Cross-Device Interaction with Large Displays in Public: Insights from both Users' and Observers' Perspectives

Jeni Paay, Jesper Kjeldskov, Dimitrios Raptis, Mikael B. Skov, Ivan S. Penchev, Elias Ringhauge
Department of Computer Science / Human Centered Computing
Aalborg University, Aalborg East, Denmark
{jeni, jesper, raptis, dubois}@cs.aau.dk

ABSTRACT

1Using a mixture of physical gestures and one's smartphone is a convenient way for people to engage and interact with large displays in public. Yet, one of the challenges of cross-device interactions is to design techniques that encourage participation. This paper presents a study of people using four different cross-device interaction techniques in a public setting, to identify how both users and observers feel about the device actions and bodily gestures required to interact with a large display using smartphones. We collected both direct feedback and observational data of users' and observers' attitudes and reactions to using these techniques in public. We identified five key factors influencing people's experience of interacting while being observed by others: Familiarity, Social Acceptability, Purpose, Easiness and Playfulness. We argue that it is important to consider observer attitudes when designing cross-device interactions for large displays in public, to encourage the participation of passers-by.

CCS CONCEPTS

• Human-centered computing → Interaction techniques

KEYWORDS

Public Displays; Smartphones; Cross-device Techniques; Users and Observers; Interaction Design

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1 INTRODUCTION

Large public displays are becoming increasingly present in public spaces, such as malls, parks, shops, railway stations, and building facades. Rather than merely displaying information, these displays are increasingly interactive, and in particular, allow cross-device interaction between the display and people's personal devices [34]. According to Mäkelä et al. [27], the transfer of information between a space and a personal device will be an important aspect of future smart spaces.

There is a growing interest in cross-device interaction with public displays, that includes how to facilitate this interaction through suitable techniques, how to attract and engage people into using them, how to make use of large interactive displays, and how people perceive and negotiate using them in social settings.

One of the main problems of interacting with large displays is that there is often resistance from the public to engage with them [8]. This has been attributed to the impact of group dynamics within the interaction space [9], as well as the problem of feeling socially embarrassed [11]. People do not like to appear awkward when attempting cross-device interactions in public [28]. Various approaches have been investigated for overcoming these problems through, for example, the choice of user representations **Error! Reference source not found.**, supporting multiple users [21], encouraging bystanders to interact [5][36] and incorporating playful elements into the design [37]. Research is also focused on finding effective ways to evaluate interaction with public displays, by measuring user engagement and tracking audience behaviour [4][22].

The ease of use of gestures and devices required in the interaction also impacts people's decision to participate [10]. According to Nacenta et al. [31] the fundamental challenge of cross-device interaction is simply how to move an object from one display to another. Ongoing research is addressing this by investigating issues such as designing easy to use, learnable and

intuitive gestures [3][14][17] and using familiar personal mobile devices in the interaction [12][23][27].

Our contribution to this research, investigating elements that impact the success of cross-device interaction, is to approach this from the perspective of both *users* and *observers*. This gives us insight into how people perceive different techniques, as either awkward to perform, or embarrassing from two different but related points of view.

In this paper, we contribute to knowledge on cross-device interaction with large public displays by studying users' and observers' impressions of four cross-device interaction techniques: *pinching*, *swiping*, *swinging* and *flicking* used to move files from a personal smartphone to a large display situated in a public place. We present related work and an empirical field study on the use of these cross-device interaction techniques in public. We then present and discuss our findings of five key factors influencing people's participation: *Familiarity*, *Social Acceptability*, *Purpose*, *Easiness* and *Playfulness*.

2 RELATED WORK

In the following we present related work on encouraging interaction with public displays, using mobile phones in the interaction, the role of bystanders and observers.

2.1 Encouraging Interaction with Public Displays

Interactions with public displays is an area where researchers from different disciplines, such as HCI, architecture, social science, design, art, and media theory have, for over a decade, been exploring potentials and challenges of taking large interactive displays and situating them in public settings [20]. This has involved taking into consideration such characteristics as diverse audiences, spatial layouts, size, lighting conditions, social meaning, etc. Hinrichs et al. [20] put forward a set of research questions and challenges, that extend from new interaction paradigms and conceptual frameworks, to real world deployments and user experience. They argue that research needs to further expand from addressing technical concerns, to investigating more broadly people's behavior and experiences with such displays. This echoes the work of Agamanolis et al. [1] who presented a framework of questions and strategies for designers wanting to make large public displays foster and enhance a sense of presence, awareness, community and togetherness.

