Balancing Privacy and Awareness in Home Media Spaces[1]

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ABSTRACT
Always-on video provides rich levels of awareness for collaborators separated by distance, yet it has the potential to threaten privacy as sensitive details may be broadcast to others. This threat increases for telecommuters who work at home and connect to office-based colleagues using video. Our research addresses the problem of how to develop and evaluate privacy-protecting strategies and user interface design techniques for balancing privacy with awareness in a *home media space (HMS)*—defined as an always-on video media space used in a home setting. First, we show that image processing techniques alone are unable to balance privacy and awareness for typical home situations involving a telecommuter. Second, using social-psychological theory, we develop a design framework for a privacy-preserving HMS. Third, we present the prototype design of a context-aware HMS, designed to balance privacy and awareness for telecommuters and others in the home.

Keywords. Casual interaction, awareness, video media spaces, privacy, telecommuting.

INTRODUCTION

Throughout a typical day, co-workers naturally converse and interact amongst each other in what is known as *casual interaction*—the frequent and informal encounters that either occur serendipitously or are initiated by one person [8, 12]. Casual interactions foster knowledge and help individuals accomplish both individual and group work [8, 13]. *Informal awareness*—an understanding of who is around and available for interaction—holds casual interaction together by helping people decide if and when to move into and out of conversation and collaboration [4, 11, 13]. Informal awareness is easily gained when people are in close physical proximity, but deteriorates over distance [9, 13]. As a result, casual interaction suffers when co-workers are distributed.

Video is one technology that is capable of providing rich levels of awareness over distance because it presents the visual cues that allow people to smoothly move into and out of interaction and collaboration [8, 14]. However, the problem with using video to support informal awareness is that an increasing level of awareness means a decreasing level of privacy for collaborators.

This privacy threat increases for telecommuters who work from home and use a *home media space (HMS)*—an always-on video link used in a home setting—to maintain a close-working relationship with particular colleagues in remote office environments. Unlike office-based media spaces, a home media space has to pay considerably more attention to how the system appropriately balances privacy and awareness, because privacy concerns are far more problematic for home users. Homes are inherently private in nature, and appearances or behaviours that are appropriate for the home may not be appropriate when viewed at the office. In addition, individuals in the home other than the telecommuter who gain little or no benefit from the HMS also incur its privacy threat.

Previous research has looked at techniques to try and present a balance between privacy and awareness in office-based media spaces, e.g., [5, 6, 10, 12, 15]. In particular, Boyle et al. [5] found that *distortion filters,* which algorithmically reduce image fidelity, are able to present levels of filtration that provide both privacy and awareness for mundane office situations, e.g., people working or reading, people chatting, people eating lunch. However, they did not test their filters on situations that may be extremely sensitive to privacy violations like those found in a home media space.

For this reason, this research develops and evaluates strategies for balancing privacy and awareness in home media spaces. First, we discuss the evaluation of one filtration technique for its effectiveness in balancing privacy and awareness in home media spaces. Second, we take a step back and look at social psychological theories of privacy to create a framework for the design of a home media space. Finally, we outline the prototype design of a context-aware home media space.

AN EVALUATION OF BLUR FILTRATION

Using a controlled experiment, we evaluated *blur filtration,* which naturally blends video images to create a blurred effect, for its effectiveness in balancing privacy and awareness for typical situations found in a HMS.

[1] This paper is a summary of:

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Figure 1: Male versions of the five video scenes: Working, Picking Nose (top row), No Shirt, Kissing (middle row), Changing, (bottom row).

Methodology

The experiment was a within-subjects design where twenty people (ten male, ten female) participated. We selected a series of five scenes that we felt typified home telecommuting situations and ranged greatly in the level of risk presented (Figure 1):

1. Working at a computer – low risk.
2. Picking one's nose – moderate risk.
3. Working with no shirt on – moderate risk.
4. Kissing a partner – moderate risk.
5. Changing clothes and shown naked – high risk.

Each scene was recorded twice, once with a male actor and once with a female actress. We then blurred each scene at ten different levels (or amounts) of blur (selected levels are shown in Figure 2).

