanced audio- and video-conferencing systems allow workgroups across the globe to collaborate. New developments change the character of meetings and vice versa. Distributed meetings become an increasingly interactive experience offering more flexibilities and functionality than supported by earlier systems. There are two main factors that have both pushed and enabled recent research efforts to explore new distributed meeting concepts and implementations: external, environmental influences and technological advancements.

Contemporary companies operate drastically different economical environments than only some years ago. Long-term effects of globalization result in the fragmentation of company structures. Workgroups are being distributed across the globe and time-zones. Workgroup setups can change on a daily basis. Life cycles of products can still be planed to a certain extent. Given the dynamics of distributed development structures, it becomes a more complicated task. Also, continuously changing production environments and fluctuating markets make a comprehensive quality and innovation management necessary. Companies need to be able to quickly respond to competitor's developments and market developments in order to keep product lines competitive and constantly reorganize distributed workgroups.

Virtualization technologies can both be used for product development processes and the management of distributed workgroups. The application of virtualization technology has become an interesting alternative for companies operating in a globalized economy. Computer processing power has reached a critical level that allows the creation of high quality and realistic virtual representations of objects. These virtual objects can be simulated in virtual environment systems and used for radical prototyping and development. Additionally, videogame-like virtual environments for virtual avatars can be employed to provide a level of corporate communication channels.

Virtualization technologies and their implementations in the CSCW context are also used to achieve a state of active awareness between physically distant collaboration partners. Awareness can be mediated across distances with the help of different media channels. Virtualization technologies foremost provide real-life or virtual representations of collaboration partners. Systems transmitting live video streams aim at providing direct visual awareness of distant persons. Virtual worlds provide interaction based on avatars that are controlled by their creators. Recognizing and inferring each other's actions is often closely connected to the perception of the collaboration partner's gaze mediated by advanced videoconferencing systems.

This paper focuses on the concept of gaze awareness for distributed work environments and draws on research done in the areas of virtualization technologies and videoconferencing systems. Companies already have, or may soon develop, have a growing interest in integrating existing virtual (prototyping) environments in the company with collaborative tools based on interaction in these virtual worlds. Until then, videoconferencing systems can be vastly improved to mediate awareness states in innovative ways.

2. Visual Awareness

Following Nguyen and Canny [20], gaze awareness can be defined as a combination of mutual, partial and full gaze awareness. Mutual gaze awareness refers to the concept impression of eye-contact. Participant experiencing mutual gaze awareness know that somebody is looking at them. The gaze awareness state can be considered partial when a participant knows the directions of other's gazes. A person is fully aware of another person's gaze when he or she can exactly see the other person's object of attention.

Alongside the growing demand for virtualization systems, the focus of the CSCW research community turned to distributed conferencing solutions. While electronic meeting systems [1,2] were mainly developed for supporting collocated workgroups in a single room, distributed conferencing systems aimed at connecting workgroups or individuals across distances. Even given a collocated setting, media choice is not the only factor that has an impact on the successful cooperation between meeting participants. There are many more important factors to take into account. Workgroups represent highly dynamic (social) systems composed of very distinctive actors with different goals and work ethics. These dynamics create several areas of conflict that need to be addressed by systems supporting collaborative processes. They can be roughly categorized into the fields of privacy, trust and awareness. It should be noted that neither of these fields can be treated separately. Collaboration processes observed during work sessions usually can be brought into connection with numerous of these fields. Also, individual perceptions of meeting participants play a major role. For example, the perception of individual privacy highly depends on the level of trust showed to other meeting participants.

Awareness is closely connected to both trust and privacy. Being aware of somebody's behavior or simply a person's presence can have a significant impact on the development of trust and the boundaries of individual privacy management [3]. However, this paper is mainly concerned with the effects of awareness and gaze in the context of distributed work environments. Gaze Awareness, including gaze awareness, has been studied both in collocated and distributed work environments. Many studies can give valuable insights into the concept of visual awareness. Most of these studies were not specifically designed for findings connected to awareness but discuss awareness issues as part of the main research question. The following provides a glance at some examples of theoretical analysis and systems aimed at supporting visual awareness for collaborative activities.

