The Magic Window: Lessons From a Year in the Life of a Co-Present Media Space

James Hyun Hoi Kim[1], Carl Gutwin[1], and Sriram Subramanian[2]

[1]Computer Science Department, University of Saskatchewan
110 Science Place, Saskatoon, Saskatchewan, S7N 5C9
Canada

[2]Media Interaction Group, Philips Research
PO Box WB 01, 5656 AE Eindhoven
The Netherlands

james.kim@usask.ca, gutwin@cs.usask.ca, sriramable@gmail.com

ABSTRACT

The windows and doorways that connect offices to public spaces are a site for people to gather awareness information and initiate interaction. However, these portals often reveal more information to the public area than the office occupant would like. As a result, people often keep doors and window blinds closed, which means that nobody can gather awareness information, even those with whom the occupant would be willing to share. One solution to this problem is a *co-present media space* – a computer-mediated video connection at the boundary between an office and a public area. These systems can provide both greater privacy control to the occupant and greater overall awareness information to observers. To see how co-present media spaces would work in real world settings, we built what we believe are the first ever co-present media spaces, and deployed them in two offices. From observations gathered over fifteen months, it is clear that the systems can do a better job of balancing the occupant's need for privacy and the observers' need for awareness better, than a standard window. However, we also identified a number of issues that affected the use and the success of the systems: the existence of alternate information sources, confusion with existing social norms, disparities between effort and need, and reduced interactional subtlety for observers in the public area. Our work contributes both a novel arrangement of a media space for co-present collaborators, and the first investigation into the design factors that affect the use and acceptance of these systems.

Categories and Subject Descriptors

H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces – *Computer-supported cooperative work*

General Terms

Design, Human Factors.

Keywords

Awareness, media spaces, privacy, public and situated displays.

1. INTRODUCTION

In many organizations, work areas are laid out such that private offices are arranged around a public or semi-public space such as a hallway, open area, or research lab. In these settings, the boundaries between the public and private space – the windows and doorways at the office entrances – are important sites for group awareness and interaction. The windows and doorways act as information portals that let people gather awareness about the people on the other side of the boundary, and also serve as communication channels that allow people to negotiate access and initiate interaction [7,15].

Although office doors and windows are ubiquitous, as are the interactions that occur through them, there are problems in these situations that affect both the office occupant and the observer in the public area.

First, office boundaries often provide poor control over privacy for the occupant – both in terms of confidentiality (control over information moving out) and solitude (the ability to limit the information coming in). In particular, ordinary doors and windows provide the same level of awareness and access to everyone in the public area regardless of their relationship, even though the occupant is likely to have different privacy preferences based on who is receiving the information [13,22]. This 'one size fits all' policy means that many people will reveal only minimal awareness information, closing doors and window blinds completely (Figure 1). This protects privacy, but greatly restricts information and access for those people with whom the occupant has a closer relationship, and with whom the occupant would be more willing to share.

Second, there are other situations for observers in the public area where office doors and windows do not provide enough awareness information, even when they are open. In particular, when the occupant is out of the office, observers get only the information that the occupant is out, but cannot answer questions such as why the occupant is away, where they have gone, and whether and when they are likely to return.

Figure 1. Three doors with different levels of confidentiality: clear (left), frosted (middle), and completely covered (right).

One solution to these problems is a *co-present media space*, a computer-controlled video window that replaces an ordinary window between the office and the public area. Adding computer

Conference'04, Month 1–2, 2004, City, State, Country.

control to the window allows different information to be given to different people, and allows observers to see a more informative display when the occupant is away. The metaphor of the glass window is preserved, but the new version has additional capabilities – such as reactivity to the identity of the person looking through it – that led us to call our system the Magic Window (Figure 2).

Figure 2. The Magic Window, seen from a public area.

The goal of the Magic Window is to both improve control over privacy for the occupant and increase the overall amount of awareness information available to (some) observers. Situated public displays like the Magic Window have been discussed to some degree in ubiquitous computing and CSCW literature (e.g., [10,27]), but there is still very little knowledge available about how to design and deploy these systems in the real world.

To determine some of these issues, we built and deployed two Magic Window systems in two office locations, and observed their use over fifteen months in total. In our evaluation, we were interested in whether the device was successful in improving control over awareness and privacy, and in the social and interactional issues that affected its real-world use. The system was successful: at the end of the evaluation, one group of participants asked for the system to be installed permanently. In addition, we identified several factors that affected how the Magic Window was used, factors that should be considered in the design and deployment of future systems.

Our work contributes both a novel arrangement of a media space for co-present collaborators, and the first investigation into the design issues that affect the use and acceptance of these systems. In the following sections, we review prior work that underlies the idea of the Magic Window, introduce the system itself, and then discuss the longitudinal evaluation and the lessons learned from it.

2. RELATED WORK

The Magic Window and the idea of a co-present media space are based on four foundations: research into informal awareness and casual interaction; past work in media spaces for distributed groups; research on privacy in video-mediated communication; and the idea of situated and public displays.

2.1 Informal awareness, casual interaction

Informal awareness of a group is the general sense of who is around, what they are doing, and who is available for collaboration [14]. Informal awareness is ubiquitous in co-located work environments [21,30], and is maintained as a side effect of ordinary work activities: for example, by walking down a hallway or working in the same space as others, people notice which offices are occupied, who is talking to whom, and whether people are busy or not. Kraut and colleagues [21] call this process 'browsing the social environment.'

One of the main ways that informal awareness is used is in the initiation of casual interaction and collaboration – unplanned and informal interactions such as chance encounters in a hallway or unplanned meetings in a person's office [20]. The purpose, duration, and degree of involvement in these episodes are not known in advance, but are negotiated during the interaction [21]; however, they are usually short, and are much more frequent for collaborators who are located close to one another.

Casual interaction supports the execution of work-related tasks, coordination of group activity, and the build-up of community among co-workers [14,21]. It also accounts for a large portion of the work day. Whittaker et al. [30] found that 31% of work time was spent in casual interaction and observed that the unplanned interactions led to detailed task oriented discussions.

