

MobiComics: Collaborative Use of Mobile Phones and Large Displays for Public Expression

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ABSTRACT

We explore shared collocated interactions with mobile phones and public displays in an indoor public place. We introduce *MobiComics*, an application that allows a group of collocated persons to flexibly create and edit comic strip panels using their mobile phones. The prototype supports *ad hoc* sharing of comic strip panels between people and onto two public displays by taking the spatial arrangement of people into account, measured with a radio tracking technology integrated in their mobile phones. *MobiComics* also includes game-like elements to foster social interaction between participants. Our evaluations show that people enjoyed creating panels collaboratively and sharing content using the proposed interaction techniques. The included game-like features positively influenced social interaction.

Author Keywords

Collocated Interaction; Handheld Devices; Public Displays.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Mobile devices have traditionally been very personal devices targeted at individual use. However, over the last years there has been growing interest in systems that couple several mobile devices together and combine them with larger display devices to create broader ecosystems of interaction. Such ecosystems allow groups of collocated users to engage in collaborative activities, thus shifting from *personal-individual* towards *shared-multi-user* interactions. From the designer's point of view, systems involving complex and dynamic geometries of interaction present many challenges over conventional ones. In their taxonomy of multi-person-display ecosystems, Terrenghi *et al.* [32] identify the physical scale of the ecosystem and the nature of the social interaction as their two main attributes.

In this paper, we are concerned with collaborative interactions within medium-size groups of approximately 8 to 25 persons in semi-public or public environments such as small cafés or pubs. According to Terrenghi *et al.* [32] such environments can be described as perch-scale ecosystems and the number of users falls between few and many. While some of the persons may be actively engaged in interaction with the system, there may be others with varying levels of awareness of the system and the interaction taking place [24]. As the scale of the system and the number of users increases, not all users can perceive the displays of the mobile devices in the system. Therefore, larger yard-scale public displays must be added to create a common display space. As there typically are far fewer public displays than users, access to the public displays may become a factor limiting the interactions within the system. On the other hand, risk of social embarrassment (e.g., due to making an error in using the system in front of a large audience) may become a deterrent for users to engage in complex interactions on public displays [3,25,29]. Therefore, the role of public displays must be carefully considered in the system design to encourage their fair and efficient use as well as to reduce their irritating or even offending use.

As a practical example of a system supporting rich collaborative interactions within medium-sized groups in (semi-) public places, we present the design and evaluation of *MobiComics*, an application that: 1) allows people to collaboratively create comic strips with their mobile devices, 2) supports different ways to share comic strip panels, including private sharing between devices and sharing with more people over public screens, and 3) features a variety of playful elements to foster social interactions between the participants. In order to allow users to work effectively in parallel without being constrained by limited access to the public displays and to enable different levels of privacy, *MobiComics* supports interactions on three different scales, based on Terrenghi *et al.* [32]. First, two users may couple their devices *ad hoc* to create an inch-scale ecosystem for direct one-to-one interactions. Second, a small number of users can bind their devices together into a yard-scale ecosystem to support collaborative creation of comic strips. Third, all users are part of a perch-scale ecosystem covering the entire physical space (i.e., pub or café) and allowing the sharing of panels on public screens to everybody. In addition to publishing, the users may also pull panels from public displays to their

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MobileHCI'12, September 21–24, 2012, San Francisco, CA, USA.

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devices, making the public displays a two-way distribution channel. For interactions, the system features extensive use of gestures and spatial interactions, supported by a radio tracking system capable of measuring the positions of the devices relative to each other and to the environment. During a series of evaluations of *MobiComics* in authentic settings, the participants made a versatile use of the different system features, illustrating different strategies for creating and sharing content.

The rest of this paper is organized as follows. We begin by reviewing the relevant related work. Then, we describe the design principles and interaction techniques of *MobiComics* in detail. Finally, we report the results of a series of user evaluations, followed by discussion and conclusions.

RELATED WORK

A large body of related work has influenced the design of *MobiComics*. We have identified three main related-work areas: mobile collocated interactions, interacting with public displays, and applications for public expression.

Mobile Collocated Interactions

One group of applications has supported *ad hoc* collocated collaborative work using mobile devices. In Luyten *et al.* [18], personal displays are tracked and used to share a common information space (i.e., a map), providing peepholes to the data set. Their setup requires external equipment in the form of three infrared towers to track the positions of the devices. Siftables [19] consist of a group of compact display devices that communicate wirelessly and form a sensor network. Although they were conceived with a single user in mind, Siftables have the potential to support mobile collaborative interactions. One limitation of this system is that the positions of the Siftables can only be detected when placed adjacently one next to the other.

