Secrets to Success and Fatal Flaws: The Design of Large-Display Groupware

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A survey of large-display groupware systems reveals the challenges to their success and serves as the basis for a set of guidelines for their development.

Research in the field of large-display groupware applications has yet to yield a killer app, a common look and feel for applications, or a set of broadly applicable design principles. It's therefore difficult to understand what constitutes a successful large-display groupware application and what affects their adoption. Although large-display groupware faces many of the same adoption and use challenges as conventional desktop groupware, how people perceive and interact with large-display groupware yields some unique challenges. We've built and evaluated several large-display groupware systems that address various workgroups, functions, and environments. This experience has given us broad expertise regarding the social dynamics and technical challenges surrounding large-display groupware's design. To enhance our understanding of these challenges, we've also undertaken a broad survey of existing large-display groupware systems to understand how their purpose, design, and deployment affect the success of their integration into everyday tasks and practices.

Large-display applications exist for many purposes—from single-user desktop workspace (such as for magazine layout) to output-only information displays in highly public locations such as airports. Our study examines an emerging subclass of large-display applications that seek to enhance workgroup interaction by supporting informal, nonurgent communication, collaboration, and awareness. Unlike more formal large-display applications, such as meeting room or classroom systems,[1,2] the systems we consider here are designed for casual, ad hoc use and are persistently available to workgroup members. We're especially interested in systems that exploit the physical properties of large displays, such as size and visibility, that make them appealing for multiuser interaction as well as for passive or opportunistic information display. We therefore focus on the subset of large-display applications encompassing groupware systems that use wall displays.

Wall displays, including vertically oriented free-standing, wall-mounted, and wall-projected configurations, foster a combination of interactive use and passive value. Unlike desktop displays, they offer content visibility from a distance and can therefore benefit users through ambient or opportunistic information even when users aren't directly in front of the display or actively interacting with it. The systems we examine in this article were deployed in a variety of office environments, targeting workgroup communication, information sharing, or work tasks. Some systems were situated in collocated workspaces in which users shared a single contiguous workspace, others were in shared group spaces such as hallways or lounges where users had individual offices or partitioned workspaces. Still others were intended to support remote interactions among users distributed across multiple locations. All of the systems we consider exploit the display's interactive properties, either through direct interaction or through manipulation of content using a desktop client, Web interface, or other remote means. The systems often offer synchronous collaboration or communication, and nearly all of the systems provide value in the passive state through the display of information of potential interest to the workgroup or through the persistence of interactive content over time. Many also exploit the displays' visibility to promote asynchronous collaboration.

Challenges for large-display groupware

Groupware's success in work environments depends on several complex social and technical factors. In a seminal 1994 article in the field of computer-supported cooperative work, Grudin outlined challenges for the successful creation of groupware applications.[3] At that time, groupware existed primarily on desktop computers, entailing certain basic assumptions about how users interact with groupware. Although the design and

