Ubi-jector: An Information-Sharing Workspace in Casual Places Using Mobile Devices

Hajin Lim[1], Hyunjin Ahn[2], Junwoo Kang[3], Bongwon Suh[4], Joonhwan Lee[5]
Human-Centered Computing Lab.[1, 4], UX Lab.[2], HCI+d Lab.[5]
Seoul National University
Seoul, Republic of Korea
{akal[1], hyunjinahn[2], bongwon[4], joonhwan[5]}@snu.ac.kr
Internet&Multimedia Engineering[3]
Konkuk University
Seoul, Republic of Korea
gaxfor@gmail.com[3]

ABSTRACT
The widespread use of mobile devices has transformed casual places into meeting places. However, in these places, it is uncommon to have shared information workspace such as a beam projector, making it inconvenient and inefficient to exchange information and to get a direct feedback. To address this challenge, we present *Ubi-jector*, a mobile system that provides a shared information space that is equally distributed to each participant's mobile device and allows group members to share documents and collaborate real-time. We first characterized the information sharing patterns and identified the limitations of the current practice in meeting places without a shared workspace, by conducting qualitative user studies. Next, we implemented Ubi-jector with the design guidelines drawn in the prior stage. Also, we performed an evaluation study that showed the possibilities of Ubi-jector to facilitate an effective information sharing and foster an active participation even in poorly-equipped environments.

Author Keywords
Co-located Interaction; shared display; information sharing; CSCW; F2F; co-located; mobile collaboration

ACM Classification Keywords
H.5.3 Group and Organization Interfaces: Computer-supported cooperative work

General Terms
Human Factors; Design

INTRODUCTION
The technology advances in mobile computing and the wide penetrations of mobile devices enable us to work and collaborate everywhere, anytime we want. These changes also enable casual places (Figure 1) such as cafés, airports, restaurants, or school lounges to be actively utilized as places for collaboration. This tendency also aligns well with the BYOD (Bring Your Own Device) mentality in organizations.

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Figure 1. Meetings in casual places.

Traditionally, meeting places where face-to-face (F2F) meetings requiring spaces that are equipped with a large round table, conference systems, network connection, and information-sharing devices, such as a beam projector, and a whiteboard in order to run an effective meeting. However, in casual places where meetings are often taken place, it is very uncommon to deploy these kinds of equipment.

The main drawback in casual places is that shared information workspace is usually absent, compared with a traditional meeting room environment where shared large displays, such as a large screen TV or a beam projector are equipped. Shared information spaces play an important role in sharing information and enabling participants to communicate efficiently [4]. The lack of shared information space in casual meeting places often makes it inconvenient and inefficient to exchange information and get feedback directly with documents.

To address this issue, we proposed a mobile information-sharing system called *Ubi-jector*, which is designed to support effective team collaboration even in poorly-equipped meeting environments. The main idea of Ubi-jector is to utilize each mobile device as a shared workspace as well as a personal workspace. This system provides a shared information space that is equally distributed to each participant's mobile device and allows group members to share documents and feedback in real-time. Ubi-jector provides specialized features and usability suited for the unique characteristics of F2F group meetings in casual places. It is implemented on Android OS using peer-to-peer (P2P) protocol without requiring any extra hardware or complicated registration process.

In previous research and commercial systems, mobile devices have been situated in remote as well as on the move collaboration contexts [2,15]. Even though there are a number of attempts to use mobile devices in F2F meeting settings, they mostly remain as a tool for personal input rather than shared information workspace [21]. Because mobile devices have limitations, such as small screen and limited interaction capacity, they are rarely utilized for providing shared information workspace.

This research aims to explore the opportunity of the use of mobile devices as shared workspaces. To address the challenge, we first conducted the user study to characterize the current practices found in poorly-equipped meeting settings. Also, we developed design guidelines, which were applied to the design and implementation of Ubi-jector. Lastly, we evaluated its usability and effectiveness, followed by discussions for improvements and its applicability to wider contexts.

The contributions of this paper were as follows:

- Performing a user study for identifying the information-sharing patterns and the limitations of the current practices in poorly- equipped meeting settings.
- Development of the design guidelines to utilize mobile devices as a shared information workspace in casual meeting places.
- Design and implementation of the research prototype; 'Ubi-jector'
- System evaluation and following discussions for exploring the issues in developing mobile applications for supporting co-located information-sharing.

RELATED WORK AND MOTIVATION

In this section, we first address the important role of a shared information space in the context of collaboration. We continue with the review of prior research on co-located collaboration. Finally, we take a look at prior systems that support co-located collaboration using mobile devices.