Another group of applications has specifically provided support for collocated photo sharing. Ah Kun *et al.* [1] propose a network of PDAs that allows any user of a group to broadcast images on the other devices in that group. Images are transferred wirelessly using Wi-Fi. Their prototype incorporates a series of floor-control policies or software locks that determine who can control the show and when, in order to study how to best manage social interaction. Mobiphos [5] supports capturing and real-time sharing of photos among members of a collocated group using cameraphones. The application presents users with an updated stream of picture thumbnails made by the group. The display is used both as a viewfinder and a thumbnail gallery. Data is transferred between devices using Wi-Fi. Disc-O-Share [14] allows browsing and transferring photos between mobile phones by creating three distal regions around mobile phones. Particular actions are triggered in response to entering or leaving these regions. An external camera tracks the position of the phones by reading visual markers displayed at the top of each device's screen.

Many of the previously described systems require a dedicated infrastructure (e.g., infrared tracking or camera) for position tracking. In *MobiComics*, we provide a 3D tracking solution that is built in the phone, which allows us to detect where the phones are with respect to each other without external equipment. We have demonstrated this technology earlier for an application that supports photo sharing [17]. In addition, studies of the systems discussed here have been limited to small groups of people from two to six persons. In this paper, we study collocated interactions for a group of nine persons.

Interacting with Public Displays

In recent years, there has been an increasing interest within the HCI community in designing, deploying, and studying the use of large interactive displays. In the following review, we focus on findings that stem from user studies of public displays, especially ones that relate to supporting collocated interactions in (semi-) public settings. BlueBoard [27] is an augmented noticeboard that supports lightweight walk up and use interactions. Identified users can quickly retrieve personal information stored on a network, display it on the board, and share it with others via, e.g., email. The authors found that collocated people interacting at the board were able to coordinate their joint actions and thus complex floor control policies were not necessary. Dynamo [12] is a set of large multi-user interactive surfaces that support sharing and exchanging media content. Whenever participants' actions overlapped, people would often speak aloud to make others aware of the overlap or to apologize for their own actions. Similar to what Russell *et al.* noticed with the BlueBoard [27], emerging social protocols allowed resolving the overlaps easily. More recently, CityWall [23] is a large multi-touch interactive display installed in Helsinki's city center that serves as an open platform for passers-by to play around and explore public photos. The authors describe the importance of repurposing existing elements in the available space (i.e., a shop window) to avoid changing how people move.

Although most of these systems have concentrated on large interactive displays, others have considered adding personal mobile devices as part of the interaction [20,25,29,31]. The Pebbles system [20] was one of the first to explore multi-user interactive displays by connecting PDAs that provide concurrent input to a large shared display. The authors suggested that the PDAs could be used as a private space whenever users feel like composing content before sharing it with the group on a public display. The MAGICBoard [31] is a public display deployed in a university setting that solicits votes and opinions on trivial topics from bystanders via SMS or from a laptop. Users post text-based items on the display, which persist until newer items push them off-screen. The authors found that users posting messages from their phones (instead of the laptop) tended to leave longer, more thoughtful messages.

Applications for Public Expression

In Schminky [25], users play together a spontaneous, networked sound-based game using mobile devices (iPAQs) and public displays. The system was evaluated during a weeklong field trial in a café. The game increased the social interaction at the bar by acting as a spur for people to find out who the Schminky players at other tables were. The authors also reported that due to the small size of the device, players were able to interleave playing Schminky with other activities such as gesturing, holding food, or drinking. MobiLenin [29] allows multi-user interaction with a multi-track music video shown on a public display. People can direct the outcome of the video in real time by voting for one of six video tracks from their personal mobile phones. The authors found that empowering people with the joint ownership of the contents motivated users to interact with the public display. During a one-session evaluation in a pub, the authors found that the system had a positive effect on the social interactions that took place at the pub. We deployed *MobiComics* in an *indoor public place* (i.e., at a pub and two social events) to study how people experience the prototype in a situation that is as realistic as possible.

DESIGN OF MOBICOMICS

Based on the relevant literature, we decided to design and implement the *MobiComics* prototype that: 1) allows a group of collocated people to flexibly create and edit comic strips from their mobile phones, 2) supports *ad-hoc* sharing of comic strip panels onto two public displays by taking the spatial arrangement of people into account, and 3) includes game-like elements to foster social interactions between the participants. In other words, *MobiComics* combines a mobile application as a creative tool, a public display as a sharing device, direct social interaction between the participants, and the use of photos from the situation, all as part of an integrated experience.

Creating Content from the Privacy of a Mobile Phone

Studies have identified social embarrassment as a core deterrent to users interacting with a public display in front of an audience [3,25,29]. For example, when typing a message in real time on a public display people feel self-conscious about making and correcting spelling mistakes, taking too long to write an entry, or formulating something inappropriate for the current social situation [3].

To help people cope with social pressure, we support creating and editing comic strips from the privacy of their mobile phones [20]. Sub-group members can discuss panels face-to-face and correct potential mistakes before sending them onto the public displays. Once published on a large display, it is possible for the others to identify which sub-group created a panel but not its individual author, thus supporting anonymous participation.

