Showing is Sharing: Building Shared Understanding in Human-Centered Design Teams with Dazzle

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ABSTRACT

Human-centered design teams must integrate diverse individual perspectives into a shared understanding during conceptual design. The team's shared knowledge of their users becomes the basis for later design decisions. We conducted a formative study that shows how generic groupware is insufficient to support the transition from individual to collaborative creative work. We developed a set of design guidelines and implemented them in Dazzle, a collaborative shared display system for co-located design team meetings. Dazzle associates the action of showing information on the shared display with granting the rest of the team access to that information: *showing is sharing*. Dazzle also records a history of shown files. Team members can annotate this log using cross-platform synchronized clients. Teams of novice designers tested Dazzle over two consecutive sessions: the first focused on synthesizing user research, and the second focused on brainstorming. Dazzle was very effective at grounding team conversations about user research, but was used less for sharing information during brainstorming tasks. Items from the shared activity log were used as sources of inspiration and decision criteria during the brainstorming task. Future work includes additional support for active decision-making, and ambient feedback on design activity.

Author Keywords

Shared Display, Design Teams, CSCW, Creativity Support

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Design, Human Factors

INTRODUCTION

Product design and development is a collaboration- and information-intensive process [8,16]. Design teams must simultaneously consider new technologies, manufacturing processes, product competitors, market demand, and cultural values. Design teams gather and generate large amounts of information, including contextual observations, stakeholder interviews, information on competing products or applicable technologies, and new design ideas. Teams create design information both individually and collaboratively; however, they often struggle to synthesize heterogeneous information and form a shared understanding of the design problem or their solution strategy.

During face-to-face meetings, creative teams discuss and establish a shared understanding of the design problem. However, current collaborative technologies do not facilitate sharing rich individual contributions during the team's discussion, nor do they effectively record the team's shared information. We explore how creativity support tools can be designed to bolster collaboration by:

- *helping individuals communicate their design research frames to their collaborators*
- *improving the team's shared memory of user research*
- *connecting shared information to team decisions*

First, we describe results from a formative study of design teams at work. These observations lead to five design guidelines for supporting shared understanding in design

Figure 1: Concept sketch of Dazzle in use. At face-to-face meetings, designers show information from their laptops on the shared display. Dazzle automatically updates its activity log, and makes the information accessible to collaborators.

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teams: 1) support heterogeneous clients and media, 2) enable individuals to selectively present design information to the team, 3) support shared meta-analysis of information, 4) record shared decisions alongside individual contributions, 5) offer an accessible, visible team archive.

Next, we embody these guidelines in Dazzle (Figure 1), a creativity support tool that helps human-centered design teams share perspectives and reach a shared understanding. Dazzle consists of a shared display, cross-platform clients, and a whiteboard capture system. Users drag files into the client to begin screensharing and show the files on the shared display. Dazzle makes these viewed files accessible to collaborators, and records the act of showing to others in a shared activity log. The shared activity log can later be searched, tagged, or annotated by everyone on the team. Dazzle can also capture images of the whiteboard and add them to the shared activity log for future reference.

Finally, we present results from an evaluation of Dazzle where we tested the system with five design teams during consecutive collaborative user research analysis and brainstorming sessions. We found that showing information to teammates using Dazzle helped ground user research conversations, but was not always used as extensively or effectively during brainstorming tasks. Materials from the shared activity log were used as a source of inspiration and decision criteria during the brainstorming task. Users requested a collaborative editing model for commenting, and the ability to assign tags to clusters of similar items. We conclude with implications for future iterations of Dazzle and other collaborative tools for creative work.

BACKGROUND

Human-centered product designers create solutions for complex, real-world problems based on current technologies, market demand, and stakeholder needs. In order to simultaneously consider these issues in early-stage design (e.g., problem formation and conceptual design [40]), companies form multidisciplinary project teams. However, communicating across disciplines is difficult and often requires additional consideration and mediation.

Design is a co-constructive collaborative activity [1], "in which the actors focus on re-conceptualizing their own organization and interaction in relation to their shared object." To understand the design problem, a human-centered design team sends out individuals or pairs to conduct fieldwork with target users [25]. Each member of a design team comes with their own set of assumptions, or *frame*, on the design problem; this guides their interpretations and actions moving forward. When the team reconvenes, each individual shares their user research – then the team must develop and agree upon a shared frame from these individual experiences and points of view [18]. From this shared frame, the team can act from a shared set of assumptions and work towards the same goals.