The Role of Shared Information Space in Collaboration

To achieve a mutually shared goal of the group, information-related works in collaboration such as identifying the needed information and creating a shared understanding [17] are essential. To meet the continued need for information exchange during a group work, a shared information space has been pointed out as a crucial component of collaboration [3]. The shared information workspace is where multiple people can see the same objects at the same time to enable knowledge held by individual and their attitudes visible to others [7]. Kraut and Fussell's research confirmed that shared visual space helps collaborators to understand the current state of their task and support their conversations efficiently, which leads to faster and better task performance [7]. A shared view is also useful in supporting knowledge processing, maintaining integrity, or supporting agreement by fostering shared awareness [20].

Co-located Collaboration

Much research about co-located collaboration has been performed in a variety of contexts. For example, Mejia et al. [14] characterized the informal co-located collaboration practices in hospital work, and Huang and Mynatt [5] focused on the application of public displays in small co-located group environments, specifically the academic lab setting. Brodie and Perry [3] examined what mobile workers do when they collaborate in a face-to-face manner away from the office.

There has been a set of research to provide effective applications for supporting co-located collaboration. A number of these focused on providing interactive tabletop surfaces or large displays, which enabled users to exchange various information and share feedback. For example, Wespace[21] proposed a collaborative workspace that integrates a large display with a multi-touch table. UbiTable [19] examined the design space of tabletops to support a kiosk-style walk-up interaction for impromptu face-to-face collaboration.

The aforementioned research often focused on introducing extra hardware and software systems to existing traditional meeting room environments where all required apparatus were already equipped. In this paper, we explore collaboration in poorly-equipped meeting environments and design the system which does not need any extra hardware or software except mobile devices.

Co-located Collaboration Systems using Mobile Devices

Mobile devices have traditionally been personal devices targeted at individual use [11]. Even in collaborative uses of mobile devices, most mainly focused on the remote contexts [2, 15]. However, the recent studies have started to explore shared co-located interactions, which allow people to have "on the spot" meetings where they cooperatively execute tasks and manipulate shared information spaces through their mobile devices [12].

A set of research focused on developing mobile systems for sharing photos among co-located people; '*Pass-them-around*'[9] supported co-located photo sharing using the metaphor of passing paper photos around, and Kun et al. [8] presented the prototype that allows users to share photos with other co-present users by synchronizing the display on multiple mobile devices. In other applications, '*WaggleBee'*[16] provided an easy means of sharing mobile Web contents among co-located groups, and '*MobiComics*' [10] allowed a group of collocated persons to flexibly create and edit comic strip panels using their mobile phones.

Building on the aforementioned research, we would like to focus on the information-sharing practices of co-located groups in casual places and introduce Ubi-jector for facilitating effective exchanges of information and feedback in real-time.

UNDERSTANDING CASUAL MEETING ENVIRONMENTS

In this section, we report the results of qualitative user studies, including interviews and observations to enrich our understanding of F2F meetings in casual places. In our user research, we aimed to reexamine the current practices of casual meeting settings by characterizing the information-sharing patterns of users. Also, we identified limitations of the current practices in poorly-equipped environments.

Methods

To gain a holistic understanding of F2F meetings in casual places, we conducted a semi-structured interview. We recruited four undergraduate students and four graduate students, aged 21 to 27 years (Avg. age: 24.4; 4 females) from varied backgrounds (social science, business, engineering, etc.). We recruited several prospect participants through postings on social network sites. Among them, only those who reported that they were involved in at least two group projects during the spring semester and reported to have group meetings in casual places frequently were selected for our user study. The interviews lasted approximately for 25 to 40 minutes.

As group collaboration situation can be varied and complex due to many contextual factors, we developed the pre-set criterion (Table 1) for interviews. We tried to dismantle a complicated group meeting context into six factors by combining the contextual elements for the analysis and design of mobile collaborative application of Alarcon et al. [1] and the classification for the realization of a collaborative environment of Shah [18].

Contextual Factors	Components
Environment Context	F2F / Co-located / Poorly-equipped place (Fixed conditions in our research)
Group Context	Type/ Size/ Purpose/ Role/ Work Phase
Activity Type	Tasks/ Communication/ Interaction
Information	Info Source/ Info Type
Info-Sharing Method	Tool/ Device/ System
Etc.	Satisfaction, Pain point, Requirement

Table 1. The pre-set criterion for the interview.

Reflecting this criterion, we formulated the interview questions to look at a larger group context, focusing on the situations that got them into collaboration, what kinds of information were shared, and how they shared information. Through several pilot interviews, we elaborated the interview questions. All interviews were transcribed and analyzed according to the criterion.

In addition, we ran two sets of observational studies to confirm the current practices that we derived from the interviews and to extend the understanding of the dynamics of real meeting settings in casual places. Among the interview participants who had been engaged in projects at that moment, two of them were requested to observe their meetings. After the groups were informed of the purpose of observations, we took field notes and some representative photos of them to capture their characteristic behaviors.