Flexible Sharing onto and from Public Displays

We extend the existing work on mobile collocated interactions by incorporating public displays. In doing so, we introduce a series of 2D and 3D gestures that allow people to physically throw panels in a given physical space (i.e., inside the pub) as opposed to requiring them to concentrate on the mobile user interface (UI) to select contents and recipients (e.g., from a pull-down menu). We include 2D and 3D gesture-based aesthetic interactions (i.e., flicking, holding, tilting, shaking, picking up) by fully exploiting the affordances of touch UIs and accelerometers in contemporary smartphones.

We support *ad-hoc* sharing of comic strip panels using devices enhanced with radio tracking technology [2], which allows tracking the relative positions of the devices (and the two public displays). The sensors embedded in the mobile phones allow us to know where each sub-group (member) is located inside the pub. In this way, we are able to send panels from one sub-group to another, as well as to send panels onto and receive panels from a public display even when sub-group members are moving in the environment.

Game-Like Elements to Foster Social Interactions

The combination of collocated use of mobile phones and public displays generates interesting possibilities for sharing information and media, as well as for socializing. Besides supporting collaboration between sub-team members, we are interested in studying social interactions as part of the larger interaction with the prototype.

We include game-like elements to stimulate social interactions between sub-groups. For example, a voting system is included as part of the interaction to motivate people to participate by creating a competitive situation between sub-groups. Public displays play a double role of allowing members of the audience to first discover the application and then potentially voice their opinions on the published comics during voting.

INTERACTION

With *MobiComics*, three sub-groups of people (hereafter teams) use their mobile phones to create and edit comic strips, as well as to publish panels onto two public displays.

Creating and Editing Panels

At the start of the interaction, nine people are split into three teams: cyan, magenta, and yellow. After starting the application, each team member is presented with their team's empty panel collection. Each team member can then start creating panels from their device. To create a panel, users must first take a photo with their cameraphone. Users must open the lens cover, which activates the viewfinder, and take a photo. After closing the lens cover, the captured photo can be used as background for a panel. Each captured photo is automatically shared to the team's panel collection, which can be browsed by flicking the panels left or right.



Figure 1. Panel Creation with the different speech bubble types. (a) A red bubble in *edit mode*, and (b) a black bubble currently being edited by another team member.

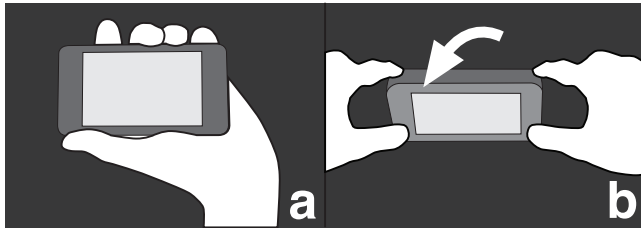


Figure 2. (a) Holding the device up in the air to receive a panel from another team, and (b) tilting vertically towards oneself to take a panel from a public display.

By tapping on a panel from the collection, people are able to edit the panel. Users can add speech bubbles to the panel by performing a long press anywhere on the panel. A red bubble is displayed under the user's finger, indicating that it is in *edit mode* (Figure 1a). Using the physical flip keyboard, users can directly type text onto the bubble, which dynamically changes its shape to accommodate text. To change the shape of the speech bubble users must shake the device, which results in cycling through three bubble types: speech, thought or text box. Users can also modify the position of the bubble and of the bubble tip by dragging either of them with their finger on the touchscreen. While still in *edit mode*, speech bubbles can be deleted by flipping the device upside down. As the screen is no longer visible, a trashcan sound effect provides feedback. To end the *edit mode*, users must tap outside the speech bubble, which then goes back to white. *MobiComics* supports creating panels collaboratively. Team members can edit the same panel simultaneously, but only one person can edit a given bubble at a time. Users can then see in real time when another team member is editing a bubble, which is shown in black (Figure 1b). Other systems such as Comeks [28], the mobile multimedia presentation editor [13] and Automics [6] provide similar ways to annotate photographs in a comic-strip style. However, these systems only allow sharing panels to one other person or to other users of the system.

Sharing Panels onto the Public Displays (Throwing)

MobiComics supports different ways to share panels. First, users can send a panel from their own collection to one of

two public displays available in the room (Figure 3.1). The public displays are positioned so that members of the three teams and the crowd members are able to get a clear view of them. To share a panel to a public display, users first select a panel from the team's panel collection and perform a long press on that panel. A thumbnail of the panel is displayed under the user's finger, which can be moved around by dragging the finger on the touchscreen. The panel can then be thrown in the direction of the desired public display by flicking the thumbnail. The devices are fitted with a radio tracking technology to detect the relative positions of the other devices and the two public displays. If no public display is found in the direction the panel was thrown, then the panel briefly shakes back and forth on the sender's device. However, if a public display is located in the direction the panel was thrown, the panel is shown on the public display. The new panel fills up the public display and is shown on top of any other existing panel until a new panel is shared by any of the three teams. An animation shows the direction the new panel is coming from. Throwing panels to public displays makes use of existing multi-display reaching techniques [21].

