# Let's Go *from* the Whiteboard: Supporting Transitions in Work through Whiteboard Capture and Reuse*

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**ABSTRACT**
The use of whiteboards is pervasive across a wide range of work domains. But some of the qualities that make them successful—an intuitive interface, physical working space, and easy erasure—inherently make them poor tools for archival and reuse. If whiteboard content could be made available in times and spaces beyond those supported by the whiteboard alone, how might it be appropriated? We explore this question via ReBoard, a system that automatically captures whiteboard images and makes them accessible through a novel set of user-centered access tools. Through the lens of a seven week workplace field study, we found that by enabling new workflows, ReBoard increased the value of whiteboard content for collaboration.

**Author Keywords**
whiteboards, workflow, information reuse and sharing

**ACM Classification Keywords**
H5.m. Information interfaces and presentation (*e.g.,* HCI): Miscellaneous.

**General Terms**
Human Factors

## INTRODUCTION

The whiteboard has become an iconic tool for grounded communication, creative ideation, and cognitive offloading. Its adoption and utility can be attributed to its strengths as a low-tech, large-screen display that permits quick, light-weight content creation. On the other hand, whiteboard space is limited, and once erased, content is gone for good. This limitation often means that one must erase board content before its useful life has expired. Furthermore, content has utility only when the board is in view. These shortcomings provide an interesting space for exploration: how should whiteboard content be captured and made accessible for future use? Furthermore, as previously raised by Mynatt [16] but not yet addressed by the research community, how will the ability to retrieve past whiteboard content affect whiteboard use?

To answer these questions, we have developed ReBoard [7]—a research platform that augments any whiteboard (including electronic ones) to enable users to retrieve, reflect upon, and repurpose board content long after its initial creation, whether it is still on the board or not. ReBoard's mixed-initiative capture system and metadata-rich retrieval mechanisms that leverage people's episodic memory for finding content differentiate it from systems such as ZombieBoard [19]. ReBoard can retrieve content by a range of metadata, including date, presence of collaborators during content creation, relative amount of flux in board content over time, and spatial location of content on the board, among others. With ReBoard, people can also print, email, download, and share board images.

Using ReBoard as a vehicle for observing whiteboard activity, we conducted a seven week field study of whiteboard use—both pre- and post-ReBoard activation—in a corporate office setting. Our procedure involved a pilot deployment of ReBoard, a heuristic evaluation of the system, a 1.5 week observation of existing whiteboard practices, and a five and a half week deployment of the ReBoard system. Our observations suggest that whiteboard content has value beyond the board on which it is created. Giving people the ability to access their board remotely and to look back in time creates new work flows around sharing and reuse, and therefore increases the content's value.

## BACKGROUND

Whiteboard-related research has a long history in HCI. Researchers have been probing issues of large, stylus-based electronic displays—often in the domain of capturing collaborative design (*e.g.,* [6,9,13])—since the early 1990s. In more recent work, the whiteboard has been identified as a quintessential medium for ideation in work contexts. In this vein, there have been a number of efforts to build a grounded set of contextual descriptions of whiteboard use [3,16,18,22,24] towards informing design of augmented and electronic whiteboard systems [10,14,16,19,24]. Although the potential for reuse of traditional and electronic whiteboard content has been identified in the literature (*e.g.,* [10,11,17,18,22,23]), and many commercial and research systems allow content to be saved, reloaded and


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* Our work is inspired by Cherubini *et al.*'s "Let's Go To the Whiteboard..." [3] and Tang *et al.*'s "Supporting Transitions in Work..." [22], papers that study how users bring content *to* the whiteboard and how whiteboards support task transitions *within* their bounds. We explore how people move content *from* the whiteboard and manage transitions *beyond* the board.

printed (*e.g.,* [2,5,6,10,12,15,16,19,20]), they offer only limited search and access methods. Further, there is a significant void in research that seeks to understand how these new methods affect content reuse in real situations.

Moran *et al.* [15] described an in-depth study on the efficacy of electronic whiteboard reuse, but focused on the reuse of content from collaborative technical meetings for the purpose of generating summary reports. Ju *et al.* [10] discussed reuse briefly, but that system also focused on collaborative whiteboard use in the context of a project report. Mynatt *et al.* [17] did not report either implementing or evaluating the retrieval and reuse features of Flatland.

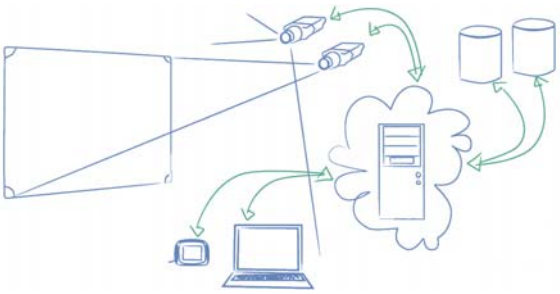

**Figure 1. ReBoard system architecture.**

## REBOARD

ReBoard (Figure 1) gathers whiteboard data via one or two networked cameras located in the vicinity of the board. A high resolution camera takes pictures of the board when content changes. In some installations, a second (wide angle) camera is used to increase accuracy of collaboration detection. Users can access whiteboard images through a web-based application, or through a networked Chumby [4]. The former allows for detailed search, the latter for lightweight access to most recent snaps. The following scenario illustrates how one might interact with ReBoard.