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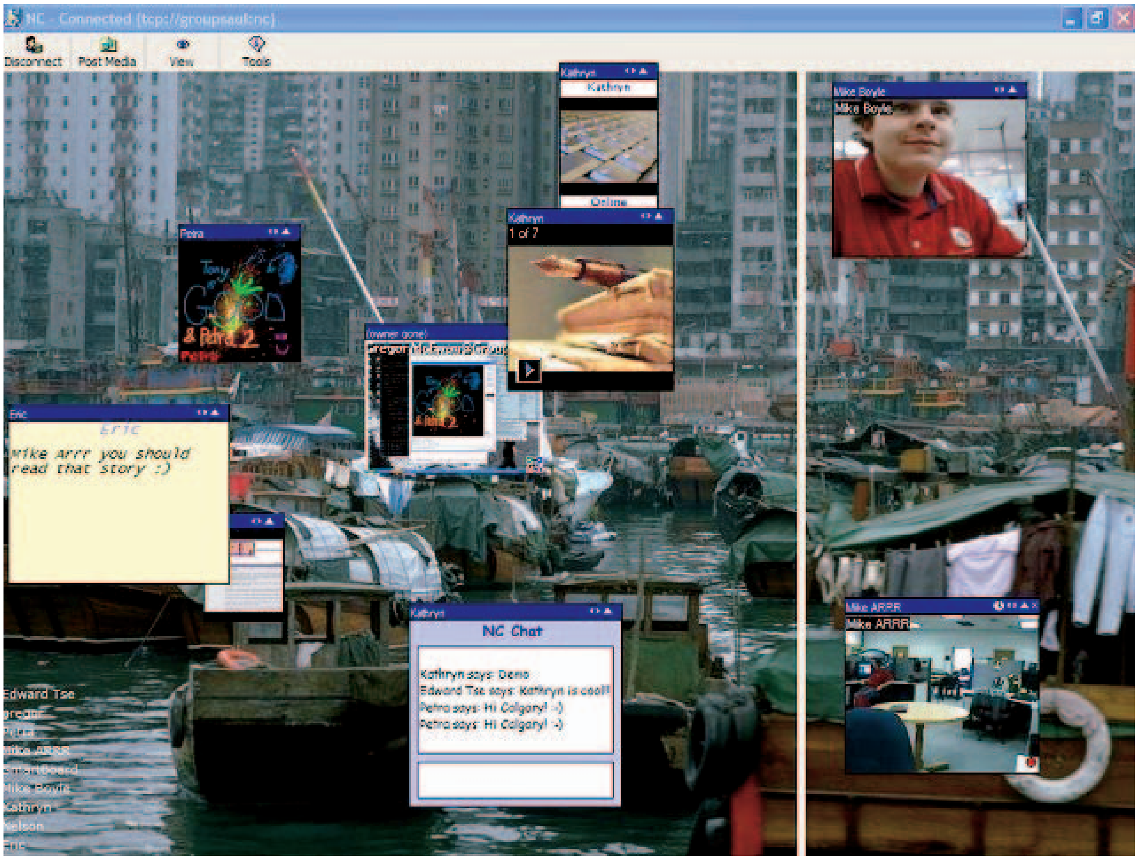


1 Notification Collage, a research system for supporting workgroup awareness, communication, and media sharing.

deployment challenges that Grudin identified hold true for large displays, the unique properties of large-display systems heighten the existing challenges and present new ones. These properties include

- *Form factor*. A large display's physical size affords different types of interactions and visibility. Large-display groupware is viewable from a greater distance than desktop groupware, and multiple users can view and interact with large displays simultaneously. Consequently, their size and visual impact affects how users perceive and interact with them.
- *Public audience and location*. Large-display groupware is usually located in shared space. The fact that these displays are generally more public than desktop monitors affects the amount and type of attention users give them. Additionally, interactions with large displays are often more visible and less private than interactions with desktop groupware.
- *Outside personal workspace*. Because large displays are usually located outside an individual's personal workspace, users interact with them differently than with groupware on their desktop machines. Users might be less willing to explore and figure out how to use large-display groupware than groupware in their personal workspace.
- *Group owned*. Large-display groupware is generally regarded as a group resource. Users feel less of a sense of personal ownership and responsibility for its use and content than they feel for personal desktop groupware clients. This difference affects the extent to which people use the applications and how they interact with the content.

Large-display groupware: A survey

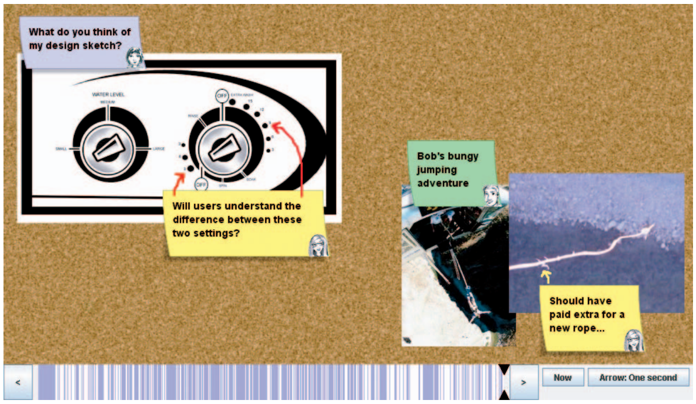
To identify common factors affecting the success of large-display applications in terms of their use, adoption, and integration into workgroup interactions, we assessed the use of our own applications and conducted extensive studies of other related systems. In addition to observations of several external large-display applications, our exploration included open-ended interviews with researchers working on large-display groupware applications and members of workgroups in which the applications were deployed. When possible, we conducted these interviews onsite and in person, in combination with informal observations of the system in use. When face-to-face interviews weren't possible, we conducted telephone interviews. We geared our conversations toward participants' personal perceptions and observations regarding the systems' use and value within the workgroup, as well as their personal use of the systems when applicable. Much of the information we collected in these conversations consisted of anecdotal descriptions of use and personal accounts that other individual evaluations of the systems haven't reported or analyzed.