2.2 Awareness through video media spaces

The value of casual interaction and informal awareness for co-located workers leads to the question of whether this value can be provided to distributed groups as well. In an attempt to provide these benefits over distance, several CSCW researchers have investigated *media spaces* – video and audio-based virtual shared spaces that provide awareness and allow communication between people, sites, and workgroups [6].

Video has been used as the basis for several media spaces [6,7,14,15,26]. The main motivation for using video is to provide rich interactions in situations where face-to-face conversations are difficult; video can also provide spontaneity of interaction, support social interactions, and cope with complex and equivocal communication [15].

There are three interaction metaphors that are evident in different video media spaces: the telephone, the overview [7,14], and the hallway [26,29]. The telephone model (i.e., video conferencing) allows a caller to interrupt the recipient whenever the caller wishes; this model requires the recipient to explicitly respond to a call. This model ensures that confidentiality is not violated (since no information is disclosed before the call is accepted), but the caller can invade solitude by calling at inappropriate times.

The overview model (e.g., Polyscope [7], or Portholes [14]) helps a user to gather awareness information about others through periodically-updated multiple video images. In these systems, users can determine an appropriate time to interact with others without explicitly interrupting, and there is no need for explicit action for a user to let others watch one's image. Overviews can provide awareness and build a sense of community among distributed groups [14]. However, some people feel that confidentiality is compromised, since images are broadcast without any indication of who is watching.

The hallway model (e.g., Cruiser [15], OfficeWalker [26], or Montage [29]) creates a virtual set of offices attached to a central hallway. Systems based on the hallway metaphor allow 'glancing' at others – short-term video connections that show the caller whether the recipient is available for interaction. Upon the recipient's acknowledgement, a full video and audio connection is

established; otherwise, the glance connection times out. In some systems such as Cruiser [15], the glance feature was seen to be too abrupt; later systems introduced subtler initiation procedures such as fade-in video [29].

2.3 Privacy in awareness systems

Privacy is much discussed in HCI and CSCW literature, and there are several possible definitions of the concept. In this paper, we consider privacy to be the ability of an individual to control the flow of information both away from and towards the self [1,9].

Confidentiality is control over information moving outward from the self towards others. It is the ability to regulate what information is disclosed, and to what extent, in different situations. Two important points in confidentiality are information fidelity and sensitivity. For instance, disclosure of high fidelity information (such as high-quality video information) can increase the chances of violating one's confidentiality. Also, highly sensitive information, such as credit card information, may need to be more carefully controlled.

Solitude is control over information moving toward the self: that is, one's control over interactions requested by incoming interruptions. Changes to the state of office windows and doors is an example of how people currently control solitude.

Privacy has always been a major concern in awareness systems because awareness provided by such systems can always include privacy-sensitive information. Many video-based system users have reported that video is highly invasive [15,24]. Boyle and Greenberg [9] state that there is still a major requirement for privacy control that is both fine-grained and lightweight in video-mediated communications.

There are several ways that video systems can provide control over outgoing and incoming information in video awareness systems. These include explicit and implicit controls over information, controls based on social groups, and control over past and present information.

- *On/off switches*. A simple switch provides lightweight control over all information moving through the system, and has been seen as an important control by users [2,11,16,23]. However, an on/off switch does not provide fine-grained control, and some researchers report that users often forget to trigger the control [3,16].
- *Relationship-based and group-based control*. Relationships can be used to control both outgoing and incoming information, since people often have different privacy preferences for different people – e.g., spouses and co-workers often get more information than acquaintances [13,22]. Organizing people into groups can also reduce the user's configuration load [28].
- *Automatic determination of availability*. Sensor-based systems can automatically assess an occupant's presence and availability; the availability level can be shown to observers, and can also be used to control incoming information [19,3].
- *Control over what others see*. In many video-based awareness systems, image processing techniques have been used to protect confidentiality. Techniques such as blur filters [23,18], venetian-blind effects, or Eigenspace filters [11] alter the fidelity or content of the live video such that the system shows enough information for awareness of presence and activity, but hides the details of identities and actions. In sensitive environments, however, even these alterations may not enough to adequately protect privacy [24].
- *Reciprocity*. Some systems protect against spying behaviour by ensuring that information flows are always symmetrical – that is, "I can see you only if you can see me" [7]. However, real-world awareness gathering is often not balanced in this way, and reciprocity can lead to increased interruption [9]. As a result, allowing non-reciprocal actions, such as quick glances without interruption, might be beneficial both for the observer and the occupant.
- *Visualization of past activity*. Visualizing past activity (as seen in the Work Rhythms system [2]) can provide useful information about a person's current and future activities and availability. By examining such visualizations, one is able to answer a question like "When is the person likely to be at the office?" However, there are also clear confidentiality concerns that are raised by the idea of collecting and visualizing summaries of past awareness information.

2.4 Public and situated displays

The Magic Window is different from most media spaces in that it is situated within a particular space (the boundary between the office and the public area) in a co-present environment. Although many types of display are situated in a co-present environment – signs, notice boards, airport arrival and departure signs – researchers have recently paid more attention to computer-mediated versions of these displays that are designed for interaction between co-located collaborators.

The situated nature of these displays critically changes the way that they must be designed, and the way that they are used. As O'Hara and colleagues [26] state,

> The vast majority of understanding of display-based interaction within the field of Human Computer Interaction centres around interaction at a desktop PC display where an individual is in a relatively bounded context in terms of proximity to the displayed information and where the interactions are typically a central focus of user attention. By contrast, the value of situated display technology and interactive signage is not dependent on it being constantly at the focus of our attention. Rather, much of the time, this information remains peripheral to our primary goals and attention. But being situated in particular contexts and locations, these displays move fluidly into focus at appropriate points in our activity contexts." ([26] p. 107).