A human-centered design team builds on user research insights to identify possible solution concepts. Designers typically brainstorm ideas both individually and as a team to collectively strive for quantity, diversity, and a shared understanding of the solution space [34]. Song et al. found that high-performing teams do not always have a high level of shared understanding at all points in the design process; these teams actually have high variation in their semantic coherence throughout the process, but manage to reach high semantic coherence just before major stage gates [39].

Hey et al. introduce the 'framing cycle' by which design teams reach a shared frame [18]. In the framing cycle, the team starts with an assumed pseudo-frame, individual frames are made salient, conflicting frames are made salient, and finally a common frame is negotiated. Given the paths that design teams take in reaching a shared frame with their users and a shared frame with each other, Hey et al. developed a series of principles to help guide teams through the framing process [17]. One principle is to 'share richly' and managing the data deluge with frameworks, using rich media, and doing research together.

Designers and design teams use information tools to make individual frames salient and negotiate shared frames. Oehlberg et al. [33] introduce a 'sharing cycle' that connects information use across user research and brainstorming phases. At each phase of the design process, designers capture, reflect, and share, first individually and then as a team. This cycle occurs as the designers navigate through private, personal, or public information tools; these frameworks allow individuals to contribute to group work while maintaining boundaries between personal and private spaces [13,38]. These boundaries are defined by users' *visibility of* and *access* to others' information.

Our goal is to enable individual designers to share rich information with their collaborators, and to help teams record shared frames and apply shared knowledge towards intermediate design decisions and goals. In the next section, we examine systems that address general and design-specific issues of information sharing and archiving collaborative work.

RELATED WORK

There are a variety of software products that offer project management [42], web conferencing [7], or file sharing [43,44] services. While these tools are in use by today's product designers [33], they are built around the general task of information work and project management, and not necessarily tailored to creative tasks such as synthesizing user research and brainstorming new concepts. In this section we examine related systems that address shared displays, whiteboard capture and reuse, design information sharing, and design activity logs.

Shared Displays & Screensharing

Several systems have explored how teams can exchange information on shared displays, e.g., by sharing pointer and

keyboard access to desktop applications on a single computer [45]; by providing a video cable to each meeting participant [22]; or by leveraging screen-sharing software [41]. Such systems provide only limited features for meeting capture.

Previous research has also offered guidelines on navigating and interacting with multi-display environments [4], including dividing semi-public displays into zones for group work [20]. Individuals use Dazzle's screensharing to show others information while still directly controlling and interacting with the display.

Whiteboard capture/reuse

Whiteboards are used in collaborative teams to synthesize information in a shared artifact [6]. Physical whiteboard capture and reuse systems have been investigated both in research prototypes [5,30], and commercial systems [28,46]. On digital whiteboards or collage walls – either hosted online [47,48] or on a shared display [11] – teams co-create annotated collages, with each annotation or image contributed by individuals. Pairs of linked digital whiteboards can facilitate distributed collaboration [23].

Other researchers have developed ways to push content from individual screens (e.g., laptops) on to shared large-scale displays that act as virtual whiteboards [3] including sharing digital sketches during brainstorming meetings [2,14]. Our research focuses on integrating whiteboard images with the team's discussion record, and allowing whiteboard information to be reused in the context of relevant information from individuals.

Information Sharing for Design Teams

In addition to more general collaboration systems, researchers have proposed several ways to share ideas with design collaborators. One approach has been to automatically share pages from digital notebooks [19]; in the case of iDeas, these individual pages are contributed towards a virtual "group notebook" [26]. Previous research systems have displayed this shared information in face-to-face meetings on vertical wall displays [27], interactive tabletops [12,15], and even floor projections [10].

Design Rationale & Activity Logs

Design rationale systems capture the history of how something was designed [36], and are used to not only record concepts and capture the design process, but also forage for inspiration and facilitate storytelling [37]. Some groupware systems also provide history [21] or focus on capturing co-created meeting artifacts — e.g., video of the team's dialogue, or whiteboard content [9]. One notable example of a design rationale system is the MemTable [21], a system that records and reflects group work during team meetings, acting as a shared memory for the team. In our research, we focus on capturing the files that individuals bring to the meeting in addition to co-created artifacts, and facilitating the active (re)use of shared design information during team meetings.