Notification Collage

The Notification Collage[4] at the University of Calgary is a nearly WYSIWIS (what you see is what I see) media space supporting workgroup awareness, communication, and media sharing. Desktop clients, often on secondary monitors, let users post notes, webcam feeds, photos, Web page thumbnails, and other media. These items appear on other users' clients and on a large display in shared space (see Figure 1). Users arrange the media items spatially as desired in their individual client space without affecting other users' clients or the large display's spatial arrangement.

The Notification Collage is well integrated into group interactions, and group members frequently use it for quick synchronous conversations; media sharing; and longer-term reminders, queries, and to-do lists. We attribute the system's success largely to the low effort required to use the system. Users add and manipulate content via a desktop client, so they don't have to leave their personal workspace to interact with the system. The system starts automatically on users' desktop machines, removing user interaction steps as well as the cognitive task of remembering to turn it on. Additionally, the system's functionality is well matched to the workgroup's practices. The Notification Collage supports the mixing of social and work interactions, spontaneous group conversations, and frequent sharing of digital media and information—all important parts of the work environment in the group for which the system was deployed—effectively and flexibly.

Interestingly, the existence of the persistent desktop client that contributed to the Notification Collage's success also obviated the large display to some extent. Because the content shown on the large display was identical to that on the desktop clients, people often didn't use the large-display projection. When the large display was off, users rarely saw reason to turn it on for ambient awareness because their desktop monitors were sufficiently ambient. Turning on the large display required effort and responsibility on the part of users who didn't perceive additional benefit from having it on.



2 MessyBoard lets users project media items to the large projected display from their desktop systems.

MessyBoard

Carnegie Mellon University's MessyBoard[5] (see Figure 2) system supports similar functionality to the Notification Collage. Users interacting with desktop clients can project various media items to a large projected display in shared workspace. Many MessyBoard items are group editable, allowing for synchronous and asynchronous collaboration and authoring.

MessyBoard's developers deployed the system to several groups, including their own. Although MessyBoard's interactions are simple, at the time of our study the system didn't have a simple installation process. This deficit proved to be a significant barrier. Because some of the workgroup wasn't using the system, it had less value to those using it because there was less content and fewer people interacting with the content. The large projected display was visible even to workgroup members who hadn't installed the system, however, so it provided value to the entire workgroup.

Like many systems we examined, MessyBoard's deployment was characterized by strong novelty use after the initial deployment, followed by sporadic use punctuated with periods of high usage. Users found that email was more effective for some tasks because it targeted specific people, who could then have their own copy of a document to work on. For tasks such as meeting scheduling, however, in which it's better to maintain a single copy of an artifact, MessyBoard provided a superior solution.

The fact that MessyBoard proved useful as a tool for group document authoring only sporadically might have been because the users' need for intense collaboration was similarly sporadic. The workgroup often appropriated MessyBoard to support periods of synchronous collaboration around important deadlines because they could use it as an instant war room and ensure that people were working on the same version of a document.

MessyBoard's developers used several strategies to encourage its adoption. The groups to which they deployed MessyBoard were often personally connected to the researchers, who exploited these connections to foster excitement and encourage use. The researchers conducted training sessions to expose the groups to the technology. They also targeted individuals, such as the administrative assistant, who had the greatest need to convey content and whose information would be of general interest to the workgroup.