Sharing Panels with Another Team (Send to Me)

Second, users can send a panel from their own collection to another team (Figure 3.2). To achieve this, one team member on the receiving side must first verbally ask for a panel and then hold the phone up in the air pointing towards the other team, thus expressing the intention to receive a panel (Figure 2a). As the user can no longer see the screen, a subtle vibration is triggered to confirm the device is ready to receive a panel. The screen on that device displays a scrolling "*send to me*" on top of the receiving team's color. With this interaction technique we are exploring the use of mobile phones to display information in public. Once a member from the sending team has spotted this cue, they can then flick a panel to the group that is holding one of their devices up. The throwing mechanism includes the same actions and visual feedback described in the previous section. Additionally, a strong vibration is triggered on both ends to confirm the panel was successfully received. The received panel is automatically shared to the team's panel collection.

Taking Panels from the Public Displays (Retrieving)

Third, users can take a panel from a public display and add it to their team's panel collection (Figure 3.3). To achieve this, users must point with their device towards a public display and tilt [4] the device vertically towards themselves by performing a quick upward movement and bringing it back to the starting position (Figure 2b). An animation showing how the panel taken from the public display is added to the team's collection together with a strong vibration provide feedback to the user.

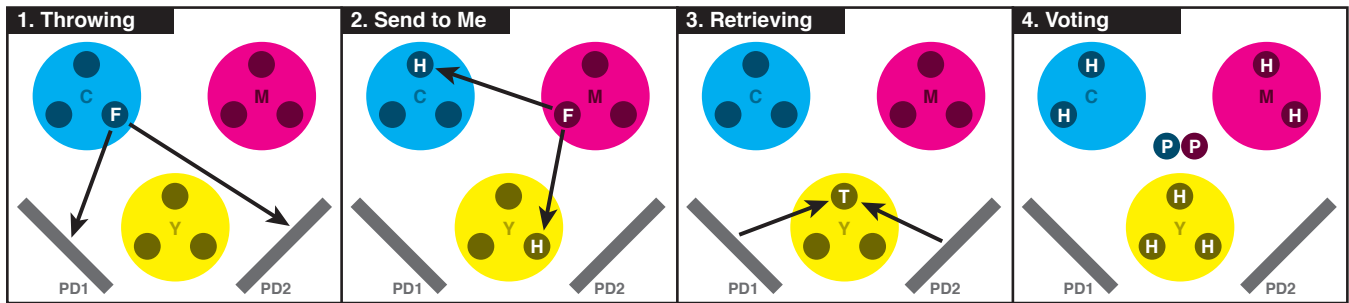


Figure 3. Interaction techniques in *MobiComics*. Nine participants split into three groups: cyan (C), magenta (M) and yellow (Y). 1) **Throwing**: flicking (F) panels to either public displays (PD1 or PD2). 2) **Send to me**: flicking (F) a panel while a member from another group holds a device up (H). 3) **Retrieving**: taking a panel by pointing towards PD1 or PD2 and tilting (T) the device towards them. 4) **Voting**: two members, each from a different team, pinch (P) vertically and hold their devices up in the air (H).

Viewing All Panels Shown on the Public Displays

The contents of the public displays are constantly changing depending on how actively participants are throwing panels onto them. As a result, users may miss some of the public display panels. To solve this, each team can access the public display contents locally. Two members of the same team must align their devices horizontally on the short edge and then pinch their devices together [16]. Alternative ways to connect two devices together include: knocking devices together to detect synchronized sounds [26], bumping devices together using accelerometer data [8], and performing pen gestures on touch-enabled devices [9]. When two devices are successfully tiled together, a collection of public panels or panels that have been shown on the public display is presented on the tiled displays. Users can simply browse the public panels by flicking the collection left or right. This composite version of the collection spans both devices allowing users to see the public panels in greater detail. Devices can be disconnected from the tiled view by physically picking them up.

Picking the Best Panels from the Session (Voting)

In an attempt to involve all three teams (and potentially the members of the crowd) in the interaction, *MobiComics* allows people to publicly vote for the best panel of the session (Figure 3.4). To trigger the voting mode, two members, each from a different team, must align their devices, this time vertically on the long edge, and pinch them together (Figure 4a). Requiring two teams to trigger voting prevents having one team dominating the situation, e.g., by continuously pushing new panels for voting. When voting is triggered, an overview of all the panels that have been shown on the public displays is presented both on the tiled devices and on the public displays, thus providing feedback for the members of the crowd. Flicking the public panels up or down results in browsing the overview. This overview is shown on the public displays to create an opportunity for other team members and potentially the audience to influence which panel they would like users to vote on. Meanwhile, the seven remaining participants (see Figure 3.4 for those participants marked with an H) are invited to join the vote by displaying a blinking “voting

ongoing” inside a large white hand with its thumb sticking up on top of the corresponding team’s color.