Method

In the study, participants first imagined themselves as the colleague of a telecommuter who used video to maintain awareness with colleagues. Next, they viewed one of five video scenes, once for each level of blur, starting from completely blurred and going to completely clear. After each blur level, participants answered awareness and privacy questions about what they saw, e.g., Is your colleague available for interaction right now? How much privacy is your colleague maintaining? Next, we asked participants to switch roles and imagine themselves as the telecommuter in the scene and choose a level of blur they would feel comfortable with using and explain their reasoning. They were also given the option to turn the camera off if they felt no blur levels were adequate. Participants then repeated the same steps for each of the remaining four video scenes.

Figure 2: A sample of blur levels: levels 1 and 3 (top row respectively), levels 7 and 10 (bottom row, respectively). Level 10 is the unfiltered scene.

RESULTS

The first point at which participants were able to accurately extract awareness cues from the video scenes fell between blur levels 3 and 5 (moderately to heavily filtered) for all scenes. However, only blur levels 1 and 2 (heavily filtered) could preserve privacy for all five scenes. Thus, at the point when people were first able to identify awareness information, the privacy of those in the video was already being compromised. Clearly, we found that there were no general-purpose blur levels that could provide both privacy and awareness for the risky situations we were interested in. Moreover, we found that people began to abandon filtration as a privacy-protecting strategy as risk increased and opted to simply turn the camera off.

The significance of this is that blur filtration by itself does not suffice for privacy protection in video-based telecommuting situations; other privacy-protecting strategies are required. We found that people simply do not trust techniques where a camera continuously faces them. It matters little *how* the image is being filtered, whether the camera is capturing or not, or even if the camera is turned on! By implication, this means that other image processing techniques will do no better than blur filtration. Rather, people prefer direct control of their privacy, e.g., being able to position the camera, control the blur level, turn the camera on/off, and so on.

A FRAMEWORK FOR THE DESIGN OF A HMS

The results of the study highlighted the importance of providing user control over information conveyed through a home media space. To provide natural mechanisms for users to control this information, we began investigating how humans regulate privacy in everyday life through various behaviors and actions called *privacy mechanisms* [2]. These privacy mechanisms are very natural and often form an unconscious act [1]. The privacy mechanisms used by humans can be classified into four categories [1]:

1. **Verbal behaviors**: the use of the content and structure of what is being said;

2. **Non-verbal behaviors**: the use of body language, e.g., gestures and posture;
3. **Environmental mechanisms**: the use of physical artifacts and features of an environment, e.g., walls, doors, spatial proximity, timing; and,
4. **Cultural mechanisms**: the use of cultural practices and social customs.

Research has shown that different cultures employ mechanisms from different categories [2].

Based on this research, we feel that to provide natural mechanisms for users to regulate privacy in a home media space, designers should leverage the four categories of privacy mechanisms used by people for privacy regulation in everyday life. This can be accomplished by designing privacy-protecting strategies for a HMS that fall into the same categories of mechanisms.

Verbal Behavior: Sound and Voice

In a HMS design, two appropriate strategies for using verbal behaviors are: verbal instructions between media space users; and, verbal instructions or sounds cues from devices in the media space to media space users.

The first approach can be trivially supported in a HMS's design for co-located HMS users (e.g., the telecommuter and others in the home): they can simply speak to others in the same location. Distance-separated users of the HMS must rely on a voice channel for this approach. The tradeoff is that we want an audio link, yet not the additional privacy threats found with a continuous audio link [12]. For this reason, a design should provide an optional audio link that can easily be engaged and disengaged.

The second approach offers a crucial component of privacy feedback. Feedback of the level of privacy being attained is most easily presented through visuals or with audio. In the case that visual feedback goes unnoticed, audio feedback is essential.

Non-Verbal Behaviors: Presenting and Using Gestures

Non-verbal behaviors can also be used suitably in two ways within a HMS design: gesture-based input for devices within the media space; and, non-verbal instructions between media space users.

The first approach offers a lightweight means to control devices; users can give the media space explicit instructions using recognized hand or body motions.

The second approach is simply a replication of implicit or explicit body language used in face-to-face situations to regulate privacy. Co-located users (e.g., the telecommuter and others at home) should have little trouble with this, yet users separated by distance must rely on the video channel for presenting their non-verbal behaviors. Video fidelity must be high enough for other participants to easily interpret gestures and postures (e.g., low level of blur, or high frame rate).

Environmental Mechanisms: Virtual Fences and Doors

Just as individuals can control their own environment in the physical world, they should be able to control their environment in a HMS. Suitable environmental mechanisms for a HMS include: lightweight mechanisms for altering the media space's physical environment; self-appropriation for controlling physical appearance and behavior; and, adjustable personal space.

