Direct, Bodily or Mobile Interaction? Comparing Interaction Techniques for Personalized Public Displays

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ABSTRACT
Interaction with personalized data on a large public display represents a sensitive scenario: first, users expose the fact of interaction in public; and, personalized data may be private. In this work we investigate how interaction design can support the user in such a scenario. Through experimentation, we compare three interaction techniques: direct, bodily, and mobile-based. We report on the users' preferences with the presented techniques at different interaction phases (identification, navigation, and collecting results). We analyze how user preferences in the personalized display scenario are similar or different to other scenarios, such as interaction with physical objects or non-personalized public displays. The analysis is summarized in a form of design recommendations that should be considered when designing for interaction with personalized public displays.

Categories and Subject Descriptors
H.5.2. Information interfaces and presentation: User Interfaces – *Interaction styles, evaluation/methodology, user-centred design*.

General Terms
Design, Experimentation, Human Factors.

Keywords
Interaction techniques; design recommendations, public displays.

1. MOTIVATION
Interaction with personalized content on public displays brings certain advantages, but also presents risks. On the one hand, users get quicker access to the necessary personal information. The display can automatically tailor its content according to the user profile, helping the user eliminate manual extraction of necessary data. On the other hand, interaction with personal data in public can result in privacy issues. Therefore, the interaction with a personalized display must be designed not only in a usable and comfortable way, but it must also be perceived as trustworthy, reliable, and secure.

In this paper we design an experimental study to examine three interaction techniques that are generally used on public displays: direct, bodily, and mobile-based. Although advantages and drawbacks of the three techniques were widely discussed in related literature [1, 2, 3, 4], the techniques have never been compared in interaction scenarios with a personalized display. A personalized display, like any other public display, exposes its content in a large and comfortable format. The content, however, contains data that reflects on the user's profile. For instance, the display can recommend goods potentially interesting to the user. Alternatively, it can present personal data of the user, which is potentially interesting for a group of observers, for example, a calendar of the user overlaid over the group calendar or pictures from a corporative event.

The current work aims at identifying aspects which are critical for fluent and trustworthy (secure) interaction with a personalized public display. In particular, we investigate which of the techniques users perceive as understandable, controllable, comfortable, reliable, privacy protective, and trustworthy. Comparing the results with the insights gained from literature, we identify critical design aspects that are specific for interaction with personalized displays. The work is summarized as a set of design recommendations that aim to inform practitioners in designing interaction for personalized public displays.

Although the investigation was done with a personalized display in a lab environment, it gives a clear understanding of the user's perception and preferences in interaction techniques. The other studies comparing interaction techniques in lab environments [1, 2, 3] show that the achieved results represent a useful input for the designers of real-life interactions. The goal of our study, therefore, is to provide an initial input for the designers of the personalized displays in a real world environment. Derived recommendations are aimed to guide the initial stages of the design process when designers are analyzing possible situational context and look for the optimal interaction solutions appropriate for the given contexts.

Despite the sensitivity of a public scenario, the use of personalized displays has become increasingly common [5]. In our study we use two different types of personalized content: The first is an application for visualizing a personal *social network*. The second is an application that presents a *persuasive display*. The user's personal data is encoded in the displayed visualization with to the purpose of influencing user behavior. The examples of similar types of public display content can be found in previous research [6, 7, 8, 9, 10], as well as in real-life projects, for example, the installation of the Interactive Video Wall in Copenhagen [11] or CityWall in Helsinki [12]. The examples show that despite the awareness of privacy issues [5, 9, 13, 14] that can result from sharing the personalized content, people do place their private data on public displays.

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2. INTERACTION WITH PERSONALIZED CONTENT

Generally, the process of interaction with personalized content on a public display can be subdivided into three phases: (1) identification, (2) navigation, and (3) collecting results.

The *identification phase*, or log-in, is when the user transmits to the display their unique identifier. Once the identifier is recognized, the user's personalized information appears on the large public screen. Identification phase is required in order to interact with the information which is personalized.

