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JuxtaPinch: Exploring Multi-Device Interaction in Collocated Photo Sharing

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ABSTRACT
Mobile HCI research has started to investigate multi-device interaction as we often have more devices at our immediate disposal. We present an application called JuxtaPinch that allows users to share photos while being collocated using several different devices, i.e. mobile phones and tablets, at the same time. JuxtaPinch use pinching to connect devices and it enables flexible physical positioning of devices and supports partial viewing of photos. Our evaluation showed that JuxtaPinch enabled participants to experience their own familiar photos in new ways known as defamiliarization. It further enabled participants to engage jointly in playful interaction with the photos and with each other. However, we also found that multiple device collocated photo sharing challenges aspects of synchronization and coordination.

Author Keywords
Collocated photo sharing; pinching; multi device

ACM Classification Keywords
H.5.2 Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
With the continuously growing number of smart phones and tablets, we are currently using and adapting these devices and technologies in more and more contexts and for many purposes. With more than 1.75 billion smart phones sold in 2012, these mobile devices have become deeply embedded into our everyday life, supporting work, social interaction, leisure, and collaboration. With such diffusion of smart phones and tablets in people's everyday lives, we see that people often have not only one, but several, of such devices at one's immediate disposal. HCI and mobile HCI research has consequently begun to explore and study opportunities and challenges of user interaction across several platforms. Often referred to as multi-device interaction or cross-device interaction, using several devices at the same time provides new opportunities for interaction and open avenues for new application areas. But currently we have only witnessed few studies on multi-device interaction, for example interaction techniques [4, 12, 14] or collaboration [3].

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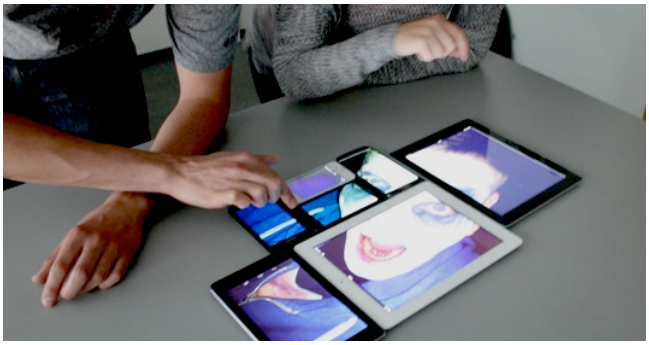

Figure 1. Collocated photo sharing where two users share a photo using JuxtaPinch and they employ seven devices namely three tablets and four smartphones.

Ohta and Tanaka [14] illustrate a pinching technique called Pinch that enables multiple devices to be connected as one device and they call for studies on cross-device interaction application designs. One such application design is photo sharing as we increasingly use smart phones and their built-in photo features [8] and especially collocated photo sharing where more people gather to share and view photos while being collocated. Often referred to as collocated photo sharing [10], this plays an important role socially and individually as it develops people's self-image, as well as creating and strengthening relationships within social groups [20]. Current collocated photo sharing HCI research attempt to investigate how to overcome some of the inherent problems when sharing photos with others on small screens [19], but also how can we utilize multiple devices for such photo sharing as people would bring not only phones but sometimes also tablets when gathered in social groups.

We present a multi-device application called JuxtaPinch that supports collocated photo sharing on multiple devices (shown in figure 1). JuxtaPinch allows flexible side-by-side positioning of devices and stitching their display areas together through a pinching gesture and allows partial photo viewing by scaling photos. Our contribution is two-folded. Firstly, we contribute to multi-device interaction research through a qualitative study on opportunities and challenges

related to using several devices at the same time. Secondly, we contribute the collocated photo sharing research through illustration of emerging patterns of use and exploration of familiar photos.

RELATED WORK

We investigate multi-device interaction through the design of JuxtaPinch and three areas of related research work have influenced JuxtaPinch: multi-device interaction, collocated photo sharing, and multi-device photo sharing applications.

Multi-Device Interaction

With the rapidly increasing proliferation of smartphones and tablets in people's everyday lives, it is now not uncommon to have several of such devices at one's immediate disposal. This creates new use situations and new opportunities for exploring interaction designs that span across multiple devices rather than being limited to just one. Researchers have responded to these opportunities by exploring a new class of "multi-device applications" that allow users to link individual mobile devices and use them as one joint interface. Examples of this include *Pass-Them-Around* by Lucero et al. [11], *Junkyard Jumbotron* by Borovoy & Knep [15], and *Pinch* by Ohta and Tanaka [14], These all create and make use of larger screen real estate by physically placing a number of mobile devices next to each other and treating their combined display surface as joint. Pass-Them-Around [11] does this with up to four devices, placed side-by-side, using a pinching gesture across two devices at a time. As a very different approach, Junkyard Jumbotron [15] combines several displays, in arbitrary arrangements, through a calibration process with an external camera and QR codes displayed on each device. Finally, Pinch [14] allows the display surfaces of iOS devices, placed next to each other, to be joint using pinch gestures. The multi-display layout can then be changed dynamically, allowing for great interactivity, and content automatically adapts to the size of the combined display. This, the creators speculate, may be useful in many different types of multi-device applications, for example for viewing videos and playing games.

