Interaction Techniques for Creating and Exchanging Content with Public Displays

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ABSTRACT
Falling hardware prices and ever more displays being connected to the Internet will lead to large public display networks, potentially forming a novel communication medium. We envision that such networks are not restricted to display owners and advertisers anymore, but allow also passersby (e.g., customers) to exchange content, similar to traditional public notice areas, such as bulletin boards. In this context it is crucial to understand emerging practices and provide easy and straight forward interaction techniques to be used for creating and exchanging content. In this paper, we present *Digifieds*, a digital public notice area we built to investigate and compare possible interaction techniques. Based on a lab study we show that using direct touch at the display as well as using the mobile phone as a complementing interaction technology are most suitable. Direct touch at the display closely resembles the interaction known from classic bulletin boards and provides the highest usability. Mobile phones preserve the users' privacy as they exchange (sensitive) data with the display and at the same time allow content to be created on-the-go or to be retrieved.

Author Keywords
Public displays; interaction; classified ads; Digifieds

ACM Classification Keywords
H.4.3 Information System Applications: Communications Applications — Bulletin Boards

General Terms
Experimentation, Human Factors

INTRODUCTION
As prices for digital displays decline, (semi-) public spaces are being augmented increasingly with public displays. Many of them are already networked, but operated mainly by large outdoor advertisers. As also smaller shops (retailers, restaurants, etc.) deploy public displays connected to the Internet, and as new business models emerge, we envision that many owners, such as retailers, could decide to share or rent out their display space in the future. Hence, content from third parties other than advertisers can be published, ranging from individuals or event organizers who currently use paper posts to charities running campaigns. Traditional forms of shared public display spaces include so-called public notice areas (PNAs) and can be found in various locations such as stores (containing mainly classified ads), restaurants and bars (events), university buildings (housing), or public institutions (announcements). As these displays become digital, we envision their content being made more visible and attractive to passersby: (1) Digital classifieds can be augmented with multimedia content and services, e.g., images, videos, or maps. (2) Networking capabilities enable easy content distribution and remote collaboration. (3) Simple means can be provided for creating and exchanging content with the display.

Figure 1: Interaction techniques for creating and exchanging content with public displays – we compare (a) direct touch at the display and (b) mobile phone-based techniques.

Many displays are already equipped with touch screens, allowing content to be created ad-hoc as users walk up to the display. However, there are many situations where using the mobile phone as an alternative interaction technology might be more suitable. First, when observing traditional classified ads, it becomes clear, that besides very simple posts scribbled onto a piece of paper, many users dedicate a lot of time to create appealing posts. In these cases, people may be better off using the mobile phone, as it provides additional artistic freedom by using, e.g., the camera, to augment posts with images or videos. Second, posts could be created on-the-go, e.g., as users commute on the train knowing that they would pass a display later on their journey. Third, inputting personal information on public displays, such as an email address or telephone number, raises privacy issues due to lurkers and shoulder surfers. With the mobile phone, such sensitive data can be entered in a secure manner.

CHI 2013, April 27–May 2, 2013, Paris, France.

One major challenge when using the phone to create content for public displays is how exchanging content with the display can be realized in an easy-to-understand and performant way. Mobile phone-based interaction with the display should enable users both to post as well as to retrieve content they are interested in. In order to tackle this challenge and to understand the potential of the mobile phone for this new communication medium, we implemented *Digifieds*[1], a digital public notice area. In a lab study, we compared different interaction techniques, including direct touch at the display, paper-based, and mobile phone-based interaction (Figure 1). Furthermore, we collected qualitative feedback from the users on their practices, motivations, and view on privacy.

The contribution of this paper is twofold:

- We report on the development of the digital public notice area, discuss challenges of porting bulletin boards to the digital world, and identify suitable interaction techniques.
- We present the findings from a lab study with 20 participants. We compared interaction techniques that enable creating and exchanging content with public displays. The results indicate that users are similarly performant using mobile phones and displays. Users prefer mobile phones to create content in a privacy-preserving way / on-the-go.

RELATED WORK

Various projects have explored the technical requirements for networking and interacting with digital displays within and across offices [1], as well as in public spaces [26, 37]. MAGIC Broker allows people to interact using SMS, the WWW, and speech. It consists of separate gateways for each interaction method and allows several user interfaces to be used in parallel [14]. Paek et al. suggested I/O modules for using different techniques simultaneously, providing a similar solution [28]. To support parallel interaction, tunneling interaction via a server has been explored [19, 31]. We drew from this work to inform the technical design of Digifieds.