One of the main problems of interacting with large displays is that there is often resistance from the public to engage with them. Brignull and Rogers [8] studied how groups of people socialize around large displays in public settings and presented design recommendations for encouraging participation. They introduce the concept of the *"honeypot effect"*, where people are drawn to a public installation by the presence of others gathered around it. In this work, they identified three activity spaces around a display installation: the space of peripheral awareness, the space of focal awareness, and the space of direct interaction. They also noted that the transition among these spaces was a barrier to interaction. This understanding was then used to give recommendations for information design of large interactive displays. Similarly, Cheung et al. [11] present a framework for overcoming interaction barriers of large public displays, identifying the problem of feeling socially embarrassed when interacting with a large display in public and in particular when using one's smartphone. Focusing on a public exhibition multi-touch display, Jacucci et al. [21] studied how people engaged with a public installation specifically designed for engagement, and stressed the importance of supporting multiple users and allowing for gradual discovery. They investigated people's engagement, flow, presence, and intrinsic motivations, and looked at the challenges involved with designing for walk-up-and-use displays, such as gradual engagement and social learning. In a study by Tomitsch et al. [37] playful elements encouraged passers-by to explore the information space. They recommend that using playful elements in public displays can help to attract attention. The work of Jones et al. [22] offers a toolkit that can be used to explore user engagement across multiple devices.

In early explorations of public displays, Greenberg and Rounding [16] combined multiple personal desktops and a large semi-public display to improve awareness among network connected colleagues in an office environment, by allowing them to post content on a collaborative surface situated in a common area. This design initiated social interaction between people and was used for live video chats. Looking at public engagement with media façades, Dalsgaard and Halskov [13] identify eight challenges that designers face, including their physical integration, social relations, and emerging use. They relate these challenges to the fact that public settings are a special domain for interaction design because they involve a range of social practices and circumstances that are very different from other domains. With a similar perspective, Fischer and Hornecker [15] analyze the spatial configurations of media façade deployments in relation to the structure of their interaction, leading to a set of basic categories, as well as new terminology, to describe these particular interactive situations.

The ease of use of gestures and devices required in the interaction also impacts people's decision to participate. For example, Müller et al. [29] presented three field studies on touch and mid-air gestures using their MirrorTouch installation, and found that the use of gestures resulted in a need for clearer affordances for touch, and that the location of the installation affected which modality people would use first. Similarly, but investigated in a lab setting, Hespanol et al. [19] tested and proposed a set of simple gestures for interacting with large displays in public, and elaborated this into a model. The model aims to assist designers to select which spatial gestures to apply in relation to the context and content of a particular design situation. Looking at the discoverability of public displays, Müller et al. [30] investigated how people passing by noticed, or missed, the interactivity of a shop window display installation, using mirrored user images, silhouettes, or traditional "call-to-action" sequences for attracting attention, finding that in general

people often noticed interactivity late, and needed to walk back to the display. Further to this, Ackhad et al. [2] found that although a silhouette of the user would attract attention and lead to more serious behavior at the display, a skeletal representation led to more play, and encouraged users to interact with the system for longer.

2.2 Cross-Device Interaction with Mobile Phones

Recently there has been a growing interest in public displays that foster cross-device interactions using mobile phones. In early work of this kind, Ballagas et al. [6] present two specific interaction techniques for enabling cross-device interactions with large public displays and mobile phones: Sweep and Point & Shoot. Both were intended as inspirational proof-of concept prototypes for opening up the design space for such interactions. Lucero et al. [26] investigated ad-hoc shared collocated interactions with mobile phones and public displays, and proposed cross-device interaction techniques that took the spatial arrangements of people into account. Alt et al. [4] similarly investigated a cross-device interaction technique for creating and exchanging information with public displays using one's mobile phone, and compared it with direct touch at the public display. While it was found that direct touch was very easy to use, it was also found that using one's mobile phone preserved the user's data and also allowed for the creation and retrieval of content on the go. Also investigating cross-device interactions between mobiles and larger displays, Schmidt et al. [34] presented interaction styles that use the mobile phone for tangible input on the surfaces in a way similar to using a stylus, reporting that despite advances in both technologies, "it remains cumbersome in practice to interact across mobiles and surfaces".