There are still only a few examples of this type of system. One main design approach is to provide a communication device for an office occupant. For example, Hermes [10] and OutCast [25] provide a way for occupants to provide calendar information, notes, and personal greetings to observers or visitors in the public area outside the office; in addition, these systems allow visitors to leave messages for the occupant. A second type of situated display involves advanced signage in a public space. For example, the RoomWizard [27] is a display system for booking meeting rooms in an organization. Unlike the Magic Window, these systems are not based on video, and are not based on real-time awareness information. That is, they are used in an explicit fashion, where occupants or users explicitly choose what messages or content to put into the display.

There are also few evaluations of situated displays, and due to the situated nature of the system and the peripheral nature of their use, these must often take the form of longer-term deployment and observation studies. Two evaluations that have been carried out, however, were of RoomWizard [27] and Hermes [10]. Issues

identified in these studies included the amount of user effort required to use the systems, trust in the information, and the impact of making information publicly visible. We return to these findings below when we discuss results from our own evaluation of the Magic Window.

3. The Magic Window

The Magic Window is a co-present media space designed to support awareness between an office occupant and observers in the public area outside the office (Figures 2,3,4). The system is not intended to support conversation, but rather to support the kinds of activities that people undertake at the doors and windows of existing offices: checking to see if people are around, what they are doing, and whether they are available for interaction.

The system has a two-way video link between the office and the public area; through this link, observers can see the inside of the office, and the occupant can see the public area. The system makes use of two PCs, two web cameras, three LCD monitors, a USB fingerprint reader, and a Phidget-based doorbell (see Figure 3). The main system was built in Java, with image capture and processing in C++ and OpenCV; communication between machines used Java RMI. A video of the system can be seen at hci.usask.ca/publications/2007/magic-window.wmv.

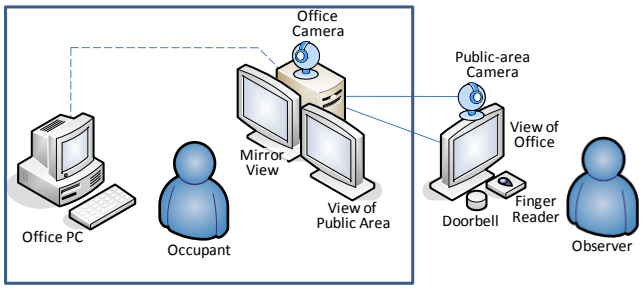

Figure 3. Main components of the Magic Window system

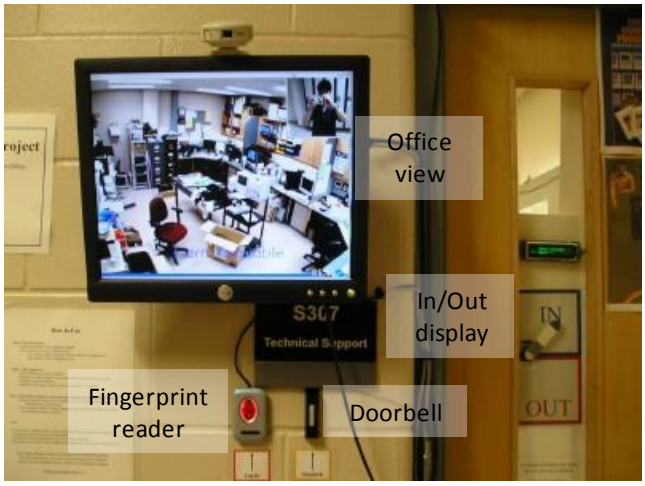

Figure 4. Magic Window from the public area (support office)

3.1 The system as seen from the public area

The main parts of the system that are visible from the public area are the window into the office (showing either a current or past view), the in/out display, the observer login, and the doorbell.

Window (current view). The 'window' is an always-on 17-inch LCD monitor that faces the public area and that shows real-time video of the office (from the 'Office Camera' in Figure 3) as long as there is someone in the office. The fidelity of the video (manipulated using a blur filter, see Figure 5) depends upon whether an observer has logged on to the system, and who they are. Between visitors, the window shows a default fidelity level (set by the occupant, as described below).

Figure 5. Fidelity levels 10, 5, and 1 (using blur filter)

Window (past view). Whenever the occupant is away from the office, the window displays a past view (Figure 6) that shows the occupant's presence history. This view shows a number of snapshots from the last time the occupant was in the office, and shows a presence timeline (based on the Work Rhythms display [2]) compiled from previous samples. Again, the amount of detail available in this view (fidelity, number of snapshots, and granularity of presence timeline) is dependent upon who is observing. From this view, an observer can draw conclusions about the occupant's activity and about the likelihood of their returning, based on past patterns.

Figure 6. Past activity view

In/Out display. This display is a simple indicator of presence that is easy to see from a distance. The display uses the same motion sensors as the window, and switches status whenever the occupant enters or leaves the office (see Figure 4 right).

Observer login. In order to specialize the display based on relationship, the system needs to know the identity of the observer. Two mechanisms were tested: a face-recognition algorithm using the OpenCV library, and a fingerprint reader (see Figures 3 and 4). During early testing it was determined that the face-recognition system was not robust enough for everyday use, so the fingerprint reader was used for the duration of the study. Once an observer has been registered by the office occupant, they can log on by placing a finger on the reader; the window will then change to show information at the fidelity level that is specific to that person. In addition, the window also shows a picture-in-picture of the observer, to show them what will be seen of them by the occupant (Figure 4 bottom).

Doorbell. A button below the display allowed observers to signal the occupant that they were interested in interacting (see Figure 4, bottom). The button acted like a real-world doorbell, except that the signal given to the occupant was also dependent upon the identity of the visitor. The ring sound that was played inside the office was dependent on the occupant's relationship to the visitor: for people who were in the occupant's high-priority group, the doorbell rang three times; for people who are unknown to the system, or who have not logged on, the doorbell rang only once, and much more quietly.

3.2 The system as seen from the office

Six parts of the system are seen or manipulated by the office occupant: the window into the public area, the reflection view, the relationship interface, visitor notifications, the privacy settings interface, and the visitor record.

Window into the public area. This display (also on a 17-inch LCD monitor) shows real-time full-fidelity video of the public area (from the 'Public-area Camera' in Figure 3).

Mirror view. This display shows the occupant a full-size view of exactly what observers will see from the public area (including the fidelity level of the video).