Following initial interviews and observations, we used affinity diagramming [6] to cluster unique characteristics and draw information-sharing patterns.

User Study Results

By conducting the user study, we could identify the information-sharing patterns and found limitations of the current practices in poorly- equipped meeting settings.

Group Context and Activity: Why they need to have F2F meetings.

Teams (mostly 3 to 6 members) were formed because of class projects or extracurricular activities to complete required tasks and yield various types of outcomes such as reports, papers, presentations, or videos.

Study participants reported that F2F meetings were preferred when they needed to exchange various opinions and information frequently and directly. Besides F2F meetings, they frequently used online channels such as chat, e-mail, video call, shared cloud storage, and instant messenger (IM) to communicate and collaborate with one another remotely. They reported that working remotely via online channels was effective when browsing information sources or making a separate piece of document.

However, in the initial and final phase of a project, team members tend to feel the necessity to have F2F meetings. In the initial phase, they need to set the goal, brainstorm for ideas, and decide the overall direction and share the workload. In the final phase, the individual pieces of work need to be synthesized into one single outcome by putting various materials and information together. Although many options are available for remote collaboration, F2F meetings still have their own merits. More specifically, we could concede that a F2F meeting is still effective, especially when various ideas and information need to be dealt with for a shared goal.

"*We tried having a meeting through Google Hangouts to make PPT; however, it did not work well. Firstly, it took a lot of time to set up. Also, most of us were easily distracted by other tasks, for example, visiting Facebook. After all, we decided to meet at the cafe the next morning*." (P2)

Environmental Context: Why they hold meetings in casual places.

They reported that they usually have meetings in school cafeterias, cafés, lounges, classrooms, or restaurants. The reasons why they preferred those places for meetings were their ease of use and affordability. As those casual places were always open and available to use, they did not need to check vacancy or make reservations in advance. Also, they thought it was relatively affordable than renting meeting spaces. On the other hand, limited accessibility to equipped meeting environments in school sometimes made them choose casual places for meetings.

"*To use* a *seminar room in school, we need to make a reservation in advance, only if they are not all booked up. Checking vacancy, making reservation, getting permission…. That's quite burdensome.*" (P5)

"*We usually go to school cafeteria, because it's always available to use and quite affordable. We just buy cups of coffee and start the meeting, right away. That's it.*" (P3)

Information Type: What kinds of information are shared.
The types of information that were shared in the meeting varied according to each work phase. In the initial phase, web links, including news articles, blog posts, online encyclopedias, or related books, were actively shared among members to go through a pre-scanning step, to get primary ideas and to examine existing solutions. In the interim phase, a relatively formal form of documents, such as a research paper, a market report, and materials of a presentation, started to be shared. In the later phase, the divided portion of final materials, which were collected separately by each member, needed to be shared and synthesized into final deliverables.

The interesting forms of information discovered throughout the group work phases were notes and memos made individually or collectively. When taking minutes, one participant usually took the role of documenting the meeting. On the other hand, during discussions, various participants participated in taking memos and notes together, using pieces of paper as a whiteboard.

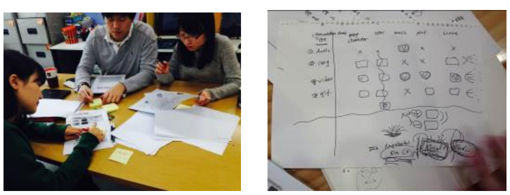

Figure 2. Taking notes and memos during meetings.

Collectively made memos and notes with rough sketches, lists, tables, and scribbles (Figure 2) tended to contain the consensus and the detailed schemes about specific tasks, even though these looked messy and not well-organized. Thus, they were regarded as very important outcomes. After meetings, the memos and notes were required to be documented and distributed to all members via e-mail or IM. However, the problem was that nobody actually wanted to volunteer to take on those tasks, so they sometimes took a picture of these papers using their own smartphones instead.

Information-Sharing Method: How they share information.
We could characterize the methods of sharing information in casual places into three patterns. The first pattern (Figure 3-1) was using a mobile device that had the largest screen (mostly laptops or tablet PCs) as a shared display on behalf of a beam projector or a large screen TV. Through one single mobile device screen, presentations and discussions were visually projected. The second pattern (Figure 3-2) was using each member's personal mobile device during a meeting after transmitting documents using shared cloud storage services (such as *Dropbox*) or e-mail. The last pattern (Figure 3-3) is that paper handouts were printed beforehand and distributed to group members.