Current research emphasizes the potential for interconnecting displays for sharing information in an attempt to create a new communication medium [13]. Its infrastructure aims at supporting multiple types of parallel interaction and attempts to reach an audience as large as possible. The impact of such applications has been demonstrated by several studies. Churchill et al. assessed the influence of introducing public displays into an office space [10, 11] and published some insights into the augmentation of the user environment. McCarthy et al. designed CoCollage, a community supporting social network applications for public displays [23]. These studies demonstrate how user awareness is increased by introducing displays and analyze the kind of content used in communication. Moreover, public display networks also support the development of communities [29, 30] and can even act as a meeting point for users with common interests [39]. In contrast to prior work that looks into effects on the user and the environment, Digifieds was designed to investigate suitable interaction techniques in such settings.

[1]The platform name “Digifieds” is derived from “digital classifieds”; we use the term “digified” to describe the content of the platform.

When designing interactive public displays, several challenges have to be confronted: first, attention needs to be attracted; second, interactivity needs to be communicated [25]; third, the user needs to be motivated to interact [8, 20]; fourth, suitable interaction techniques need to be provided. This work focuses on the latter challenge. The advent of cheap (multi-) touch technologies has shifted direct interaction with displays into the focus of research. Touch surfaces allow (multiple) users to interact in parallel. Yet, mice, keyboards, and such devices as levers or buttons [18] turned out to be good, well-known alternatives that promise fast adaption. NFC can be used to simulate button-based interaction behavior [17]. Finally, Nawaz et al. explored eye gaze and head gestures [27].

At the same time, a large proportion of the HCI community focuses on using mobile phones for display interaction as users are so familiar with them that little learning is required. Several mobile phone interaction techniques have been proposed. Sahami et al. use the mobile phone’s flashlight [32], while Ballagas et al. use the camera to control a cursor on large displays [5]. PhoneTouch is a novel technique enabling phones to select targets by direct touch [33]. Transparent markers embedded on the display allow any camera-enabled device to interact with the display [22]. Several dedicated mobile apps have been developed which make use of different connectivity options such as Bluetooth, WiFi, SMS and MMS [12, 38]. Schmidt et al. enable cross-device interaction [34].

Overall, prior work investigated different interaction techniques separately. In contrast, this paper compares multiple interaction techniques based on realistic use cases. This allows for understanding the particular strengths and advantages of each interaction technique. Our research explores how deploying more than a single interaction technique can help to support different types of users in different situations and with different preferences as this is a particular challenge when rolling out such a system in a public setting.

As users have different preferences with regard to privacy we draw upon prior work that looked into how mobile computing technologies can be used to make display interaction more secure. Sharp et al. presented a system that censors sensitive information on the display and shows the uncensored version only on the mobile phone [36]. Berger et al. blur sensitive words in emails on projected displays and make them visible only on the mobile device [7]. An architecture for increasing web browsing security on public terminals by hiding confidential information is presented by Sharp et al. [35].

Finally, novel interaction methods have been studied with regard to user behavior [9, 24] and technologies [15, 16]. Of particular interest is Huang’s finding that people spend less time learning about system capabilities when not supporting current practices [21]. Also, user motivation and interests in novel systems need to be taken into account [24]. This suggests that interaction techniques that are intuitive, easy to use, and privacy-preserving are promising. In order to achieve this for public displays we opted to investigate the parallel use of (1) mobile interaction techniques that are more privacy-preserving and (2) interaction techniques directly at the display which are supposedly more natural.

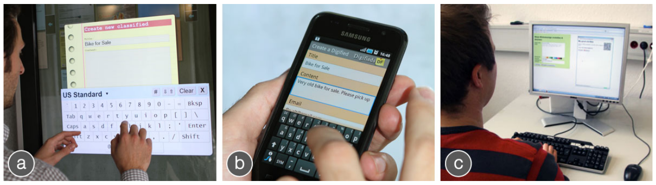

Figure 2: Creating content for a PNA – (a) on the display, (b) on the phone, (c) on the PC at home/work.

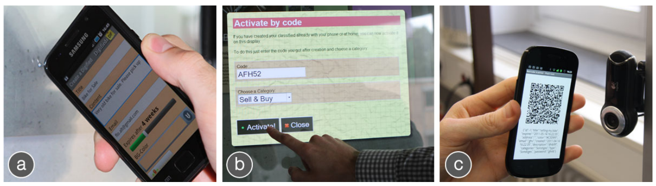

Figure 3: Posting content on a PNA – (a) phone/display bump, (b) alphanumeric code, (c) QR code on phone display or printed paper.

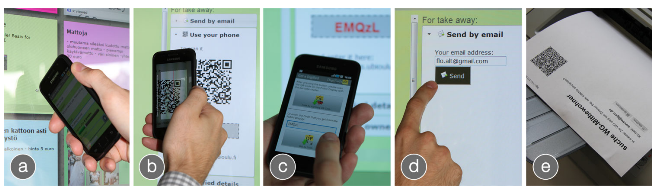

Figure 4: Retrieving content from a PNA – (a) phone/display touch, (b) QR code, (c) alphanumeric code, (d) email, (e) paper printout.