The first approach allows for easy and simple privacy regulation. Users should be able to control attributes such as the camera state, capturing angle, and video fidelity.

The second approach lies in the hands of media space users. Self-appropriation involves creating an appearance and behavior suitable for the current situation [3]. Given enough visual and audio feedback of the level of privacy currently being attained, users have the power to control their own privacy by simply appropriating themselves correctly [3]. This can be difficult in a HMS however. Participants at the home location may be forced to appropriate themselves for the office, which itself can be an infringement on their autonomy. To help alleviate this problem, users can rely on lightweight controls to help users appropriate themselves correctly for both home and the office, e.g., video fidelity.

The third approach allows HMS users to utilize personal space for controlling privacy, just like in face-to-face situations. First, the media space can be setup in any location within the home. Privacy will be easier to regulate in rooms that are not commonly used by many people within the home. Second, within the media space, the camera can be positioned in any number of locations; camera placement determines what background information is captured. This typically becomes unremarkable over time, but care can be taken so that background information is not privacy sensitive, e.g., an open doorway into a living room with many people.

Cultural Mechanisms: Social Solutions

In a HMS, social practices should develop about the purpose of the media space, who is allowed to view what is captured, and what content is appropriate to be seen. Given an established set of social protocols, users can rely on them to regulate privacy when technology does not suffice. In the case that social norms are not followed, social ramifications may be in order.

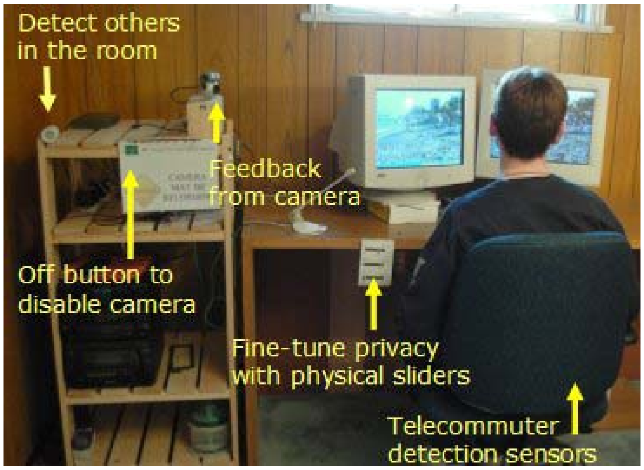

Figure 3: The context-aware home media space.

THE DESIGN OF A CONTEXT-AWARE HMS

Using the design framework, we have created a context-aware home media space where users are provided with *implicit* and *explicit control* over their privacy, along with *visual* and *audio feedback* of the amount of privacy currently being maintained. The design enables one specific location—a home office/spare bedroom shown in Figure 3—with context-aware technology that senses who is around and then infers privacy expectations through a simple set of rules. Context-aware systems can make mistakes [7] and it is important that these mistakes do not increase privacy threats. As a result, we first warn users if an implicit action has initiated a privacy decreasing operation; and second, we provide an opportunity for users to override this operation. Continuous visual and audio feedback makes it easy to know how much privacy is currently maintained and users are able to fine-tune privacy and awareness levels with dedicated physical and graphical controls.

The HMS design is a first prototype and has not yet been formally evaluated. However, it does illustrate how to apply the design framework and shows how context-aware computing can be used in real-world applications.

Elements of a Context-Aware HMS

The design contains specific elements that can be used together to balance privacy and awareness. The design attributes that can be controlled are:

Camera state. The camera can be in one of three states: Play (the camera is recording), Pause (the camera is not recording), and Stop (the camera is not recording and only an explicit action will move it out of this state).

Capturing angle. The camera, mounted on a rotating motor, is placed near the door and, given the captured desired angle, can capture any region of the room, except the doorway.

Video fidelity. Users can adjust the captured video's fidelity by explicitly adjusting the level of blur filtration used, the camera's frame rate, or the camera's frame size.

Audio link. An optional audio channel can be engaged.

Table 1 summarizes how the remaining elements are either used for explicit or implicit control, or as feedback. Each row in the table describes how one attribute (column 1) is controlled either explicitly (column 2) or implicitly (column 3). The fourth and fifth columns describe the feedback that indicates to the users that the attribute in column 1 has changed and what its current value is.