FORMATIVE STUDY

To ground the design of new technology around current design practices, we conducted a formative study of product designers' work on early-stage design tasks; we re-analyzed interviews with 17 professional and 17 student designers (published by Oehlberg et al., [33]) and observed three student teams in a graduate-level product development course during meetings on user research and brainstorming. Of the three teams, two were co-located (Team A, Team B) and one was distributed (Team C).

Our formative study expose challenges in sharing, control, attention, and recall, as well as the challenge of connecting disparate information sources together into a shared reference. In the following sections we describe specific anecdotes from our formative studies, and the resulting design guidelines for collaborative design tools that support building shared understanding from individual perspectives.

Guideline 1: Support heterogeneous clients and media

In our interviews with professional and student designers, we did not find any consistent personal technology use across collaborators. Each designer preferred a different set of platforms and software tools to support their practice. In all observed team meetings, everyone entered with their own set of personal information tools – including laptops, notebooks, or mobile phones. Even with shared infrastructure (e.g., file sharing over Dropbox [43]), design team members differ in their note taking practices [29,32,33]. While some companies may formally mandate specific information infrastructures, student team members or freelancers may not share any infrastructure beyond Web access. Therefore, we focus on flexible groupware systems that can run on a variety of computing platforms, and practices that are compatible with a range of media.

Guideline 2: Enable individuals to selectively present design information to the rest of the team.

In the two co-located meetings (Team A, Team B), the teams shared information verbally and more on an abstract, summative level. As each student summarized their individual notes, one student took notes on a whiteboard, or typed meeting minutes to be distributed to the team via email or posted to a shared file system. As the team discussed and synthesized their user research into higher-level themes and personas, there were few connections to concrete user experiences or interview quotations.

The distributed group (Team C) had three co-located members and a Skype call with the fourth member. The group had a shared display, which was also screenshared over Skype with the remote participant. This shared display was locally controlled by one team member — as a result, any time someone wanted to show information, the files had to first be uploaded to a shared filespace (e.g., Dropbox [43]). They then had to verbally instruct the student controlling the public display to open the correct file, or navigate to the relevant information at the right time. Despite not having direct control over the shared display,

individuals on Team C managed to share rich information with each other — often sharing photo slideshows or primary sources with the team. Designers must be able to select relevant information from their own individual tools to share with the team. This includes controlling of how design research is presented to others, and supporting best practices, such as using rich media.

Guideline 3: Support shared meta-analysis of information.
When teams share information with each other, their goal is to not only learn from others' experiences but also to find patterns and connections between individuals' divergent points of view. For example, during the brainstorming meeting, individual members of Team A contributed their paper concept sketches to a clustering exercise of everyone's concepts on the floor. As the team discussed the concepts, they also labeled the clusters to understand the overall direction of the team's summative efforts. After individual designers share their information contributions, the team must collectively understand, analyze, and prioritize information to make shared decisions. This analysis should be supported and documented by collaborative design tools.

Guideline 4: Record shared decisions alongside individual contributions.
Co-located Teams A and B both used whiteboards throughout their meeting to record their shared decisions; inevitably the meeting ended with a team member taking a photograph of the whiteboard. These images not only capture the team's co-constructed whiteboard, but also their individual contributions to the discussion. At the end of Team A's brainstorming meeting, two team members photographed each cluster of ideas – not only capturing individually contributed ideas, but also how the team chose to juxtapose and thematically cluster their collective set of concepts. Co-constructed artifacts reflect the team's shared understanding. Putting this alongside information that individuals have brought to the attention of the rest of the team creates a centralized team resource.

Guideline 5: Offer an accessible and visible team archive.
Recall of information from previous meetings is critical, particularly during team decision-making. During a brainstorming meeting, Team A needed to decide which concepts to pursue, based on their user research. One student asked about a previous shared decision – what were the top user needs from the last meeting? For a full minute, the meeting halted while half of the team searched through individual notes, team email, and shared files to locate the correct information. In the previous user research meeting, several team members took photos of the whiteboard with these top needs; no one could recall these images at the later meeting. The team's top user needs were eventually found in an individual's design journal; these needs were then written on a whiteboard for the rest of the team to reference. Co-created artifacts reflect team decisions and design rationale, and therefore a shared frame. This archive of shared information should be accessible to both individual designers and the team as a whole.