Relationship interface. A custom system running on the occupant's PC allows observers to be registered with the system and placed into groups, each of which can be associated with a different fidelity level. This level indicates the quality of video and the detail of the past view that the observer will see after logging on to the system from the public area.

Visitor notifications. As an additional indication that people are observing the office, a notification pops up on the occupant's PC when an observer logs on to the system from the public area.

Privacy settings interface. A set of controls, both manual and automatic, allow the occupant to change their privacy settings to match their current activity. First, a global solitude slider allowed the occupant to display one of four availability messages on the outside window ("I am available," "I might be available," "I might not be available," and "I am not available"). Second, a global confidentiality slider adjusted all pre-set video fidelity levels upwards or downwards. This allowed the occupant to adjust the overall level of information disclosure based on their current activity. Third, a telephone sensor automatically changed both the solitude and confidentiality sliders (increasing both levels) while the telephone handset was in use, and displayed a special message ("I am on the telephone") on the outside window. Finally, a global on/off switch allowed the occupant to quickly turn off all outgoing information.

Visitor record. To show office occupants who visited them while they were away, the system keeps a visitor log that records names and login times.

4. Evaluation of the Magic Window

We carried out a fifteen-month evaluation of the Magic Window, in two office environments. Our goals were both to determine whether the system was able provide a better balance between privacy protection and awareness for observers (than ordinary doors), and to determine what factors in day-to-day operation affected the use and adoption of the window.

We designed our evaluation in a way similar to that of an earlier long-term evaluation of the Hermes display system [10], which both tested the technology on the research group themselves, and which allowed the users to participate in the evolution of the system that occurred during the trial period.

Therefore, one of the office settings that we tested was a faculty office inside our own research lab, and we were regular users of the system. To provide a second set of data that did not include our own opinions, however, we also deployed the system in a second office with which we had no connection.

4.1 Office environments

The Magic Window was deployed in two office settings – a faculty office in a research lab (Figure 7), and a university tech-support office (Figure 8). In the first setting, the occupant was a professor in the HCI lab (and is an author of this paper). The observers in the public area, in order of frequency, included graduate and undergraduate students, other faculty, and departmental staff. There were approximately 15 visitors per day to the faculty office (about 30% of these are regular visitors); in addition, the occupant leaves the office (and the lab) 10-15 times per day to carry out various tasks and attend other meetings.

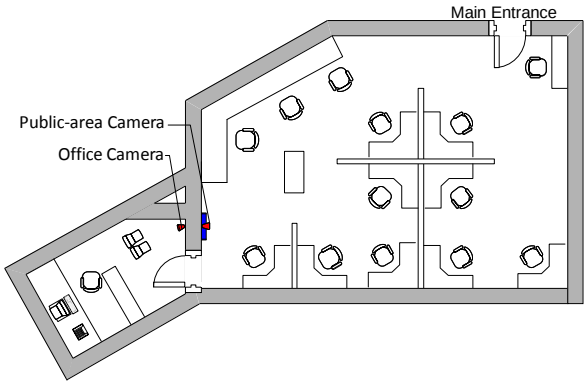

Figure 7. Layout of the academic office setting.

The second office was not connected with our research group, and was also different in that it involved two occupants. These were staff members responsible for maintaining computers in the undergraduate labs. The office is located on a main hallway in the undergraduate section of the building, and the hallway was the public area in which the Magic Window was installed. The observers in this setting included the same groups as listed above, but visits by other staff and undergraduate students were the most frequent. The occupants had, on average, eight to ten visitors on a daily basis, 10-20% of whom were regular visitors. The occupants also left their office regularly (5-10 times/day).

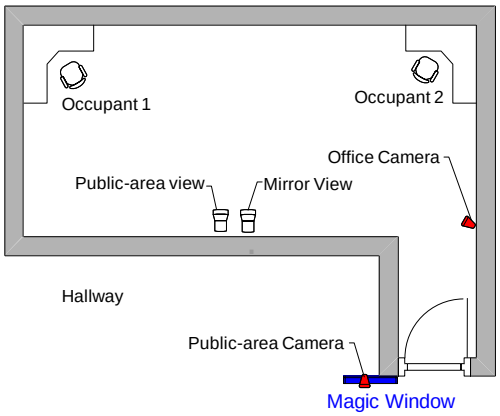

Figure 8. Layout of the tech-support office setting.

The system was deployed in these two offices at different times. The evaluation began with the academic lab (five months, October to February, during a typical academic year), and then continued with only the tech-support office (ten months, April 2005 to January 2006).

4.2 Data collection

Data was collected in several ways during the trial. First, observations continued throughout the entire trial period; some of these observation sessions were dedicated sessions where the experimenter would sit in one of the settings and watch what happened over a morning or an afternoon; other observations were collected informally during everyday activities.

Second, several people were interviewed during the trial, including the three occupants, six other users in the faculty-office setting, and five other users in the tech-support setting. Open-ended interviews were conducted with occupants five times during the trial (two in the faculty-office setting, three in the tech-support setting); questions involved usage patterns, basic usability issues, effectiveness of the system, and privacy issues.

Third, more focused interviews were carried out with various users in both settings to evaluate the usability of different displays in the system, as these evolved through the trial period. For example, we changed the past-activity view twice during the trial to improve its usability, and interviews were carried out for each of these new designs.

5. Results

We first outline the basic usage of the system, then discuss the overall success of the system in the two settings, and then move on to the set of issues that affected the way that the system was used during the trial.

5.1 Usage of the system

The system was clearly used regularly throughout the trial period in both office settings. Through observation and discussions with the occupants, we estimated the number of times observers logged on to the system, and recorded the number of registrations and groups in both settings. However, these numbers do not reflect all of the uses of the window; as a peripheral display that was always on and always visible in the space, it is difficult to determine exact usage. From our discussions with users, it is clear that all of the people who worked in these two settings at least noticed the window and looked at it regularly as they moved through the space. This means that people picked up some information simply as a side effect of proximity, as has been observed with other situated and public displays (e.g., [26]).