*After meeting with Ann to plan a user study, Mark returns to his office, sketches some rough ideas for the study design, and uses his Chumby to save a picture of the board.*

*A few days later, he uses the Web UI to find the drawing that has since been erased from his board, and prints a copy to bring with him to the next meeting. During the meeting, Ann uses it as a reference while they sketch some new thoughts on her own whiteboard.*

*After the meeting, Ann uses ReBoard to share the image of her current board (that was saved automatically) showing both the printout of the old content and the new annotations. Mark receives an email that includes a copy of the picture and a link to the shared object.*

### Implicit and explicit capture

As illustrated in the previous scenario, ReBoard implements a mixed-initiative capture system. Changes to board content are detected and saved automatically, but the user can also save snapshots at any time. In automatic mode, the system attempts to detect and ignore changes due to lighting or to the presence of people or chairs. Automation reduces the cognitive overhead of saving and naming content [17] given the lightweight nature of whiteboard interactions [16]. Even if capture mechanisms are sufficiently simple, studies suggest that users do not always know when content will have future utility [10,11] and thus may miss opportunities for reuse. On the other hand, explicit capture can be effective when users are changing content rapidly.

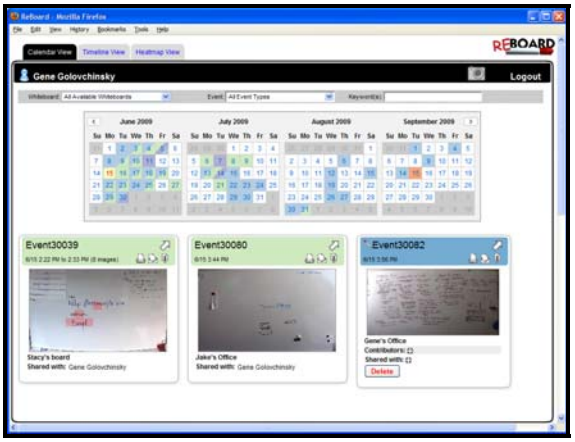


**Figure 2. Web UI, calendar view**

### User-centered access methods

ReBoard is designed to help people find information based on their episodic memory of prior interactions with the board. Mynatt's work suggests that general date ranges, thumbnails of images, and location on the board may all be effective ways of finding archived board images [16]. In keeping with these guidelines, ReBoard implements the calendar (Figure 2), timeline, and heatmap views [7]. Each view is used to select a set of board images that can then be examined in detail. Each image has a timestamp, an optional title and description, a list of collaborators, and a list of people with whom it is shared.


**Figure 3. Chumby UI**

### Dedicated control

In addition to the web interface, ReBoard can also be accessed through a Chumby, a touchscreen device about the size of a mug that is capable of running simple networked applications. The Chumby UI (Figure 3) was designed to give the user one-touch access to some of the core features of the system. The user can "snap" a picture, "email" the latest snap to herself, "stop" or "start" the system for privacy reasons, or navigate back and forth

among board images. In addition to these buttons, the Chumby displays the last snap of the whiteboard and the date/time of capture. Placed on a nearby desk, the Chumby is intended to make it easy for users to access ReBoard with minimal disruption to their current activities.

#### Any whiteboard will do

Despite commercial offerings of electronic whiteboards for the past 20 years, these systems have yet to replace traditional whiteboards in the workplace. This lack of adoption cannot be ascribed only to cost. Electronic whiteboards fail on a number of dimensions in comparison to traditional whiteboards: they lack resolution, they are often turned off to save power [8], they have technological dependencies that often result in unreliable availability, they are not as easy to use, input mechanisms do not provide nuanced stroke expressions, etc. With Saund [19], we believe a camera-based approach for capturing electronic and conventional boards is useful to accommodate physical content (*e.g.*, sticky notes, papers, pictures) that users often attach to their boards. This content adds a layer of richness and contextual reference unavailable on digital boards.

#### Flexible export media

In addition to capturing whiteboard images and displaying them in a web browser, ReBoard can also export images to other applications. With a single click, a user can email a whiteboard image, open it in an arbitrary application, print it, or share it with others through ReBoard. This flexibility enables appropriation [22] through reuse [18].

## STUDY

We conducted a seven week field study in a corporate setting to better understand work practices around whiteboard use. The target organization was our own research lab, comprised of nearly 50 employees with whiteboards in their personal offices and access to two public meeting spaces with whiteboards. We recruited 10 subjects (eight male, two female) based on their willingness to participate. In informal interviews, four participants claimed to use office whiteboards rarely, while others reported moderate to heavy use. Six were research scientists, three were software developers, and one was a multimedia specialist.

The study was carried out in two consecutive phases, the first of which was a 1.5 week observation of current whiteboard practices on personal whiteboards. The second was a 5.5 week deployment of the ReBoard system. We begin with the methodology and results for Phase I.

## STUDY, PHASE I

The goal of Phase I of the study was to establish a baseline of whiteboard practice for comparison with post-ReBoard deployment observations. Nine of the 10 participants were observed during this first phase. One person was excluded because she had been exposed to ReBoard during early iterations and we did not want that knowledge to affect the results of this part of the study. In this first phase, each office was outfitted with cameras and a Chumby. While all functional components of ReBoard were in place and active, these features were not accessible to participants in this initial stage. Instead, these devices were used to collect baseline data on whiteboard use.

#### Data collection

We used the core ReBoard infrastructure to take automated snapshots when changes to board content were detected. This allowed us to be less intrusive in data collection, and also to take advantage of ReBoard visualization and searching tools for data analysis. Furthermore, this pre-populated participants' ReBoard archives with content for potential reuse at the beginning of Phase II of the study.

In addition to automated board snapshots, we developed an audio diary capture system for the Chumbys. Participants were asked to make diary entries whenever they referred to content on their boards. For Phase I, the Chumby was configured to show only a "diary" button. Pressing the button triggered an automatic capture of the board and an audio prompt asking the user to record a 30 second message about the board: which content she referred to and why, and where on the board it was. The data was saved, and later transcribed and analyzed.