While specific application areas for multi-device interaction are still underexplored, some call for further explorations [14], and one of the areas where this approach may have immediate value is for collocated viewing and sharing of photos as people gather and bring their own devices. We will return to this choice in our discussion and relate our findings to other areas of potential application.

Collocated Photo Sharing

Even in today's technologically mediated, distributed, and digital world, collocated photo sharing is an important social activity. In [20] van House present and discuss three themes that describe why this is. The first theme is related to *memory, storytelling, and identity*. Memories and narratives related to a photo are dynamic and change over time. How we remember a story related to a photo may not be the same today, as it will be in five years [20]. The stories that are told about photos help constructing the self-image of the individual as well as the group. When we tell our stories to other people, we then make sense of our lives for ourselves.

The second theme is related to the role of photo sharing in *relationships*. Sharing photos, and their stories, with someone face-to-face enacts the relationships between the people involved. This typically happens either through *storytelling,* linking it to the previous theme, or through *reminiscing* [1, 6, 19, 20]. Storytelling here describe the situation where a person presents a photo where the viewers were not present, and often happens around photos of events where the owner feels that the viewers should have been there too. Reminiscing, on the other hand, happens around photos with several of the viewers present, giving them an opportunity to relive parts of a shared past, and through this reinforce their relationship in the present [19].

The third theme is related to the *orality* of collocated photo sharing. When co-located, people are able to tell stories, and reminisce orally rather than through writing, as in for example online sharing services like Flickr, this gives the storyteller dynamic control over the story as told in that specific moment. This allows him or her to adjust the story in an ad-hoc manner in response to the specific audience, their interests, and their reactions along the way [20].

In today's digital and connected world, many people have access to large portions of their personal photo collection at all times through smart phones, tablets and cloud services [11, 20]. Combined with the role of collocated photo sharing this has created a growing interest in photo sharing applications for mobile devices that allows people to share, view and explore photos together. One of the most commonly used ways of digital collocated photo sharing is to pass devices (usually mobile phones or tablets) around and letting people see the photo one person at a time [19]. However, research studies have identified several limitations. Firstly, smartphone screens are rather small for viewing photos [5, 19], making it hard to identify what is happening on the photo, and easy to lose details. Secondly, it is difficult to use the photo as anchor point in a shared social interaction as one can't "point-and-tell" and because only a few people can see the photo at the same time [19]. When only people in close proximity can see what is on the screen and what is pointed at, it becomes difficult for the whole group to follow any story and take part in the social interaction, leaving part of the group as outsiders and thus impairing the photo sharing experience.

Collocated Photo Sharing on Multi-Device Applications

Several studies have addressed the identified limitations of collocated photo sharing on single devices. Schmidt et al. [16] and Greaves and Rukzio [7] explore transferring photos to larger display areas such as an interactive surface or a projector. However, such infrastructure is far from as

commonly available as mobile devices. Another solution, proposed by Kun and Marsden [1], suggests transferring photos to everyone in a group, and then looking at it on one's own device. This allows simultaneous viewing, but complicates point-and-tell and also takes attention away from a common focus and the shared social interaction. Also, the limitation of small screens, i.e. viewing details, remains unsolved. As an alternative, Stelmaszewska et al. [19] propose combining multiple mobile device displays to compose one larger one screen or display. This allows simultaneous viewing, point-and-tell, a common focus, and adds screen real estate.

Most of the systems exploring this approach make use of some sort of multi-device interaction as we have discussed earlier. Systems such as *Phone as a Pixel* [17] and *Junkyard Jumbotron* [15] use camera infrastructure to assess the geometry of individual devices being used, and then use this information to split a shared into smaller sections that are then transferred to and displayed on the appropriate device. However, as the approaches suggested by Schmidt et al. [16] and Greaves and Rukzio [7], this approach is somewhat cumbersome due to the need for extra hardware infrastructure besides people's individual mobile devices.

Taking a different approach, as mentioned earlier, *Pass-Them-Around* [11] is a collocated photo sharing application that allows viewing on composite display surfaces without the need for additional hardware. In this system, up to four devices can be made into one larger display by placing them side-by-side and connecting them using a pinching gesture across two devices. The use of this system has been studied extensively, in a controlled environment, involving different tasks of storytelling and reminiscing, and with very promising results. Similarly, the Pinch system [14] also allows collocated photo sharing on a composite display surface made up by several devices, in this case in arbitrary geometrical configurations, and also using the pinching gesture to configure the layout.