Plasma Poster

Designed and deployed at FX Palo Alto Laboratory (FXPal; see http://www.fxpal.com), Plasma Poster[6] is an electronic bulletin board that lets users post and view items of interest on large displays in shared spaces in the work environment (see Figure 3, next page). Unlike the Notification Collage and MessyBoard, Plasma Poster doesn't use a desktop client as output, so users can view postings only on the large shared displays. Users post items to the Plasma Poster via email or through a Web form. Plasma Poster content therefore revolves primarily around announcements and events and is generally of longer-term interest than the more transient and informal items appearing in the somewhat more synchronous and WYSIWIS Notification Collage and MessyBoard applications. Although users post items from their desktops, the output display is still interactive. Users can leaf through the postings, which appear one at a time on the display. Users can also email items to individuals in the workgroup using the large display.

3 Plasma Poster, in which users post and view items of interest on large displays in shared spaces via email or Web forms, is most effective for general announcements and events.

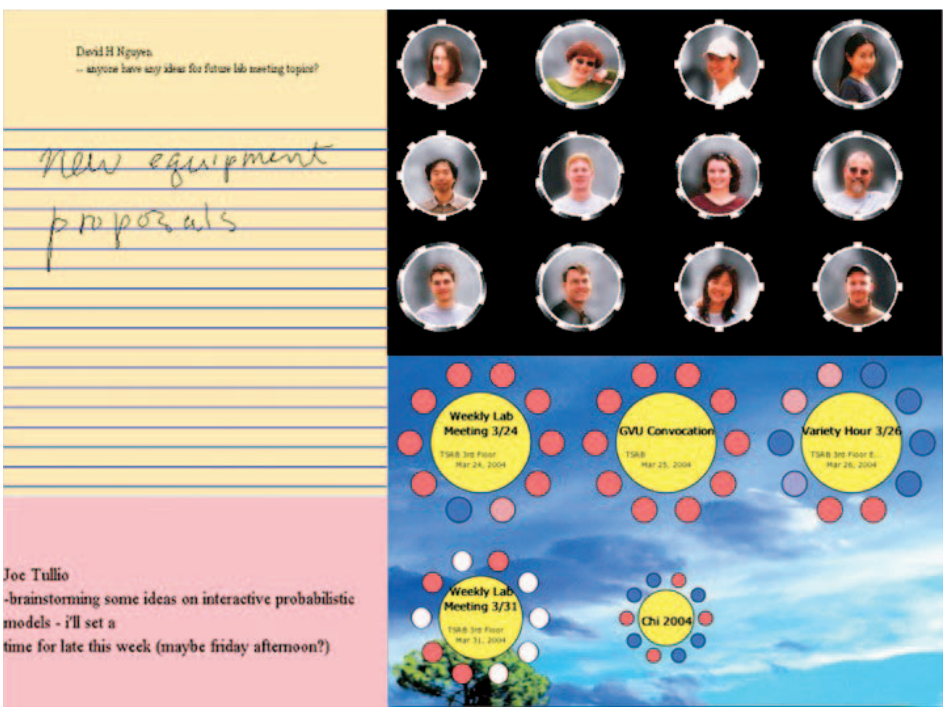
Early deployments of Plasma Poster in office environments exhibited a pattern of high initial novelty use followed by a sharp drop-off. Unlike many other systems, however, Plasma Poster's use began to climb after the early drop. We largely attribute this steady improvement to the system's strong champions. When other workgroup members stopped using the system, a handful of dedicated users, including the project researchers, continued to keep the content fresh and interesting. This helped the members understand the system's potential value and created the perception of steady use. The perception of regular group use encouraged other workgroup members to post information because they believed the information was going to a dynamic and well-used system, rather than a system with little content and few users. The system also helped encourage the perception of use by making interaction with the board visible to users even when they weren't in its direct vicinity by allowing email postings. When a user emailed an interesting post to a colleague, the colleague receiving the post knew that it was an instance of Plasma Poster use, contributing to the perception of the tool's integration into workplace interactions.