INTERACTION TECHNIQUES FOR PNAS

Our central use case for exploring mobile interaction techniques for public displays are traditional public notice areas. These can nowadays be found in a wide variety of locations. People use them to post classifieds, information on events, community activities, and the like. At the same time, platforms such as Craigslist or eBay offer similar and successful services on a national or even global scale. Therefore, simply deploying these platforms for public displays seems viable. However, the persistent success of paper-based PNAs indicates that people often prefer them over online platforms.

Previous work has identified the following reasons [3]: on one hand, PNAs have a strong *local character*, often addressing certain communities only. By contrast, web-based platforms allow a large number of people to be reached, even at a distance. Yet, there are various situations in which such platforms are inconvenient. When selling items, especially those which are difficult to handle due to size and weight and cannot easily be shipped (e.g., furniture, bikes), addressing the local community provides a better opportunity to find buyers who can easily pick up the items personally. The same is true for services such as babysitting or private lessons, which cannot be offered supra-regionally. Finally, the generally high level of trust in local communities, contributes to a good seller/buyer relationship.

On the other hand, even more importantly, traditional PNAs are *very easy to use*. They have only low barriers for entry, as papers and pen can easily be used, even spontaneously as people pass by. The fact that no additional equipment is required makes it possible to generate messages within an extremely short timeframe (often less than one minute) and without any need to be familiar with the technology. At the same time, also professional content, such as high-quality event flyers, are supported. Furthermore, physically retrieving information (e.g., tear-aways or flyers) contributes to high usability. As a consequence creating and understanding suitable interaction techniques as well as users' practices is crucial to make future public display applications successful and support a quick and high uptake among the users.

In order to explore different interaction techniques, we designed a networked digital version of a public notice area, supporting different interaction techniques for creating, posting, and retrieving content. These interaction techniques use technologies (sensors) nowadays widely available at public displays and on smart phones. Figure 5 provides an overview of the supported techniques.

Creating Content

We support three situations for creating content. First, creating content using a *display client* is meant for ad-hoc users, either coincidentally passing a display (e.g., on the way to the supermarket) or in a waiting situation (e.g., at a bus stop). The display client allows content to be created directly at the display by means of an on-screen keyboard (Figure 2a). Users could enter text, choose the background, and augment it with an image/video from a USB stick. Second, a *mobile phone client* can be used by people to create content on-the-go and prepare it for publishing it later in cases they know that they will pass a display. The mobile client enables users to create a post by entering text (similar to writing an SMS) and transferring it later to the display (Figure 2b). The message could be augmented with images or videos taken with the mobile phone. Third, through a *web client*, users can create digital classifieds remotely at a PC, e.g., at home, at work, or on-the-go from a laptop (Figure 2c).

Posting Content

Content created at the display using *direct touch* input is stored directly in the system and appears on the screen. In addition, there are three different ways to transfer pre-generated content using additional interaction techniques. First, we provide a *phone/display touch feature ("bump")*, similar to Schmidt et al. [33]. After creating a post, users can touch the screen with the phone at the position where they want it to appear (Figure 3a). Second, *alphanumeric codes* can be used in a similar way to activate a previously generated digital classified at the display (Figure 3b). Third, we use *QR codes*. After users create a post on the phone, a QR code is generated on the mobile phone's screen which can then ne captured by a camera attached to the display (Figure 3c). The QR code is read and the digital classified placed on the screen. Similarly, QR codes can be used that are generated on print-out posts created through the web site.

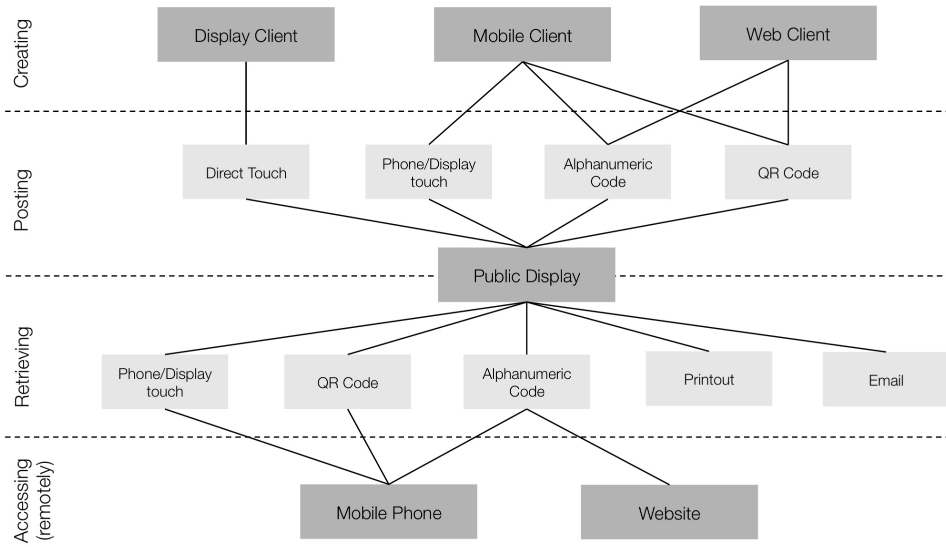

Figure 5: Digifieds provides different display- and mobile phone-based options for exchanging content with a public display.