Opportunities for Design and Research

Based on related research we see a number of opportunities for exploring multi-device applications for collocated photo sharing. Firstly, we need additional studies on multi-device interaction in different application domains to explore and understand opportunities and limitations of interacting with several devices at the same time. As part of this exploration, we would like to facilitate flexible physical side-by-side device positioning, as seen in Junkyard Jumbotron [15], but using more simple interaction mechanisms for aligning and connecting devices without external hardware. Secondly, for collocated photo sharing on multiple devices, we would like to explore what happens when allowing partial viewing of photos. Rather than including as much of a photo as possible on a sometimes odd-shaped shared display canvas by zooming out and adding white space (as seen in Pass-Them-Around [14]), we would like to see what happens when photos always fill the canvas, and thereby removing parts of the photo.

JUXTAPINCH

JuxtaPinch is an application that supports collocated photo sharing and exploration on multiple handheld and mobile devices. JuxtaPinch combines ***juxtapositioning***, which is the act of positioning objects (i.e. devices) side-by-side, and ***pinching***, which is the act of stitching devices together. The basic idea of JuxtaPinch is that photos from one device can shown across multiple devices as illustrated in figure 1, by connecting them through the act of pinching (and removing through lifting and moving of devices).

We employ cross-device pinching as a simple and intuitive interaction technique as Otha and Tanaka argue that cross-device pinching resembles the action of stitching something together [14]. Lucero et al [11] also found that the pinch technique to be natural for connecting devices. JuxtaPinch combines the screens of several devices to appear as one. This means that a photo shown on the system will extend over a multitude of devices. We would like to stress that it is not our purpose to investigate issues of effectiveness or efficiency of the pinching interaction technique nor is it the purpose to understand basic usability of the JuxtaPinch application. Instead, we wish to investigate opportunities and challenges of multi-device interaction in the domain of sharing photos with others, and we want to explore how people experience their own photos when shown across several devices.

Functionality

JuxtaPinch basically offers three different functionalities for exploring photos over several mobile and handheld devices namely selecting a new photo, connecting devices, and disconnecting devices.

JuxtaPinch allows the users to select photos among the photos stored in the library on the device. Users can access the gallery of their device and choose any photo from it. When a new photo has been chosen, all connected devices will disconnect such that the system provides a clean screen to build the new photo.

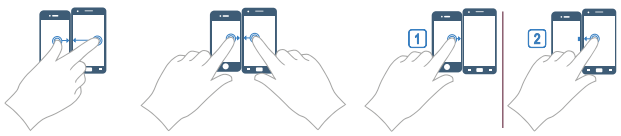

Figure 2. The three pinching techniques in JuxtaPinch for connecting devices: one-hand pinching (left), two-hand pinching (middle), and two-step pinching (right)

JuxtaPinch allows three cross-device pinching techniques to connect devices: One-hand pinching, two-hand pinching, and two-step pinching. Inspired by Otha and Tanaka [14], we implemented one-hand pinching where users typically use their thumb and index finger on the two devices. The user then slides the fingers towards each other to connect

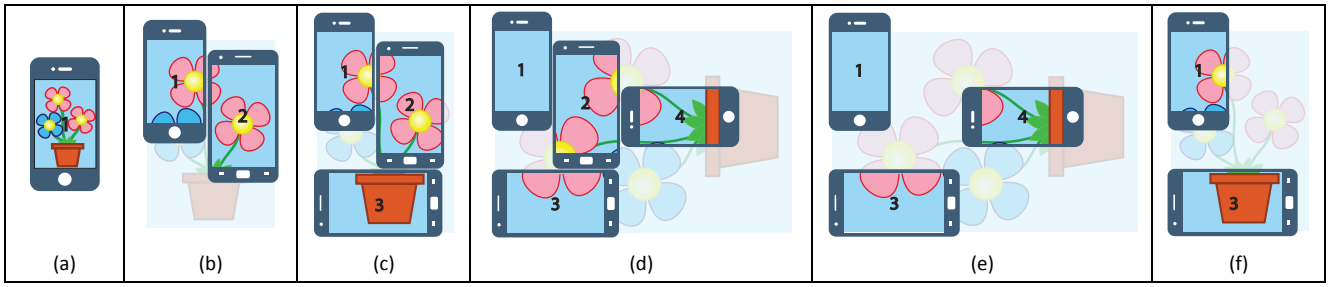

Figure 3. Use scenario for JuxtaPinch illustrating six steps of connecting and disconnecting devices – with up to four different devices and rotation and scaling of the photo

the devices at the adjoining edges (as illustrated in figure 2, left). Two-hand pinching inspired by Lucero et al [11] uses two hands. Here the users typically uses index fingers on both devices and slides them towards each other (see figure 2, middle). Finally, we developed a two-step pinching technique during the testing phase of JuxtaPinch. Here the user slides his index finger to the edge of one device and then afterwards to the edge of the other device (as shown in figure 2, right).