2.2 Bystanders and Observers

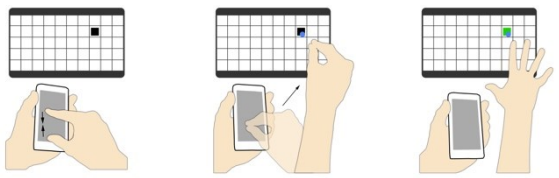
Looking at the concept of bystanders and observers, from observational studies, Azad et al. [5] identified patterns of how people use public displays and identified two types of observer: the active observer, who would help guide the user; and the passive observer who did not interfere or contribute. Tang et al. [36] described three types of bystanders: passers-by, who are simply on their way to somewhere else; standers-by, who stay in the area, and may read the display, but do not interact with it; and engaged bystanders who actively stare at the screen and make use of the content. In our study, we wanted to learn more about the impact that these engaged bystanders, or as we call them observers, have on the person who is interacting with the system, the user.

3 STUDY DESIGN

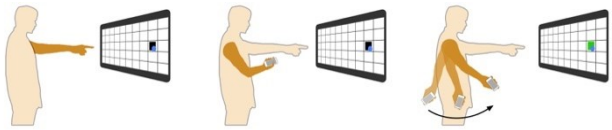
In order to understand, how people feel about using and watching different cross-device interactions in public, we conducted a study with four cross-device techniques in a public setting, collecting data on the experience of participants as both users and observers.

3.1 Interaction Techniques

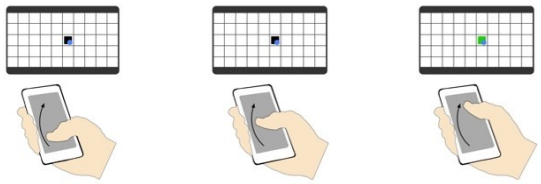
The four cross-device techniques chosen for this study represent a set of common approaches for transferring data between a smartphone to a shared display [24]. While similar techniques have different names in different studies, we describe them as pinching, swinging, swiping and flicking. This approach was chosen because phone gestures "have the potential to be easily understood by end-users" [23] and mobile phones are good for carrying data around, while large displays offer "a better scale for interaction with content" [34]. The interaction elements of these four techniques include both touch and mid-air gesturing and facilitate the transfer of information from a mobile device to a large display. The first two techniques require the user to use both hands, while the latter two can be performed with only one hand. A detailed description of these four techniques can be found in Paay et al. [33], which is a similar study using quantitative measures to compare effectiveness, efficiency and error size of these techniques. The four interaction techniques are depicted in Figure 1.



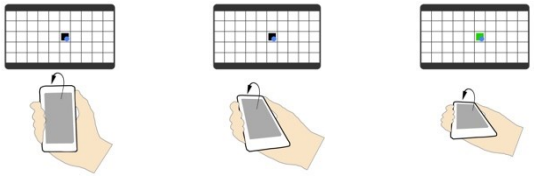
(a) Pinching



(b) Swinging



(c) Swiping



(d) Flicking

Figure 1: The selected four interaction techniques: (a) pinching, (b) swinging, (c) swiping, and (d) flicking

Pinching is based on mid-air gestures of "picking up" a small icon on a handheld device and then "releasing" it onto a large public display. This simulates the real-world action of picking up an object from one location and placing it on another. Swinging is based on first "selecting" an icon on a mobile phone and then using a combination of mid-air gestures for "pointing" with one hand and "swinging" with the other. This simulates the action of propelling an object in a certain direction. Swiping is based on a combination of the mid-air gesture of "pointing" at a target location on a large screen, "selecting" an icon on a mobile phone and a swiping gesture on the phone's touch screen. This simulates the action of selecting and then swiping, or sliding, an object from one location to another. Flicking is based on a combination of a mid-air gesture for "pointing" at a target location on the large screen, "selecting" an icon on a mobile phone, and then physically tilting the smartphone toward the screen. This simulates the action of flicking an object away from oneself.