The *navigation phase* allows the user to manipulate the personalized data displayed on the screen. The navigation is usually governed by a specific goal. For instance, the user looks for a meeting in their personalized schedule [14], with a desire to save it to a mobile device. The method of manipulation may vary greatly depending on the application: users can browse through displayed items, edit content (e.g. draw), type in a text request (e.g. requesting a train timetable), or even do complex collaborative work. In this work, however, we limit the scope of navigation activity to browsing through the displayed items. Such manipulations are often employed on outdoor displays for wide-public usage. For example, the Interactive Video Wall [11], in Copenhagen, enables simple browsing of sightseeing pages. The CityWall [12], in Helsinki, provides browsing through pictures taken by citizens. Another reason to choose browsing, as a navigational activity, is the consistency of the interaction process; the browsing action does not depend much on the particular design solution. The user navigates through the items displayed on the screen, with the ability to highlight and select each item.

The *collecting results phase* refers to the accomplishment of the navigation goal. The goal followed during the navigation phase is usually directly related to the browsing process: the user looks for a specific item to retrieve the necessary information. For example, the users of the Interactive Video Wall [11] look for interesting city sights to get information on the opening hours, shortest route, etc. The users save the retrieved information on a mobile device, such as a personal mobile phone, or send it via email.

Logging-off (removing personal data from the public screen) can be seen as an additional phase. However, since we focus on the interaction particulars of the phases, we consider the log-off process to be similar to the identification phase. Indeed, for consistency reasons, the log-off is usually designed identical to the log-in (or identification).

It is important to notice that personalized display applications do not always involve all three phases. For instance, the CityWall [12] presents pictures of citizens; users may browse through the pictures (navigation), upload their own pictures (identification), or download existing pictures (collecting results). In this case, each phase is independent and can be skipped. In this work, however, we aim to investigate user preferences in the three phases. Therefore, our experiment was designed and conducted with applications involving all three phases.

3. INTERACTION TECHNIQUES ON PUBLIC DISPLAYS

In general, three techniques are usually employed when interacting with public displays: direct, bodily, and mobile-based.

Direct interaction assumes physical proximity between the user's interactive tool and the display. The interactive tool can be the user's hand or an assisting device, such as an NFC-enabled mobile phone. The technique exploits a real-life metaphor of "touching", where an individual activates an object by touching it. The display may enable the direct interaction by means of touch-surfaces or by other technologies, such as a matrix of NFC tags [16, 17] or using hand recognition [18, 19]. The studies on direct interaction show that users perceive the technique as natural [1], fast, reliable, enjoyable, and easy [2]. However, since the interaction is possible only at a short distance, the users have to make an additional physical effort to move closer to the object [1].

Bodily interaction is enabled by spatial gestures, body postures or proximity. The technique is particularly beneficial if the display is located far away from the user and thus it is physically impossible to reach the display. Bodily interaction is usually supported by camera-based recognition [15]. Previous studies show that this technique is quick and intuitive [1]; it increases the user's engagement, enjoyment, and is considered to be fun [20, 21]. However, the user may see gestural interaction as artificial and hard to memorize. As a consequence, the gestural interaction can negatively impact user's cognitive load [22]. In addition, users expressed concern about performing gestures in public: they feel uncomfortable attracting attention of bystanders [9, 23].

Mobile-based interaction utilizes a mobile interface to control the public display. The mobile interface may offer specially tailored tools for control or it can replicate the entire content of the public display [24]. The main advantage of the mobile-based interaction is the ability to interact from any distance, with minimal physical effort. However, users may find the technique boring [2], too technical [1], and inconvenient [1], due to the constant focus switch between large and mobile displays.

4. COMPARING INTERACTION TECHNIQUES

Although each of the interaction techniques described in the previous section were discussed widely in literature, the techniques have never been compared in the scenario of interaction with a personalized public display.

Rukzio et al. [1] compared the techniques touching (direct), pointing (bodily), and scanning (mobile-based) in interaction scenarios with real-life objects. Although the study was conducted in a controlled lab environment, it gives an insights into the user perception of interaction preferences. Similar lab studies were conducted by Broll et al. [2], who compared direct and mobile-based techniques in interaction scenarios with paper posters, and by Boring et al. [3] and Ballagas et al. [4], who compared mobile-based and gestural (bodily) interactions for controlling a cursor at a distant public display.