Finally, we conducted hour-long semi-structured interviews at the end of the observation period. Transcripts of diary entries were read aloud and sometimes re-played to trigger participants' memories of board activities. Photographs collected during the observation period were printed and used for grounding discussion of board use. Participants were asked to group board content changes, to specify which were collaborative, and then to identify whether the content had temporal value (*i.e.,* useful after at least one day after creation) and/or spatial value (*i.e.,* useful to access the content when not looking at the board). They were also asked to number content in the order they would erase it, if they had to erase the board piecemeal.

#### Analysis

After transcribing interviews and diary entries, we selected salient quotes, and used an open coding approach [21] to categorize them, creating a holistic representation of user data. We derived the coding scheme from group discussion. Emerging categories were discussed, and a shared understanding was developed iteratively by the authors. We classified comments as frequency of use, reasons for use, erasing, temporal vs. momentary value, workarounds, and desired features.

## PHASE I VIGNETTES

We use three representative vignettes to ground discussion of our observations of current practice. Each vignette corresponds to a single participant's account of her own whiteboard use. Vignettes were chosen to demonstrate a wide range of board-related attitudes and behaviors; quotes from participants highlight particularly revealing aspects of use. These vignettes are intended to illustrate broader trends that were recorded in interviews and through the Chumby, (Table 1). We build on these personas in discussing Phase II to highlight the effects of the deployment.

#### Daphne

Daphne is a research scientist and she absolutely "love[s]" her whiteboard. She uses it to organize her thoughts, to design, to make to-do lists, to collaborate with others, and to serve as a constant reminder. She sometimes hangs objects on her board. Her board use ranges from daily to once in a few weeks, with heavier use during design stages.

Daphne erases things only when she knows "for sure, for sure, for sure that [she] doesn't need it" anymore, and she writes small to fit as much as she can on the board. She describes her whiteboard as "persistent." Erasing is her least favorite thing about her whiteboard; she's "afraid of erasing things—it's not big enough to keep everything."

Items on Daphne's board have different levels of value, ranging from "things that can [be erased] any time because [she] explained something to another person, so [she doesn't] need that" to content that has been up for months if not longer. These include her to-do list, a diagram that she was discussing with colleagues that they didn't quite complete, and several pictures she keeps taped to her board because "they're conversation starters." Even though Daphne wanted to use her board for data analysis, she did not want to erase an existing diagram.

Daphne has taken pictures of boards after collaboration and she has also written "do not erase" on public boards, but she has not done either of these recently. She does not recall ever referring back to saved pictures of whiteboards intentionally, but remembered accidentally stumbling upon one on her computer. Daphne wishes "there would be a more persistent thing" so that she can "capture things from it easily—then [she] would use it more." She says that she would like to be able to see her whiteboard to-do list when at home. Daphne recalled referring to her board once in a discussion with coworkers outside her office, when she described a diagram on her board that she had memorized.

| Existing Whiteboard Behavior | People |
|---|---|
| **Frequency of board use** | |
| Varies widely, depends on project | 6 |
| Is rare, less than once a week | 3 |
| **Reasons/purpose for board use** | |
| Individually, to work things out | 9 |
| Collaboratively, to communicate momentarily | 7 |
| Individually, to remember something | 6 |
| Collaboratively, to remember something | 5 |
| Personal effects | 3 |
| **Erasing habits** | |
| Bit-by-bit, as space is needed | 5 |
| Whole board, when it fills | 4 |
| **Workarounds for board inadequacies** | |
| Take a picture of board | 8 |
| Manually copy board content to paper or PC | 5 |
| Choose not to use the board | 4 |
| Erase valuable content | 2 |

**Table 1. Board use in Phase I of the study (pre-ReBoard) based on nine participants.**

#### Eunice

Eunice is a software engineer who is "not very attached" to her board and "wouldn't miss it if it was gone." She does, however, use it to structure thoughts, to draw charts and graphs, to maintain a to-do list, to brainstorm with colleagues, and to manage reminders. Most of her board activity is collaborative as opposed to individual, because it helps to "communicate something I have in my mind that cannot just be done verbally." She does not hang content on the board because she "[doesn't] use paper" in her office. Whiteboard use fluctuates greatly based on the phase of a project she is in: "design phases, requirement phases—it's all whiteboard; a month from the demo—nothing."

Eunice erases her board only as space is needed "because it's going to be painful to rewrite them again." Often, she will start a collaborative writing session on an empty part of the board and then have to erase something of value because space has run out. One problem she finds is that she "write[s] things of temporal value, but then there's no way to keep them or reclaim the space."

Eunice sometimes copies content into a text editor to save it permanently. During the week of observation, for instance, she copied some items from her to-do list into a text editor on her computer to free up space on her board. Sometimes after collaboration in a public meeting room, she has taken pictures of a board with her cell phone "just in case it gets erased." But these pictures were not consulted after the fact; they served primarily as a "security net." She does, however, think that it is helpful to go back to drawings made on conference room boards because the board helps the group pick up where it left off. During the observation period, Eunice referred back to her whiteboard three times, including once to copy to-do list items from the board into a digital text editor.

#### Francesca

Francesca is a software engineer who "[does not] have much of a relationship with [her] whiteboard." She finds that the board "hasn't been particularly useful" since she got it in her office two months ago. She does not like to hang things on her board because she is "a bit of a neat freak." In fact, her whiteboard use is so rare that she "[does not] even see it as part of [her work flow]."

When she does use the board, it is "purely for collaboration...to illustrate something for someone." Most of the drawings on her broad are made by other people: "some people draw things on my whiteboard and I don't

want to wipe them off in case they go by and see that I've removed what they've drawn." However, "sometimes, at least once in the past two months, [she has] been just frustrated that the board looks like a mess and [has] just cleaned everything off."