3.1 Choosing a Public Location

For our study, we chose a University cafeteria as the public space. Using Fischer and Hornecker's model [15], which considers technology interventions by analyzing their spatial configuration in relation to the structure of the interaction, we selected the optimum location in the cafeteria based on the following selection of model qualities: Display Space, for defining the areas where the display can be seen by others; Interaction Space, as the area where a potential interaction can occur; Comfort Space, as a space providing physical and psychological ease through protective features such as walls, pillars, etc.; and Activation Space, as spaces where displays can be observed from, but not interacted with. In the end, we succeeded in making the display visible to others, with enough space for interacting, where the space also provided physical and psychological comfort for our users through nearby pillars and walls, and to still leave sufficient space for observers (Figure 2). As in the study by Azad et al. [5], the chosen location necessitated the existence of passive observers, who did not interfere or contribute, except by their very presence. This further strengthened the user's sense of being observed.

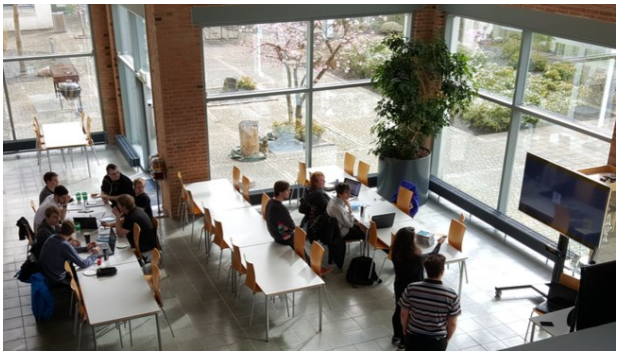


Figure 2: The selected public location for the large display, in the corner of a busy University canteen

3.2 Setup

We studied the use of the four techniques using a hardware setup comprising of a Microsoft Kinect for Windows v2, a 65' inch Panasonic display with a resolution of 1920×1080, and a LG Optimus G E975 smartphone. The server side of the software was written in C#, while the mobile device software was written in Java. Users mostly interacted at a distance of 2.35m from the display (the optimal operating distance for the Kinect, but were allowed to move away from this distance. An overview of the study setup can be seen in Figure 3.

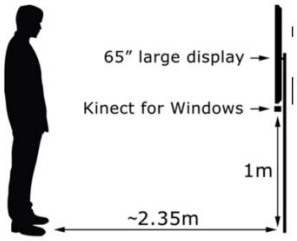
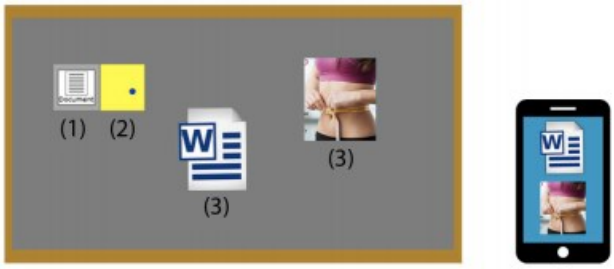


Figure 3: Study Setup

Two user interfaces were designed for the study, one for the large display and one for the smartphone. The large display

showed three main elements: (1) an icon indicating the file type to be transferred and where to place it on the display, (2) a blue dot within a yellow highlighted area to indicate the current position of the pointer, and (3) files that had already been transferred to the display from previous interactions (Figure 4a). In the beginning, the display was empty, but as the use of the public display progressed over time, the files transferred to it during each individual test session would gradually build up. The smartphone interface only showed two icons, an image file and a text file, in order to allow the users to make an informed choice on which file to transfer to the large display (Figure 4b).



(a) (b)

Figure 4: Public display (a), and smartphone display (b)

3.3 Experimental Design

A within-subjects study design was used, with each user experiencing the four different interaction techniques as both a user and an observer. This was done so that participants were able to express how they felt about using each technique, as well as report on their experience of watching others use them.

3.3.1 Participants. Our participants were recruited using posters placed around the University campus and through social networks. In total, we recruited 24 participants. The participants were between 21-55 years old (M: 26.5, SD: 7.3) and between 1.63 and 1.95 meters tall (M: 1.77, SD: 0.09). 95.83% of them were right handed, 79.17% were male, and 95.83% of them were regular smartphone users, who had used their smartphones for between 2-12 years (M: 6.29, SD: 2.7).

3.3.2. Tasks and Procedure. In the user role, participants were given the task of moving files (i.e., image or text documents) from the smartphone to the large display, using the four interaction techniques. They performed a set of transfers, moving a total of 12 files, including 3 practice transfers for each technique. At the beginning of each set they were shown a video on how the technique should be performed. In total, each user performed 48 transfers. The order in which the technique sets were presented to users was controlled so that there was an even number of users starting with each technique. This was done to minimize the learning effect. Furthermore, the type of file the users had to move changed randomly on each attempt.