Visual awareness has been studied in both collocated and distributed settings. Systems supporting collocated teamwork processes can be classified as Electronic Meeting Systems (EMS) [4]. A collocated workgroup context does not necessarily mean that all meeting participants can see each other while working on group tasks. Analyzing collaborative writing systems, Dourish and Bellotti [5] discuss two distinctive levels of privacy: Awareness can both provide the character and the content of other's actions. Understanding the character of activities allows workgroup members to structure their own activities, thus creating the context for their own actions. Understanding of the actual content of activities enables the individual to make more fine-grained adjustments. These can be expressed as a change of behavior or work habits. The Colab meeting room system [6] has been the basis for many studies of support tools and systems in advanced meeting rooms (e.g. [7]).

Work in collocated groups often needs to be interrupted in order to gain a visual impression of the cooperation partner, i.e. by looking up from a desk. This creates a high-level awareness of the collaboration partner's state of mind and general current availability. The observer can directly interpret facial expressions and gestures of other participants. However, when looking up the direct awareness of the shared content is lost. Gaze can also play an important role in this scenario. Gaze signals the current focus of attention of meeting participants. In order for participants to both benefit from high-level and low- level awareness interfaces need to implement an accurate visual representation of the cooperation partners that is combined with the awareness information of the shared object. Two systems that pursue this idea in a distributed setting are presented in chapter 4.

Awareness can be achieved by using different media types. Cadiz, Venolia et al. [8] introduce a software system for individuals. The software was intended to be installed on desktop PC at individual workplaces in an office environment. The implementation introduces a novel user interface that combines several tools that are supposed to enhance personal information awareness. The modular setup of the software application allows user defined customizations. The authors point out that customization has been used a lot. This shows that awareness requirements cannot be generalized. They are situated and embedded into the daily personal information management of individuals. Systems build with the aim to support awareness should support these dynamics and support sufficient flexibility.

The discussion so far showed that (gaze) awareness represents an active research area in collocated settings. At first glance, it appears straight forward to support a supposedly natural sense of gaze awareness in collocated situations. However, in most cases looking at their colleagues requires individuals to detach themselves actively from shared work objects. One of the long-term goals needs to be to integrate shared collaborative content with state information and feedback channels in a single interface.

So far this paper mainly addressed awareness issues in the context of collocated communication scenarios. However, as outlined in the introduction, worldwide economic developments and changing customer demands create a growing demand for systems supporting distributed workgroups. Communication across distances adds a significant overhead and creates additional seams that need to be overcome in order to successfully mediate a sense of gaze awareness.

Olson and Olsen [7] studied the effects of geographical distances on workgroups. Their main argument is that in spite of the availability of advanced information and telecommunication technologies, distance in synchronous interactions cannot be rendered entirely insignificant. Specific differences, for example cultural influences, time-zones, geographical conditions and language, will always persist and have an impact on the communication processes. The study provides several principles for creating systems that support distributed work processes. Awareness is an important element of these principles that contributes to creating a common ground among cooperation partners. Common ground refers to a commonly held knowledge of each other's knowledge state. This state can be established by using communication tools and repositories that provide equal access to shared data. Awareness and impression management are closely related to the establishment of common ground. If meeting participants should be able to establish a sense of awareness both for the shared content and the current states of colleagues at the same time.

Communication across distances can be established using various media types or combinations of them. Each media type inherits different implications for awareness and has been implemented by researches in various ways. Bonnie and Bradner [8] undertook an ethnographic study of instant messaging. The authors found that text-based communication channels were not only used for essential information exchange but also for building a relationship based on common ground between the communication partners. Yankelovich, Kaplan et al. [9] found that audio quality does have a significant influence on the perceived social presence of meeting members connected via audio only.