Retrieving Content

As users often want to take content with them from the display, we provide five options: *phone/display touch* – similar to the technique used for posting on the display (Figure 4a), transferring it to the phone via *QR code* by scanning the code next to the post with the phone's camera (Figure 4b), using the alphanumeric code (Figure 4c), sending it to an *email* address by providing the address directly at the display (Figure 4d), and *printing* it out on paper using the printer installed next to the display (Figure 4e).

IMPLEMENTATION

Our Digifieds platform consists of four components: (1) a server back-end for data management, (2) a web-based display client for visualizing information and direct interaction, (3) a mobile client as an alternative interface for interaction with the display, and (4) a web client.

Digifieds Server

The Digifieds server is the central component of the system. It is responsible for the data management and storage and provides access for arbitrary clients (display, mobile phone, web) through a RESTful API. To provide a robust server application for real-world deployment we opted for the Java Enterprise Edition 6 Framework (JEE6). The Glassfish 3.1 application server ensures scalability (easy thread management and clustering) and trouble free updating of the running server application without compromising active sessions. A MySQL database stores data permanently and can be accessed through a Java Persistency API (JPA) layer. Furthermore, caching optimizes database access and hence reduces CPU usage and overall access times.

Besides storing the content and layout information of each digital classified, the central database manages the information, configuration, as well as available categories for each connected display client. For evaluation purposes, all API interactions can be logged. The lightweight JSON data format transfers data between server and the connected display clients. We provide an XML format for external applications. It can be used by simply changing the corresponding HTTP request headers.

Digifieds Display Client

The main goal when designing the GUI of the display client was to preserve the advantages of traditional paper-based PNAs while at the same time enhancing it with digital features, such as multimedia content (pictures, videos), interactive content (maps), popularity-by-click count, sorting posts by various criteria (date, popularity), automated removal of outdated messages, search functionality, and novel retrieval techniques. For the display client's graphical layout, three challenges needed to be tackled. First, it had to be recognizable as a PNA, not just as a digital display; second, content had to be presented in a well-arranged manner (even if containing a lot of content); third, interaction had to be enabled in a very easy and intuitive way.

We adapted the layout of traditional PNAs, making content look like paper classifieds attached to a wall. In order to cope with scarce space, we decided not to display all content on one single screen but to split the PNA into several views. The concept is depicted in Figure 6. Each view holds posts related to a certain category, e.g., 'Housing', 'Sales', etc. Using buttons on the left and right side of the display (see Figure 1a) enables switching between these views horizontally. In case a single view is overloaded with entries, it can also be scrolled vertically using swipe gestures. The dimension of the active view adjusts automatically to the screen resolution. The background layout of a PNA can also be customized for each category. Using different views for scaffolding does not only help to solve the space issue but we also envision easing the use of the board and making browsing more convenient.

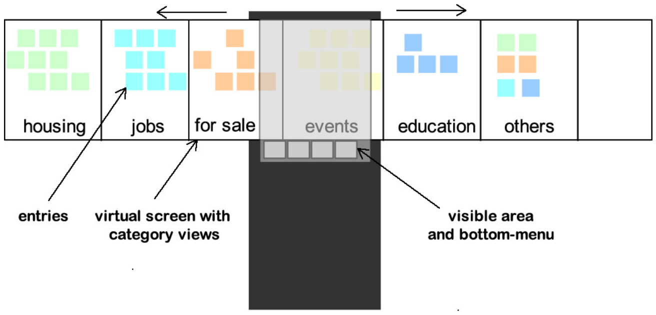

Figure 6: Layout of the display client interface.

Finally, the client provides an on-screen keyboard that allows users to create and send posts without using additional devices. Users can choose color and category of the digital classified from predefined values. Using the system does not require any registration or login process. Digital classifieds can also be retrieved in different ways, e.g., by sending them to an email address, printing them out, or using one of the mobile phone techniques described in the following section. A shopping cart function allows multiple digital classifieds to be retrieved easily at the same time.

The display client uses AJAX to create an interactive UI capable of attracting and enticing people through immediate feedback. HTML5 and CSS are used to layout the content and a browser in kiosk mode to run the client. Using asynchronous HTTP requests, the display client periodically polls for data changes. If there is any new content, the corresponding GUI elements are updated. Currently, the default update rate is 30 seconds. However, since each display's configuration can be modified on the server, adjustment to arbitrary update rates as well as dynamic rates based on the data load can be easily realized. The internal browser cache minimizes the data traffic and is used for media documents (images, videos, HTML, CSS). The browser's local storage API saves the classified's data in JSON format even between browser sessions or in network-loss situations.