In terms of value of board content, Francesca notes that "there's some useful stuff… but it's really stuff that [she] could just get by Googling." For the majority of the content, "its moment has passed" and is no longer valuable information. She "see[s] things that are on the whiteboard as obsolete as soon as the conversation is over." On the other hand, Francesca says that she has actually drawn one particular sketch several times because it had been erased by collaborators who needed drawing room.

## PHASE I RESULTS AND DISCUSSION

These vignettes illustrate five interesting phenomena observed broadly among participants: tension between erasing and writing new content, dynamic lifespan of board content, ways in which content moves from the board into other work, range of value of board content, and the role of serendipity in referring back to useful content. We discuss these further below, tying in observations of other participants and data gathered outside of interviews.

### Tension between erasing and writing new content

Five people (typified by Eunice and Daphne), tended not to erase the board until space was needed (*i.e.,* they were "space scavengers" [16]). Four others, including Francesca, reported clearing the entire board when it gets too messy or outdated, exhibiting "clean desk user" behavior [16].

People place different value on different items on the board. Some said that they erase personal drawings first because drawings created by others are "something that [they] can't reproduce." Others said the opposite: "these are my personal ideas for research, I think it is important." Some items, like the conversational aids noted by Daphne, could be erased at any time because they had been internalized, while others could be erased because people no longer remembered what they were. Some useful items might be erased because they are stored elsewhere: "this one has been there for a long time and probably…we have already put this in our code" and "when something concrete is finished, I usually erase the sketch from the board." Importance of items on the board is not the only determining factor: four participants noted that erasing is also affected by the "convenience" of the drawing space. Two of them said that the space closest to their office doors was often used by others and thus exhibited more flux.

Drawings on the board vary in their importance. On one end of the spectrum, Daphne was hesitant to erase content because she was "afraid that [she would] lose some of [her] thoughts." One diagram "has been up since after CHI, and I didn't want to erase it." Another participant identified a drawing she was saving because she "really [didn't] want to lose the discussion" with her co-workers. Others were not as concerned. As one participant explained, "finite space is...probably the biggest problem…I get rid of things before I had intended to...there's things that I may want to look back at, but if I had to make the decision of whether I want to get the new space or...delete it, usually the sort of creative urge wins." Five participants fell between these extremes: "if it's actually useful, it will probably end up in a piece of code" and "if it's gone it's gone, and I probably don't have to think about it anymore."

### Lifespan of board content

It is no surprise that whiteboards are dynamic, that the content is both fleeting and persistent, but the extent of variation is quite dramatic—content lifespan can range from seconds to years. During our observation period, we saw 101 preexisting or created items on participants' boards, 49 of which remained on the board at the end. Across all users, 10 items created during this period were erased within a week, two of which were erased within two days. Seven participants identified 41 items to be several months old. Some reported erasing content within seconds or minutes of it being created. Although not documented by ReBoard[1], two such short-lived items were observed during interviews with two different participants; they were drawn as conversational aids and erased immediately after. Due to a short observation period, and because intensity of board use varies greatly with project cycles (as reported by six participants and Ju *et al.* [10]), we report values only to show the wide range of content persistence.

### Getting things off the board

All three personas identified ways in which content moved from their boards into other work: copying content into other media, taking pictures of the board, looking back at the board itself, or simply internalizing the content. Through the diary data, we documented 21 references to content on the board. While users thought the diary study was accurate in capturing these events, it is likely that some were not recorded; we consider these measures to be a lower bound of the actual number of events, rather than as representative averages.

Eight participants reported having taken pictures of whiteboards in the past, but only one reported ever referring back to such pictures. Most are like Eunice and Daphne in that they take pictures as a safety net and do not refer back to them. Five people reported copying board content into other media (such as sticky notes, emails, documents, Visio diagrams, code, etc.) and then using those as primary references. One person said "I sketch [the board drawing] again on paper to save it, or I take a picture of it to save it, but that's all pretty rare. There's usually nothing up here that hasn't turned into something else…" Another identified a diagram she had drawn collaboratively and noted: "and then that got written down into a paper... I'm going to refer to the paper."

[1] Automatic capture happens only during periods of inactivity for privacy and image quality reasons, making it harder to capture transient board content.

### Value of board content

Whiteboard content can have value beyond short-term representation. To gauge this, we asked participants to classify board content value for all items on their boards. Classification took place along two lines: temporal and spatial value. We define *temporal value* as value beyond the 8-hour work day in which the content was created (so, a board item has temporal value if it would be useful the morning after it was created, as a reference). *Spatial value* is value beyond the surface on which the content was created (so, a board item has spatial value if it would be useful in a different room as the whiteboard it is authored on, perhaps on different media, like paper). Participants identified their content to have one, both, or neither of these traits. Of the 101 drawings categorized, 24% were identified to have both spatial and temporal value, 30% had only temporal, 5% had only spatial, and 41% had neither. Although we cannot conclude that all items were actually valuable, the numbers suggest that content does have value beyond the time and place of creation. Taken together with the observations of varying lifespan of content, the tension between erasing and authoring new content, and the movement of board content into other media, the explicit assessment of board value by participants provides compelling reason to believe that a great deal of board content—perhaps as much as 60%—is valuable and would be retrained if space on the board was not constrained.

### Serendipitous content encounters

In most cases, the whiteboard is an explicit source of information, but board content sometimes presents value in unexpected ways—at different times, under different circumstances, and with different outcomes than anticipated. These interactions may result from unplanned encounters with information in the environment or from pre-meditated placement of items in the environment [1]. We found evidence of both in our qualitative interviews.