When a panel is selected from the tiled devices, all remaining team members are prompted to vote. The large white hand starts slowly blinking together with a gentle vibration to encourage users to cast their votes from their devices in favor or against the currently displayed panel. To vote, users must briefly hold the device in the air with the image of the hand pointing its thumb up or down for a positive or negative vote respectively (Figure 4b). This is a second interaction technique that we implemented to explore the use of mobile phones to display information in public. To provide feedback, a strong vibration is triggered on the device, “Positive/Negative vote cast” is shown on the device’s display, and the number of positive and negative votes is updated on the public display. Voting continues when the next panel is selected, triggering a new voting round. Users can only cast one vote per round, however it is possible to have more than one round per panel. To stop the voting mode, users must physically pick up the connected devices. The remaining participants can then resume the activity they were on when voting started.

EVALUATION

In order to assess the proposed interaction techniques and study how people experience the *MobiComics* prototype, we arranged four evaluation sessions in authentic settings. We collected qualitative data both during the interaction with *MobiComics* and later during semi-structured interviews. Quantitative data was collected by means of a validated questionnaire after a task related to the prototype.

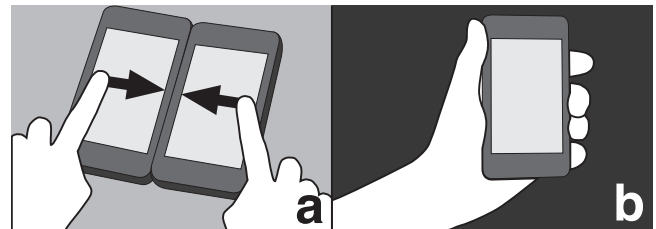


Figure 4. (a) Pinching two devices vertically to trigger voting, and (b) holding a device upright to cast a positive vote.



Figure 5. Evaluation setup. Members of the yellow team creating panels (left), two pub guests conversing (center), a public display showing a panel from the magenta team (right).

Participants

The evaluation was conducted with 36 participants. Each of the four sessions included nine people (i.e., three groups of three friends). We recruited groups of friends, rather than isolated individuals, so participants would feel comfortable expressing themselves around one another. In each session, there were two groups of three friends who knew each other well and at least one acquaintance in common in the third group. The participants were chosen to represent a variety of user types, including parents, international students and professionals. The participants varied in gender (27 male, 9 female), age (between 20 and 43), and background (26 technical, 10 non-technical). All of them owned a mobile phone, different from the one used in the study. Most participants often went to pubs and cafés.

Method

Each two-hour session consisted of four parts: introduction, exploration, task, and semi-structured interview. First, we gathered participants' background information and we explained the purpose of the evaluation to them (10 min). Second, we briefly explained participants how to interact with the *MobiComics* prototype. We then allowed them to explore the available functionality and get acquainted with the application (20 min.). Third, participants freely used *MobiComics* to create and share comic strip panels between teams and onto the public displays (30 min.). At the end of the session, we asked participants to fill-out the AttrakDiff [7] questionnaire to quantitatively measure pragmatic and hedonic aspects of the prototype. AttrakDiff measures the attractiveness of interactive products along four dimensions. Pragmatic quality (PQ) refers to the product's ability to support the achievement of behavioral goals (i.e., usability). Hedonic quality refers to the users' self: stimulation (HQ-S) is the product's ability to stimulate and enable personal growth (i.e., aspirations), and identification (HQ-I), is the product's ability to address the need of expressing one's self through objects one owns (i.e., social aspects of product ownership). Both HQ-S and HQ-I have been found to contribute to perceived attractiveness (ATT), which describes a global value of the product based on the quality perception. Participants indicate their perception of the product by rating 28 pairs of opposite adjectives that relate to the four dimensions on a 7-point scale (-3 to 3).

Finally, we had semi-structured interviews with each group in which we asked a consistent set of open-ended questions, prompting participants to reflect back on some of their interaction experiences with the prototype (60 min.). All sessions including the semi-structured interviews were recorded on video using three stationary cameras, one for each group. After the interviews, participants were given one movie ticket each to compensate them for their time.

The four sessions were conducted in three different indoor locations. The first session was conducted in the common room area of the Game Research Laboratory at the University of Tampere during a social event of an international research seminar. The second and third sessions took place at The Dog's Home pub in the city center of Tampere (Figure 5). The fourth session was done in a common room area of the Innovation Center, a facility for cooperation between local universities and companies. Despite the differences between these three locations (i.e., *semi-public* vs. *public* places), the four sessions had many things in common. There was roughly the same amount of people at each location (less than 30 persons, including the nine participants), creating a natural and quiet atmosphere. The two pub sessions were conducted in the evening to ensure that there would be enough guests. In all sessions, there was music playing in the background, people were chatting and drinking. Each participant was provided with one device running the prototype. Participants were either sitting or standing around three tables. The tables were (as much as possible) evenly spaced from one another, in a triangle formation. The two public displays (i.e., projection displays or large LCD screens) were placed on opposite sides of the rooms. By maintaining this spatial structure, we hoped that the interaction would be smoothly balanced both across teams and with the respective public displays.