Digifieds Mobile Phone Client

To allow content to be created on-the-go, we developed an Android application. With this client the user can create new digital classifieds, containing a title and content (text, images and/or videos), and define additional information such as the expiration date, address, or contact data. Once a user creates a new post on the phone, it is stored permanently on the phone and in the central database but it is not yet visible on the displays. To preserve the locality of a display's content, we wanted people to personally come to the display. Hence each post created with the mobile client needs to be activated. Note that remote posting is technically feasible.

To enable content exchange between phone and display in a transparent and understandable way, we implemented three techniques:

1. *Phone/Display Touch*: We implemented an interaction technique where the user can touch the display with the phone at an arbitrary position. In the posting mode, the digital classified created on the phone is transferred to the display (activated) and inserted at the touched position (Figure 3a). In the retrieval mode, the digital classified located at the position where the user touches the screen with the phone is transferred to the mobile phone. The phone/display touch feature is implemented by synchronizing actions between the display and the phone. Once a touch gesture is detected, the phone and display are matched via timestamps. Subsequently, the selected post is transferred via the digital classifieds server between the devices. This method was primarily developed for displays with IR touch frame.

2. *Alphanumeric Code*: Similar to the phone/touch feature, a 5-character alphanumeric code (e.g. 4XB6A) can be used to activate a digital classified (Figure 3b). This code is associated with each post and available on the mobile phone after creating the post. It then needs to be entered on the public display of the user's choice. Furthermore, alphanumeric codes are also used for content retrieval. The code can be entered into a form on the website (see below) or directly into the mobile phone client to download the post.

3. *QR Code*: Based on the alphanumeric code we also create a QR code that can be displayed on the mobile phone's screen and be captured by the public display's camera in order to transfer and publish the digital classified (Figure 3c). For retrieval with the mobile phone client, QR codes are also displayed next to each digital classified shown by the display client (Figure 4b). On the phone the QR code can either be used to open the classified in the mobile browser, or, if it is scanned with the Digifieds mobile client, be transferred and stored on the phone.

Finally, the mobile client provides an interactive map with the locations of all Digifieds-enabled public displays.

Digifieds Web Client

For people who do not own a smartphone or who prefer composing their digital classified on a PC at home or at work, we provide a public website[2]. This website serves two purposes. First, it provides further information about the digital classifieds platform, e.g., a tutorial about how to use it, information on where to find displays running digital classifieds (interactive map), and a download link to the mobile app in the Android Market. Second, similar to the display and mobile client, the website can be used to create new digital classifieds or retrieve classifieds that have been found on one of the public displays. When creating a digital classified on the website, images and videos from the local PC can be embedded, and the PC keyboard as well as the computer monitor may be used to create sophisticated designs in a more flexible way. However, like with the mobile app, a created digital classified still has to be activated on the public display (using an alphanumeric code) before becoming publicly visible. In order to retrieve one or many digital classifieds that are on a public display remotely, a user only needs to enter the alphanumeric code. Subsequently, the original classified, that includes all images, videos, maps, and a form to contact the owner is displayed on the website.

[2]Digifieds website: `http://www.digifieds.org/`

Figure 7: Study arrangement – (a) Display client with printer and camera for reading QR codes, (b) Web client on PC.

EVALUATION

In order to evaluate the suggested interaction techniques with regard to usability and suitability, we conducted a lab study where users had to solve familiar tasks from traditional PNAs (e.g., selling items, etc.). As pointed out by Alt et al., the evaluation of public displays usually needs to make a tradeoff between external validity (generalizing the findings), ecologic validity (realistic task/environment) and internal validity (control over confounding variables) [4]. Achieving all three at the same time is impossible. Our focus in this paper was clearly on obtaining comparable results in a controlled setting, which allowed statistical data analysis to be performed post-hoc. Hence, we deliberately decided to sacrifice external validity while trying to optimize ecologic validity through realistic tasks. This allowed an evaluation without external influences and the use of cameras to assess user behavior and enable interaction, which would have been a major privacy issue in public. A separate in-the-wild evaluation of the system with a focus on user acceptance is reported by Alt et al. [2].

Tasks

We developed realistic tasks to simulate situations in which participants were free to behave around the display, as they would normally, e.g., in a supermarket. Hence, we created a controllable, yet realistic situation in which people behaved both naturally and were not aware of what was being measured, thus avoiding having any influence on their behavior.