As we wanted to learn about the users' perceptions on the usefulness of each technique as well as their feelings about using them in public settings, we ensured that observers were present during each session. To achieve this, we recruited groups of 3 or more people, including both friends and strangers in each group, and asked them to shift between the roles of the user and observer. Throughout the study, one researcher conducted unstructured interviews with the users in English, and encouraged them to think-aloud about their performance as well as their thoughts about performing the techniques in public. Another researcher observed and took notes on the observers' behaviors while the test session was taking place. All sessions were audio and video taped. At the end of each set of transfers (each technique), participants filled in surveys of their experience of those techniques with respect to their current role (user or observer).

3.3.3. Data Analysis. Audio and video were used to produce a transcript for every test. Two researchers each coded a single test session using Open Coding from Grounded Theory method [25][35] and then compared and resolved codes, to create an initial coding scheme. They then independently analyzed the rest of the transcripts, researcher's notes, and survey comments, resolving conflicts at the end. This was done to achieve concordance and inter-rater reliability, to get different perspectives on the data, and to ensure that important events were not missed. At the end of this process 115 codes were created. Through applying an iterative thematic analysis approach, and by using affinity diagramming [7], the research team grouped these codes into 38 sub-categories with relation to techniques, people, and technologies. By identifying overlapping categories, we were able to get a reduced set of categories and refine this to find five emergent high-level themes representing those factors that influence people's experience of using these cross-device interaction techniques in public: Familiarity, Social Acceptability, Purpose, Easiness and *Playfulness*.

4 FINDINGS AND DISCUSSION

In the following we present and discuss our findings under the five themes of Familiarity, Social Acceptability, Purpose, Easiness and Playfulness, and exemplify them with quotes from users (U) and observers (O). Each of the themes is an amalgamation of various facets of cross-device interaction, providing unique insights into user and observer perceptions of different techniques.

4.1 Familiarity

Familiarity involves people's ability to easily and quickly understand the gestures required to interact with the large display using their phone, especially in a walk up and use situation. In relation to familiarity, the challenge for each technique is how to align with the user's expectations in the most optimal and straightforward way.

To compare the different techniques in terms of familiarity and naturalness, we examined how both users and observers talked about these techniques. We identified two techniques that were perceived as the clearest and most familiar: swiping and pinching. For example, a user describes the swiping technique as being fast and familiar, thus making it easier to use:

"Yeah, and I am also quite faster since it is a lot more natural. I am familiar with the gesture and I also don't have to think how to do it." (U18)

Observers also felt Swipe looked natural:

"Swiping seems the best…natural position." (O6)

Furthermore, even though pinching is more complex than swiping since it requires both hands, it was also considered to be as clear and easy to use, because it was seen as a very natural gesture for putting information onto a large display.

"I think it's pretty positive that it feels like one motion; that I pick up the image and I place it again." (U12)

"I think this one feels quite natural. It's almost the same way as you would have done it in real life." (U17)

4.2 Social Acceptability

Social acceptability represents the notion that most people like to fit in, and not be too conspicuous when in public spaces. In our study, it influenced how comfortable users were with the physical movements that each technique required and how they felt about performing them in public. Since we conducted our study in a public canteen we were able to capture both user's and observer's responses to enacting these techniques in front of others.

Before the beginning of each session, we found that a key concern for our users was to feel comfortable with what they were doing while being in a public space. Most of our users claimed to not experience any social discomfort, explaining they were too busy doing the task at hand to worry much about how they looked to others.

"I have actually not thought about me [looks around] being in public, because I'm very concentrated on this." (U24)

"Yes, I don't have any problems I feel confident. I still focus like 99 percent of my concentration to trying to do what I am doing." (U8)

At the same time, one did claim usually having social anxiety:

"Yeah, I do [feel comfortable], I can't really see them [the observers] … I usually have social anxiety." (U13)

In contrast, some techniques did appear embarrassing from the observer's perspective:

"Swinging seems embarrassing because you need to point first and then throw. It is more suited for a playful environment and not a professional situation." (O6)

"The system does not seem intuitive which could create embarrassing moments until the user is familiar with the system." (O20)

Users did things they were unaware of, such as looking funny, or strange to the observers:

"She is pulling faces while using swiping to reach the top targets." (O23)

"Flicking makes him position his body in a strange, unnatural way." (O6)

Observers also commented on how some specific movements could create the potential for embarrassment:

"Wearing a short t-shirt, you might show some skin when you raise the phone." (O12)

However, one observer noted that there should not be any problem using the techniques in public as they required familiar movements:

"It doesn't look embarrassing because Kinect and Wii games are very popular and the interaction in this system is similar." (O8)

While the users were comfortable in the public space, the swinging technique stood out as the most unacceptable due to its exaggerated movement.