5.1.1 Usage in the faculty office / research lab

For the faculty office setting, there were 14 people registered over the five month trial, and these people were organized into three groups (the faculty member's own graduate students, other students, and other faculty and staff) in addition to the default setting.

There were approximately 12 logins per week in the faculty office setting. This number is fairly low compared with the approximately 15 visits per day reported by the occupant. There are several reasons for these low usage numbers, as discussed in the following sections. However, there were many instances of the system being used without anyone logging in; several of the members of the research lab outside the office stated that they looked at the window regularly, even if they did not log in.

5.1.2 Usage in the tech-support office

For the tech-support office setting, there were eight people registered in the system (seven co-workers, and one undergraduate who was a regular visitor). These people were organized into two groups (the co-workers in one group, the undergraduate student in another) in addition to the default settings.

There were approximately 19 logins per week during peak use (late academic term). Again, there were considerably more visitors per week that used the window; we regularly saw visitors walk up to the window or check the in/out indicator, and then walk away again without logging on to the system. The occupants estimated that most of the 8-10 visitors per day would at least glance at the window.

5.1.3 Usage of different system features

The present view (e.g., Figures 2 and 4) was the main way that the Magic Window was used in both office settings. People checked the window, both in the default view and after logging in, to get a sense of what was going on inside the office, and whether the occupant was available. Although some users felt that the quality of the present view was too low to determine the specifics of the occupant's activities (see Section 5.3.4), most of the people who used the window felt that they could get what they needed from the video image. In addition, it was clear that the present view provided more information than a frosted-glass window or a window with blinds drawn.

The past view (Figure 6) was also used regularly, and was noted by users as the main feature that improved upon a regular glass window. All three main areas of the past view were identified as useful: first, the indication of how long the occupant had been away, which gave observers an idea of whether the occupant was nearby; second, the snapshots from the last time the occupant was in, which showed some users with whom the occupant had left the office; and third, the activity display, which gave observers at least some information about whether the occupant was likely to return to the office. Users stated that the past view could be improved to show a variety of other information, such as the occupant's current calendar entry, but in general, this feature of the system was seen as the most valuable for the observer.

The system settings features of the Magic Window (the privacy controls, the relationship and group interface, and the past visitor list) were not used extensively by the three occupants. In particular, the occupants set up their groups at the beginning of the trial, and rarely changed them afterwards (usually only to add a new registered user). In addition, two occupants reported that they sometimes forgot to change the global privacy settings, which has also been seen in prior research [3,16].

Finally, the doorbell feature was used frequently in the tech-support setting (it was not installed in the academic office setting). We did not record total use of the doorbell, but the occupants estimated that 80-90 per cent of visitors pressed the bell rather than knocking on the door.

5.2 Overall success

It was clear from interviews with the three occupants that the Magic Window provided better control over privacy (both confidentiality and solitude) than with either a translucent glass window or with a partly-open door. All three occupants stated that their overall level of confidentiality was higher than it was without the Magic Window, and all three agreed that they could

use the system effectively. The best indication of the system's success is in the response of the two tech-support occupants, who asked that the system remain installed after the trial was finished – it has now been deployed for more than two years, and will remain in place permanently.

There was, however, a considerable difference in the overall success of the Magic Window between the faculty office and the tech-support office, as we describe in the next section.

5.3 Factors affecting use of the window

From our observations and our own use of the Magic Window, we have identified a set of situational and social issues that affected the way in which the window was used and the window's effectiveness in mediating awareness and interaction. These issues include the existence of alternate information sources, confusion with existing social norms, a discrepancy between effort and need, problems caused by the quality of information in the system, remaining privacy issues for both occupants and observers, and the overall reduction in interactional subtlety that was caused by the window.

5.3.1 Multiple information sources

The existence of other sources of information (e.g., an open doorway) changed the way that the Magic Window was used.

Awareness information may be available from more than one place in an office environment, and these different sources may provide different levels of quality and may require different levels of effort. In these cases, people use the information source that best fits their current needs. In the faculty-office setting, we saw two situations in which observers in the public area gathered information through alternate means

Coming and Going. The layout of the lab around the office meant that several people in the public area were able to maintain awareness of the occupant without using the window. The occupant's office is located inside the lab, and he had to walk through the lab whenever leaving or entering the office. As a result, people in the lab could easily track the occupant's presence, and did not have to use the window to determine if the occupant was in or out. For example, one student whose desk was in the lab stated that he almost never used the window for this reason, because he always knew when the occupant was in. We saw that people from outside the lab were much more likely to use the Magic Window to check presence. For example, another faculty member whose office is down the hall often checked the Magic Window to see if the occupant had been in that day.

The Office Door. At the start of the trial in the faculty-office setting, the occupant generally kept his office door partly open, and as a result, awareness information became available through two sources: the Magic Window, and the open door. When the door was open, observers in the public area often looked through the doorway, and bypassed the window altogether. The open door allowed people to use a conventional mechanisms to obtain awareness, and they often chose this source rather than the window. There are three possible reasons why people chose the open door rather than the Magic Window. First, the doorway required much less effort than the window (i.e., no log-on required). Second, the doorway often provided higher-quality information (a clear picture instead of blurry video). Third, the practice of looking through the doorway was already standard practice, and observers were already familiar with this means for gathering information.

In contrast, this issue did not arise in tech-support office setting, since the layout of the space does not lead to multiple information sources. The public area outside the tech-support office is a hallway rather than a lab, and since no observers are permanent residents of the hallway, there was much less opportunity for people to track comings and goings. Second, the tech-support office door was regularly kept closed (to reduce both noise and interruption), and so there were no low-cost or high-quality alternate sources of awareness information.

5.3.2 Confusion with existing social norms

Altering strong social practices (such as door state) as a way to push interaction towards the window led to confusion.

Prior to the Magic Window, the door in the faculty office would typically be left open about halfway (see Figure 2), which prevented casual observers from seeing the occupant at his desk, but still left the door open. The occupant stated that he liked keeping an 'open-door policy' for the other members of the lab, and that the half-open door provided a reasonable balance between privacy protection and an invitation to interact.