While both text and audio can support awareness in general, video certainly shows most potential to overcome physical and virtual seams between distant collaboration partners. Video can be used to mediate communication, convey awareness and transmit data in general. Only video can be used to specifically convey gaze awareness across distances or in virtual worlds.

In 1988, Kraut, Edigo et al. [10] were amongst the first to look at technologies that would support research collaborations. They draw the conclusion that "omnipresent video might provide the low-cost and therefore frequent and spontaneous interactions that are crucial to initiating collaborations, monitoring and coordinating the project and maintaining a smooth personal relationship." [10, p. 11] What the authors envisioned is available today. Most institutions willing and financially able to invest in videoconferencing systems can draw on high-speed network connections and computer systems that are powerful enough to handle high-quality video-streams. End user hardware (e.g. displays, control- and input-devices) developed both in size and functionality. These technological advancements enable the research community to create tools that can better support mediated gaze awareness. The more fine-grained a video image is, i.e. the more details of the remote location it is able to convey, the more high- and low-level awareness information can be transmitted and perceived.

Advanced videoconferencing systems create the impression that distributed workgroups all appear to be in the in the same room. This creates the impression of collaboration partners to be tele-present. Perceived qualitative factors, such as facial expressions and gestures, lead to an improved awareness state.

So far, the discussion of video used as a possible medium for transmitting awareness information has focused on the transmission of representations of collaboration partners. However, Nardi et al. [11] make an import point in that video in the context of collaborative systems must not only be used to create tele-presence but also as "video-as-data". Video-as-data can play an important role for systems that convey awareness information. Systems available on the market today, like the immersive solutions CISCO TelePresence[1] and Hewlett Packard Halo[2], introduce additional cameras and displays specifically designed to provide low-level awareness information. Large main screens

[1]http://www.cisco.com/en/US/products/ps7060/index.html, access on 02/25/2009.

[2] http://www.hp.com/halo, access on 02/25/2009.

on the other hand show images of the collaboration partner. Gaze awareness in particular requires a representation of the communication partner. This can be a real-life image or a virtual avatar representation.

Before introducing two concrete examples for conferencing systems attempting to mediate gaze awareness across distances in chapter 4, the next chapter discusses seams that occur between the physical and virtually mediated world. It is important to understand the concept of seams in order to build systems that will eventually bridge these seams and make mediating awareness information possible.

3. Seams and Social Ergonomics Influencing Awareness

Designers of systems supporting collaborative and distributed work processes constantly need to overcome seams that exist between the real, physical world and a virtual world or mediated video-representations of collaboration partners.

Irani, Hayes et al. [12] focus their research paper on sense-making and interaction processes in virtual environments. Their analysis unpacks activities in virtual environments from the user's perspective of looking through a personal avatar. "Looking" in virtual worlds represents a very situated practice and is attached to many seams that occur when crossing the "real world baseline" [12, p. 187]. These seams are not immediately obvious and can be influenced by various external factors in the virtual, but also in the real world. Interfaces that allow the control of virtual characters play an important role. They determine the way looking is perceived by individuals. Infrastructure in the real world thereby defines the level of awareness among participants.

This perspective can be transferred to gaze awareness in the context of CSCW systems as well. Mediating gaze awareness across distances creates various seams that can partially be bridged by technology and media choice. A combination of high quality audio and video can add to the experience of mediated communication and thus lower the barrier of interaction. The metaphor of "looking" can also be understood in terms of looking at certain shared objects. Gaze can be directed at certain objects within a set of objects a distributed team is working on. Examples for this technique can be found in the area of distributed software development projects. Some authors also refer to distributed software development as global software development in order to express the long distance relationships between distributed workgroups [13, 14]. Software development can especially benefit from gaze awareness during work processes and possibly during meetings while discussing code segments. Referring to a certain line of code can be expressed by "looking" at the specific section.