As for many other systems, low-barrier interaction that was well integrated into existing tasks also fostered use. Users who submitted content almost always used the email interface rather than the Web submission form. Because email interaction is less taxing than finding and filling out a form, and because users already regularly emailed colleagues to share items of interest, sending content to the board via email was natural for them.

Semi-Public Displays

The Semi-Public Displays[7] project at Georgia Tech provides informal, nonurgent information awareness using a large display in shared workspace with minimal user effort (see Figure 4). The system relies on existing data that it gathers automatically for content, such as the group's weekly status reports and keyboard activity sensing. The system displays group-relevant information such as emailed help requests and reminders, making such information ambient and persistently visible in the environment. Semi-Public Displays also provides a digital whiteboard area for synchronous and asynchronous collaboration.

The system's greatest benefit to the workgroup was the persistent display of information culled from help requests—relevant information that they frequently forgot to address. Workgroup members found that the display of such information often prompted them to engage in spontaneous, informal face-to-face conversations regarding a question or request emailed by another group. This feature was suc-



4 Semi-Public Displays automatically gathers and displays information relevant to the group, such as help requests and reminders.

cessful largely because the process of putting such information on the board was tightly integrated with existing practices and required almost no additional user effort. We found that people included more help requests in their status reports when the system was deployed because it was a simple way to post their questions to the display.

Workgroups rarely used the system for synchronous collaboration or active interaction with the board. They also rarely used the whiteboard space for any purpose other than making lists. Considering that the group almost never engaged in synchronous collaboration around an information artifact, the whiteboard likely failed because it didn't sufficiently match the group's practices. Another challenge arose because, as with many large-display groupware applications, users didn't feel a sense of system ownership. Thus, although users turned the system off at night (perhaps out of a sense of shared ownership of the projector), they rarely turned it on when they arrived the next day. The fact that the system was only available when the researcher working on it was there to turn it on contributed to a perception of lack of regular use.

BlueBoard

Blueboard,[8] developed at the IBM Almaden Research Center, aims to facilitate informal synchronous collaboration using a large, touch-sensitive plasma display (see Figure 5). The system's functionality includes a digital whiteboard that allows freehand drawing and writing, a proprietary Web browser, and access to individual BlueBoard data repositories. Users can swipe their ID cards through a radiofrequency identifier (RFID) badge reader to log into the system, letting them access their own personal data repository on the board. When a user logs into the system, a small photograph of the user—a P-con—appears on the side of the screen. Users can drag documents onto their P-cons to add them to their repositories.

BlueBoard faced significant challenges in its deployment. Although workgroup members frequently used it as a display device for laptop content when giving talks, the BlueBoard collaboration software was less successful. Users appreciated that they could email files to themselves from the board, but ultimately found little reason to do so because the board didn't fully support most common file formats. One of the primary difficulties that users had with the software was that it supported proprietary applications; the Web browser and whiteboard applications weren't integrated with common desktop applications. Because of this mismatch, individuals could rarely use the data products they produced on their personal machines on the BlueBoard with full editing and authoring capabilities. Users also said they weren't comfortable standing in front of the display to collaborate; it was easier to gather in small groups around someone's laptop.

Migrating laptop content to the board required additional user interaction that didn't fit the workgroup collaboration's informal nature, and the required effort outweighed the larger screen's benefits. There was also some conflict in how users perceived the display.