Sometimes board content becomes unintentionally useful at a later time. For example, one user explained that his whiteboard is not terribly organized, but "that's OK because sometimes it also reveals that two UIs I'm working on are about the same; yeah, and maybe I should do something different." Eunice said that drawings from earlier meetings in the same conference room may still be on the board and can be spontaneously re-incorporated into their discussion. Content sometimes also serves as an implicit reminder to participants of earlier ideas and of ongoing collaborations. For example, one person "didn't look at anything specific" on her board, but it gave her "a sense of where [she] was" that day. Another participant uses the board similarly: "you know if I come in and I'm like 'what am I going to do today'—I have no ideas—I just have to turn around and go 'oh, ok, that was one of the things that I did.'"

Several participants placed content on their boards more deliberately so that either they or their co-workers would "stumble" upon them later. Three participants kept items on their boards because they are "good to start some conversation." Daphne hung printouts of images from the board's pen tray because "they…capture people's imagination…they are conversation starters." Another person called items on her board "pictures on the wall." She was going to erase the board once ReBoard was installed, but the picture of the guitar is still there: "well, my daughter drew that." Five others indicated that they kept content (to-do lists, diagrams, notes) to jog their memories about things they have done or need to do. One participant keeps a list of "difficult problems that are still important, but [she doesn't] know how to solve them… open questions that [she's] not going to get to" so that she can use them for inspiration.

## STUDY, PHASE II

The second phase of the study ran for 5.5 weeks and involved the launch and observation of ReBoard system use. Each participant had access to the ReBoard Web UI through personal accounts and Chumbys. ReBoard cameras were also installed in conference rooms and accounts were created for these rooms. Participants were given an hour-long live demo of the interface and a quiz of core system functionality on the first day of deployment to familiarize them with its features. In addition, a formative analysis of ReBoard usability was carried out during the second week of deployment, and changes were rolled out in the beginning of the third week.

### Data collection

We continued to collect board captures from the ReBoard system, and participants were asked to make Chumby diary entries whenever they referred to content on their physical boards or through the ReBoard interface. In addition, server logs of interaction with the Chumby and Web interfaces were collected. Two semi-structured interviews were conducted. The first interview was a half-hour discussion about ReBoard activity and likes/dislikes of the system as part of a formative analysis of the system. These interviews were grounded in server logs, board printouts, a walkthrough of the UI, and diary transcripts. The second interview was an hour-long discussion about ReBoard use and the impact of the system on whiteboard practices. Analysis was the same as in Phase I, with an open coding scheme followed by more focused categorization.

## PHASE II VIGNETTES

Building from the vignettes presented in the Phase I section, we follow Daphne, Eunice, and Francesca in their post-ReBoard whiteboard activities. As in Phase I, these vignettes represent a sampling of the range of behavior we elicited in interviews and through the Chumby diaries; the full results are shown in Table 2.

### Daphne

Now that she has ReBoard, Daphne feels free to use her whiteboard more often, and "erase[s] more and more often …because [she doesn't] need to be afraid that [she's]

erasing something that is useful." ReBoard serves as a backup of board contents before she erases: "if [she needs] to go back to something and see what [she] erased, [she] can do it." Daphne's increased board activity is reflected in the pictures of her board, which show "dramatic" changes in content and sometimes large white spaces that she doesn't "remember having...for a long time." Now she can "more freely use the whiteboard for what [she's] currently focusing on." In the period of six weeks, Daphne has created two large diagrams on her board that involved numerous paper printouts; she hadn't "done that before—[she] feel[s] more comfortable erasing things and then [she] can use it for displaying other things."

Throughout the six week period, Daphne used ReBoard to share images, to look at her board while working from home, and to view erased content that she could not recall. Most of the pictures Daphne shared were drawings created during group meetings in a conference room. Daphne wants "to make sure that...things are preserved and everybody has access to what you were discussing." In one case, Daphne shared a picture of her personal office whiteboard with colleagues. Once Daphne "felt confident that ReBoard captured it and [she] made a note on that [picture] and shared it with the people that were involved..., [she] felt that [she] could erase everything." She also used ReBoard to retrieve items that had been erased and redrew them in a larger, modified rendition of the original diagram.

Daphne finds that ReBoard has made her "feel more free with [her] whiteboard," and thus alleviated the "anxiety" associated with erasing her board; "[she] know[s] that it captures things and that even if [she doesn't] go in there and make a conscious effort…it will be there and [she] can find things." Daphne would like to keep ReBoard in her office ("don't take it away!") and thinks it will continue to be useful in the conference rooms.

### Eunice

Eunice's habits have changed with respect to the type and form of the content created. She has begun using the board for "putting together more coherent thoughts; now [she is] actually using it to write meaningful content that stands on its own, perhaps because it's archived." In addition, she is now "writing neater" and adds "more details" when she anticipates sharing her whiteboard via ReBoard with coworkers. She says that "earlier I wouldn't be putting [the details] in there knowing that I would be adding those details digitally" when re-creating the diagram in another application. The ability to share has made Eunice use her board more often for collaborative diagrams; before, she used it "only when words were failing."

Eunice used ReBoard to take pictures for archival purposes, to email collaborators in preparation for meetings, to generate discussion materials, and to recreate drawings on the whiteboard. While in Francesca's office, she snapped a picture of the board they had coauthored so that Francesca could be "free to erase it;" later, she asked Francesca to print it to use in a meeting with another colleague. In yet another situation, she used ReBoard to display "a drawing that [she] had put up on Francesca's board...so that [they] could build on it rather than start from scratch." Eunice printed the image out and then the two drew on that sheet in a continued collaborative discussion.