After the Magic Window was deployed, the 'multiple information sources' issue was identified as a reason for reduced use of the window (see above). As an experiment to try and force observers to use the window for awareness instead of the alternate information paths, the occupant attempted to keep his door closed.

The strong signal of the closed door, however, went too far towards suggesting that the occupant was never available, even if the window showed different information. Interviews with lab members indicated that they were more reluctant to interrupt the occupant because of the closed door. The perception was strong enough in the lab that the occupant put a sign on the door stating that "a closed door does not mean I'm unavailable – please check the window."

In contrast, this issue did not cause a problem in the tech-support setting, primarily because door state was not a primary indicator of availability. The tech-support office door opened onto a public hallway, and was kept closed more regularly even before the trial, in order to reduce interruptions and noise from the hallway.

5.3.3 Disparity between effort and need

A mismatch between the amount of effort people had to expend and the amount of information they received, reduced the use of the window.

People have differing needs to stay aware of an office occupant: if they absolutely must talk with the occupant by the end of the day, they are likely to have a high need for maintaining awareness (so that they can catch the person at the earliest opportunity). In contrast, if they are only casually interested in the presence and availability of the occupant, they have a low need – at this low end of this scale, the need to interact is entirely discretionary.

These differing levels of need define implicit thresholds of effort that people are willing to expend to gather the awareness information: a high level of need implies that people will go to more trouble to gather the information, whereas discretionary or casual awareness must be obtainable for very little effort.

We found that for several kinds of awareness gathering, the Magic Window required a higher level of effort than people were willing to expend. The main problem in this regard was the log-on procedure: to log on to the system, observers in the public area had to walk up to the window, place a finger on the fingerprint

reader, and wait approximately three seconds before the screen changed to show additional information.

Walking over to the window was the major problem, particularly when there was not a strong need to maintain awareness. For example, one observer in the faculty-office setting stated that he often checked the occupant's presence (prior to the trial) by looking at the state of the door and lights in the office. With the Magic Window, however, he could not determine presence at a distance, and was not willing to make the effort to walk up to the window, merely to check if the occupant was in the office. (As a result of this experience, we enlarged the In/Out display so that it could be seen at a much greater distance.)

This issue has also been identified by O'Hara and colleagues [27], who state that situated displays should design for "different spatial zones of interaction around the device." For their RoomWizard display, for example, status lights allowed information-gathering from a distance: "while people are walking about, simple binary judgments can be made quickly with minimal cognitive effort […] without need for more detailed analysis of the booking information on the display" ([27] p. 114).

Although some steps can be taken to reduce effort, and to provide information that is appropriate to the different zones of interaction, one problem remains – that of being able to provide individualized information to the specific observer but without requiring undue effort. The fingerprint reader was not simply an information switch, but was an identification process so that the window could provide information tailored to the individual. Unfortunately, it is difficult to assess identity at a distance (even with other technologies such as face recognition), which makes it difficult to specialize the display of awareness information.

5.3.4 Quality of information

Low quality of awareness information affected the ways the system was used by both the viewers and the occupant.

Quality of awareness information may be defined in terms of three dimensions: fidelity (how closely the received information resembles the original source), granularity (how detailed the information is), and richness (the number of different kinds of information available). The evaluation showed that the use of the Magic Window differed from what we expected because of information quality issues.

First, for those people who had the highest privileges, the best video that the system could show was still far lower quality (in size, field of view, resolution, and frame rate) than a glass window. Our cameras had only 45 degrees of view angle, and used a frame rate of 15 FPS and a resolution of 240 by 320. Several users mentioned that they would have liked a much higher quality view, and that they would have been able to better judge availability with a better view. In addition, we did not consider auditory awareness at all in the system, and some users stated that it was difficult to determine availability from the video alone (e.g., in situations where the occupant was wearing a headset, and could be involved in a conversation). Some of these quality issues will be addressed by better hardware and the addition of audio support, but video windows are still unlikely to reach the quality of a glass window or a partially-open door.

Second, the quality of the default view was too low for most observers. Although the default levels were set by the occupants, several observers stated that they were unable to gather much awareness information from the window at all. It is worth noting that over time, the occupants of both offices raised the default level of quality (by making the video less blurry), perhaps agreeing with these concerns. As discussed above, there was also no way to differentiate high- and low-priority observers from a distance, and the low-quality default view frustrated some high-priority observers in the faculty office setting.

Third, the quality of awareness information about the public space proved to be insufficient for the occupant in the faculty office setting. We had not really considered the needs of the occupant to stay aware of the public area, and in this setting the Magic Window did not provide enough information. In particular, the narrow angle of view, and the lack of auditory information made it difficult for the faculty member to determine who was in the lab, and a general sense of awareness about people's activities. This need for rich informal awareness was another reason that the occupant kept the office door partially open.

Fourth, there were problems with the accuracy of the In/Out display that led to reduced trust in that part of the system. For various technical reasons, the sensors that assessed the occupant's presence (video tracking and motion sensors) could occasionally be wrong, and also took up to a minute to recognize a change in state. Observers in the tech-support office stated that this was a major problem, since all of the other information gathered from the window is interpreted in terms of the presence display. It was clear that trust in sensed information is brittle; after a few experiences with an incorrect display, several users stated that they stopped believing the In/Out view.

5.3.5 Privacy for the observers

Observers in the public area felt that their privacy as occupants and awareness seekers was compromised.

One unexpected finding of the study was that some of the observers in the public area were concerned about their privacy – essentially, they had many of the same attitudes as 'occupants of the public area' as the office occupant. There were two ways in which this issue came up. First, observers did not like the fact that full-fidelity video images of them were being taken as they walked up to the Magic Window, particularly given that the video images that they were looking at were highly blurred. This seemed to several users like an unfair imbalance, which would not have occurred with a regular window or doorway (e.g., both parties' views are partially obscured by a translucent window or a half-closed door).