Affinity diagramming [11] was used to analyze data from the observations of use and the semi-structured interviews. Two researchers independently made notes as they watched the videos for each session. The qualitative data was then collaboratively analyzed through several interpretation rounds. The affinity diagram supported categorization and visualization of the main themes emerging from the data. These themes form the heart of our findings section.

Implementation

We developed a prototype of *MobiComics* on Nokia N900 mobile devices running the Maemo Linux operating system. The prototype was built on top of the Social and Spatial Interactions (SSI) software platform [15] that provides reusable components for rapid development of mobile applications that support rich local collaborative interactions. The SSI software platform was implemented in C++ using the Qt 4.7 software framework. The user interface was developed with Qt Quick and OpenGL ES 2.0 rendering was used for fluent user interface graphics, e.g., animations for moving, rotating, and zooming the panels. A local Wi-Fi network was used to connect the devices to

each other and coordinate the application state between the devices. In order to display events across different devices, the devices' clocks were synchronized.

The N900's internal accelerometer was used to detect when a device was picked up from the table, when it was tilted, or when it was held up in the air. When the sensor showed a constant pull toward the back of the device, it was deduced that the device was on the table. When there was a constant and distinguishable pull in a given direction, it was recognized as a tilt or as holding the device up in the air in a certain position. In all other cases, the device was considered to be in free manipulation in the user's hands.

To detect the positions of other devices and the public displays inside the room (e.g., to flick a panel to another device or to a public display), we utilized N900 devices enhanced with radio tracking technology [2]. This particular technology tracks the angular position and distance between devices by embedding multi-antenna receivers under the devices' screen and running sensor array signal processing algorithms on each device. This allows the technology to track multiple emitters such as active RF tags for the public displays or mobile phones.

FINDINGS

Different Panel Creation Strategies

People used different strategies to create panels within each team. All participants were able to create panels by taking a photo and adding speech bubbles. In general, participants considered adding and editing speech bubbles an important part of creating panels and thus took their time to carefully craft each panel. The within-team collaboration created a safe environment for people to freely express themselves before exposing the content to a wider audience. In that sense, working from the mobile devices and checking the panel contents before making them public helped reduce the embarrassment reported in other studies [3].

The device gestures introduced during panel creation (i.e., *shaking* to change bubble shape and *flipping upside down* to delete a bubble) were often used and described as "*natural and logical*." Most participants (32/36) were positive about *shaking* to change bubble shape due to a combination of clear visual feedback and a familiar interaction style: "*Shaking the bubble was really clear, the feedback was quite fast and you see the bubble changing*." (P8) Deleting a speech bubble by *flipping the device upside down* was often used and was well received by the participants. However, two participants commented that the trashcan sound was strange: "*Deleting is really nice. If (panel creation is) only based on touch, then people will feel bored*." (P30) "*But the sound is weird*." (P31)

We observed three main panel creation strategies, which evenly occurred during the four sessions. First, in some teams, members worked individually taking their own photos and editing their own panels. Although some social

interaction was observed between team members (i.e., showing panels to other team members from their own devices, helping each other out), these participants spent most of their time focusing on their own devices during panel creation. There was a sense of ownership to the panels made within these teams as a single person created them. Due to this, some participants were unsure about editing someone else's panel: "*I think I added something to the pictures created by others, but there was a barrier to start tampering with somebody else's work*." (P25)

Second, other teams more openly collaborated during panel creation. Some groups planned how to create panels within the team and coordinated their actions accordingly. These groups used the real-time editing possibilities offered by *MobiComics* to create panels collaboratively, which provided clues to what other team members were doing: "*It was fun that you could see the bubbles that the others were editing in real time on your own display*." (P27) The team members in these groups flexibly changed between tasks and thus there were no fixed roles for each team member.

Finally, a third strategy consisted of having fixed complementary roles throughout the session. Similarly to the second group, the members of these teams collaborated during panel creation, however in this case they had a clear role division. As a result, one person took photos, another was in charge of adding and editing speech bubbles, and the last dealt with sharing and retrieving panels: "*It was kind of fun to create collaborative panels: one takes pictures, one adds the bubbles, and one sends it*." (P8)

Regarding the panel contents, participants mainly captured objects found in their immediate surroundings. They did not intentionally manipulate the environment much. The other source of content for the panels was people, including team members and members of the other teams. A few participants (4/36) raised their concerns about taking photos of other people as the subject for the panels, especially if they were members of the audience. From the participants' point of view, the main motivation to create panels was to make something funny and creative: "*We were trying to make funny stuff; maybe some arty or creative stuff*." (P8)