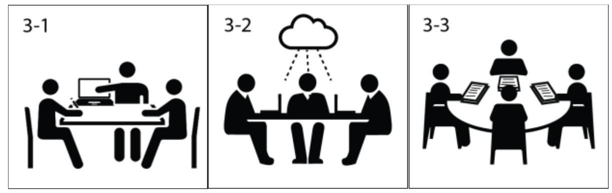

Figure 3. Three patterns in sharing information
3-1. Using one mobile screen as a shared display
3-2. Using personal devices after transmitting documents
3-3. Using paper handouts

Each pattern had its merits and limitations. First of all, in terms of the convenience in setting up, the first measure, making use of one single mobile device as a shared display was preferred because it could be set up easily on the spot unlike other methods (e.g. sending emails or preparing printouts in advance). On the other hand, as for *archivability,* the second method (sharing files) was regarded as a better option because all materials were already shared through individual e-mail or cloud storage, therefore, there was no need to share them after meetings. In addition, the third option (paper handouts) received the most favorable remarks on making annotations freely.

Nevertheless, we could find that those information-sharing patterns had their own limitations, hindering the effective exchange of information and feedback. When participants adopted the first method, the screen size was usually not large enough to allow all members to share information and interact with it, so makeshift measures accompanied with physical rearrangement, such as leaning over to the screen or gathering behind the presenter (Figure 4), were required. Meanwhile, a risk of a personal message and a push alert being likely to be exposed to others unintentionally was also pointed out.

"*When group members are more than three or four, using a laptop or tablet as a shared screen is getting tough."* (P2)

Figure 4. Sharing a mobile screen as a group

In the cases of adopting the second or third measures, we could observe that group members usually had difficulties in catching up with the current progress during a collective review session. For example, when one pointed out a particular table, figure or sentence in documents, some members were observed to browse each page back and forth hastily to find the page that was currently being addressed. In those cases, although the materials themselves had been distributed through each participant's personal device or handout, the shared view was absent to enable multiple people to see the same object simultaneously.

The common problems among the three patterns were identified in the turn-taking process and in the process of making simultaneous contributions.

First, the current turn-taking process to switch information resource or presenter was not smooth. Every time in switching information sources, they should switch devices, transmit files to others or print new copies. Furthermore, the roles of each member were constantly switched between the presenter (who presented the information or personal opinion) and the audience (who listened to presentations or other opinions). Due to the constant change in materials in presentation and roles, the turn-taking processes in the current practices often prolonged each meeting and made it less productive.

Also, the current measures in reflecting all members' ideas and opinions simultaneously had shortcomings. For example, pointing out, evaluating, or making comments about certain parts of a document could not be delivered and reflected upon effectively between members due to a small screen (pattern 1) or the lack of a shared view (pattern 2, 3). Also, individual memos and annotations were hardly recognized and integrated. Consequently, various interview participants pointed out that most parts of the contribution tended to be predominated by a few members.

Interestingly, these problems could be found in well-equipped meeting environments as well. However, they seemed to be more intensified in poorly-equipped meeting conditions due to the lack of sophisticated presentation and meeting equipment.

Design Guidelines

In the user study, we could identify the current information-sharing practices and their limitations found in poorly-equipped environments. In this section, we presented five design guidelines along with this user study. The design guidelines would be importantly considered and applied to the design and implementation of Ubi-jector.

A. Minimize the steps to set up the meeting

In the user study, we could find that the first pattern to share information (using a single mobile device) was most preferred because of its convenience to set up. Conversely, the second and third measures were less adopted since those required redundant efforts (transmitting or printing materials) to set up. Therefore, the system for supporting information-sharing in casual places needs to minimize the efforts to set up.

B. Support the simple turn-taking process in switching information source and presenter

We could find that the information-sharing process got harder as information sources were increasingly varied and the presenter was changed constantly. These turn-taking processes often obstructed the flow of meetings and made the durations of meetings longer. To address this issue, the turn-taking process to share scattered information from various members should be simplified.

C. Support the coexistence between individual and group works

In the user study, we could find that each member's personal mobile device was frequently used as a shared display. Also, people often had difficulties in catching up with the current progress due to the lack of a shared view among participants. These practices inform us that a shared display is essentially required in co-located collaborations. At the same time, we observed that individuals often browsed materials personally and made personal memos during a meeting. It means that both individual and group works are usually progressed simultaneously. Accordingly, the system should provide users with the workspaces both for individual and group works.

D. Make all members' contributions equally reflected and recognized simultaneously

Due to the limited capacity of one single mobile device as a shared display (Measure 1) or the absence of a shared display (Measure 2, 3), reflecting all members' ideas and opinions simultaneously was tough. Also, each member's contribution was not recognized noticeably. Consequently, it was reported that most parts of the contribution were predominated by only a few members, which hindered the productive collaboration process. To fix this issue, all members' contributions should be equally reflected and recognized simultaneously.