Although these works provide interesting insights into the speed, reliability, physical effort, and error rates of the techniques, the results can inform the design of the personalized displays only partially. The sensitive scenario of interaction with personal data applies specific restrictions to the user's acceptance and preferences of an interaction technique. Therefore, there is a need to investigate how the distinct techniques can fit into a scenario of interaction with personalized content. Since the public setting introduces an additional sensitivity condition, to the interaction process, we need to find the design aspects that are critical for the use of public displays with this particular condition.

5. EXPERIMENT

We setup a study to investigate the users' preferences amongst the three interaction techniques (direct, bodily, and mobile-based) with personal data on public displays. The aim of the study was to identify specific aspects that are critical when interacting with personalised displays. Moreover, we aimed to identify how the user preferences in the personalized display scenario differ from the preferences in other scenarios, such as interaction with physical objects or non-personalized public displays.

The study explored the users' perception of three interaction techniques (direct, bodily, and mobile-based) used in the various interaction phases (identification, navigation, and collecting data).

5.1 Public Display Application

The experiment was conducted with two sample applications, Friend Finder and Late-o-Meter.

Friend Finder visualizes the social network of a user, rendered over a local map (see Fig.1). The friends are depicted by icons containing their pictures and names.

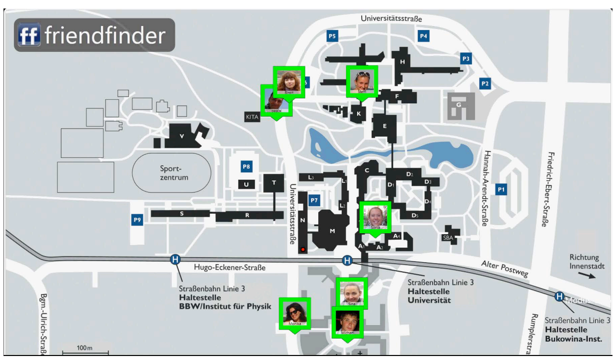

Figure 1. Visualization of a user's social network using Friend Finder

The application was designed by students in the framework of a term project [25]. A survey conducted amongst university students revealed that the students need a support in locating their peers on the campus, for instance, to gather for lunch or to work on a project. So far such appointments were done by phone calls or short messages, which is generally found inconvenient and expensive. A display that employs the Friend Finder application and located in a public area, on campus, could help the students to quickly locate their friends.

Friend Finder takes advantage of the large size of the public display. First, the large screen estate gives a good overview of broad social networks. The media such as a map is difficult to observe on a smaller screen, such as a mobile display or a desktop. Second, several users can observe the social network at the same time. This case is widely spread in the student environment: a group of friends may share a friend circle and would like to view the location of their friends together. Moreover, several independent users may merge their friend networks on the same map. In this case, each network is presented in a unique color of frames. In the study, however, we focus on a single-user scenario.

Once the user has loaded the social network on the screen, he or she can browse through the friends' icons, and retrieve the shortest path to the selected friend. The path can be downloaded to their mobile device for later navigation. This function was especially appreciated by the students, since many of them have orientation difficulties around the campus.

Late-o-Meter displays the weekly delays of a group (such as a group of students attending the same lecture course) and aims to persuade the group members to be more punctual. The idle view (see Fig. 2) shows anonymous black silhouettes. Each silhouette represents one group member; the silhouette's height is mapped to the person's delay in minutes. Since the identity of the silhouettes is hidden, a passer-by can only see how punctual the whole group is. A group member can personalize the display and see his or her own delays and compare them with others. The personalized view highlights the user's silhouette in orange and it shows their exact delay (see Fig. 3). The user is then able to go into the details of their weekly performance that shows how well they managed their delays to lectures.

Figure 2. Visualization of a group delays using Late-o-Meter (idle view).

Late-o-Meter originated for a students' term project. A survey conducted amongst university peers revealed that many students wish to improve their punctuality. In spite of the shame in front of the lecturer and the class, their habit of being late does not change by itself. With the help of Late-o-Meter students believed they can become more punctual.