"It would more be like if there were seventeen people standing behind me and I throw it like this… [Interviewer: Bump into them?] Yeah. Or toss my phone at them." (U16)

"Yeah, if you are in London underground then there will be a lot of people behind you. There it won't always be good to make a

throw with the arm. Then the other, flicking, will perhaps be a little better." (U21)

4.3 Purpose

The purpose of the interaction has an influence on how appropriate people imagine a particular gesture will be. For example, swinging was identified as a technique that people felt would not be appropriate for transferring files from a mobile device to a public display when standing in a crowd, but commented on how it would be better for a game played on a shared screen in an open public area. We also discovered that the concern for whether a technique was perceived as accurate or not depended on the purpose. The following comments were made specifically about the throw technique:

"Yeah, it would have to fit the context." (U23)

"I would say this one is really good, like for games for somewhere outside, a bar maybe." (U7)

"It might be, if I was in a sports stadium doing something…competing in a sports thing, it's a lot more. . . [throws as if throwing a ball]." (U23)

The purpose of an interaction can also influence how accurate people imagine a technique needs to be. During the test, some users did not spend much time aiming at the target points on the large display. They reasoned that for this kind of task, sending image and text files to a specific location on the display wasn't that important:

"Maybe I won't be precise but I would say hey it's ok because it's up there." (U21)

"Depending on the context. If it was in … some room where you need to make a lot of posts right next to each other, then precision would be key, but in a place where I just need to show this document, or this picture and it's just like a presentation, they need to see this right now, then precision wouldn't be key." (U13)

4.4 Easiness

Easiness relates to how easy a technique is to learn and use effectively, so that the user is confident that they are able to send the data where they want it go, and when they want it to go, with minimal effort. During the study, we observed some people being frustrated by their lack of precision while using the one-handed techniques (swiping and flicking) due to difficulty seeing the target since often the arm they were holding the with device was blocking their view of the target. They also complained of arm fatigue from the repeated use of the gestures, and difficulty of gripping larger smartphones with one hand:

"It is just the target thing, because if I have to stretch my hand it's quite hard to see what I am swiping." (U15)

The problem of easily holding a smartphone in one hand and swiping across the whole surface caused some of the users to prefer performing the intended one-handed technique with two hands.

"I felt really good. The only problem I had it is difficult to have a hand motion that is possible to both swipe the top off and the bottom off accurately. This is the reason why I decided to use my second hand." (U14)

Additionally, many of the users reported that the two-handed gestures gave them increased coordination:

"Yeah, I feel like it is easier this way. Basically, I use one hand for pointing and the other is like the controlling one." (U13)

"There are definite advantages to using two handed techniques because you can handle both aiming with one hand and managing stuff with the other hand." (U14)

"I was able to do Throw very precisely because you use two hand coordination." (U21)

Some of the users were also concerned with their inability to control the flicking technique. This led to a feeling that they were being inaccurate.

"Okay. I feel it's hard to both keep my hand steady and make this hard motion [flicking] at the same time. I don't feel very confident that the image will land where I'm trying to throw it, because I feel the bop - the pointer moves when I do the gesture." (U12)

"Flicking was quite less accurate as you would do a tilt and that would move the pointer, so I always hit the area around [the target]." (U21)

Observers also noted that not being able to easily use a particular technique made the user look silly or awkward:

"The throw looked a bit silly because she waved back and forth and had more trouble with it." (O23)

"Flicking seems a little difficult and people around may think he doesn't know what he's doing." (O21)

"When it doesn't work, swinging might be a bit embarrassing." (O1)

4.5 Playfulness

Finally, playfulness is about enjoying the interaction and having fun. During the study, we noticed that both users and observers expressed an affinity for certain techniques that they saw as fun to enact, or having some "magical" quality about them. This led to the techniques of pinching and swinging being favored by users for their qualities of novelty and fun, over easier techniques. They also claimed these techniques as more useful and expressed greater confidence in performing them properly. Additionally, in talking about purpose, many users made it clear that although those two techniques might not exactly suit the tasks in this study, there would be situations where they would be better and more enjoyable to use:

"Pinching is not easy to learn. But it is hilarious." (O1)

"I think it [Swinging] could be fun in a game." (U17)

Even the observers noted that the users were enjoying using the pinching technique:

"She looks very happy using pinching!" (O23)

Some even imbued it with special qualities:

"I think it is futuristic." (O2)

5 IMPLICATIONS FOR DESIGN

In this section, we discuss how the five key aspects have implications for the design of cross-device interaction techniques for large public displays.