E. Archive materials and annotations within the flow of each meeting

Sharing materials and memos that has been discussed during a meeting is essential to proceed with further works. Thus, files of materials and memos, including collectively made ones, should be transmitted to each member's device in order to review them later. However, to transmit this information, one should take charge of organizing and distributing them through e-mail or IM after each meeting. We found that some members felt these post-sharing processes sometimes made them tired and resulted in some additional burdens. To relieve the burdens, we should lessen the steps required to transmit memos, annotations, and shared documents to other members after meetings.

SYSTEM DESIGN AND IMPLEMENTATION

As we drew several design guidelines above, we could ascertain the specification and the features of Ubi-jector and implement our research prototype; Ubi-jector.

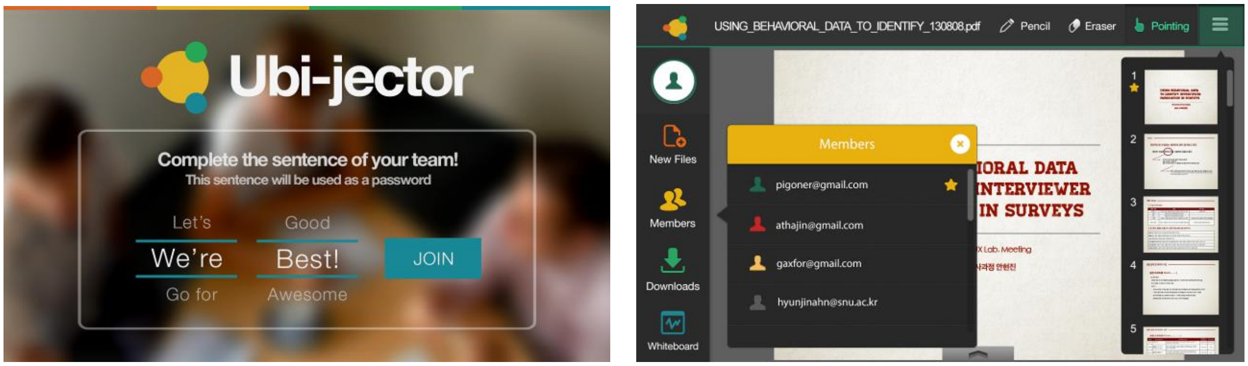

Figure 5. User Interface of Ubi-jector. (Left: Launch View / Right: Workspace View)

Ubi-jector:

Ubi-jector is a mobile application that provides a shared information space for supporting group works held in poorly-equipped environments. The main idea of Ubi-jector is making use of each mobile device as a public shared display instead of using one single device. Ubi-jector aims to create an effective and pleasant collaboration environment even in poorly-equipped places.

It is developed based on a P2P network model, allowing participants to share information without a central server and Internet connection. Also, making a group in Ubi-jector is very simple and quick, requiring no extra hardware and registration process.

Once members run Ubi-jector and are provided a shared view, every document is sent page by page by the presenter to the other members' mobile devices. Also, interactive annotation and pointing features are available to allow all members to actively participate in-group discussions. Lastly, the integrated archiving feature is designed to eliminate the post-sharing process of documents and memos that were presented and made during meetings.

System Architecture

Ubi-jector adopts a P2P ad hoc network model, allowing participants to be connected easily and share information promptly. For adopting a P2P model to Ubi-jector, we sought several options for P2P networking protocol enabling ad hoc, device-to-device communication without the use of an intermediary server. After inspecting several options, we decided to use the *Samsung Chord* [22], which enables us to make the prototype of Ubi-jector easily using its API. *Chord* supports the discovery of each group member using a UDP broadcast-based discovery and creates a P2P local network to share data, binary messages, and files with selected members of the network. Ubi-jector was developed on Android OS using JAVA code.

In Ubi-jector, all three canvases run at the same time: one for s shared screen, the other for private browsing, and another for a whiteboard. In the canvas for the shared screen, the presenter's page and every participant's annotation and pointing motions are processed.

One person who starts to import a document from her or his device to share is empowered as a super user in a shared space. A super user is allowed to present a document that has been converted to segmented images page by page. When a presenter turns to the next page or slide, the data, which includes the image file of each page, the total page number, the current page number, the presenter's device ID, and the current file name, are transmitted to all members. Documents are transmitted per page, instead of the whole file at once, so delay time to transfer file is minimized.

Using Ubi-jector

In this section, we describe the user interface of Ubi-jector and its features. Figure 5 shows Ubi-jector interface, which is commonly applied for both smartphone and tablet PC. The overall design consists of two main views. One is the "Launch view," and the latter is the "Workspace view." Launch view helps users to open and participate in their group's shared space easily and quickly. Workspace interface facilitates the group/individual information sharing process.