DAZZLE: SYSTEM DESIGN

Dazzle is a public display system that supports design teams during face-to-face meetings on user research and brainstorming (see Figure 2). We tailored Dazzle's features to address the identified design guidelines (see Table 1). Design team members control Dazzle through **client applications** on laptops. Digital content can be dragged and dropped on to the laptop client to show it on the large-scale **shared display**. As individual designers bring the team's attention to specific content, Dazzle associates the action of ***showing*** information on the public display with ***sharing*** the shown files through synchronized shared file folders: each team member receives a copy of the file. The client also displays all shared files in a chronological list, the **shared activity log**. Team members can add tags or annotations to items in the log, which can be revisited during subsequent meetings. A camera captures whiteboard images and adds them to the shared activity log, alongside other files.

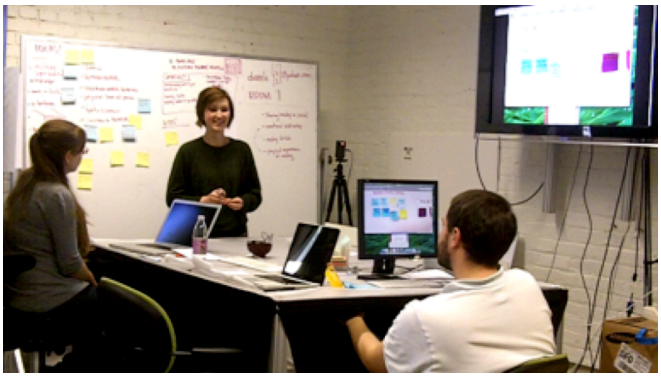

Figure 2: A design team (D2) engages in a brainstorming task. Dazzle is implemented in the space with a) a large shared display, b) client applications, running on two laptops and a desktop computer, and c) a whiteboard with a capture system to add its content to Dazzle

Table 1: Dazzle's features address five design guidelines for collaborative tools that support building shared understanding from individual perspectives.

	Design Guideline	Dazzle Feature
G1	Support heterogeneous clients and media	Cross-platform application (Adobe AIR)
G2	Enable individuals to selectively present design information to the team	Showing is sharing
G3	Support shared meta-analysis of information	Annotation & tagging
G4	Record shared decisions alongside individual contributions.	Shared activity log Whiteboard camera
G5	Offer an accessible and visible team archive	Showing is sharing Shared activity log

The following scenario illustrates how a team of designers might use Dazzle:

*Dan needs to debrief his design team on an in-home interview he conducted last week. At their meeting, Dan opens a folder of photographs from his interview on his laptop. He drags the first photo onto the drop target on the Dazzle Client (*Figure 3*A). Once he drops the file, it is opened locally on his laptop (*Figure 3*B), and Dazzle initiates a screen sharing session to project his desktop on the shared display (*Figure 3*C). In the background, the file is added to the activity log and copied into a folder. When his collaborator, Julie, wants to return to that photo later in the meeting, she can drag and drop the photo back from her activity log on to the drop target; this opens the file locally and begins screensharing with the shared display.*

Over the course of their discussion, the team has filled a whiteboard with shared notes on their conversations. Dan presses a button on the whiteboard – an overhead-mounted camera photographs the board. This photo is uploaded to the shared folder and added to the activity log.

The following section details the system interface (see Figure 4) and design, specifically the shared display, shared activity log, and whiteboard capture.

Shared Display & Screensharing

We chose screensharing to connect users to the shared display, as different team members may not have the same software installed on their computer (G1). For example, in a multidisciplinary team only one user may have CAD or video editing software. The user initiates screensharing in their client application by dragging a file from their desktop or the client's activity log into the screensharing drop target. Dazzle responds by: 1) opening the file locally on the user's computer, 2) initiating screensharing with the shared display, and 3) uploading the file to a shared directory. Dazzle also adds this action to the shared activity log. With just one action, the user can bring select items to their team's attention (G2).

Shared Activity Log

When the user logs into Dazzle, they can see a *shared activity log* that reflects all individual actions that have been taken on Dazzle (G4). Users can *annotate or tag* entries in the shared activity log. The annotations and tags allow the team to highlight and prioritize information that is important to the group's decision-making process (G3). The user can view the comments panel (Figure 4) by clicking on the comments button on the right of each menu item. Here, the commenting system has similar affordances to instant messaging – comments are listed in chronological order, and once authored cannot be edited or deleted.