For each of the tasks the users were asked to (1) generate a digital classified on a given topic (e.g., selling a bike or a mobile phone, renting their apartment, offering private lessons), (2) post it on the display, and (3) retrieve one of the digital classifieds. To include all interaction techniques[3], each task combined a set of three techniques (one each for creating, posting, and retrieving content). We used a within-subject design. The task order and the topics were counter-balanced.

[3]Note, that the alphanumeric code techniques was not evaluated. We included it later as a substitute for the phone/display touch feature during a deployment on capacitive displays.

Task 1: Display

We asked the users to imagine a situation in which they wanted to spontaneously post a digital classified, e.g., when passing a display in the supermarket. They were requested to create a post directly at the display using the on-screen keyboard. Once finished, we asked them to look for a particular older post and send it to their email address (Figure 4d).

Task 2: Phone/Display Touch

Users were asked to create an on-the-go classified on the phone with the knowledge that they would pass a display on the way. Once they were finished, they were to post it on the display using the phone/display touch feature. Before leaving the PNA, they had to pick up a specific digital classified by using their phone (Figure 4a).

Task 3: QR codes

In the QR code task, users created their digital classified on the phone. To post it on the display, they had to use the QR code technique. Therefore the mobile client generated a QR code, which users had to present to a camera attached to the display. The display client reads the QR code and publishes the classified on the screen. The users also had to look for a certain classified and scan the associated QR code using the mobile phones' camera (Figure 4b).

Task 4: Paper

For the paper task, users generated their post at a PC, simulating the preparation of a post at home or at work. The web client generated a QR code of the digital classified, which users had to print out and present to the display's camera. Users then had to search for a certain classified and print it out using the printer installed next to the display (Figure 4e).

Setup

For the study, the system was setup in our lab. The display client ran on a 42“ touch-enabled public display (Figure 7a), containing an initial set of classified ads in different categories. The system was reset after each participant, so that everyone started with the same initial set of classified ads. Note that classified ads of different length would have influenced the subjects with regard to the post length. A camera was attached to the display in order to allow scanning QR codes from paper or from the mobile phone (Figure 3c).

In addition to the display, we setup a PC and a printer simulating a home/work environment. The PC initially displayed the website of our platform in the Firefox browser (Figure 7b).

Data Collection

We collected the following quantitative data, derived from questionnaires, from a server logfile, and from video recording followed by a post-hoc data analysis.

- **Demographics**: We collected data on the age, gender, and profession of the participants.
- **Mobile Phone Usage**: We were interested in the subjects' habits when using their phones. Therefore, we asked whether their phone supports multi-touch, if they surf the web on the phone, whether they have unlimited Internet access, and if they use third party apps.

- **System Usability Scale (SUS)**: After each task, the subject filled out a System Usability Scale (SUS) questionnaire [6] to compare the perceived usability per technique.
- **Task Completion Time**: For each technique, we measured how long it takes the participants to create, post, and retrieve content (including upload and download time). The measurement was conducted post-hoc, based on video footage. Walking time (from PC to display) is not included.
- **Length of Content**: We analyzed the length (number of characters) of the classifieds the users create for the different interaction techniques. We believe this to be an indicator for the ease of creating content with this specific interaction technique.

Qualitative data was gathered via a questionnaire and semi-structured interviews, after the study. We asked about problems, personal perceptions, likability, and areas for improvement. Interviews were videotaped for post-hoc transcription.

Procedure

Participants were recruited in the days prior to the study via mailing lists, Facebook, bulletins, and on an opportunity basis as people passed by the lab. After a short briefing and signing a consent form, we asked them to fill out the demographic questionnaire. We then led them to the room where the digital classifieds system was deployed. We gave each participant five minutes to explore the system, asked them to 'think aloud' and provide feedback on what they were exploring. Next, they were given a phone (Samsung Galaxy S) with the preinstalled mobile client and given another five minutes to make themselves familiar with the digital classifieds application. The users then had to complete the four different tasks presented above in randomized order. We read out the task description to each user (e.g., *"Imagine you are at the display in a shopping center and want to sell your bike. Please create a classified ad using the display client and post it in the 'Sales' category."*). There was no time limit for completing the task. The experimenter did not intervene and only answered questions if the subject got stuck or explicitly asked for help. After finishing each task, the user filled out the SUS and provided written feedback. Interviews took place afterwards.

RESULTS

Prior to analyzing our data statistically, we performed a post-hoc video data analysis, and coded input time, time for uploading content, and time for downloading content. We transcribed the interviews and printed them. Qualitative findings were pasted on a wall in a meeting room, so that each team member could familiarize themselves with the data. The data were discussed and annotated, and extracted patterns as well as high-level observations were collected on a separate board.

Quantitative Results

In total, 20 subjects (10 male, avg. age 26.8 years) participated in the study. They are students, employees, and civil servants, most without a computer-science background. 9 participants have a touch-enabled phone, 10 use their phones for web surfing (avg.=10.85 times/day, SD=13.1), 13 have unlimited mobile Internet access, and 11 use third party apps.