There are additional factors that need to be taken into account that are not immediately obvious. Spatial and location faithfulness greatly contribute to lowering the negative effects of seams and to creating an atmosphere that retains gaze awareness. Here, it is especially worthwhile to consider social ergonomics at all stages during the development of systems for virtual collaboration.

Social ergonomics [15] describe the interaction of users with information systems and how specific system designs can influences the social behavior of workgroups or individuals. It is important to understand how an envisioned system could change social behavior in order to better design towards user's needs. Hofer, Lin et al. [16] studied media spaces to understand the effects of social ergonomics of advanced collaborative environments. Media spaces [17] are not particularly well suited to provide gaze awareness but represent a class of systems that allows informal communication. They provide coordination and a general sense of awareness between distant individuals. Media spaces often aim at replicating informal information sharing that usually occurs during face-to-face encounters of individuals. Hofer, Lin et al. [16] found that social ergonomic related problems are most often caused by irregularities in information flow through systems. Specifically when looking at gaze awareness, their findings can be interpreted as follows: Gaze awareness can limit information asymmetries between distributed sites by indicating concrete information needs and reference points. Communication channel limitations can cause problems as well. They can be addressed by adequate high quality multi-media streams that convey gaze and other visual clues about the state of the collaboration partner. Also, inadequately mediated communication can lead to the misinterpretation of visual clues. If gaze is not mediated correctly it is possible that the wrong participants are made responsible for actions they never performed. Camera placement and angle can have unforeseen social effects. Looking down on a person can make that person to appear unintentionally more dominant.

Specific room layouts can address some of the issues of social ergonomics discussed so far. Lewe [18] suggests room layouts specifically suited for cooperative meeting situations and studied the influences on the productivity of teams. Commercial systems, like HP Halo and Cisco TelePresence, also built on fixed room layouts. These specific setups can reduce problems caused by camera angles and transmission quality. But more research is still required when systems ought to support true spatial and location faithfulness that include gaze awareness.

4. CSCW Systems Supporting Gaze Awareness

Video conferencing systems made significant advancements in recent years. Comprehensive systems adopt high-quality audio- and video-communication. Many systems support multiple participants at distributed sites. Individuals can connect to conference session using low-tech equipment also. Most systems however are not specifically designed to support gaze awareness and spatial faithfulness. Some video conferencing conceptions supporting gaze awareness are presented in this chapter.

Olsen and Meader [19] analyzed the impact of high-quality audio and –video on groups of three participants working at a distance. The system created by the authors preserved spatial faithfulness and allowed the participants to make eye-contact (see Illustration 1).

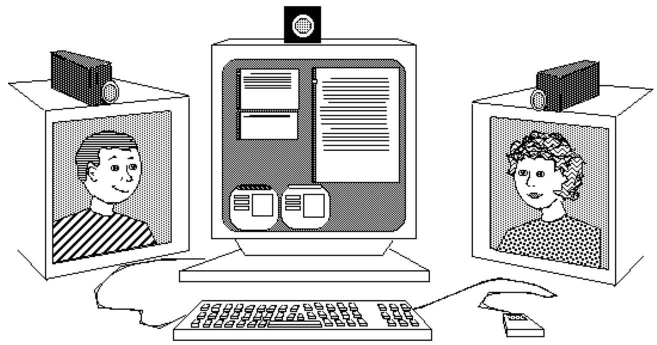

Illustration 1: Videoconference setup supporting gaze, taken from [19]

Participants are shown on multiple screens. Each screen is equipped with a separate camera so that turning to a person on one site is mediated to the distant site. This way, virtual gaze awareness can be established. It was found that the application of both audio and video enables distributed groups to produce results of the same quality as teams working in a face-to-face setting. The study did not test for differences in perception of standard video and spatial faithful video transmissions.