A list of all tags is at the bottom of the main Dazzle window (Figure 4). The user can click on the tags for each item and edit the tag in a pop-up menu. The default view of the shared activity log is in reverse-chronological order;

Figure 3: To bring a file to others' attention, the participant drags that file on to the drop target (A). This opens the file locally on that person's computer (B), as well as initiates screensharing with a public display (C).

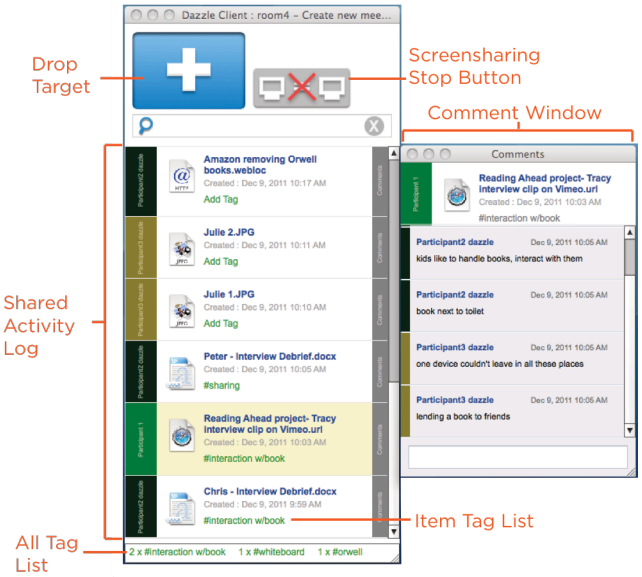

Figure 4: The Dazzle interface shows a drop target, a shared activity log, and a comment window.

users can filter its contents by selecting a set of tags, or by searching over filenames, comment, and tag text.

Whiteboard Capture

A ceiling-mounted SLR camera captures the contents of a nearby whiteboard. To capture the whiteboard, a user presses a large button on the conference table. Dazzle takes a whiteboard photo and adds it to the shared activity log. Individuals can either review the image locally, or bring that image to the team's attention by dropping it on to the screensharing drop target. This helps refresh the team's memory, particularly when the whiteboard has been erased.

SYSTEM IMPLEMENTATION

Dazzle leverages distributed collaboration technologies for screen sharing and file sharing (Figure 5). Dazzle uses Actionscript and Adobe AIR[1], a platform-independent application framework that enables users to run Dazzle on a wide range of operating systems. We implemented Dazzle using Adobe Live Cycle Collaboration System (LCCS)[2], a cross-platform, hosted toolset for screen sharing and messaging, with synchronized data structures. Dazzle uses Dropbox [43] as a backend for peer-to-peer file sharing. Each client has a local copy of files that are synchronized with the shared Dropbox folder. If one client copies a file to this folder, others automatically have access to and receive copies of the file. Dazzle uses a file monitor to watch this folder on each local client, and updates the shared activity log based on files added to this folder.

The whiteboard capture system is a remote-triggered digital SLR camera. The whiteboard photo is color-corrected, copied to the Dropbox folder, and added to the activity log.

EVALUATION

We conducted a user study to learn more about how Dazzle's features, following our design guidelines, would affect the team's ability to share information, develop a shared memory, and synthesize a shared understanding.

Methodology

We recruited graduate students and recent graduates from multiple disciplines (e.g., mechanical engineering, computer science, information, architecture) with experience in human-centered design. While Dazzle is motivated by the needs of designers in general, we used graduate students as a proxy for professional designers. However, the study tasks were structured to be authentic in that they contained activities practiced by professional designers and also used in design classes.

We assigned participants to teams of three, and brought each team in for two sessions – one on user research, the other on brainstorming (see Figure 6). To familiarize participants with Dazzle, we demonstrated Dazzle and participants performed warm-up tasks at the first session.

[1] http://adobe.com/products/air

[2] http://adobe.com/products/livecycle/collaborationservice

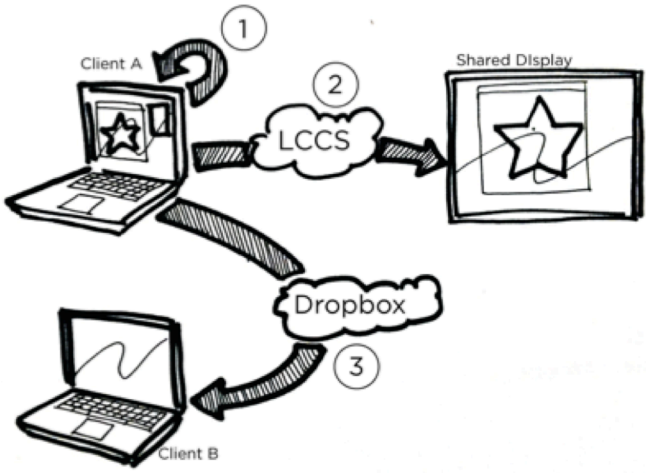

Figure 5: Each time a user drags and drops a file on its drop target, Dazzle responds by 1) opening the file locally, 2) initiating screensharing with the shared display over LCCS, and 3) making the file available to others over Dropbox.