Simplified Joining Process Ubi-jector does not require making any account or user profile to use it. Instead, we implemented simple authorization methods to simplify the process for making and joining a group workspace. After connecting their devices to the same Wi-Fi or mobile AP, there is one more hurdle to ensure only group members can join in a specific shared space. When a group of people makes the same combination of text set, they can get to join in the same private channel. Two sets of picker for text completion (3*12, total 36 sets) are provided in Launch view (Figure 5), so they can pick the text set together by holding a conversation on the spot.

Easily Controllable and Switchable Presentation Area In Workspace view (Figure 5), the presentation area is where a document is presented and a whiteboard is used. Just importing a file using the "new file" button presents information to all members page by page. A member who initiates to import and present a document becomes and assumes the role of the presenter that has the right to control page turn and occupy shared view. At the same time, other members will become the audience naturally, who cannot control the shared view. In short, the shared view is controlled differently according to the role of each user. The presenter can influence how each document is showed in other members' devices by controlling not only the page turning but also the page size, which is adjustable by zooming and scrolling actions. To summarize, Ubi-jector provides easily controllable-shared space by dividing the member's roles into presenter and audience for effective presentation.

Furthermore, Ubi-jector supports the easily switchable turn-taking process. When an audience member wants to be a presenter and imports a new file, the right for controlling the shared view and the presenter status is handed over to the new presenter. It enables various types of information from multiple members to be circulated and switched smoothly.

Interactive Annotation and Pointing Although the right for page control is assigned to the presenter only, the right for making annotation and pointing is open to all members during a presentation. The toolbox containing the pencil, eraser, and pointing features works within the presentation area. Every participant is assigned with each unique color at the moment when participants join a shared space. Each annotation and pointing would be colored with their unique colors, which makes them easier to recognize and be aware of the contribution each member made. (Figure 6) Through these features, reflecting all members' ideas and opinions simultaneously is possible and each member's contribution will be recognized more prominently.

Figure 6. Interactive Annotation and Pointing

Private Browsing/Sync As we mentioned previously, a presenter controls the shared view. However, we also allowed the audience members to browse pages privately within the pages that were already presented. For example, when a presenter presented pages from 1 to 3 and now proceeded to show page 4, audience members were able to go back to page 1, 2, or 3 and browse them freely in case they needed to review them privately. Private browsing is done separately from the shared view. At the same time, the *sync* feature makes an audience quickly come back and follow up the page, which is being presented by a presenter. (Figure 7) Through this feature, we would like to support the seamless connection and transition between group and individual information processing.

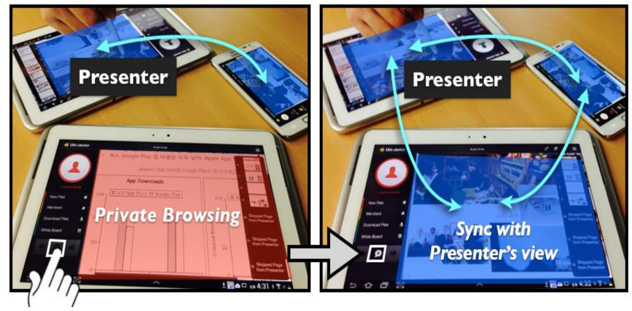

Figure 7. (Left) Private Browsing (Right) Sync with Presenter's View

Integrated Archiving of Previous Meetings When a new document is presented, the previous shared documents, including annotations, are integrated and archived in "Downloads." It would be helpful to revisit and make use of previous records of meetings. Because Ubi-jector records and archives all kinds of information being shared during a meeting, it should lessen the burden of users transmitting them later through IM or e-mail.

EVALUATION

In order to investigate the usability and effectiveness of Ubi-jector, we conducted a user study. (Figure 8) Also, we attempted to draw some lessons to improve Ubi-jector further. We recruited a total of 15 participants and divided them into five groups (three participants for each group). They were college or graduate school students from various backgrounds (music, sociology, computer science and etc.), and their average age was 25.3 years (nine females). They were recruited through social network postings. We tried to team up a group wherein participants would have known each other in advance, to minimize the possible impacts of social contextual factors such as level of closeness. Thus, we encouraged them to participate in this user study with his or her colleagues and teamed up them based on each personal intimacy.

Because we needed to mimic the meeting environments in poorly-equipped settings as similarly as possible, each group session was held in school cafeterias and lounges. There were two Android 10.1 inch tablet PCs and one Android 4.1-inch smartphone running Ubi-jector for the group session. These devices were connected to same mobile AP network. Each group was asked to conduct a group task together and complete an in-depth questionnaire. Then, we conducted post-group interviews to hear their opinion of Ubi-jector. Each group session took approximately 1 hour.