JuxtaPinch allows the user to use all the above pinching techniques for the sake of flexibility in the interaction. We also chose to allow all three pinching techniques because we were not interested in assessing or comparing these individual techniques (for such studies please refer to [11, 14]). Finally, JuxtaPinch permits users to remove and reposition devices when exploring photos. In order to reposition (or remove) a device, the user simply moves or lifts the device. Inspired by the repositioning in Otha and Tanaka [14], we utilize the accelerometer and gyroscope to detect movement as it is recognized as both tilting the device from side-to-side or top-to-bottom as well as acceleration on all axes.

Implementation

We implemented JuxtaPinch as a web application enabling cross platform interaction through the use of browsers. The client was implemented in HTML5 and we developed Android and iOS wrappers to let the users experience the system as a full application. However it is also possible to use the system directly from a web browser. JuxtaPinch was implemented using the socket.io library for a Node.js websocket server. The accelerometer and gyroscope was used to detect when devices were being moved around in order to disconnect the moved device from the photo, i.e. a detected acceleration above zero or tilting the device more than 10 degrees would disconnect the device. The Hammer.js library was used for detecting swipe, drag, and hold gestures.

We implemented pinching as swiping or dragging on two devices in opposite directions. When swipes (or drags) are detected on two devices, we then collect device data on screen size, resolution, pinch location, and pinch direction using JavaScript. We use the four-step algorithm from Ohta and Tanaka [14] to calculate the relative positions of the devices according to the following: 1) we position screens from the two devices (A and B) as overlapping completely, 2) afterwards we move screen B by the distance between swipe A's location and center position of screen A, 3) then we rotate screen B by the difference of the two devices' directions, and 4) finally we move screen B further by the distance between the location of the swipe on screen B and the center position of screen B (please refer to [14] for further explanation of this algorithm). Finally, from the calculated positions and sizes, we calculate the joined size of all connected devices that make up the viewing display. The relation between the size of the viewing display and the size of the photo is then used to determine the photo scaling and rotation.

Use Scenario

We exemplify how JuxtaPinch operates in the following use scenario and also visualized in figure 3. The scenario shows a photo of flowers in a pot where up to four devices (mobile phones) are used in different configurations.

> *Alice wants to share a photo of a flower to her friend Bob while being collocated. At first, the photo is on her device only (#1) (figure 3a). Bob then connects his device through pinch and the photo is now shown on two devices (#1 and #2) but only partially as parts of the photo is now hidden (b). They then connect a third device (#3), which shows the lower part of the photo (c). Alice wants to show Bob a detail in the photo and connects a fourth device to make the photo bigger (#4 is pinched together with #2). As a result of adding device #4 the joint canvas is now longer horizontally than vertically and therefore the photo is rotated 90 degrees (d). Bob wants to tease Alice, so he removes device #2 from the configuration, which creates a hole between the devices, as they are no longer positioned side-by-side (e). Finally Alice removes devices #4 making the photo smaller rotating it 90 degrees (f).*

EVALUATION

We evaluated JuxtaPinch in a lab evaluation. Our aim was to explore how people would interact with JuxtaPinch as a multi-device application and it supported collocated photo sharing. In particular we were interested in investigating the three opportunities raised earlier in the paper on flexible

physical positioning of devices, partial viewing of digital photos, and multi-device collocated photo sharing that works across different mobile operating systems.

Participants

22 people (6 females) participated in the lab condition in six different groups. The participants were between 21 and 49 years old (M=27.6) and they had different backgrounds including 12 university students, two high school students, and eight work professionals. We recruited participants through Facebook, our extended network, and snowball sampling. Participants were required to use their own devices (mobile phones or tablets) during the evaluation with either iOS version 6.0 or later or Android version 4.0 or later.

Our participants participated as groups (six groups in total) and we included four groups with four participants and two groups with three participants. As suggested by Miller and Edwards [13] and Stelmaszewska et al. [19] who report that people primarily share photos within their social network, we required that participants knew each other in advance, for example work colleagues, family, roommates, and friends. We furthermore required that they were able to bring at least one photo from a joint event, for example a holiday or attending a party together.

Procedure

The lab evaluation was conducted in the usability lab at Aalborg University in Denmark. The lab allowed us to video record the tests for later analysis. The evaluation consisted of six sessions – one session with each of the six groups of participants. The three or four group participants arrived at the lab facilities together. All participants were required to bring at least one personal device – typically their mobile phone, but some brought tablets as well. The evaluation was conducted around a high table without chairs allowing the participants to freely move around while interacting with JuxtaPinch and the mobile devices.

Participants were asked to bring at least one personal photo that would enable them to tell a story about the photo, i.e. story telling according to Van House [20], and one photo that could support a conversation between the group members, i.e. reminiscing Van House [20]. This could be a photo from a shared group event where all participants were present. The photos had to be stored on their own device, which allowed JuxtaPinch to access the photos during the test. Since they brought their own devices, the sessions featured different combinations of devices ranging from a session where all participants brought their own smartphone to a session where all three participants brought both a smartphone and a tablet.