Different Panel Sharing Strategies

We introduced three main methods to share panels onto and retrieve panels from the public displays (i.e., *throwing*, *send to me*, and *retrieving*). First, participants could *share panels onto the public displays*. All participants were able to share their individual panels by throwing them across the room to one of the two public displays available. Participants created and shared a total of 150 panels onto the public displays during the four sessions (Mean=37.5, SD=5.5). Each team created on average 12.5 panels per session (SD=4.75). A new panel was shared on either of the public displays every 48 seconds. This provides a rough estimate of how often the contents were changing on the public displays. As mentioned previously, participants took their

time to carefully craft each panel, which partly explains why participants did not create and share panels more often. Out of the total number of panels, 23% of the panels were direct responses to a panel that had previously been shared on the public display (35/150). Some of those responses were made by members of the same team (19/150), and the rest came from other teams (16/150). The longest chain of direct responses published on the public displays was four panels long. Participants said the use of the spatial arrangement of people inside the pub or social event allowed them to easily share panels to the public displays and other teams. *Throwing* was an intuitive gesture to share panels onto the public displays and the other people in the pub. *“It is really nice, it makes it easier to send something to a person or just aim wherever you want.”* (P14) On the AttrakDiff questionnaire (Figure 6), the prototype is located in the above-average region on the attractiveness (ATT) dimension and thus the overall impression of the prototype is very attractive. These high ratings indicate that the participants perceive the prototype as motivating and appealing. Members of a same team successfully but only occasionally tiled two of their devices together to browse the collection of public panels.

Second, participants shared panels with other teams by holding a device up in the air in all four sessions. The gesture itself was often used and was perceived as *“fun and unique.”* On stimulation (HQ-S), the first hedonic quality dimension of AttrakDiff (Figure 6), the prototype is clearly in the above-average region implying that people think the prototype is creative and inventive. Most participants referred to the two interaction techniques that explore the use of mobile phones to display information in public (i.e., *‘send to me’* and *voting*) as fun and novel, and this rating on the AttrakDiff questionnaire supports that notion. The gesture was originally designed so that if a user would spot a member of another team taking an interesting photo (e.g., a person making a funny face), the user would be able to request that photo immediately (*‘send to me’*) without having to wait for the panel to show up on a public display. A few participants (9/36) explicitly commented that the initiation to share panels should come from the sending side: *“It’s almost as if it should be the other way round. ‘Oh, I’ve got a cool photo, I want to send it to you.’”* (P30) However, as the users on the receiving side were unable to see the panel contents beforehand, in some cases they requested the sending team to share the panel to the public display first, and after checking the quality of the panel, they retrieved it to their own collection from the public display. In practice, we observed that members of both the sending and the receiving ends had genuine reasons to initiate the sharing of panels. Regarding the device gesture (i.e., holding the device up in the air), some participants (9/36) raised their concerns about performing large, visible gestures while holding their mobile phones in public, which can be socially awkward [22]. Since the use of mobile phones to display information in public is not widespread, a

few participants thought the crowd might start wondering what that person holding the device in the air in the middle of the pub is up to: *“It might look strange to hold the phone up if not everyone is in on what I am doing.”* (P17)

Third, participants again described the gesture for *retrieving* panels from the public display as *“natural.”* Participants retrieved panels several times during each session, although less frequently than they sent panels directly to another team. Participants used this gesture mostly to directly respond to another team’s panel or when they saw something interesting on the public displays. *“When I saw something cool up there, I asked P28 to grab it.”* (P30)

One additional sharing strategy consisted of showing panels directly from the devices. Participants shared information about panels by showing their devices’ screen to one or two other members of the same team. As an example, in session three one participant (P26) took her device to show everyone in her team a panel that she had just made, while she explained her intentions to them.

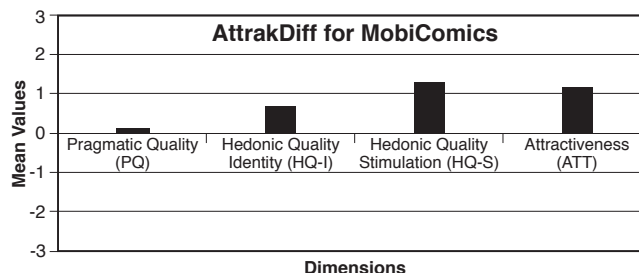


Figure 6. Mean values along the four AttrakDiff dimensions.

Social Interaction Between Groups

As previously mentioned, *voting* was created to involve all three teams and the audience in the interaction by means of a public vote. Voting was triggered between one and three times per session. Each voting session lasted between one and four minutes. It took the teams approximately one minute to select a panel, open the voting, cast the votes and close the voting to select a new panel. Therefore, between one and four panels were voted upon in each voting session. In MobiLenin [29] voting also took one minute, which gives participants a chance to contemplate, celebrate and prepare before the next voting round takes place. During voting, the social interaction between team members was at its peak with lively discussions and laughter. On the other hedonic quality dimension of AttrakDiff, i.e., identity (HQ-I), the prototype is located in the average region, which means that people think the prototype is connective and integrating, but at the same time is not stylish enough for users to fully identify with it. However, this rating confirms the prototype encourages social interaction between people.