CONCLUSION

While we have concentrated on one specific use of video in homes, this research contributes ideas that have a broader significance for home-based videoconferencing in general. Regardless of the specific use of video in a home, people need and desire methods to regulate their privacy; many video conferencing systems (e.g., Webcam

1 **Attribute Controlled**	2 **Explicit Control**	3 **Implicit Control**	4 **Audio Feedback**	5 **Visual Feedback**
Camera State: Stop to Play	Click play button	None	Camera clicking; Camera rotating	LEDs on; Camera rotates to face you; Mirrored video
Camera State: Pause to Play	Click play button	Telecommuter sits in chair; Family/friend leaves room	Same as above; Camera Twitches	Same as above; Camera Twitches
Camera State: Play to Stop	Click stop button; Block camera with hand; Touch off button	None	Camera rotating	LEDs off; Camera rotates to face the wall; Mirrored video
Camera State: Play to Pause	Click pause button	Telecommuter stands up out of chair; Family / friend enters room	Same as above	Same as above
Camera State: Pause to Stop	Click stop button; Block camera with hand; Touch off button	Telecommuter leaves the room for an extended period of time	None	Mirrored video
Capturing angle	Adjust physical or graphical slider	Change in camera state	Camera rotating	Slider position; Camera position; Mirrored video
Video fidelity	Adjust physical or graphical control	None	None	Control position; Mirrored video
Audio link	Moves hand over microphone base	None	Own voice	None

Table 1: Control and feedback mechanisms found in the HMS.

for MSN Messenger) ignore these user requirements.

REFERENCES

1.Altman, I.: The Environment and Social Behavior: Privacy, Personal Space, Territory, Crowding, Wadsworth Publishing Company (1975) pp. 1-51, 194-207.

2.Altman, I., and Chemers, M.: Culture and Environment, Wadsworth Publishing Company (1980) pp. 1-12, 75-119, 155-214.

3.Bellotti, V.: Design for Privacy in Multimedia Computing and Communications Environments, in Technology and Privacy: The New Landscape, Agre and Rotenberg eds., MIT Press, (1998) pp. 63-98.

4.Bellotti, V., and Sellen, A. (1993), Design for Privacy in Ubiquitous Computing Environments, Proc. ECSCW'93, Kluwer Academic Publishers, Milan, pp. 77-92.

5.Boyle, M., Edwards, C. and Greenberg, S.: The Effects of Filtered Video on Awareness and Privacy, Proc. CSCW'00 [CHI Letters 2(3)], ACM Press, (2000) pp. 1-10.

6.Crowley, J.L., Coutaz, J., and Bérard, F.; Things That See, Communications of the ACM, ACM Press, Vol. 43, No. 3, (2000) pp. 54-64.

7.Erickson, T.: Some problems with the notion of context-aware computing, Communications of the ACM, Vol. 45(2), February 2002, (2002) pp. 102-104.

8.Fish, R.S., Kraut, R.E., Rice, R.E., and Root, R.W.: Video as a Technology for Informal Communication, Communications of the ACM, Vol. 36, No. 1, ACM Press, (1993) pp. 48-61.

9.Greenberg, Saul: Peepholes: Low Cost Awareness of One's Community, Proc. Of CHI'96, Companion Proceedings, ACM Press, (1996) pp. 206-207.

10.Greenberg, S. and Kuzuoka, H.: Using Digital but Physical Surrogates to Mediate Awareness, Communication and Privacy in Media Space, Personal Technologies, 4(1), January (2000).

11.Gutwin, C., Stark, G., and Greenberg, S. (1995), Support for Workspace Awareness in Educational Groupware, Proc. ACM Conference on Computer Supported Collaborative Learning, LEA Press, pp. 147-156.

12.Hudson, S.E., and Smith, I.: Techniques for Addressing Fundamental Privacy and Disruption Tradeoffs in Awareness Support Systems, Proc. CSCW'96, (1996) pp. 248-257.

13.Kraut, R., Egido, C., and Galegher, J.: Patterns of contact and communication in scientific observation, Proc. CSCW '88, (1988) pp. 1-12.

14.Whittaker, S., and O'Conaill, B. (1997), The Role of Vision in Face-to-Face and Mediated Communication, Video Mediated Communication, Finn, Sellen, and Wilbur eds., Lawrence Erlbaum Associates Inc., pp. 23-50.

15.Zhao, Q.A., and Stasko, J.T.: Evaluating Image Filtering Based Techniques in Media Space Applications, Proc. CSCW'98, ACM Press, (1998) pp. 11-18.