Second, some observers did not like the fact that they were unable to gather any detailed awareness information without this activity being made obvious to the occupant. These users were quick to state that they were not interested in being able to spy on the occupant, but rather that there were situations where their interest was only in determining the occupant's availability, not in starting an interaction. The Magic Window showed the identity of the current visitor as soon as they had logged in, and this in some cases led to the occupant saying hello or making a remark to the visitor. In one case, after being greeted by the occupant, the visitor said "Oh, nothing, I was just checking to see if you were in."

This issue suggests that there are reasons to allow less-obvious information-gathering activities – primarily because they protect the occupant from interruption. A half-open office door allows people to tailor the degree to which their information-gathering activities are public (e.g., to peer in without attracting much attention), whereas the Magic Window provided only a single mechanism that was much less flexible. Although this ensured

that the occupant was never spied upon, this knowledge came at the cost of more frequent interruptions.

5.3.6 Privacy for the occupants

Minor issues of confidentiality and solitude caused minor concerns, although these did not greatly affect use.

Although for the most part the occupants were satisfied with the privacy controls in the Magic Window – and as discussed above, better control over confidentiality was seen as one of the major advantages of the system – a few issues were still recorded. First, the faculty-office occupant stated that he was concerned with the snapshots in the past view display (see Figure 6). These were shown at full fidelity, and the occupant was concerned that these longer-term pictures could be embarrassing or unflattering. We updated the system to allow these snapshots to be shown at a specific fidelity level, and this seemed to be a reasonable solution for the occupant.

Second, one of the occupants in the tech-support office stated that the automatic sensing of presence actually reduced his ability to control solitude. Prior to the installation of the window, the occupant had been able to appear to be away, by turning out the overhead light and closing the office door. With the window in place, however, the In/Out display would sense and display his presence. The occupant stated that he was reluctant to turn off the entire system, because he still wanted to be available. This shows that people's willingness to share even the most basic information is subject to context, and also that automatic sensing solutions may sometimes interfere with existing practices for maintaining solitude.

5.3.7 Reduced subtlety in negotiating interaction

An issue that underlies several of the other factors discussed above is that the Magic Window seemed to reduce the richness and subtlety with which people could organize both their information-seeking behaviour and their negotiation of interaction.

On the awareness side, the issue discussed above shows the problem: that the Magic Window did not support some of the subtle ways that people go about gathering awareness – instead, they were forced to make it an explicit act.

On the initiation-of-interaction side, we also noticed that the Window's simple mechanisms (like the doorbell) prevented any kind of subtle negotiation about whether it was a good time to interrupt or whether the visitor should wait for a few minutes. Instead, the window made interactions both narrower and more explicit, which may force interaction down a more formal path (as is the case with real-world visitors ringing real-world doorbells).

It is certainly possible to add in greater subtlety to a co-present media space. It should be possible to give observers more control over the visibility of their information-gathering activities, and allow them to use this visibility as an opening in the negotiation of interaction (since showing interest in someone is often a precursor to starting an interaction).

6. Discussion

Here we consider lessons that can be provided to designers of co-present media space systems, and address the issue of where systems like the Magic Window will be most successful.

6.1 Lessons for designers

The primary lesson from our experience with the Magic Window is that co-present media space systems can provide increased control over both confidentiality and solitude, and have been shown to work successfully over a long term. However, there are many design issues that require careful consideration from designers of future systems. The following list gives the lessons that we believe designers should take away from our evaluation:

- Systems should provide different awareness information at different distances, and should ensure that the information is appropriate to the distance.
- The amount of effort to gather information should be matched to quality of information and information need; in particular, there should be some very low-cost ways of gathering information (e.g., presence) at a distance.
- Relationship-based tailoring of information is a powerful means for controlling privacy; however, this approach requires low-effort identification of observers, which is difficult to achieve at a distance.
- Designers should consider the privacy rights of people in the public area as well as the office occupant, particularly in terms of video fidelity and how images get stored over time.
- Designers should use video and computing hardware that increase the quality of awareness information presented to high-priority observers.
- Trust in sensed information (e.g., in/out status) is brittle; automatic decisions must be accurate and reliable, or observers will stop using the information.
- Multiple levels of awareness, and multiple mechanisms for obtaining that awareness, will be necessary to support subtle interactions from the public area. However, a media space is unlikely to ever be as rich as a traditional office boundary; therefore, there will be some loss of subtlety in the ways that people can gather awareness and negotiate interaction

6.2 Where does the window work best?

The two office settings that we studied – the academic lab and the tech-support office – resulted in different overall rates of adoption and degree of use. The tech-support setting was a more successful environment for the Magic Window (evidenced by the desire to keep the system in place). There are several characteristics of this setting that we believe can be generalized, and that indicate other situations where co-present media spaces can be successful.

- *A more public area outside the office*. The public area outside the tech-support office was fully public, unlike the semi-public research lab in the faculty-office setting. This difference meant that people spent less time in close proximity to the tech-support office, and were therefore less able to gather awareness information from comings and goings. This meant that the Magic Window was more likely to provide valuable information to a visitor.
- *Office doors likely to be closed*. The tech-support office door was often closed for reasons other than availability (e.g., noise). Therefore, there was less of a problem for the Magic Window with existing social norms, and also removed another alternate information source.
- *More formal interaction styles*. Visitors to the tech-support office already use a more formal style of interaction than in the academic lab – people are more likely to knock, and many visitors (e.g., undergraduate students) do not know the occupants well, if at all. In these cases, the reduced subtlety of the Magic Window was not as much of a problem, and the built-in interaction mechanisms work reasonably well.

7. Conclusions and Future Work

The Magic Window is an example of a co-present media space, a system that attempts to provide better control over privacy for an office occupant. To see how co-present media spaces would work in real world settings, we studied the Magic Window in two office settings. From observations gathered over fifteen months, it is clear that these systems can successfully balance the occupant's need for privacy and the observers' need for awareness. There are several social, environmental, and interactional issues that affect the use and the success of these systems, but the end result of our evaluation is that systems like the Magic Window can be very successful in some office environments.