	Mean A[sec]	Mean B[sec]	Std. dev.	T	Sign.
Creating Content (A vs. B)					
Mobile vs. Display	182.10	166.80	85.10	.804	.431
PC vs. Mobile	184.54	114.75	107.7	2.897	.009
PC vs. Display	114.75	166.80	66.88	-3.5	.003
Posting Content (A vs. B)					
QR_{phone} vs. QR_{paper}	36.10	17.70	24.39	3.374	.003
P/D_{touch} vs. QR_{paper}	29.24	17.70	16.92	3.050	.007
Retrieving content (A vs. B)					
QR_{phone} vs. Paper	50.70	37.70	30.13	3.110	.006
P/D_{touch} vs. Paper	49.55	37.70	41.20	2.149	.045
Paper vs. Email	37.70	29.75	19.86	-1.8	.089

Table 1: Differences in task completion times (paired T-Tests; df = 19)

The analysis of the *SUS* reveals the following average scores: display (86.6), paper (82.1), QR code (73.5), phone/display touch (70.0). A series of paired t-tests indicate that the usability in the display task is rated significantly better than phone/display touch (T=-4.25, $p<.001$) and QR codes (T=-3.37, $p<.01$). Also, paper-based interaction is ranked significantly higher than phone/display touch (T=-4.25, $p<.05$).

Interaction Times

Using paired t-tests (Table 1), we compare the *interaction times* of different techniques with regard to creating, posting, and retrieving content. Not surprisingly, we found that *creating content* on a PC/laptop is significantly faster than directly at the display (T=-3.480, $p<.01$) or on the phone (T=2.897, $p<.01$). More interestingly, there are no significant differences between phone and display. For *posting content*, scanning the printed QR code on paper is significantly faster than both QR codes on the phone (T=3.374, $p<.01$) and phone/display touch (T=3.050, $p<.01$). This could be due to the fact that posting a classified using the phone, the additional step of activating it on the display was necessary. With respect to *retrieving content*, printing is significantly faster than digitally through phone/display touch (T=2.149, $p<.05$) or QR code (T=3.110, $p<.01$); yet, sending via email is not significantly slower than printing.

Lengths of Posts

With regard to the length of post (number of characters), we found that posts created on the PC/laptop were significantly longer than texts created on a phone (T=-3.716, $p<.001$) and at the display (T=3.373, $p<.01$). There was no significant difference in the length of classified ads created on the mobile phone and directly at the display (T=-.707, n.s).

Correlation Analysis

We looked for correlations in our data (Likert scales) using Pearson's r and testing for significance. The most important findings are: (1) People who use touch devices frequently wrote significantly less text at the display (r=-.490, $p<.05$) and on the phone (r=-.054, $p<.822$). Additionally, there was a significant correlation between the amount of text written on the phone and on the display ($r=.580$, $p<.01$). (2) The more and the longer people used the phone, the better they performed with the phone-based techniques (e.g., positive correlation for amount of written text on phone ($r=-.573$, $p<.01$), interaction time for retrieving content with QR codes ($r=-.448$, $p<.05$), and rating of phone/display touch feature ($r=-.505$, $p<.05$) with how long participants used the phone on average per day). (3) We found strong correlations between age and usage of the phone-based techniques. Younger participants performed significantly better, for example, when uploading content with phone/display touch ($r=.586$, $p<.01$) and when retrieving messages with the phone's QR code scanner ($r=.512$, $p<.05$).

Next, we analyzed how performance impacts usability. We found that when inputting and retrieving messages with the phone takes longer, participants rate this technique significantly lower (e.g., creating messages ($r=-.451$, $p<.05$), retrieving messages using QR codes ($r=-.829$, $p<.001$)).

To reveal differences in gender and for users with unlimited mobile Internet access, we performed a univariate analysis of variance (ANOVA). Participants who have unlimited mobile Internet access are significantly faster when creating content using the phone (on avg. 230% faster, $F=11.838$, $n=7$, $p<.01$) and touch display ($F=13.548$, $n=7$ $p<.01$) as well as retrieving content using the mobile techniques ($F=4.653$, $p<.05$).

Qualitative results

Though there is not a clear preference for one technique, many participants feel that direct interaction at the display most closely matches their expectations from traditional PNAs (P2, P6, P15, P19). P2: *"Touch input is most similar to writing a classified on paper"*. Yet, they feel that there are several privacy issues with these techniques, as email addresses are entered publicly. As a result, numerous participants state that they would prefer using the mobile phone, since it is more private (P5, P7, P10, P11, P18, P19, P20). P18: *"I don't want the people standing behind me to know my email address"*. Furthermore, the participants could imagine to use the mobile phone on-the-go (e.g., on the train) to prepare a post.