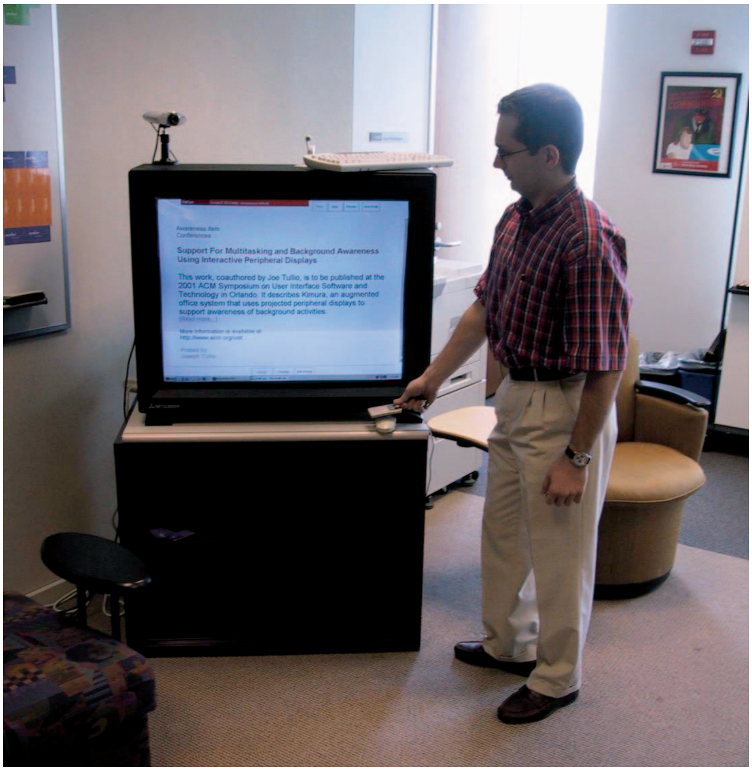
5 **BlueBoard provides a digital whiteboard for freehand drawing and writing, a Web browser, and access to personal data repositories.**

6 **MERBoard provides many of the same functionalities as BlueBoard but also includes tools specific to the Mars Exploration Rover's missions.**

Although most users considered it a tool for synchronous collaboration, at least one user wanted to use it as an ambient information display as well. This user tried to share screenshots of recent projects on the display when it wasn't being used interactively but found that people often switched the display off when no one was in front of it.

MERBoard

NASA built the MERBoard[9] collaborative display to support scientists and engineers involved in the Mars Exploration Rover (MER) missions. The IBM BlueBoard inspired its design. MERBoard (see Figure 6) provides many of the same basic functionalities as BlueBoard as well as tools to support MER mission tasks. After logging into the system, users have access to their own personal MERSpace repositories. MERBoard also provides extensive whiteboard capabilities for freehand drawing and authoring. The system supports many common desktop applications and file formats. Additional tools



7 **Awareness Module lets users post milestone information from their desktops using a Web form.**

support MER mission tasks—for example, the SolTree planning tool lets scientists visualize possible courses of action for the rovers.

An early premission deployment of the system for mission scientists offers interesting insight into the balance between general and specific functionality and the power of visibility of use. Although the system was deployed to mission scientists, engineers who saw the system in use began using the system after recognizing its potential value for their own tasks. Because NASA designed much of the system's functionality, such as the whiteboard capability, to be general and not constrained to scientists' tasks, the MERBoard was highly successful in this deployment.

In the mission deployment, some general functionality led to an unexpected difficulty. When the system wasn't in active use, scientists used the display as a clock showing Mars time for the rovers' locations, Pacific Time, and Greenwich Mean Time. This information was of general importance to all workgroup members and consequently people hesitated to appropriate the display for small group interactions.

As with the BlueBoard deployment, many people found it easier to simply collaborate around a colleague's laptop and that the larger display's benefits for small groups didn't warrant the extra effort necessary to display work artifacts on them. The SolTree tool was an exception. SolTree supported a critical task for scientists and was only available on the MERBoard, making the system invaluable because workarounds using laptops or desktop terminals were inferior.

Awareness Module

Accenture Technology Labs' Awareness Module[10] lets workgroup members post milestone information about their work to large displays in shared areas of the work environment using a Web form from their personal machines (see Figure 7). Postings consist of a high-level blurb and can include detailed information or images. In passive mode, the system cycles through the blurbs one at a time. Passersby interact with the display using a mouse to read the detailed information for items of interest. Alternately, they can swipe RFID badges at an attached card reader to have the current posting's full content emailed to them or sent to a peripheral display in their personal workspace.

Unlike the other systems we've described, which have been deployed for months or years, developers deployed the Awareness Module only briefly. We were, however, able to gather preliminary feedback during that time. As with other systems, a small set of devoted users encouraged others in the workgroup to use the system, leading to a perception of use and value. Users especially appreciated the simple interaction required to have interesting information emailed to them. Not only was this a low use barrier, but it helped fit the system to group members' needs. They could read the information at their leisure in their personal workspace, rather than having to stand in front of the display.