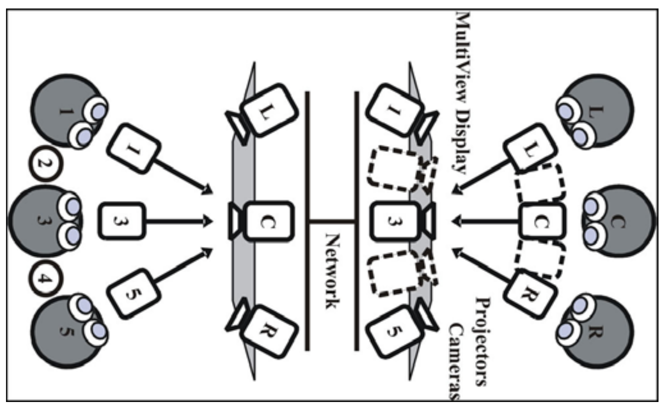

Illustration 2: MultiView system, taken from [20]

Instead of multiple screens, the approach by Nguyen and Canny [20] (see Illustration 2) makes use of one large projection screen while still maintaining spatial faithfulness and gaze awareness. The MultiView system interprets the video screen as a virtual window between two dislocated meeting rooms. The implementation builds on a custom-build, layered display that offers different viewing zones. Each person participating in the conference is assigned a camera, projector and viewing zone on the screen. The system is then able to emulate individual experiences for each participant. It is thereby possible to create gaze awareness for each participant individually.

Both systems presented so far strictly separate the shared workspace from the video representations of the cooperation partners. Ishii and Kobayashi [21] present a novel architecture that allows direct eye contact while working collaboratively on a shared whiteboard component at the same time. The whiteboard component is layered on top of the representation of the remote user. The background of the interactive area represents the image of the remote partner and combines both drawings. The aim of the system is to maintain gaze awareness the collaboration on the same object. This conception shows some advantages that even add to the experience of face-to-face meetings. A physical whiteboard requires the user to look up from the board in order to gain awareness. Standing next to each other also requires to gesture at areas of interest. Direct and constant gaze awareness might convey a broad sense of the partner's attention focus. The application of transparent projection displays creates new possibilities for further improving the quality of visual representations. Systems integrating both video screen and interactive display show promising results.

5. Critical Discussion and Conclusion

In daily life and face-to-face meetings gaze awareness occurs naturally. We look at each other to initiate conversations or to signal general interest. As Monk and Gale [22] put it: "A look is worth a thousand words." The human brain is trained to unconsciously interpret posture, gestures and gaze of peers and infer complex information. Also, human interaction is based on complex, situated social frameworks that are available to humans. Machine learning capabilities are still not advanced enough to replicate complex social structures. Collaborative and distributed group work demands systems bridging the distance between work groups. Video conferencing systems are partially able to bridge the gap. However, even the application of high-quality video processing and hardware often creates communication channels that omit fine-grained, yet very important communication details. Gaze awareness is based on these hidden structures that too often cannot be reproduced at distributed sites.

Recent CSCW research acknowledges the problem and concentrates on improving the ability of systems to convey human interaction processes as they occur in real time. Capturing human behavior and coding the information to imitate machine learning processes might be a concept for the future. However, even today systems are not only aiming at replicating face-to-face meetings. The Clear Board system [21] adds to the face-to-face experience and thus follows Hollan and Stornetta's [23] example to build systems that explore possibilities for systems beyond primarily recreating a virtual social presence. System designers can use the gaze metaphor to implement new support tools for various distributed development endeavors.

Current developments that handle gaze awareness and have been discussed in chapter 4 show promising results but also have apparent limitations.

A meeting can represent a very dynamic bundle of events and interactions. Participants leave or join a meeting. Members can change seats or stand up to point at shared objects. Systems like MulitView [20] only have limited capabilities to support such dynamics. Most systems need to be carefully calibrated before a meeting can start. Moving the participants' positions during a meeting might cause the system to lose synchronization. Additionally, systems using multiple displays and projectors might be difficult and expensive to scale. The Clear Board [21] approach allows more flexibility. Active users can switch dynamically. The problem of scalability still persists. Maybe a combination of the two systems could be envisioned that deals with both problems at the same time.