Each session consisted of four parts and the session would last approximately one hour. First, we gave an introduction to JuxtaPinch (approx. 10 minutes) where we introduced the overall idea behind the application and gave a quick tour of the functionality with a particular focus on the implemented pinching techniques and how to connect and disconnect the devices. Participants were then allowed to try out JuxtaPinch to get comfortable with using the application and the pinching techniques. Secondly, the actual evaluation started where participants were asked to share their own photos with each other (approx. 20 minutes). They were asked to talk about and discuss their photos (both the story telling and reminiscing photos). They could freely choose the order among the members of the group. Thirdly, we gave them five devices (two Samsung Galaxy SII, one iPad 3, one Nexus 7 and one Acer Iconia Tab A200) to enable further exploration of the photos. Participants were then told to play and interact with the system and freely choose any photos from their devices (approx. 10 minutes). Fourthly, we had a debriefing session where we had them to fill out an AttrakDiff questionnaire and we conducted a semi-structured interview (approx. 20 minutes). The interview consisted of a set of open-ended questions. The goal of the interview was to understand personal experiences the participants had during the session. Also, we wanted to ask into their relationships to each other, to their photos and to their own versus other's versus public devices.

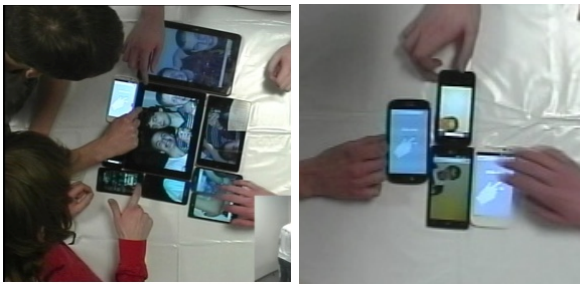

Figure 4. JuxtaPinch in use from two of our lab evaluations where participants are connecting and disconnecting mobile phones and tablets.

Data Collection and Analysis

We automatically logged the number of viewed photos (from the different devices), the number and type of pinches (connects), and the number of movements (disconnects) during our evaluation. The recorded video sessions from the evaluation were divided into smaller segments containing interaction with one single photo. We then analyzed these video segments from a quantitative point view where we identified pinch techniques (which one of the three pinching techniques), movement of devices and whether participants moved their own device, another persons device, or a public (shared) device.

Interviews were transcribed and afterwards analyzed by grouping answers for each of the 23 questions from the interview guideline. Homogeneous answers were color-coded to emphasize repeated answers. We used inductive analysis to analyze the qualitative data. Through repeated assessment of the interviews and viewing of the videos, we identified a number of topics and themes.

FINDINGS

In the following, we present findings from the evaluation of JuxtaPinch. We have identified themes evolving around the use and application of JuxtaPinch as a multi-device system that supports collocated photo sharing. Participants have been renamed for anonymity.

Organizing Multi-Device Interaction in Groups

The inherent collaborative nature of using multiple devices in groups was tackled in several ways. Here we observed different collaboration behavior between the six groups during the first part of the lab sessions (where they viewed and explored photos using only own devices). As an example, participants in one of the groups took turn when interacting with JuxtaPinch and the devices. Here the photo owner would control and organize the session. Other groups employed a more chaotic process where participants would all attempt to connect and disconnect at the same time resulting in application errors. As third example of how collocated photo sharing took place, we saw one group where all participants brought their own mobile phones and they shared one tablet. In this evaluation session, the tablet primarily served as a stationary or fixed-place device left in the same spot during the whole session and the participants would only connect and disconnect their mobile phones, i.e. they would only move these devices.

Considering the interactions made, we found 871 pinches and 583 device movements were made. We counted and classified all pinches made in the six lab sessions and the single most used pinch technique was one-hand pinch with 55.6%, followed by the two-step pinch 34.9%, and two-hand pinches with 9.5%. We observed that some groups would employ the same pinching technique again and again throughout an entire evaluation session, as an illustrative example we saw one group that used the two-step pinch 96.4% of the time during their session, while another group used the one-hand pinch 93.6% of the time, and finally a third group used the two-step pinch 88.9% of the time. Furthermore, we also observed that participants would move mobile phones more often than tablets (64% of the movements).

Our participant argued that they found it unproblematic to interact with other participants' devices, but perhaps more surprisingly they also found it unproblematic that the other participants interacted with their personal device. Lucero et al. [11] made a similar observation, but their participants used handed-out mobile phones and not their own phones. All participants expressed that they did not think of this during the session and some of them further articulated that they experienced the situation and environment as safe involving people they knew and trusted and this made the sharing of devices uncomplicated. While these statements point in one direction, our analysis of the interaction with the devices shows that 66.3% of the pinches (connects) was made on own devices and 53.8% of the movements (disconnects) were made with own devices.