Late-o-Meter benefits from the large screen: the ambient display provides an overview of the group success and helps students fight for punctuality as one team. Personalization enables students to see their own success and compare it with the rest of the group. Personalizing the Late-o-Meter, users can see the details only of their own delays. The rest of the group remains anonymous. Thus, the users can compare their delays with the delays of the others respecting privacy of the group members.

In spite of the slightly private character of the personalized data, the students appreciated both applications and expressed their willingness to use them. This positive feedback is in line with the observations of other research projects dealing with personalized displays: despite awareness of privacy issues [5, 9, 13], caused by the personalized content, people do use public displays to interact with personalized data [5, 11, 12].

5.2 Interaction Phases

The interaction phases (Identification, Navigation, and Collect Results), for each application, are described in the Table 1.

Table 1. The three interaction phases in Friend Finder and Late-o-Meter.

	Friend Finder	Late-o-Meter
Identifica-tion	User brings the personal social network on the large screen.	User's silhouette is highlighted in orange.
Navigation	User browses through the friends, selecting the friends' icons on the map.	User views the daily performances, represented by bar graphs, selecting the exact delays per day.
Collect Results	User saves the shortest path to the currently selected friend.	User saves the memo of the selected day.

5.3 Design of Interaction Techniques

The Friend Finder and Late-o-Meter applications were developed in three versions that individually support one of the three interaction techniques (direct, bodily and mobile-based).

Direct technique presumed contactless interaction with visual markers that are displayed on the large screen. The contactless interaction was enabled by a mobile phone. In an initial version of the application, the direct interaction was supported by camera-based marker scanning with an Android mobile device. The user had to capture a marker integrated into the content of the large screen. Once the mobile camera has recognized the marker, it sent the command to the server, and thus the necessary action (e.g. identification or selection) was triggered on the large screen. Although the camera-based scanning was reliably working, the marker capturing procedure caused unacceptable interaction delays. Therefore, for the experiment we used the Wizard-of-Oz approach, imitating an immediate contactless touch.

The users interacted with the visual tags in all three phases. For identification, the user made a "contactless touch": bringing their mobile phone close to the log-in marker that is displayed at the bottom of the screen (see Fig. 3).

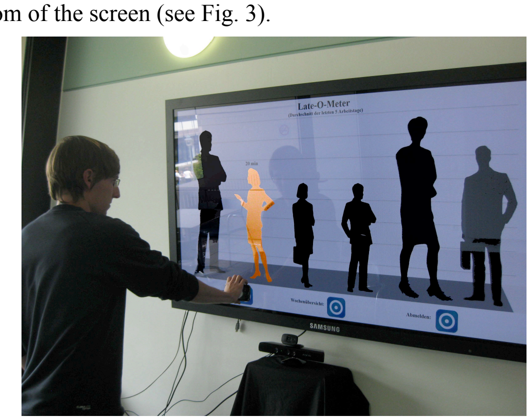

Figure 3. Identification with direct interaction.

The user identification succeeded through the recognition of the unique ID stored on the mobile device. Once the user was identified, the personalized data (social network or the personal delay) appeared on the large screen.

To navigate through the items, the users selected the items by the "contactless touch" directly at the item location. Using Friend Finder, users had to touch the icon of the friend, while in the Late-o-Meter application, they touched the marker associated with the representation of a day graphical bar (see Fig. 4). The collecting result and log-out were performed similarly to the identification: the user had to touch a marker at the bottom of the screen.

One can argue that the described direct interaction is indeed a mix of direct and mobile techniques, since the user touches the tags with a mobile phone. However, the mobile technique in our understanding implies an active interaction with the mobile screen. The presented direct technique on the contrary exploits the mobile phone only as a tool to enable the touch. Such tool can be substituted by the user's hand, finger or a pen [26].

The current implementation is though more complex than a hand interaction, however, it can be applied to a wider range of the displays which are not equipped with a touch surface. The interaction by physical touch supported by a marker-scanning is more universal and realistic; it can be provided by any display assisted by any camera-equipped mobile phone.