Some, e.g. [22], have criticized that current systems conveying gaze awareness are not accurate enough. This might be a valid argument given low-quality video transmissions. However, if the goal is to realistically mediate gaze awareness, the goal should not be to provide exact pointers where a person is currently looking at. Virtual environments might interpret looking in a different way (see [12] as an example). Some, on the other hand, might argue that this could be another example for “beyond being there” [23]. Systems implementing laser pointer-like indicators for gaze awareness purposes could enhance the natural abilities connected to looking. The question remains if this can be realized in an unobtrusive way that does not have a negative effect on overall meeting performance. Further research in this area is necessary. Ubiquitous computing specialists might add to the discussion.

A current CSCW research area that could possibly most benefit from advanced gaze awareness support is virtual radical collocation. Technology used in these settings can certainly be put to good use for systems supporting gaze awareness. Gaze can be used as a very accessible indicator for signaling availability or opinion. Common ground that is essential for virtual radical collocation settings could thus be established in a more intuitive way.

Overall, gaze awareness can be seen as a very promising area that could be applied to many CSCW-related developments. The technological framework is available today. However, a groundbreaking conception for capturing and mediating gaze awareness across distances has yet to be presented.

LITERATURE

[1] Stefik, M., Foster, G., Bobrow, D. G., Kahn, K., Lanning, S., & Suchman, L. (1987). Beyond the chalkboard: computer support for collaboration and problem solving in meetings. Commun. ACM 30, 32-47. New York: ACM.

[2] Moran, T. P., Chiu, P., Harrison, S., Kurtenbach, G., Minneman, S., and van Melle, W. (1996). Evolutionary engagement in an ongoing collaborative work process: a case study. In: Proceedings of the 1996 ACM Conference on Computer Supported Cooperative Work (Boston, Massachusetts, United States, November 16 - 20, 1996), 150-159. M. S. Ackerman, Ed. CSCW '96. New York: ACM.

[3] Palen, L., Dourish, P. (2003): Unpacking "privacy" for a networked world. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, p. 129 - 136. CHI'03. New York: ACM.

[4] Nunamaker, J. F., Dennis, A.R., Valacich, J.S., Vogel, D., George, J.F. (1991): Electronic meeting systems. ACM, 34 (7), 40-61. New York: ACM.

[5] Dourish, P., and Bellotti, V. (1992). Awareness and Coordination in Shared Workspaces. Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW 1992), 107-114.

[6] Stefik, M., Foster, G., Bobrow, D. G., Kahn, K., Lanning, S., & Suchman, L. (1987). Beyond the chalkboard: computer support for collaboration and problem solving in meetings. Commun. ACM 30, 32-47. New York: ACM.

[7] Moran, T. P., Chiu, P., Harrison, S., Kurtenbach, G., Minneman, S., and van Melle, W. (1996). Evolutionary engagement in an ongoing collaborative work process: a case study. In: Proceedings of the 1996 ACM Conference on Computer Supported Cooperative Work (Boston, Massachusetts, United States, November 16 - 20, 1996), 150-159. M. S. Ackerman, Ed. CSCW '96. New York: ACM.

[8] Cadiz, J. J., Venolia, G., Jancke, G., and Gupta, A. 2002. Designing and deploying an information awareness interface. In Proceedings of the 2002 ACM Conference on Computer Supported Cooperative Work (New Orleans, Louisiana, USA, November 16 - 20, 2002) 314-323. CSCW '02. New York: ACM.

[7] Olson, G., Olson, J. (2000): Distance Matters. Human-Computer Interaction, 15, 139-178.

[8] Nardi, B. A., Whittaker, S., and Bradner, E. (2000). Interaction and outeraction: instant messaging in action. In Proceedings of the 2000 ACM Conference on Computer Supported Cooperative Work (Philadelphia, Pennsylvania, United States), 79-88. CSCW '00. New York: ACM.