Using Devices to Create Irregular Viewing Shapes

As argued above, we deliberately designed JuxtaPinch to support flexible viewing configurations where users can create various shapes using the devices – as opposed to, for example, the application *Pass-Them-Around* [11] that solely enables rectangular viewing canvas. This feature of JuxtaPinch led to different kinds of photo explorations and encouraged playfulness.

We observed that several groups started their sessions by creating rectangular viewing area in attempt to simulate a larger screen where they were able view the whole photo. Most groups would actually try to imitate a rectangular screen as much as possible for the first couple of photos. Some groups would keep constructing rectangular shapes throughout their entire session and one of the groups even repositioned the devices beforehand to display as much of the photo as possible, as this example illustrates. Before selecting his photo the owner, Hans, said: "*Now we want to try something else, because this is a tall photo*" and he restructured all the devices. *"Now you are making it wide?"* Walter asked and he responded: *"Yes, it is on purpose. The photo is long and tall"* as he pinched all devices together. However, he had to disconnect and re-connect one device to ensure that the whole photo could be seen correctly on all the included devices.

Opposed to the above, some participants started creating more irregular shapes of their photos. Here they utilized the opportunity for flexible positioning in JuxtaPinch to shape irregularly viewing displays as the example in figure 7, right or photo in figure 5, left where participants created a partial view to show a beer bong. We found that JuxtaPinch sometimes encouraged playfulness when exploring photos. This was visible in more ways namely to show specific parts, to hide specific parts, and to create funny views.

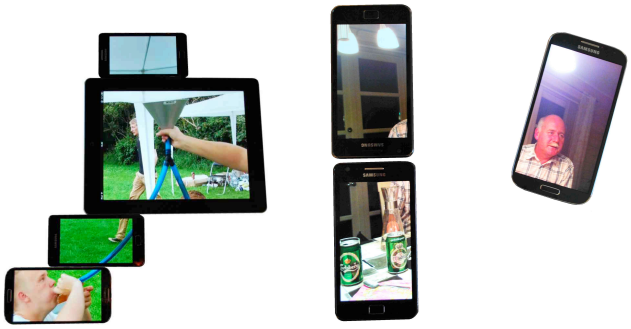

Figure 5. Using JuxtaPinch to create partial views of photos (left) and to create playful situation where people are "removed" from the photo

Playfulness

Our participants would occasionally use the multitude of device to create playful situations where they intentionally played with the photos to create funny layouts. Five of the six lab groups used the flexibility of positioning devices in JuxtaPinch to create funny views, i.e. devices were

positioned to make a face span across two devices, which created funny optical illusions due to the gap between the actual screens. As an example of the creation of a funny view, Zoe, a female participant, mentioned that by positioning the devices in different ways, she was able to split the photo in ways, which made it humorous to look at. *"In an old photo I have a 1000Kr. bill in my mouth I could [by repositioning] get the bill to be on one device and my face to be on another, which was quite funny to look at"*.

Several participants discovered (some of them by chance) that if they carefully moved the devices around, they would not detach from the photo (disconnect) as they would not activate the disconnect functionality (e.g. tilting over 10 degrees or acceleration). Thus, participants were then able to carefully rearrange devices, for example to switch bodies or heads of two people. Also, "incorrectly" pinching with a device not positioned to the edge of it, meant that the photo would be showed more like a swap-tile puzzle.

Other groups used the flexible positioning of JuxtaPinch to reconfigure the viewing display repeatedly. One of our lab groups would constantly change positions of the devices to either display other parts of the photo or hide parts that were currently visible. This was a family (mother, daughter, and son in law) who were looking at a photo from a family vacation and the photo included several family members. As they played with the photo, a new family member appeared on the display several times, which is illustrated in the following example: *"well, that was lovely! [ironic] Now Trudy is in the photo again. That was not the plan" the son in law argued and he quickly repositioned the device "There we go! Much better! Now I am in focus!"* For several photos, this group of participants kept repositioning devices to hide certain parts and to highlight other parts. A similar situation of playfulness occurred in another lab groups where they removed the father from the other devices while exploring and discussing the photo (as illustrated in figure 5).

Defamiliarization through Multi-Devices

Our evaluation showed that several participants experienced their own familiar photos in new ways – sometimes referred to as defamiliarization. Shklovsky [18] originally proposed the concept of defamiliarization in 1917 as a technique for presenting something familiar in an unfamiliar or "strange" way. Our evaluation showed that some participants would uncover new details of an otherwise familiar photo while using JuxtaPinch. Originally, Shklovsky used the term to illustrate how art could defamiliarize [18], but recently we have seen how defamiliarization can been applied within HCI [2, 9].

We identified defamiliarization in several situations as it occurred during our lab evaluations. Actually, all six groups experienced aspects of defamiliarization where familiar photos were experienced in new and sometimes surprising ways. Defamiliarization typically occurred unintentionally when participants were connecting and disconnecting their devices. Usually our participants would discover details that they had never seen or noticed before. For example, some discovered a lamppost on a photo of a bike trail and made comments on that and explored the photo even further, while another group learned that a specific football club was 50 years old as they noticed details on a birthday cake. In both situations the participants had never noticed these details before.