The Awareness Module was used infrequently, however, even early in its deployment. We attribute this lack of use primarily to the barriers imposed by the Web input form. Users not only had to compose or paste content, they also had to remember where to find the Web form. Although the system's output was highly visible, the means for input was obscure and difficult to find and remember. A simpler interaction, such as that used by the Plasma Poster, might have fostered better use.

Recommendations for large-display groupware

In exploring these systems, we recognized patterns in design and deployment that affected subsequent adoption success, and developed a framework of guidelines based on these patterns. We don't mean to suggest that adhering to the guidelines guarantees successful adoption, nor do the guidelines account for all the phenomena we observed in large-display groupware deployments. Rather, they emerged from design and deployment decisions we observed across many or most of the systems that strongly affected the system's successful integration into workgroup interactions.

Task specificity and integration

Whenever possible, designers should integrate systems into existing workgroup interactions rather than suggest new types of collaboration or information sharing. Users are unlikely to attempt to discover a large-display groupware system's value on their own if they aren't already aware of some of its potential benefit. The system's design and deployment methods, such as training sessions or demonstrations, should make the system's value immediately evident. (This is more important in large-display groupware systems than for conventional groupware because users typically spend less time exploring and experimenting on large displays than on their desktop systems.) In many of the systems we explored, task specificity was crucial to the adoption of tools that seemingly supported general collaboration practices. Users generally adopted systems introduced to promote specific workgroup tasks more successfully than those introduced for general collaboration purposes.

Tools designed or deployed to support specific tasks were more likely to succeed when they were deployed for tasks that required their use or for tasks whose content was critical to the user. For these critical tasks, the systems needed to present a clear benefit over existing methods for accomplishing the same task. One of the most common mistakes we observed in the design of large-display collaboration applications was the assumption that the increased screen real estate and ability to save digital artifacts would sufficiently motivate users to migrate their collaboration to the display from a laptop, conventional whiteboard, or other tool. More space and the ability to save documents are desirable but unnecessary for many types of informal collaboration, however, and users generally didn't expend the effort to collaborate on the large-display application if they didn't need to. MERBoard's SolTree tool demonstrates how task-specific functionality led to good use of a collaboration system—in addition to being physically amenable to group work, MERBoard provided support for a necessary task by design that other surfaces and displays did not.

Tool flexibility and generality

Although large-display groupware introduced for specific tasks or tightly integrated with important tasks often has adoption success, we've also observed the value of systems designed for general collaboration tasks. Most successful systems support a breadth of collaboration practices, even when they were deployed to support specific tasks. (Many successful systems were designed and built to support a broad range of tasks but deployed to support specific critical tasks.) The project researchers showcased system uses that addressed workgroup-specific tasks and interactions, thus making the system's value immediately evident. Once users began to use the system and understand its value, they often appropriated the tool for additional purposes if its design was flexible enough to support their new needs.

The Awareness Module's deployment is an example. Because users had expressed a need for high-level work status information about their coworkers, we deployed the system to them, introducing it as a tool through which they could broadcast information about publications, ventures, and product commercializations. Early use centered around milestone information items, but people later used it for more informal purposes, such as to announce when they would be absent from work. Because the system's deployment for a specific and necessary task let users see its value, they began to use it. Once they learned how to use it and understood its potential for information sharing, users appropriated it for an unexpected purpose, and the flexible design allowed them to do so.

People can also use systems that support a broad set of collaborative practices beyond their intended purpose. For example, in the case of the MERBoard premission deployment, teams of resident engineers appropriated a tool designed and deployed to help visiting scientists collaborate because it provided general tools for creating shared digital artifacts as well as an easy method of distributing documents among users.

Visibility and exposure to others' interactions

Users often discovered potential uses for the system after observing other users interacting with the display. Because large-display systems are highly visible, one user's interaction can serve as both instruction and advertising for the system to other group members. In some cases, users were aware of certain features, but appreciated their value only after observing others using and deriving benefit from them. For example, the highly visible use of the MessyBoard for scheduling meetings prompted people in the group who hadn't previously used the system to install it so that they could participate in the scheduling. Although they were previously aware of the MessyBoard's ability to facilitate such interactions, not until they saw others using it did they realize it was a better tool for the task than email.