[9] Yankelovich, N., Kaplan, J., Provino, J., Wessler, M., and DiMicco, J. M. (2006). Improving audio conferencing: are two ears better than one?. In Proceedings of the 2006 20th Anniversary Conference on Computer Supported Cooperative Work (Banff, Alberta, Canada, November 04 - 08, 2006). CSCW '06. ACM, New York, NY, 333-342.

[10] Kraut, R., Egido, C., and Galegher, J. (1988). Patterns of contact and communication in scientific research collaboration. In Proceedings of the 1988 ACM Conference on Computer-Supported Cooperative Work (Portland, Oregon, United States, September 26 - 28, 1988). CSCW '88. ACM, New York, NY.

[11] Nardi, B. A., Schwarz, H., Kuchinsky, A., Leichner, R., Whittaker, S., and Sclabassi, R. (1993). Turning away from talking heads: the use of video-as-data in neurosurgery. In Proceedings of the INTERACT '93 and CHI '93 Conference on Human Factors in Computing Systems (Amsterdam, The Netherlands, April 24 - 29, 1993). CHI '93. ACM, New York, NY.

[12] Irani, L. C., Hayes, G. R., and Dourish, P. (2008). Situated practices of looking: visual practice in an online world. In Proceedings of the ACM 2008 Conference on Computer Supported Cooperative Work (San Diego, CA, USA, November 08 - 12, 2008). CSCW '08. ACM, New York, NY, 187-196.

[13] Avritzer, A., Hasling, W., Paulish, D. (2007): Process Investigations for the Global Studio Project Version 3.0. In: Proceedings of Global Software Engineering, 2007, ICGSE 2007. IEEE Computer Society.

[14] Herbsleb, J. D., Mockus, A., Finholt, T. A., Grinter, R. E. (2000): Distance, dependencies, and delay in a global collaboration. In Proceedings of the 2000 ACM Conference on Computer Supported Cooperative Work (Philadelphia, Pennsylvania, United States). CSCW '00. New York: ACM.

[15] Brown, J.S., Newman, S.E. (1985): Issues in cognitive and social ergonomics: from our house to Bauhaus. Human Computer Interaction, 1, 359-391.

[16] Hofer, E., Lin, J., Finholt, T. (2004): Towards a social ergonomic understanding of advanced collaborative environments. WACE.

[17] Bly, S. A., Harrison, S. R., and Irwin, S. (1993): Media spaces: bringing people together in a video, audio, and computing environment. ACM 36, 1 (Jan. 1993), 28-46. New York: ACM.

[18] Lewe, H. (1995). Computer Aided Team und Produktivität: Einsatzmöglichkeiten und Erfolgspotentiale. Wiesbaden: Gabler. Zugl.: Hohenheim, Univ., Diss., 1994.

[19] Olson, J. S., Olson, G. M., and Meader, D. K. (1995). What mix of video and audio is useful for small groups doing remote real-time design work?. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Denver, Colorado, United States, May 07 - 11, 1995). I. R. Katz, R. Mack, L. Marks, M. B. Rosson, and J. Nielsen, Eds. Conference on Human Factors in Computing Systems. ACM Press/Addison-Wesley Publishing Co., New York, NY.

[20] Nguyen, D. and Canny, J. (2005): MultiView: spatially faithful group video conferencing. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Portland, Oregon, USA, April 02 - 07, 2005). CHI '05. ACM, New York.

[21] Ishii, H., Kobayashi, M., and Grudin, J. (1993). Integration of interpersonal space and shared workspace: ClearBoard design and experiments. ACM Trans. Inf. Syst. 11, 4 (Oct. 1993), 349-375.

[22] Monk, A. F. and Gale, C. (2002). A look is worth a thousand words: full gaze awareness in video-mediated conversation. Discourse Processes, 33, 257--278.

[23] Hollan, J., Stornetta, S. (1992). Beyond being there. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Monterey, California, United States, May 03 - 07, 1992). 119-125. P. Bauersfeld, J. Bennett, and G. Lynch, Eds. CHI '92. New York: ACM.