We observed characteristics of defamiliarization in three different but somewhat related ways – we refer to these as defamiliarization through segregation, through scaling, and through hiding. These will be explained and illustrated in the following.

Figure 6. Situation where defamiliarization through segregation was experienced with a photo of a person wearing a t-shirt with a Nicki Minaj print.

Defamiliarization through segregation happened when parts of a photo was segregated (or isolated) on one single device such that particular details would stand more out and thus be emphasized by the isolation and framing of the device. One group (with student participants) viewed and explored a photo from their group room at the university; suddenly one of them discovered that one group member was looking at his Facebook-page in the photo, as this part of the photo was isolated on one device. Another group was viewing and exploring the photo illustrated in figure 6 (left) on multiple devices. They were discussing and talking about the photo (which is a little spooky and unusual) when suddenly one of the group participants, Carl, asked, *"What is that",* pointing to a specific part of the shirt of the person in the photo (figure 6, lower right). Parts of the t-shirt had been isolated or segregated on one device and the image on this device looked strange by itself (as illustrated in figure 6, lower right). The other participants from the group looked closer at the photo on the device and after a short period of time, Oscar, the photo owner said *"Aaah, it's a t-shirt with a Nicki Minaj print on it. Because it is black outside the print [points at the black spot and the print], it looks as if he has cleavage" The rest of group started laughing and one of them said "It looks very weird"*.

This particular element of the photo, and the interpretation of it, had never been experienced by the owner of the photo before. The participants elaborated this during the interview, for example Carl stating, *"it [JuxtaPinch] was brilliant for experiencing new details in a photo you already know, because they suddenly appear on a single screen"*. The photo owner, Oscar, further elaborated this, stating, *"for instance, Dave's t-shirt – I never noticed before that it really looked weird"*. This particular situation illustrated how defamiliarization through segregation occurred when using JuxtaPinch. One could argue that the t-shirt was not the main objective of the photo and the isolation of parts of the photo on individual device screens empathized other qualities of the photo.

Defamiliarization through scaling happened as participants used multiple devices to view a photo and the scaling of the photo would occasionally magnify and thus highlight new details in the photo. As an example, one participant, Victor, was showing a photo of an ambulance bus. Suddenly, they noticed a new detail on the bus indicating defamiliarization through scaling (but also through segregation). Victor explained the experience as *"Suddenly, someone noticed that you could read the full technical specification on the right front wheel of the bus … these small details would normally disappear in the entirety but they are suddenly visible"*. The group noticed the technical specification of the bus, which they had never seen before. However, as it was now isolated on one screen and scaled compared to viewing the photo on only one device. Our findings suggest that randomness can be used to incite defamiliarization, which is in agreement with Leong et al. [9] who used randomness to provoke defamiliarization in photos.

Figure 7. Defamiliarization through hiding (on the left) where participants noticed details in the photo when the kayak was not visible on any device, and on the right a situation where participants created irregular photo shapes through flexible positioning of devices

Finally, defamiliarization through hiding happened when participants on purpose or accidently hid the primary element of a photo, and thereby caused other elements to become more notable or emphasized. As an example, we observed a group looking at a photo of a kayak at sea (figure 7, left). Since the kayak was so dominant (due to its placement and color), other parts of the photo were not noticed at first. However, when this part of the photo was left out, the group experienced it in a new way, and suddenly noticed new details on the shore behind it.

AttrakDiff Questionnaire

The result of the AttrakDiff questionnaire showed that JuxtaPinch scored above average in both Hedonic Quality - Stimulation (HQ-S) and Attractiveness (ATT). Above-average on HQ-S means that JuxtaPinch stimulates the users, awakens curiosity and motivates the users. Words such as inventive, creative and captivating are rated high by the users to describe JuxtaPinch in terms of HQ-S. Above-average on ATT means that the overall impression of the product is very attractive.

DISCUSSION

We investigated multi-device interaction through the design of JuxtaPinch an application that allows sharing of photos across multiple devices. JuxtaPinch allow partial viewing of photos, which seemed to stimulate our study participants to create irregular viewing canvases with their devices and this led to defamiliarization where participants experienced new details in familiar photos or experienced details in new and different ways. Extending previous research on collocated photo sharing, our findings illustrate that the combination of multiple devices do not equal the same experience as a bigger screen. It creates new experiences and interactions. We found that the opportunity for flexible configurations of devices encouraged playful sharing of photos where our participants would intentionally attempt to create funny situations in the photos. While the insights on multi-device interaction constitute one key contribution of the paper, the unique features of JuxtaPinch also formed basis for some additional themes that constitute a second contribution of the paper. These are discussed in the following.

Creative Device Configurations

As illustrated above, the partial viewing of photos enabled by JuxtaPinch led to creative exploration where our users configured their devices in many ways. During this, they arranged the devices in rather irregular configurations.