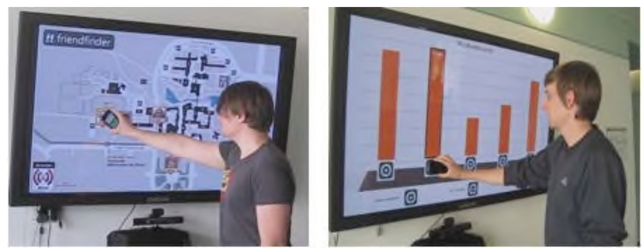

Figure 4. Navigation with direct interaction: Friend Finder (left) and Late-o-Meter (right).

Bodily interaction was enabled by integrating depth sensors of Microsoft Kinect (MS Kinect) [27] and the face detection software of SHORE [28] into the multimodal SSI framework [29]. For identification, we used a proximity-based technique [19]. In order to log-in, the user had to come closer to the display and cross a certain proximity border (1.5 meters) (see Fig. 5). To log-off, the user had to step back behind the proximity border.

Figure 5. Identification with bodily interaction.

The recognition of the user's proximity was based on a distance computed from the face recognition software SHORE [28]. The SHORE software can detect faces in the range of a camera attached to the display, and deliver a computation of how far the user is from the camera. This proximity information indeed can be obtained by other means, for instance, using Kinect. However, we used face recognition technique since it was already build into the system for the sake of individual identification of the users. For the experiment, we disabled the individual recognition, in order to avoid the extensive training of all test participants. For simplicity reasons the identification succeeded once the face of a participant is detected to be inside the proximity zone.

Navigation through the content was supported by MS Kinect, where the user's hand coordinates are tracked using depth sensors. In order to select an object, the user had to point with the right hand at the respective item on the large screen (see Fig. 6).

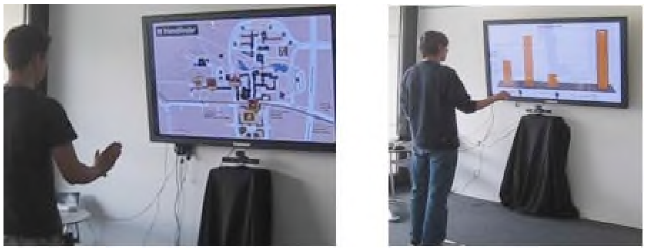

Figure 6. Navigation with bodily interaction.

Collecting results was also supported by MS Kinect: in order to save the path to a friend (Friend Finder) or save a delay memo (Late-o-Meter) the user had to raise their left hand.

Mobile-based interaction was supported by a mobile client running on an assisting mobile device. The client for Friend Finder was implemented on a Windows Mobile device; the client for Late-o-Meter was implemented on an Android phone. In both applications, the users could log-in, log-out, and collect the result using a respective button. The identification succeeded once the unique mobile ID was sent to the display.

Navigation, however, was designed differently for the Friend Finder and the Late-o-Meter applications. Generally, it is a challenging task to design a "blind" mobile phone control for interaction with a large screen; so that the mobile interface minimizes the uncomfortable focus switch between two heterogeneous displays.

In the Late-o-Meter application, such a blind control was easier to design. The linearly arranged day delays on the large screen can be spatially mapped to the similarly arranged mobile buttons (see Fig. 7). The mapping is made by pressing a button on the mobile screen, which in return activates the respective bar on the screen.

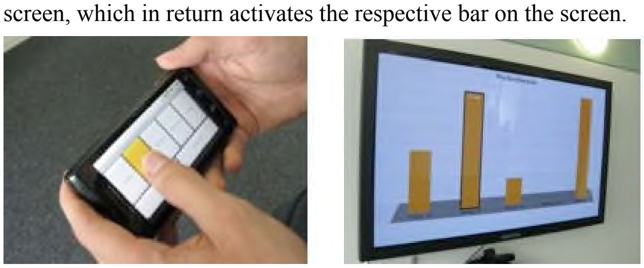

Figure 7. Mobile-based navigation in Late-o-Meter.