Eunice uses the Chumby almost exclusively because it provides a "very simple UI." She has used the Web UI from home and for printing copies of the board; "any other time, the Chumby is a lot more useful." She uses it to take pictures and send them to herself through email because "email archives it."

While she finds the presence of a camera in her personal office space to be a downside to the ReBoard system and desires the ability to reproduce erased drawings back to the whiteboard, Eunice "definitely" wants to keep ReBoard in her office after the study. She sees it as a "required thing" for any whiteboard—especially conference room boards—and it would be "sorely missed" if taken away.

### Francesca

Francesca did not use the whiteboard during Phase I, but used it 26 times during Phase II, and she converted from a "space scavenger" to a "clean desk user" [17]. The system "allows [her] to erase her board more often" and as a result,

| Post-ReBoard Behavior | Events | People |
|---|---|---|
| **Frequency of board use** | | |
| Used ReBoard >=3 times | | 7 |
| Used ReBoard < 3 times | | 3 |
| **Reasons/purpose for board use (new workflows)** | | |
| Referred to erased content via RB image | 7 | 5 |
| Shared RB image with colleague | 8 | 4 |
| Viewed own board remotely | 4 | 3 |
| Looked at image shared via RB | 4 | 3 |
| Printed RB image for discussion | 3 | 3 |
| Printed RB image to carry to meeting and referred to it while copying to whiteboard | 2 | 2 |
| Looked at or printed RB image to make sure it was captured | 2 | 2 |
| Used RB to share jokes | 4 | 3 |
| Emailed/shared RB image with colleagues to prepare for meeting | 3 | 1 |
| Looked at RB image of current, co-present whiteboard on PC monitor | 2 | 1 |
| **ReBoard concerns** | | |
| Chumby is on desk, not on whiteboard | | 3 |
| Privacy concerns | | 4 |

**Table 2. Board use from Phase II of study (with ReBoard) based on ten participants**.

she finds that collaborators "seem more willing to write on the board when it's empty." In some instances, however, she is still "hesitant to erase [her board] because [she is not] convinced that the image quality would actually be good enough." She finds herself writing larger and clearer on her board given the limitations of the camera.

Francesca uses ReBoard to access drawings when working from home, to act as a "paging mechanism" when space runs out on the board, and to bring pictures to meetings. In one collaborative session in her office, she used ReBoard to snap two pictures before erasing the board "to make sure [she] didn't lose anything... [she] needed to record the to-do aspect of it." She printed out the drawings, redrew the final diagram in a Visio document, and also used it in a subsequent discussion with a different coworker.

Francesca thinks "the Chumby, as a physical item, is just completely disconnected from the board" and that "the natural instinct is to press something on the board." Francesca primarily uses the Web UI to take snapshots, and to find, print and share images. Although Francesca found ReBoard useful on several occasions and continued to use ReBoard after the study ended, she says she would prefer not to keep the system in her office because the cameras raise privacy concerns for her, and she finds the wiring messy. She would like to see higher quality images, as sometimes details are lacking in the current system.

## PHASE II RESULTS AND DISCUSSION

### New workflows

Tang *et al.* [22] suggest that the whiteboard supports transitions between related sets of tasks within the physical boundaries of the board. ReBoard enables transitions beyond the physical boundaries of the board by making whiteboard content available for a range of tools and work practices. We gave examples of these workflows in the accounts of our personas; in Table 2 we provide a more complete list of workflows we observed that were made possible by the ReBoard System. Table 3 complements the observational data with log-based results. The data shows automatic capture rates for Phase I, the same rates scaled to the Phase II deployment length, Phase II auto and manual capture rates, the number of sessions of UI use (Phase II only), and sharing and print rates for Phase II.

| | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|
| Phase I Auto | 1 | 7 | 0 | 0 | 10 | 21 | 3 | 30 | 21 | 16 |
| Phase I adjusted | 3 | 21 | 0 | 0 | 30 | 63 | 9 | 90 | 63 | 48 |
| Phase II auto | 72 | 33 | 64 | 81 | 10 | 73 | 15 | 118 | 77 | 28 |
| Phase II manual | 1 | **9** | **18** | **9** | 1 | **12** | 3 | 2 | 2 | **20** |
| ReBoard Sessions | 9 | 15 | 26 | 6 | 6 | 3 | 13 | 3 | 8 | 7 |
| Sharing | 5 | 5 | 4 | 1 | | | 2 | | 3 | |
| Printing | | 2 | 2 | | | | 1 | | | |

**Table 3. Frequency of use of whiteboard and ReBoard. Each column represents one participant.**

Six participants shared data through e-mail or within-ReBoard, and three printed images for sharing with others.

We also saw different attitudes toward controlling the system: five users (shown in bold) captured many images manually, while the rest relied more on automatic captures. Even in manual cases, however, the system still caught many changes the person failed to record explicitly. Phase I adjusted board use did not predict ReBoard use (r=0.42 for auto, r=0.12 for manual, r=0.39 for sum). We note that extreme light level fluctuation in the office of participant K confused the change detection algorithms, resulting in a higher rate of observed changes. Overall, however, this variability supports the range of individual differences in board use we found in interviews.

We also observed more frivolous uses: people used ReBoard to exchange humorous sketches, to create amusing drawings, and to leave funny messages for researchers. Freeform interaction with the whiteboard coupled with an easy sharing mechanism translated into opportunities for people to inject affect and humor into their work.