Lucero et al. [11] designed their application differently as they deliberately chose configurations where devices were strictly aligned either as 2x1, 3x1, 2x1x1, or 2x2. While this removes some of the complexity of calculating photo presentation, as basic assumptions can be made about devices aligned side-by-side, it also prevents users from applying devices of different sizes. We observed that users particularly welcomed this type of challenge of putting their devices together in unconventional ways in order to obtain a particular result, for example showing specific parts of a photo, or leaving a particular part out. Because the system scale and rotate the photo continuously when devices are added, moved, or removed, this was a highly social and interactive activity, which appeared to challenge the users akin to solving a puzzle together. Thus, they engaged more actively with each other and with the shared photo.

Using Different Kinds of Devices

JuxtaPinch supports an extensive range of mobile devices, i.e. smartphones and tablets (and more operating systems), to enable more realistic use. As illustrated in our findings, the effects of using different devices contributed positively to aspects of defamiliarization and participants experienced photos in new and sometimes more interesting ways.

Lucero et al. [11] stress that the flexibility of devices may introduce challenges when trying to combine devices with very different properties and physical form factors. This was confirmed in our study. We observed three factors of device difference that influenced people's interactions and use: different display qualities, different size frames/bezels, and varying screen sizes and aspect ratios. Variance in display quality included properties such as brightness, contrast, and colors, making individual parts of photos appear different when distributed over several devices. This would, for example, sometimes made it difficult for people to see if two displays were pinched together correctly. Variance in frame/bezel size happened very often when devices of different make were pinched together. This sometimes caused the composite photo to appear distorted, for example, making a head look taller if spanning two devices. In response to this effect, some participants suggested omitting the part of the photo that would sit "behind" the area with no display, but others expressed concerns that this would make parts of the photos impossible to see. Finally, variance in screen sizes and aspect ratios caused participants to interact with devices differently. Here, we observed a tendency towards placing larger devices (tablets) stationary in the middle of the table, while moving smaller devices (Smartphones) around more frequently, like satellites.

Sharing Your Own Device

Another unique feature of JuxtaPinch was the possibility for our test participants to use their own mobile devices. We did this so that the social interaction would not be impeded by different preferences for operating systems, and also to investigate further the questions raised by Lucero et al. [11] and Stelmaszewska et al. [19] about people's comfort with using someone else's personal mobile devices, and letting others use theirs.

Our findings somewhat confirm those in Lucero et al. [11] that people are generally willing to share their own device with others, but with the added detail that this is more likely accepted with *familiar people* and not so much with strangers. This observation confirm those in [19] where it was reported that digital photo sharing rarely involves strangers, as people generally do not trust unfamiliar people with their own mobile devices or digital content. Adding to this, we often observed that people who had stated that sharing their own device, and using someone else's, was not a problem, in reality in fact kept mostly to their own.

Multi-Device Interaction: Other Use Applications

While we have explored collocated photo sharing as one potential area for multi-device interaction, our work points potentially a number of other applications of multi-platform interaction that may be useful and explored further. We saw that our participants used JuxtaPinch to hide parts of the photo when they were trying to focus on selected elements in a photo. Such hiding could potentially inform other kinds of applications, for example, when planning a route on a map or inspecting building blue prints. Secondly, an increasing number of digital games are utilizing several devices to support the game play, for example, card games and racing games where some devices are used as controllers while others (usually a tablet) is used a the shared gaming space.

CONCLUSION

We have implemented and evaluated JuxtaPinch, which is an application for flexible multi device collocated photo sharing. JuxtaPinch supports a wide range of devices through the use of web technologies. The application allows users to combine several mobile device displays to form a larger display area for joint sharing and viewing of photos. JuxtaPinch will scale and rotate the photos to show as much of a photo as possible.

Our evaluation suggested that our participants experienced their own familiar photos in new ways also known as defamiliarization where we identified three causes namely segregation, scaling, and hiding. We also found that JuxtaPinch would encourage participants to play with their photos where they created new views and re-composed photos by moving the different devices around. Participants expressed no direct concerns about sharing their personal mobile device with other participants (in this case friends, family members or work colleagues), but we also found that our participants would predominantly interact with and move their own devices.

Our work with JuxtaPinch proposes a number of avenues for future work. First, we need to further investigate how to control the interaction and synchronization for a multiple device collocated photo-sharing application. We identified situations where JuxtaPinch had to be restarted, as our users simultaneously attempted to connect or disconnect devices. Part of this can be explained by the prototypical nature of our implementation of JuxtaPinch, but some problems were also a result of the simultaneous and collaborative nature of use. Secondly, using pinching (or other techniques) for multiple device interaction could be further investigated for other applications within collaboration or social interaction. It could, for example, be interesting to explore how different pinching techniques can be used for collaborative technologies using large interactive displays or boards in connection with small handheld devices such as mobile phones or tablets.

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