We will continue our investigations of co-present media spaces in several ways. First, we will continue our observations of the Magic Window system in the tech-support setting, since it will remain in operation. Second, we will experiment with ways to add more levels of awareness information to the system, to increase the subtlety that is possible. Third, we will consider the design of an 'open door mode', where the window could be used as an adjunct to a second information source. Fourth, we plan several technical refinements to enable higher-quality video and an experience that is more like a real window – for example, multiple cameras and position tracking to allow 'directional looking' through the window.

8. References

[1] Altman, I., *The Environment and Social Behavior: Privacy, Personal Space, Territory, and Crowding*, Brooks/Cole Publishing, Monterey, CA, 1975.

[2] Begole, J., Tang, J., Smith, R., Yankelovich, N. Work Rhythms: Analyzing Visualizations of Awareness Histories of Distributed Groups, *Proc. CSCW 2002*, 334-343.

[3] Begole, J., Matsakis, N., and Tang, J. Lilsys: Inferring Unavailability Using Sensors, *Proc. CSCW 2004*, 511-514.

[4] Bellotti, V., Design for Privacy in Multimedia Computing and Communication Environments. In *Technology and Privacy: The New Landscape*, MIT Press, 63-98, 1998.

[5] Bellotti, V. and Sellen A., Design for Privacy in Ubiquitous Computing Environment, *Proc. ECSCW 1993*, 77-92.

[6] Bly, S. Harrison, S., and Irwin S., Media Spaces: Bringing People Together in a Video, Audio, and Computing Environment, *CACM*, 36(1), 1993, 28-46.

[7] Borning, A., and Travers, M., Two Approaches to Casual Interaction over Computer and Video Networks, *Proc. CHI 1991*, 13-19.

[8] Boyle, M., Edwards, C., and Greenberg, S., The Effects of Filtered Video on Awareness and Privacy, *Proc. CSCW 2000*, 1-10.

[9] Boyle, M., and Greenberg, S., The Language of Privacy: Learning from Video Media Space Analysis and Design, *ToCHI*, 12(2), 2005, 328-270.

[10] Cheverst, K., Fitton, D., and Dix, A., Exploring the Evolution of Office Door Displays, in *Public and Situated Displays: Social and Interactional Aspects of Shared Display Technologies*, K. O'Hara et al, eds., Kluwer, 2003, 141-169.

[11] Coutaz, J., Bérard, F., Carraux, E., Astier, W., and Crowley, J., CoMedi: Using Computer Vision to Support Awareness and Privacy in Mediaspaces, *Proc. CHI 1999*, 13-14.

[12] Dabbish, L., Kraut, R., Controlling Interruptions: Awareness Displays and Social Motivation for Coordination, *Proc. CSCW 2004*, 182-191.

[13] Davis, S., and Gutwin, C. Using Relationship to Control Disclosure in Awareness Servers, *Proc. GI 2005*, 75-84.

[14] Dourish, P., Bly, S., Portholes: Supporting Awareness in a Distributed Work Group Systems for Media-Supported Collaboration, *Proc. CHI 1992*, 541-547.

[15] Fish, R., Kraut, R., Rice, R., Root, R., Video as a Technology for Informal Communication, *CACM*, 36, (1), 1993, 48-61.

[16] Fogarty, J., Lai, J., and Christensen, J., Presence Versus Availability: The Design and Evaluation of a Context-aware Communication Client. *IJHCS*, vol.61, 2004, 299-317.

[17] Friedman, B., Kahn, P., and Hagman, J., The Watcher and The Watched: Social Judgments about Privacy in a Public Place, *HCI*, vol. 21, 2004, 235-272.

[18] Hudson, S., and Smith, I., Techniques for Addressing Fundamental Privacy and Disruption Tradeoffs in Awareness Support Systems, *Proc. CSCW 1996*, 248-257.

[19] Hudson, S., Fogarty J., Atkeson, C., Avrahami, D., Forlizzi, J., Kiesler, S., Predicting Human Interruptibility with Sensors: a Wizard of Oz Feasibility Study Modeling User Behavior, *Proc. CHI 2003*, 257-264.

[20] Kraut, R., Egido, C., and Galegher, J., Patterns and Communication in Scientific Research Collaboration, *Proc. CSCW 1988*, 1-12.

[21] Kraut, R., Fish, R., Root, R., Chalfonte, B., Informal Communication in Organizations: Form, Function and Technology, *Proc. CHI 1993*, 37-48.

[22] Lederer, S., Mankoff, J., Dey, A., Who Wants to Know What When?: Privacy Preference Determinants in Ubiquitous Computing, *Proc. CHI 2003*, 724-725.

[23] Lee A., Girgensohn, A., and Schlueter, K. NYNEX Portholes: Initial User Reactions and Redesign Implications Issues in Technology Supporting Learning, *Proc. ACM Group 1997*, 385-39.

[24] Neustaedter, C., Greenberg S., Boyle, M., Blur Filtration Fails to Preserve Privacy for Home-Based Video Conferencing, *ToCHI*, 13(1), 2005, 1-36.

[25] McCarthy, J., Costa, T., and Liongosari, E., UniCast, OutCast & GroupCast: Three Steps Toward Ubiquitous Peripheral Displays, *Proc. UbiComp 2001*, 332-345.

[26] Obata, A., and Sasaki, K. OfficeWalker: A Virtual Visiting System Based on Proxemics, *Proc. CHI 1998*, 1-10.

[27] O'Hara, K., Perry, M., and Lewis, S., Situated Web Signs and the Ordering of Social Action, in *Public and Situated Displays: Social and Interactional Aspects of Shared Display Technologies*, K. O'Hara et al, eds., Kluwer, 2003, 105-140.

[28] Patil, S., Lai, J., Who Gets to Know What When: Configuring Privacy Permissions in an Awareness Application, *Proc. CHI 2005*, 101-110.

[29] Tang, J., Rua, M., Montage: Providing Teleproximity for Distributed Groups, *Proc. CHI 1994*, 37-43.

[30] Whittaker, S., Frohlich, D., and Daly-Jones, O., Informal Workplace Communication: What is it like and how might we support it?, *Proc. CHI 1994*, 131-137.