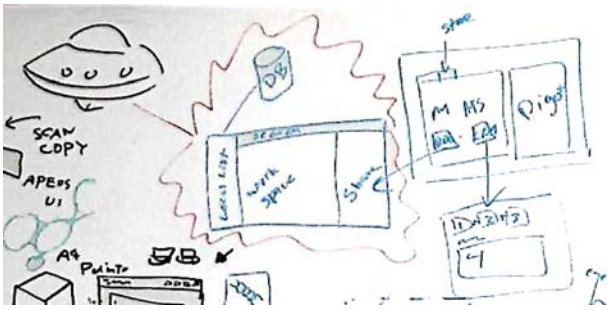


**Figure 4. UFO blasting away a data structure.**

### Tension between ephemerality and persistence

We found that, whiteboards encourage people to make "noncommittal" sketches as they "follow the flow of [their] thoughts" at the board. The erasability of the board "helps to frame the psychology of the design activity" [10] and leads to pre-production material [16]. ReBoard, however, converts ephemeral board content into persistent media. With persistence comes the ability to reuse content; content may become more purposeful and of greater longevity, as it can easily be transferred into more "production-ready" media (email, printouts, presentations, etc.) potentially intented for a wider audience. ReBoard can thus be seen as creating tension between the ephemerality and persistence of board content. We saw that both Eunice and Francesca now pay attention to the production quality of their board content in anticipation of future use. While most users report that they still write on the board in much the same way as before—with rough doodles and scribbles still prevalent on their boards—it is important to consider how characteristics of whiteboard augmenting technology may alter the psychology and activities of users at the board.

### Perceptions of privacy

Cameras in people's offices are a well-documented source of concerns about privacy. One person declined to

participate in the study due to our use of cameras for capturing board content, and four participants commented on the use of cameras. One used a lens cap on his camera as a privacy measure because he did not trust the system "off state;" another wanted to add physical distortion to blur the collaboration detection camera; a third wanted to make sure camera access was password-protected.

While our research goals were not directly related to exploring privacy, we tried to mitigate these concerns in the design of the system. ReBoard grants access to camera output only to the owner of a camera, unless the image is shared explicitly. Raw camera feeds are only accessible to the ReBoard server. This level of security is comparable to that offered by other corporate infrastructure such as the e-mail server. The collaboration detection camera can operate in a de-focused state, mitigating concerns for at least one of our participants. Finally, our use of a camera to capture whiteboard images was a decision of convenience; a better approach would be to use networked still cameras, which would not only mitigate some privacy issues, but also produce higher-quality images.

### Out of sight, out of mind

Content on the whiteboard is valuable because it is always available for active and passive use. The board has a physical, visual presence in the users' offices that software cannot match. While the Chumby does provide a dedicated representation of the system, its small display limits its utility as a detailed content reference. Francesca was concerned about the separation of the Web UI from the physical board and the activities that take place at it—a sentiment echoed by two other participants. One user identified the benefit of not having to "boot up [her] computer, visit a website, log into anything" to use the whiteboard. In addition, finding content on her physical board does not require her to search; "it's always right there;" with ReBoard, it would be "out of sight out of mind." Another participant reports: "I have all kinds of problems staying out of my browser as it is... I'm not trying to go there." Finally, because ReBoard encourages higher turnover of board content, it may require explicit seeking to find erased content, perhaps reducing the chances of serendipitous discovery.

## LESSONS LEARNED

### Grease the wheels

In addition to handling multiple workflows, it is important to support transitions between them since sketches with similar physical traits can have widely different uses at different times. For example, a sketch drawn only to help understand a concept may transition to a personal reminder to write a summary of the concept, and later may play a role in a brainstorming session with others interested in related ideas [22]. Furthermore, the importance a person places on a sketch can change without any physical change to the sketch itself. While use can correlate with physical traits (*e.g.,* to-do lists are likely to appear on the side of a board) the relationships are weak and exceptions are common. Thus, it is important to design systems that allow sketches to move seamlessly between tasks, persistent and ephemeral use, and analog and digital re-representations. ReBoard's flexibility created a range of new workflows around whiteboard content (Table 2).

In our deployment of ReBoard, we found in many cases that users were able to make these transitions simply—images were printed, and printed and analog sketches were pasted on the whiteboard and converted back into digital form. ReBoard relies on the inherent flexibility in the board itself to allow users to decide whether content is persistent or ephemeral rather than designing features that might make this decision too rigid.

We can also augment ReBoard to make it easier for content to move between different types of tasks. For example, tools that automatically improve the aesthetics of whiteboard pictures can make it easier to share printed content (after the field deployment we developed such a tool, which is derived from earlier work with scanned documents [25]). Other features might make it easier for people to move images directly from their ReBoard stream onto digital annotation tools.

### To each his own

Whiteboard system design must recognize that people will develop widely different ways of using the tools. While we focused our efforts on a fully featured Web interface, our formative work suggested the importance of light-weight interactions for key functions such as snapping and sending a photo and turning the system on and off. We designed the Chumby interface to fill this role. Some participants used the system in exactly that way—the Chumby for quick interactions, and the Web UI for browsing and collaboration. Some people used only the Chumby because they found the Web UI too cumbersome, while others used only the Web UI because they wanted a more complete interface. Thus, although the use of the system did not exactly match our predictions, the formative work paid off.

Given that people tend to appropriate tools to meet their needs, it benefits designers to release a broad set of tools initially to encourage adoption. We could push on this approach in future deployments of ReBoard, introducing an even more lightweight interface than the Chumby that users could mount next to their board to recreate the physicality of reminders. Similarly, a hybrid deployment of ReBoard and another electronic whiteboard system might address problems some participants reported. For example, relying on an eBeam system rather than a camera to capture stroke data could mitigate concerns Eunice and Francesca had about image quality and having cameras in their office.