Procedure

Before the study, participants completed a short questionnaire to gather their basic information. Each study began with the short introduction session for 10 minutes to let them familiarize themselves with our system. Next, we gave them a group task, that is, to choose one of homepage design among six options. On each device, there were several PDF format files that contained several design options. We asked to assume themselves in the same team that needed to assess all options and made a decision. We encouraged them to utilize Ubi-jector as actively as possible and take both presenter and audience roles during conducting the task. After they discussed and made a decision, we asked them to fill out an in-depth questionnaire, and the following group interviews were conducted. During group sessions, their activities and uses of Ubi-jector were video-recorded, and observation notes were taken throughout. In the post-group interview, all of their comments were also recorded and transcribed.

Figure 8. Group sessions for the evaluation.

Results

In the pre-study questionnaire, 87% of the participants replied that they have had meetings in casual places very frequently. Also, 90% of the participants answered that they have known other group members very well as a friend or co-worker.

Taking the post-questionnaire responses, the first part of the questionnaire asked them to rate the difficulty level of the task and the overall satisfaction level of the task on a five-point scale (from 1 = low to 5 = high). The average rating of task difficulty was 2.2, and task satisfaction level was 3.8.

In the second parts of the questionnaire, we asked them to rate usability such as effectiveness, utility, and learnability of Ubi-jector based on 7-Likert scale (from strongly agree=7 to strongly disagree=1). The subjects evaluated the usability (5.4/7), utility (5.2/7), and applicability (5.4/7) of Ubi-jector prototype very positively.

In the third part of the questionnaire, participants evaluated each feature of Ubi-jector separately. They were given five statements describing each feature of Ubi-jector and rated the level of agreements. Most of features received high scores. Especially, "simplified joining proces" (5.8/7) and "easily controllable and switchable presentation area" (5.6/7) got the most positive responses.

In the last parts of the questionnaire (Table 2), we attempted to scrutinize the effectiveness of Ubi-jector in terms of the improvement of group communication efficiency. Using 7-point Likert scale, we estimated how much they thought this system improved their group communication effectiveness. The first two statements (d1 and d2) were designed to evaluate the effectiveness of communication compared with when they were the presenter and the audience; the other statements were about evaluating the qualities of communication (d3 and d4) and active participation (d5). At this part of questionnaire, we have got generally positive responses, too. This result showed that Ubi-jector has the possibilities that could enhance the effectiveness of information sharing and active participation in a group communication context.

Given statements	Score
D1. (When I present) the contents of information were conveyed well to other team members.	5.1/7
D2. (When I was a audience) I could get the contents of information fully.	5.1/7
D3. (Comparing previous experiences) it is more effective to share information.	5.8/7
D4. (Comparing previous experiences) it is more effective to share ideas and discuss.	5.5/7
D5. Every group member participated actively in group discussion and decision-making.	5.8/7

Table 2. Evaluation of effectiveness of group Communication

Beside these results from the in-depth questionnaire study, observations and interview also gave us powerful insights and helpful feedbacks to improve Ubi-jector further. These findings described in the Discussion section.

DISCUSSION

In this section, we first discuss the conflict patterns found and reported in the evaluation and seek possible solutions, which need to be addressed in future work. These conflicts are raised by contradicting factors and merits, so exploring each side and comparing the trade-offs needs to be conducted in developing the mobile application for supporting co-located information sharing. Also, we describe the limitation of this research and the potential extension of Ubi-jector to other environments.

Tensions between Public Space versus Personal Space

Mobile devices mainly have been used and controlled for personal purpose [9] and recognized as a private space for each individual. However, bringing a shared, public space over to a mobile device in Ubi-jector may make users feel a little awkward. In Ubi-jector, there are several considerations to address this tension between them, such as private browsing and sync features. However, especially when a presenter controls a shared view, some audience members feel uncomfortable because they feel like their territory and autonomy has been compromised.

"*I felt something uncomfortable when I saw my display was controlled by others. Maybe, as I could always do anything that I want on my own mobile device, the feeling that I could not control my device freely is a little weird.*" (P7)

Furthermore, regarding the annotation feature, many requested for private annotation space. According to Marshall and Brush's research about the relationship between personal and public annotations, only a small fraction of annotations made are directly related to those shared in discussions and personal annotations undergo dramatic changes when they are shared in public discussion [13]. Many participants said that it is somewhat uncomfortable when all of the annotations they made were shared to other members publicly because they were not ready to show them or they did not need to be shown to others.