The participants identified several advantages of the digital PNA. Most important is the search functionality. Second, the filter and rank feature (e.g., by popularity/date) enables the users to search the classified ads easier and faster. Third, the digital classifieds can be enhanced with different designs, images, videos, and GoogleMaps. P13 also likes the fact that people can not simply remove or tear away classifieds like on traditional PNAs. Participants mention the high 'fun factor' of using the phone-based techniques (P3, P6, P7, P9, P10, P14, P17, P18). P14: *"Bumping and scanning were the biggest fun"*.

Finally, we received feedback on how to enhance the system. This concerns the visualization (e.g., highlighting new classified ads or providing a more casual layout; P17: *"Could be more oldschool"*), but also ideas for new features and techniques (speech input for creating posts, enabled remote posting via web/email, linking the platform with Gmail).

IMPLICATIONS

Based on the findings from the study, we extracted the following implications for designing digital PNAs.

Mobile phones are preferred by young people. We found that users of different age groups or with diverse backgrounds and technical skills perform very differently and prefer different techniques. Whereas young users like the mobile interaction, less mobile-savvy users favor the display or PC. This is also reflected by the statement of an interviewee: *"I think this is for young people – I should bring my grand children."* (P19).

Multiple means on content production are required. User feedback indicates that the preferred interaction technique often depends on the current situation. Whereas participants incidentally passing by mainly want to use the display directly, the advantage of being able to prepare a classified ad at home is that more sophisticated designs can be created. The largest benefit of the mobile client is seen in creating content while being underway. As there is no significant difference in the duration for creating content, this indicates that several interaction techniques can be offered in parallel.

Ease-of-use is crucial. The correlation analysis supports the assumption that, similarly to traditional PNAs, the acceptance and success of digital PNAs depends substantially on how easy and intuitive they are to use – even though our participants report on the fun / coolness of the mobile techniques. While ad-hoc and occasional users are probably not willing to install software on their phone, people interested in more sophisticated designs or those who know that they will later pass a display and want to use waiting times to prepare content are happy to do so. Yet, the study results indicate that if interaction techniques are difficult to understand or "flakey" (e.g., requiring multiple attempts to use them successfully) users become frustrated and acceptance decreases significantly.

Mobile phones can preserve the user's privacy. Our study revealed that some users are concerned about their privacy, with regard to entering sensitive or personal data, such as an email address directly at the display. The reason for this is not just the fact that this data is shared with the PNA provider, but also that other people are able to see it. Participants of our study stated that they consider the mobile client to better preserve their privacy and that they would prefer to use this techniques in places were many people are present.

Overall, we observed that interacting directly with the display best resembles the functionality of traditional PNAs. This interaction technique also provides the highest usability. However, the findings from our study indicate that aspects other than usability should be considered when choosing suitable interaction techniques. There is considerable potential for the mobile phone as an alternative: (1) Content can be created on-the-go and in a manner that preserves privacy. (2) There is no significant difference between display and mobile phone with regard to how quickly content can be created. (3) Our results indicate that there will be high uptake among younger people and they perform very well in exchanging content between phone and display, especially those familiar with touch-enabled devices and mobile surfing.

CONCLUSION

We presented a platform for creating digital classified ads on public displays and elaborated on mobile phone-based interaction techniques to exchange content with the display. In a controlled lab study of 20 participants, we evaluated suitable interaction techniques and derived implications with regard to the design and deployment of digital PNAs.

Our findings suggest that there is not a single best technique for creating and exchanging content. While usability is best for creating content directly at the display, there is no significant difference with regard to the time required to do so. From a user acceptance perspective, the preferred interaction technique depends both on the type of user and his current situation. Young, technology-savvy users not only prefer but also perform better using the mobile interaction techniques. Nevertheless, the situation (i.e., whether the users are accidentally passing by the display vs. they intend to pass by the display later) is important. Our results show that display interaction is favored as users decide to ad-hoc post on the display, whereas mobile interaction techniques are preferred as users are on-the-go. At the same time, the mobile techniques are also preferred by privacy-aware users as the mobile phone allows sensitive information (e.g., an email address) to be entered without needing to bother about other users in the display vicinity.

Future work could more closely investigate gender differences, focus on different types of content, and explore effects on local communities.

ACKNOWLEDGEMENTS

We thank Firas Zaidan, Markus Ortel, Björn Zurmaar, and Tim Lewen for their help with implementing the system and running the user study. We also thank Julian Mennenöh for his advice on the statistical data analysis.

The authors acknowledge the financial support of the Future and Emerging Technologies (FET) programme within the 7th Framework Programme for Research of the European Commission, under FET-Open grant number 244011. This project is furthermore partly funded from the German Research Foundation within the Cluster of Excellence in Simulation Technology (EXC 310/1) at the University of Stuttgart.

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