## CONCLUSIONS

We explored how and when whiteboard content is reused in a real workplace context. We built the ReBoard system to retrieve captured images based on whatever metadata the user can recall, and to reuse those images through sharing, printing, and transferring them to other applications. Using

this system as a foil, we have identified and explored the notion of the whiteboard as an *information repository with permeable boundaries through which information can readily flow into new work practices*.

Through our initial deployment, we have identified key issues related to whiteboard work practice that must be addressed in the design of augmentation systems: the tension between transience and persistence, between the visible and the hidden; serendipitous interaction with content; and sentimental items on the board. As we change the whiteboard by digitally mimicking or augmenting it, we change users' perceptions, interactions, expectations, and workflows associated with this ubiquitous technology.

Ongoing exploration of how people use whiteboards in different phases of their work, coupled with long-term exposure to ReBoard interfaces should yield additional insights into how work practices are augmented by making content available for sharing and reuse.

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## REFERENCES

1. Bernstein, M., van Kleek, M., Karger, D. and schraefel, m.c. 2008. Information scraps: How and why information eludes our personal information management tools. *ACM Trans. Inf. Syst*. 26, 4, 1-46.
2. Brotherton, J.A. and Abowd, G.D. 2004. Lessons learned from eClass: Assessing automated capture and access in the classroom. *ACM Trans. Comput.-Hum. Interact.* 11, 2, 121-155.
3. Cherubini, M., Venolia, G., DeLine, R., and Ko, A. 2007. Let's Go to the Whiteboard: How and Why Software Developers use Drawings. In *Proc. CHI*2007, ACM, New York, NY, 557-566.
4. Chumby. www.chumby.org
5. eBeam. www.e-beam.com
6. Elrod, S., Bruce, R., Gold, R., Goldberg, D., Halasz, F., Janssen, W., Lee, D., Mccall, K., Pedersen, E., Pier, K., Tang, J., and Welch, B. 1992. "Liveboard: A Large Interactive Display Supporting Group Meetings, Presentations, and Remote Collaboration," In *Proc. CHI92*, ACM, New York, NY, 599-607.
7. Golovchinsky, G., Carter, S., and Biehl, J. 2009. Beyond the Drawing Board: Toward More Effective Use of Whiteboard Content. arXiv:0911.0039v2.
8. Huang, E.M., Mynatt, E.D., Russell, D.M., Sue, A.E. 2006. Secrets to Success and Fatal Flaws: The Design of Large-Display Groupware. *IEEE Computer Graphics and Applications*, 26, 1, 37-45.
9. Ishii, H. 1990. TeamWorkStation: towards a seamless shared workspace. In *Proc.* CSCW '90. ACM, New York, NY, 13-26.
10. Ju, W., Ionescu, A., Neeley, L., and Winograd, T. 2004. Where the wild things work: capturing shared physical design workspaces. In *Proc.* CSCW '04. ACM, New York, NY, 533-541.
11. Kidd, A. 1994. The marks are on the knowledge worker. In *Proc.* CHI '94, ACM, New York, NY, 186-191.
12. Mimio. www.mimio.com
13. Minneman, S. and Bly, S. 1991. Managing a trois: a study of a multi-user drawing tool in distributed design work. In *Proc. CHI '91*. ACM, New York, NY, 217-224.
14. Moran, T.P., Chiu, P., Harrison, S., Kurtenbach, G., Minneman, S., and van Melle, W. 1996. Evolutionary engagement in an ongoing collaborative work process: a case study. In *Proc.* CSCW '96. ACM, New York, NY, 150-159.
15. Moran, T. P., Palen, L., Harrison, S., Chiu, P., Kimber, D., Minneman, S., van Melle, W., and Zellweger, P. 1997. "I'll get that off the audio": a case study of salvaging multimedia meeting records. In *Proc.* CHI97. ACM, New York, NY, 202-209.
16. Mynatt, E.D. "The Writing on the Wall" 1999. *Proc. INTERACT '99*, IOS Press, Edinburgh, UK 196-204.
17. Mynatt, E.D., Igarashi, T., Edwards, W.K., and LaMarca, A. 1999. Flatland: New Dimensions in Office Whiteboards, *Proc. CHI99*, ACM, New York, NY, 346 - 353.
18. Perry, M., and O'Hara, K. 2003. Display-Based Activity in the Workplace. In *Proc INTERACT'03,* IOS Press, 591-598.
19. Saund, E. "Bringing the Marks on a Whiteboard to Electronic Life," 1999. *Proc. 2nd Intl. Workshop on Cooperative Buildings*, 69-78.
20. SmartBoard. www.smarttech.com
21. Strauss, A. and Corbin, J. *Basics of qualitative research: Grounded theory procedures and techniques*. Sage Publications, Inc., Newbury Park, CA, 1990.
22. Tang, A., Lanir, J., Greenberg, S., and Fels, S. 2009. Supporting Transitions in Work: Informing Large Display Application Design by Understanding Whiteboard Use, In *Proc. ACM GROUP 2009*, ACM, New York, NY.
23. Tang, J.C. and Minneman, S. 1991. VideoWhiteboard: video shadows to support remote collaboration. In *Proc.* CHI '91. ACM, New York, NY, 315-322.
24. Voida, S., Mynatt, E.D., Macintyre, B., Corso, G. 2002. Integrating virtual and physical context to support knowledge workers. *IEEE Pervasive Comp*, 1, 3, 73-79.
25. Wellner, P.D. 1993. Adaptive Thresholding for the DigitalDesk. Technical Report EPC-1993-110.
26. Xiao, Y., C. Lasome, J. Moss, C.F. Mackenzie, and S. Faraj, Cognitive Properties of a Whiteboard: A Case Study in a Trauma Centre. In *Proc. ECSCW 2001*, 259-278.