We believe that these tensions between personal and public space found in Ubi-jector are due to the fact that Ubi-jector prototype has no clear distinction between personal and pubic space. Also, it mostly focuses on the public uses of mobile devices rather than personal uses. It was a design trade-off when we implemented Ubi-jector. As many participants pointed out, we need to consider the separation between public and personal space in our future prototype. One alternative could be providing 'dual view' (one for the presenter's view and one for private browsing). Another option would be 'invisible annotations', which can be made and used only for personal purposes.

Role and Control: Presenter versus Audience

Because of the spontaneity of F2F meetings, each member's role of members (presenter/audience) is constantly switched and various materials are shared very frequently in Ubi-jector. However, as their roles and materials are changed so frequently, they can hardly recognize their current role and status, we need to consider a clearer visual cue to show their current status and role.

On the other hands, we could find that there were clear differences in opinions according to each participant's role toward control.

"*When I was a presenter, I felt various features of controlling the shared view, such as page turning and zooming, were nice and effective. In contrast, when I became a member of the audience, I wished this system to be more flexible in terms of control.*" (P4)

This user's statement shows the different needs of users evidently; the presenter needs more hard control over the shared view, but the audience wants more flexible control. For example, some users asked us to restrict private browsing and lock all members in the presenter's shared view. Others said that the current control is so strong that it needs to be less rigid. We could not conclude which side to take at this moment, so we need to conduct further user study to address this conflict.

Screen Size: Smartphone versus Tablet PC

As each mobile device has various screen sizes, the screen size issue should have been considered very importantly in designing Ubi-jector. In our user study, we provided both a smartphone and tablet PC, so we could observe the performance and capacity differences between them. The participants who used a smartphone in the user study were more apt to try zooming and scrolling the screen than the tablet PC users. Also, they made fewer annotations on the presentation area than tablet PC users. This means that the smaller screen size of a smartphone often blocks users to use Ubi-jector freely because of its limited screen size and capability to adopt various interactions. To address this issue, we need to support users to get the optimal view of each material even in small mobile screens by allowing scrolling and zooming interactions freely. Also, offering an adjustment tool for resizing materials should be taken into account. Furthermore, we need to consider text input as an annotation method along with the current pen tool. Writing a memo using pen tool seems too uncomfortable for smartphone users, so receiving text inputs using a virtual keyboard would be a better way for making annotations.

Information Type: Text Based versus Image Based

Ubi-jector needs to be responsive for the types of information being shared, as one of study participants expressed:

"*In the case when the presented materials were filled with stuffy texts, I cannot be sure that this Ubi-jector could accommodate those kinds of documents effectively.*" (P2)

Due to the small screen sizes of mobile devices, we need to seek more effective ways of showing various types of information in mobile devices. In Ubi-jector, image-based information or PPT documents with larger and fewer texts can be presented relatively easily. However, presenting text-based documents, such as research papers, can be problematic. Thus, we need to be responsive for the characteristics of each information types, to provide more optimal presentations possible in Ubi-jector.

Study Limitations

In addition to the conflicts patterns and possible solutions in Ubi-jector, we now describe the limitations of our research. First, the situations that we created in the evaluation processes were controlled and artificial. Also, it was conducted with a limited number and range of people. Also, the amount of time spent that we observed was insufficient.

In our future research, it is required to conduct a longitudinal user study with volumes of people in real meeting settings. Furthermore, we should evaluate the effectiveness of Ubi-jector in comparison with conventional meeting environments. Finally, the current prototype is necessary to be developed further which can support varied mobile OSs and various types of information.

Extension of Ubi-jector to Other Environments

Our study demonstrated the potentiality of shared information space using mobile devices in casual places. However, we can also extend the applicability of Ubi-jector into broader scopes. Ubi-jector can be applied readily at any place and by any organization that needs to have shared information space in poorly-equipped conditions. For example, specific educational environments or industrial settings would be considered.

CONCLUSION

In this paper, we proposed a mobile system, Ubi-jector for supporting group work held in casual places where the shared information workspace is normally absent. Ubi-jector provides a shared information workspace by making use of each participant's mobile device as a shared display. Ubi-jector was designed to create effective meeting environments even in poorly-equipped conditions.

This research has its own contributions in Mobile HCI and CSCW fields because it explored the opportunity of the collaborative use of mobile devices as a shared workspace. By performing a user study, we figured out the characteristic information-sharing patterns and drew design guidelines for poorly-equipped meeting conditions. Also we implemented a mobile system, Ubi-jector that provides competitive features suited for the unique characteristics of F2F group meetings in casual places. Furthermore, we conducted an evaluation study to measure the effectiveness and usability of the prototype. The evaluation results showed that Ubi-jector has the possibilities to facilitate information sharing effectively and foster active participation. Lastly, we discussed the conflicts of contradicting factors in designing Ubi-jector and compared their trade-offs. In the future research, we would elaborate the user study further and expand the possible application of Ubi-jector to other environments.

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