5.1 Familiarity

Our users indicated that it was important that the interactions they were performing felt familiar and easy to do. This helped them to feel they could transfer what they wanted, when they wanted, to a particular location. They especially like the actions of swiping the smartphone screen as this was a gesture that they used all the time with their phone and tablet devices. The familiarity of the pinch technique was based on their experience of the physical world, where such a gesture would be used for picking up and placing something in a particular place.

Thus, in order to design for familiarity, it is important to consider how natural or familiar the gestures feel to the users, and not just focus on how accurate or fast one technique is in comparison to another. Being able to perform a cross-device interaction technique in a way that makes sense to the user is very important for people's sustained engagement level with a public display. It is also important in encouraging participation of passers-by. This is very important in the context of cross-device interaction with displays in public, where it is a design aim that people are able to just walk up and use a system using their personal smartphones, with little, or no instruction. As one user said, "if I wasn't shown how to do it…then I would just go away and say it's just not working for me".

5.2 Social Acceptability

While enacting cross-device interaction between their smartphone and the large public display, our users reported feeling very comfortable due to the fact that they were immersed in the task at hand, and often forgot about the observers around them. Therefore, the vast majority of users did not state that they found any of the techniques unacceptable, or embarrassing to use in public. It was the observers who were much more aware of the users appearing silly, or incompetent, than the users themselves. The challenge is that in a public situation people will usually shift between being observers and users, and while being observers they will form an opinion about how they will appear themselves, when the time comes to take the role of a user. Consequently, if they believe current users are acting or looking silly, or the situation is embarrassing, they are less likely to engage with the display themselves. This then contributes to the difficulty in encouraging people to participate in interactions with large displays in public. It is therefore important to understand how a technique appears to observers when designing them.

Our participants also expressed concern for maintaining personal space while conscious of the comfort of others by not encroaching on their personal space. This was discussed in relation to situations where there is little room to move, where people are standing close to each other, and in situations where somebody is surrounded by strangers. In these situations, techniques with large movements (e.g. swinging) were perceived as socially unacceptable, as they would negatively impact others. However, many social situations where somebody might interact with a large public display are not crowded, or only involve familiar people, such as friends at a party using a large screen to share music. In such settings, large physical gestures have the opposite effect because they are perceived as playful and friendly.

To design for social acceptability, it is important to understand how immersive the interactive experience will be for the users. If it is very immersive, then people are less likely to become concerned about whether or not a technique feels embarrassing. However, as people are also concerned about the impact of their gestures on those around them, the social relationships among the people interacting next to each other, and the amount of bodies that will populate the same interaction space, should also be taken into consideration when deciding how expressive or subtle an interaction gesture should be.

5.3 Purpose

The importance of purpose was a recurring concern for both users and observers. The purpose for which an interaction is intended can affect how different aspects of the techniques are perceived, such as how accurate or fast to use they need to be. When assessing how users and observers felt about a particular technique, they usually suggested alternative purposes that would suit that technique better. For example, swinging was not perceived as suitable for the context of our study but was often suggested as better for playing games. In general, people were less concerned about the accuracy of the techniques for our study, but offered suggestions of places where accuracy could be important, for example, a public noticeboard with detailed posts on it.

To design for purpose, it is important to be aware that people have strong preconceived expectations and perceptions about the applicability and suitability of different techniques to different situations. Recreational purposes tend to be more relaxed, but something like a public voting system requires a technique that supports accuracy [33]. If a fast response is required, for example a fast-paced competitive game, then users will get frustrated if the interaction technique stands in the way of winning – even if the faster technique is uncomfortable.

5.4 Easiness

The interaction techniques perceived as the easiest to use were swiping and swinging, while pinching and flicking were perceived as the more difficult. Furthermore, they were perceived as easier to use because users were faster, or more familiar with them (e.g. swiping), or because the techniques required a more natural gesture (e.g. pinching).