Team	Participant	Discipline	Gender
A	1	Architecture	F
	2	Mechanical Engineering	M
	3	School of Information	M
B	1	Mechanical Engineering	F
	2	Architecture	M
	3	School of Information	F
C	1	Computer Science	M
	2	Electrical Engineering	M
	3	Computer Science	M
D	1	Mechanical Engineering	M
	2	Mechanical Engineering	F
	3	Mechanical Engineering	F
E	1	Chemical Engineering	F
	2	Computer Science	F
	3	Mechanical Engineering	F

Table 2: Summary of evaluation participants. References are made to specific participants during either the first or second session. For example, a comment made during the brainstorming meeting of Team D by Participant 3 would be noted as (P3D2)

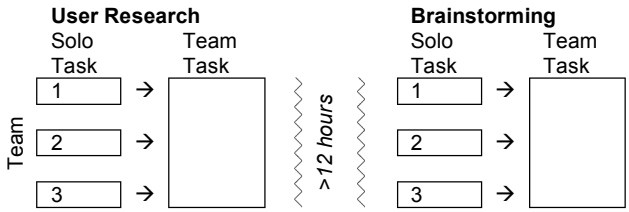

Figure 6: Concept diagram of evaluation. Each team participated in a user research and a brainstorming session, separated by at least 12 hours. In each session, the team works individually on a task before working together.

Session One: User Research Analysis

In the first session, we provided each designer with a different set of seed user research data. The original user research was conducted by a professional design research consultancy for an open-source project on the future of reading [35]. This included an interview protocol, summaries of interview participants, video excerpts from interviews, images from diary studies, and outside articles and videos about reading practices.

In the individual task, we gave each designer 30 minutes to review and become familiar with the unique set of user research data on their local computer. In the team task, we asked the team to share their research with each other, address a set of questions about the nature of reading (similar to those addressed in the final findings of the professional designers [35]), and arrive at an agreed-upon list of prioritized needs, personas, or themes. We instructed the team to use Dazzle to document their process, as this documentation would be available to them in the following session on brainstorming.

Session Two: Concept Brainstorming

In the second session, we asked the teams to leverage their user needs analysis from the previous session and brainstorm concepts what the "Future of Reading" could look like. In the individual task, participants were asked to generate 15 ideas, and were allowed to use Dazzle to refer back to previous information. As a team they were tasked with sharing their ideas and generating 10 more ideas as a group, before deciding on three to five ideas that they would want to prototype in the future. The teams were asked to document anything that they would want in future team meetings. During this second session, the teams could additionally use Post-It notes and sharpies to hand sketch and document their ideas.

We conducted consecutive user research analysis and brainstorming sessions to give an opportunity for teams to use the activity log. We also wanted to provide a task where the original sources for the shared information were from external sources (user research analysis) and from the designer's imagination (brainstorming).

We tested Dazzle with five teams of three participants (fifteen participants total, see Table 2). The two sessions were at least 12 hours apart, so that the participants could not rely on memory to remember the events of the previous meeting. The design tasks were followed by a brief group interview where we asked specific follow-up questions on a team's usage of the system during the session, and general feedback for future iterations of system design. We took notes and recorded video during each session.

RESULTS & DISCUSSION

We structure the findings from our evaluation of Dazzle according to our design guidelines G1-G5, in order to show whether Dazzle effectively realized these guidelines.

G1: Support Heterogeneous Clients and Media

Our study did not directly test supporting heterogeneous clients, as we provided computers to all participants. However, we did observe teams' use of physical and digital media during both sessions. For example, most teams chose to use Post-It notes and the whiteboard during the brainstorming session. However, Team C elected to not use tangible tools for brainstorming or sharing ideas. During the individual brainstorming task, one participant (P2C2) first reached for Post-It notes before noticing that his teammates had started typing; this participant switched to typing his ideas in order to match his teammates. For the collaborative task, one participant (P1C2) used Dazzle to compile the team's ideas in a text file live on the shared display instead of listing ideas on the whiteboard. While it's important to support heterogeneous clients when sharing individual information (G1), the team must agree on a common technology when building information together.