Making use visible in other ways—especially ways that are observable by people who aren't physically near the display—can also influence a system's adoption success. For example, Plasma Poster's item-forwarding feature existed in the interface for approximately three months before anyone used it. Although the feature was highly visible and people were aware of it, users didn't perceive it as useful until they saw others using it. After observing others forward items and possibly receiving forwarded items, users began to use the feature regularly. One key to this feature's success was that users receiving the email knew that someone had used the large-display system to generate it, thus promoting the knowledge of the system's use.

Low barriers to use

Users must be able to interact successfully and easily with the system early if they are to adopt the system into their normal tasks. Systems that require significant time to install or configure, have time-consuming steps to initiate use, or have functionality that isn't readily visible tend to find small audiences or experience a drop in use after initial deployment. Although all of the systems we examined received positive feedback regarding the technology and the functionality, many users simply didn't find that the benefits outweighed the system's inconveniences. These inconveniences included not only the application's interaction steps, but also factors inherent in large-display use, such as having to go to the display's physical location, having to stand up to work with the display, writing on a glass surface, and dealing with visual parallax on a plasma screen or shadows on a projected display.

All of these issues add barriers to large-display groupware that don't exist in desktop groupware. The system's design must therefore let users derive benefit without extra interaction steps because the use of a large-display application already entails additional overhead. For this reason, workgroups underused several of the systems offering whiteboard capabilities for small informal synchronous collaboration because gathering around a laptop—although not ideal for collaboration—was sufficient and required no additional steps.

Permitting desktop interaction helps alleviate some of the barriers inherent to large displays. The workgroups generally used systems that let them interact with the display through a desktop client more frequently than they used those that allowed interaction only at the large display. Simple interactions yield better use—for example, Plasma Poster users can post information via a Web form or an email address. Because users perceive email as quicker and easier than finding and filling out a form, they often use email instead of the Web form to post. Similarly, although MessyBoard users install the system onto their desktop machines, the lack of a simple setup process discouraged potential users from installing it during its early deployment.

Dedicated core group of users

With all groupware applications, achieving critical mass is crucial to adoption.[3] Because large-display groupware systems are generally less amenable to exploration and experimentation than desktop groupware, they're more likely to fall into disuse soon after deployment. In many of the systems we studied, having a dedicated core group of users early in the deployment encouraged use. This group, which often included the project's researchers, used the system regularly and encouraged others to use it after the initial burst of novelty use died down. Especially for systems that rely on user-submitted content for success, the core group's continued use ensured that displays remained dynamic and the content stayed fresh. The perception that others were using the displays encouraged further adoption into everyday use by a wider audience.

Core groups also directly encouraged others to use the applications. In several applications designed to share user-submitted items, core users encouraged coworkers to post information onto the displays that they had previously emailed to others. This encouragement was positive feedback to the information senders and helped lower initial hesitancy to interact with a new system, both technically and culturally.

Recruiting influential users is another strategy for encouraging a large-display groupware system's success. In both the Notification Collage and the Awareness Module, the workgroup manager's use of the system attracted other people to it and increased the content's value. Having users such as managers, administrative assistants, and others whose interaction is of general interest act as the system's champions benefits its adoption.

Conclusion and future work

Deploying large-display groupware to support workgroups remains challenging. Even systems that fill a need can fail to be adopted or fall into disuse because large displays present inherent hurdles that are often difficult to remedy solely through design. The set of guidelines we present offers a holistic approach to the design and deployment of large-display groupware, incorporating social, technical, design, and environmental issues that have arisen as we've built and studied large-display groupware systems. We've applied these guidelines to the subsequent design of a large-display groupware system, IM Here,[11] with promising success. We derived several of our design and deployment decisions for this system directly from this set of guidelines. User studies of IM Here during its deployment further validate the benefit of these guidelines for adoption.

We're continuing to refine our framework of design heuristics iteratively as we apply them to the design and evaluation of more large-display groupware systems. ■

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