Our users indicated that it was important that the interactions they were performing felt easy to do. This helped them to feel they could transfer what they wanted to, when they wanted to, to specific location. This feeling of ease and reliability of an interaction type is important for user satisfaction and engagement [32]. The one-handed techniques (swiping and flicking) led to a perceived lack of control and as a result users reported a preference for the two-handed techniques. When they used both hands, they could separate the gestures for aiming and transferring data, thereby making the transfer easier. They also reported that swiping, which requires a large touch motion to be performed while holding the phone, caused a weaker grip on the phone, and made some users fear that they might drop it. This ultimately led to some users executing a two-handed swiping, and this adjustment to the technique made them look silly or incompetent from the observer's point of view.

Being unable to perform a gesture in a way that could be recognized by the system also caused a lot of frustration. This indicates the need for users to easily understand how to do a technique in the "correct" way according to the recognition software. Recognition of particular techniques by the system should also be forgiving and adapt to different users. When using a data transfer technique in public, people want to feel competent, as well as not look inept to observers.

To design for easiness, the interaction technique should fit the user's expectations on how to perform it, as well as their physical capabilities. The system should be robust and flexible enough to register multiple interpretations of the same technique. For example, if users are required to hold a phone in one hand, then the phone needs to be of a size that can be gripped firmly by just one hand. If this is not the case, and a user chooses to use both hands, the system needs to be able to recognize this variation. Depending on the size of the display, and the size of the user, absolute targeting with the pointer may not be a good choice if accuracy is needed, because it is often difficult to control such pointing with great precision over time, due to physical fatigue of moving arms, or occlusion of targets by raised arms.

5.5 Playfulness

When we encouraged users to compare the different interaction techniques in terms of preferences, they really liked the pinching technique, even though it was quite difficult to do and to get right. They described it as the most fun and novel technique. Pinch involves a gesture which is perceived by participants as "magical", hilarious, happy and futuristic. From our observations, we could see that people clearly enjoyed using this technique, regardless of whether they thought they looked silly, or whether they could place the file exactly where they intended. As Tomitsch et al. [37] found, people were more concerned with playing with a public display than exploring its content. They suggested that this kind of playful engagement would help attract interaction as well as aid the learning of the necessary interaction gestures.

To design for playfulness, we should remember that having a positive user experience, through fun or playfulness, can be as important to a user as the perceived usability of a technique [18]. This depends on the use situation, but from our study we can confirm that with large displays in public, being sociable and having fun with others can be as important as the actual exchange of information.

6 CONCLUSIONS

In this paper, we have taken a new perspective on the challenge of encouraging users to interact with large displays in public places, looking specifically at both users' and observers'

attitudes, perceptions and experiences of using different cross-device interaction techniques. We have presented a study of 24 people using, and observing the use of, four different interaction techniques involving a mobile phone, mid-air gestures, and a large public display. Through observations and interviews we collected data on both users and observers with respect to using these techniques in public.

From our analysis, we identified five key aspects that influenced people's willingness to participate in cross-device interaction with a large display in public, namely Familiarity, Social Acceptability, Purpose, Easiness and Playfulness. We have presented and discussed these aspects, and exemplified them with quotes from our study. We have also discussed the implications of this knowledge for the design of cross-device techniques for interaction with public displays, with consideration to both users' and observers' participation.

6 LIMITATIONS AND FURTHER WORK

The applicability of our findings has to be considered in relation to our implementation of the four cross-device interaction techniques. Although they represent common cross-device interaction techniques reported in the literature, it would be worthwhile repeating the study with additional techniques.

The role switching between user and observer made it possible for us to gather as many impressions as possible in a short amount of time. In terms of validity, this was not ideal, and the order in which it happened was not controlled. This is a limitation of the study, that a real in-the-wild study could reduce. Additionally, the use of a University cafeteria as the public space, having the majority of participants being university students, limits the immediate generalizability of our findings to those types of settings, users and observers. The ecological validity of the study is clearly weakened by the presence of experimenters, video cameras, as well as the fact that both users and observers knew that they were participating in a study, with non-real tasks. It is therefore necessary to conduct a study in a more natural public context, with other users, a real task and more random observers to validate the five factors that we found influencing people's willingness to engage in cross-device interaction with their personal phones and public displays.

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