G2: Enable individuals to selectively present design information to the team

During the user research analysis sessions, Dazzle's approach of making visible information accessible to collaborators was effective at allow individuals to selectively present their design information to the rest of the team (G2). All participants shared all of their interviews, and enhanced their verbal summaries by showing interview debriefs, photographs, and videos on the shared display. Participants drew their team's attention to specific aspects of items on the shared display by highlighting text, gesturing with the mouse over a specific area, or talking over the audio in a video. Participants described why presenting design information directly to the team (G2) was so important: *"Sometimes I wanted to just give an idea, but sometimes I wanted the other people in my group to see what I was seeing, so they could form their own opinion, they could see the source not the secondary source. I'm a secondary source, and I'm reporting on a primary source. So, if I wanted them to get a sense of the primary source, they'd need to see it."* (P2B2).

Another participant noted: *"I thought it was easier, the barrier to participation was taken down a little bit by being able to show pictures and, like, "Look at this thing that I'm actually talking about" instead of all the onus being on me to describe what it was."* (P1D1)

However, being able to directly show rich information also impacts the team's cognitive efforts to understand the information as group. In the course of their user research discussion on "The Future of Reading", Team B brought up the impact that moving from verbal descriptions to visual media had on creativity and imaginations: *"Why would you need to imagine something if you could immediately Google it and see it? Describing a dinosaur or describing a landscape is really different from looking it up"* (P2B2).

When asked about how Dazzle may have impacted the team's creative imaginations, one participant said: *"It*

serves as a crutch – you wouldn't have to necessarily think about it critically and then describe it to us, you could just say 'here, watch this'. So, maybe there's not that next step in your own thinking about the thing when you bring it to this discussion" (P1B2).

Because presenting new information does not necessarily support designers' creative thinking, this sharing mechanism is less helpful during generative conversations. For example, Team A used Dazzle in the brainstorming meeting to show each other existing product and services that address 'the Future of Reading'. Their brainstorming conversation stagnated in two ways. First, participants spent time looking up and sharing references rather than making a quick verbal reference in passing. This delay rendered these references irrelevant to the rest of the team, and prevented the team from keeping a quick pace of concept generation. Second, these references to competing technologies often included more information than necessary to make the point. Instead of a passing reference that highlights relevant similarities, the team saw the full details of the competing technologies. The richness of the conversation afforded by Dazzle's ease of sharing left too little to the imagination. While this guideline is beneficial when sharing descriptions of observed user behaviors, it is less helpful when generating possible solution paths.

G3: Support shared meta-analysis of information

Several teams annotated items in the shared activity log to take meeting notes (Team D, Team E), switching note takers as each individual took turns sharing. However, they had difficulty keeping up with the latest file shown on the public display. Our participants requested that items could be continuously annotated and collaboratively edited.

None of the teams used tagging extensively. Dazzle assumes that team members would tag items as they were shared using an emerging coding scheme. However, most teams generated key terms, which could be used as tags, at the end of their user research analysis exercise: *"I didn't like having to assign a tag. It seems like it's forcing you to converge too quickly. Instead of holistically thinking about all the stuff people said and then coming up with words, you have to go through each thing and see if you have similar tags. It seems like it's going backwards; you have to categorize specific things too quickly instead of coming up with general ideas. I had trouble with that since the tagging feature forces you to do it per post."* (P2D1)

This particular implementation did not support shared meta-analysis of information (G3) as intended. Suggestions to address this shortcoming included allowing tags to be created without assigning them to any items, or spatially clustering similar items before applying an appropriate tag to that clustered set. Participants also wanted to annotate the tags themselves with notes on a set of themes, as the team often looked for patterns across sets of information: *"I thought it'd be helpful to sort the shared things into folders, so that there's a [interviewee] folder. I was putting in a couple tags and comments, but they applied more to the overall person than a specific document, so I didn't know if I should be repeating them of if they'd get lost."* (P2D1)

Tagging and annotation are critical to synthesizing individuals' contributions into a larger framework. Future work should include tools to construct these frameworks using shared individual information, such as the items in the shared activity log, as input.

G4: Record shared decisions alongside individual contributions.