Initiating voting required a team member from one team to move to another team’s table and connect their devices. All participants were able to successfully tile the displays together by performing the pinch gesture. However, some participants (13/36) commented that this procedure felt

artificial and that it broke the flow of interaction. Participants would have preferred to be able to start the vote from within their teams: *"It would've been nice to initiate voting without having to go to another group but having the three of us and we want to vote on this."* (P30) When voting is triggered using two devices, all ongoing activities are interrupted on the remaining seven devices. Although users can later resume the activity where they left it off at the end of the vote, participants felt it was distracting: *"The whole system shut down when there was voting. I would like to continue taking pictures and (then vote) whenever it says 'vote now.'"* (P6) On the AttrakDiff questionnaire (Figure 6), the prototype was only rated as average on the pragmatic quality (PQ) dimension, which means there is room for improvement in terms of usability. Forcing participants to join voting while in the middle of another activity may have impacted the ratings on this dimension.

With voting we were also trying to study the use of mobile phones to display information in public. To cast a vote, users had to briefly hold their device in the air showing an image of a hand pointing its thumb up or down. This gesture was highly visible due to a combination of holding the device up in the air and the bright graphics displayed on the screen. Members of the crowd were easily able to identify whether people were giving a panel a thumbs up or down from a distance (i.e., from anywhere at the pub or social event). In that respect, the mobile phones were successfully used to display information in public. This is further confirmed by the comments from a few participants (6/36) who felt the pressure of publicly revealing their vote to others: *"I have the desire to vote in secret, especially when voting thumbs down."* (P25) Some participants even cheated the system by either doing a small secretive gesture that was not visible to others, by turning the screen away from the crowd (i.e., when located near a wall), or by physically faking a thumbs-up gesture while the image on the screen is displaying a thumbs-down.

DISCUSSION

Collocated Interactions Using Personal Mobile Phones

Participants were positive about using their personal devices to create a common interaction space, but some of them (8/36) were more specific and said they would share their devices with people they know and trust, rather than with complete strangers. One limitation of the *MobiComics* evaluation is that participants were not using their personal mobile phones during the interaction. Participants were using N900 devices enhanced with position tracking, and thus we are unable to fully answer whether they would actually lend their personal phones. In spite of this, the evaluation setup provided a realistic enough situation for us to study. For example, participants were able to raise some privacy concerns regarding taking pictures of strangers at the pub (18/36) and keeping *MobiComics* panels at the end of the session (10/36). For more details on privacy while people interacted with *MobiComics* see [10].

Overall Impression

We have presented the AttrakDiff results by mapping its four dimensions to the different interaction strategies used by the participants. We will now discuss these results in more depth. On the AttrakDiff questionnaire (Figure 6), *MobiComics* was rated in the above-average region on the hedonic quality stimulation (HQ-S) and attractiveness (ATT) dimensions, and as average on the hedonic quality identification (HQ-I) and pragmatic quality (PQ). In other words, the pragmatic value is considered as average while hedonic values are high. *MobiComics* includes 2D and 3D gesture-based aesthetic interactions (i.e., flicking, tilting, shaking) by maximizing the affordances of touch UIs and accelerometers. Participants found these interaction techniques to be novel and fun, but at the same time the interaction techniques were not particularly better in terms of helping participants achieve their goals. Some of the proposed interaction techniques could indeed be simplified and make use of more conventional (mobile) interaction techniques to improve the overall usability of *MobiComics*.

Mobile Devices as Public Displays

MobiComics makes use of users' mobile phone displays to show information in public. Both *send to me* and *voting* display a large scrolling text and an animated hand that are visible to any user from a distance of several meters. All people in the room, including the users not actively engaged with the system, can easily observe these large animations. These uses of mobile device displays lead us to consider the more general idea of using mobile devices as public displays to share information among larger groups of people. While the physical size of a mobile device display is small, it can still be observed from long distances – only the resolution of the display will decrease as the distance increases due to the limited resolution of the human eye. Even if the mobile device display only allows low-resolution images to be shown, larger amounts of information could be presented by using animations, e.g., scrolling text. Ultimately, with increasing distance, the mobile device display would become a one-pixel display. Knowing the relative positions of the devices would allow creating more complex visualizations [30]. The idea of utilizing mobile device displays as public displays offers an interesting line of research for further study.

CONCLUSION

The *MobiComics* prototype allows a medium-sized group of people to create, edit, and share comic strip panels. The prototype encourages people to create panels from the privacy of their mobile device and with the help of their team members by discussing face-to-face. Using devices fitted with radio tracking technology to detect their current location, people are able to share panels to other team members and onto two public displays. Playful elements are included in the prototype to foster social interactions between the participants. Evaluations in authentic settings (i.e., at a pub and at two social events) showed that people

enjoyed creating and sharing their panels using our interaction techniques. The game-like elements of the prototype positively influenced social interactions, but at the same time raised some concerns about the visibility of some gestures in public settings.

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