Some teams used a text file to keep notes for the team, either instead of, or in addition to, the commenting system. This file was then shared with the rest of the team at the end of the meeting, along with the supporting individual contributions to the conversation. In Team D, multiple individuals kept meeting notes, and both sets of notes were added to Dazzle. The whiteboard was also used as a shared note taking surface, to summarize the user research or brainstorming conversation. All teams captured the whiteboard at the end of both meetings for future reference.

G5: Offer an accessible and visible team archive

Participants had access to the shared activity log from the user research session during the brainstorming session. During the individual brainstorming exercise, most participants found inspiration by referring back to their personal notes, images from others' interviews (P1C2), secondary references and articles (P2D2, P3D2), or the whiteboard image from the last session. In this way, Dazzle acted as a shared record for the team: *"I opened up the whiteboard [photo], I also opened up my notes that I had taken so I could remember that one more time, be reminded of the personalities. I feel like yesterday [Dazzle] was more of collaborative tool and today was more of a… you know, more of just a reminder, like a notebook."* (P1D2)

During the team meeting itself, the teams primarily referred back to the whiteboard image from the user research meeting (Figure 7). Having access to the whiteboard's history allowed the team to root their discussion and decisions in their previous shared frame. Some previously shared individual resources were also brought up during the team meeting. Team B reviewed secondary research – a video of interviews with teachers about the use of iPads in classrooms – to generate new ideas specifically around how reading might be taught in differently in the future.

Unlike sharing new information during a brainstorming session, re-sharing information from the shared activity log supported specific ends: re-introducing a shared source of inspiration to generate more ideas, or reminding the team of the user-centered basis for their decision-making.

CONCLUSION & FUTURE WORK

We are interested in how to design technology that supports the human-centered design team's process of reaching a shared understanding of a design problem. This includes exploring features to help individuals communicate to

teams, recording and augmenting the team's shared memory, and helping the team apply their shared knowledge to design decisions. We presented the results of a formative study of design teams at work, which informed a series of design guidelines for tools that support information sharing, and shared documentation, reuse, and synthesis. To evaluate these guidelines, we embodied them in a collaboration system, Dazzle. To evaluate Dazzle, we brought in teams of human-centered design students to use Dazzle for user research analysis and brainstorming meetings around the topic of "The Future of Reading." From these studies we found that participants shared their user research using direct sources and rich media (photos, videos). In the brainstorming meeting, the team was able to refer back to shared conclusions from the previous user research meeting and use that to both inspire new ideas and inform which to select for prototyping.

Looking forward, there are several directions to further develop Dazzle and other creative collaboration systems:

Active Decision-Making with Shared Data

Currently, the shared activity log is chronologically organized. However, shared activity log items could be organized spatially to further support the team's shared meta-analysis of information (G3). After drawing the team's focus on an item, the set of items could be spatially rearranged to cluster like items and identify emergent relationships, similar to past research systems that have focused on mind-mapping [31]. This higher-level abstraction becomes its own design artifact that reflects the team's shared understanding, while being constructed of elements contributed by each individual.

Ambient Activity Feedback

When no one is actively sharing his or her screen, Dazzle's shared display is blank. This is an opportunity to make the team's shared activity log accessible and visible (G2) not only by explicit request, but also when implicitly relevant to the conversation at hand. This shared display could instead become an ambient visualization of the team's design process while they are not directly interacting with it [24]. *How might we present ambient information from the shared activity log to the team while no one is sharing?* Possible visualizations could include participation statistics from past meetings, whiteboard images from the previous session, a slideshow of the most recent or most popular shared items, or a calendar with upcoming deadlines. Based on visualizations of past design activity and decisions, teams could make better-informed decisions about how to navigate the next steps in their design process.

Longitudinal Evaluation

We would like to conduct a longitudinal evaluation of Dazzle with teams of multidisciplinary graduate students working on semester-long projects in a new product development course. This will test how Dazzle accommodates larger sets of data, across later phases of the design process, and with evolving team roles and behaviors.

We are also interested in applying Dazzle to distributed design teams – student and professional design teams are sometimes distributed across different campuses or offices, sometimes spanning time zones. For example, a company may have groups at two sites collaborating on the same design project, or a design team may send members into the field to conduct user research or meet with manufacturers. As distributed teams may not have identical technology at each site, we are interested in how remote designers might access or contribute to the 'home' design studio using mobile phones or laptops.

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