In the Friend Finder application, locations of the user's friends on the map represent rather an unordered structure. The icons of the friends are placed according to the different locations of their friends, which can also change over time. Following user-centred approach, we evaluated several controls for navigation through the icons [25]. The final version of the circle-based control was inspired by the iPod-wheel [30] (see Fig. 8).

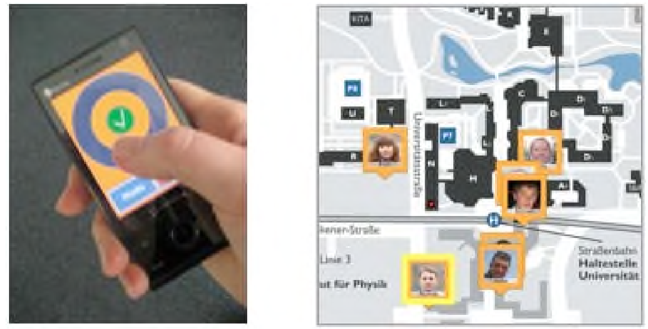

Figure 8. Mobile-based navigation in Friend Finder.

By looking at the disposition of the friends on a large display, the user can arrange the friends' icons into an imaginary circle. Scrolling the mobile wheel in either direction allows the user to select friends, one by one, located at the current navigational angle on the map. This technique was seen more convenient and quick than tabulation or navigation with arrows.

5.4 Experimental Design

We designed an experimental study that is aimed at finding how users perceive different interaction techniques in both applications (Friend Finder, Late-o-Meter[1]). We aimed to identify the similarities, understand the differences, and explain the user preferences for each of the interaction phases (identification, navigation, collecting data).

The experiment was conducted as a between-groups test, in order to exclude learning effects caused by experiences with other application. One group evaluated only Friend Finder, the other group evaluated only Late-o-Meter.

Within either group, participants were evaluating all three interaction techniques: direct, bodily, and mobile-based. The order of the techniques was counterbalanced.

The test was conducted individually, in a public area of a university. After a short introduction about the experiment and the applications, every participant was given a task: they had to log-in, select several items one after another (friends for FF and days for LoM), collect the result (path to selected friends and delays for a selected day), and to log-off. In every task, the routine was repeated three times, to assure that the participants got sufficient interaction experience. The same social network and delays were used for all the participants.

Each participant had to go through the task using the three versions of the application: direct, bodily, and mobile-based. After conducting the task for each version, participants were asked to fill in three questionnaires: for identification, navigation, and collecting results phase. Each questionnaire aimed to capture how well the current interaction technique supported the given phase.

Based on the work of [1, 2, 3, 23], which compares different interaction techniques, we derived questions that focus on investigating six design properties: how the users find the interaction technique in terms of transparency, controllability, comfort of use, reliability, privacy protection, and trust.

The questions were a set of statements that participants had to rate on a 5-Likert scale, from "strongly agree" to "strongly disagree".

Q1: *The system behaviour was comprehensible*

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[1] Here and further, FF stands for Friend Finder, LoM stands for Late-o-Meter.

***Q2:** I had control over the system behaviour*
***Q3:** It was burdensome to use the system*
***Q4:** I found the system reliable*
***Q5:** The system appropriately protected my privacy*
***Q6:** I found the system trustworthy*

At the end of the experiment, the participants were asked which technique they would prefer in each phase and why.

5.5 Participants

In the experiment, a total of 34 students participated in the study (17 Friend Finder, 17 Late-o-Meter). There were 10 females and 24 males, aged from 21 to 36 (mean 28.7), engaged in IT, Law, and Literature. All participants had previous experiences with mobile devices; 18 of them were experienced in bodily interaction (mostly from entertainment games), just 7 participants had experiences with contactless technologies. None of the participants was familiar with FF and LoM.

6. RESULTS

In this section we provide the results obtained from the statistical analysis of the questionnaires. The results per application were analyzed using paired samples t-test.

Although the experiment was conducted with two different personalized applications, user preferences results for the interaction techniques in Friend Finder and Late-o-Meter were surprisingly very similar. The following sections describe the results.

6.1 Identification Phase

In the identification phase, 56% of participants gave their preferences to mobile-based interaction, 32% preferred bodily technique, and 12% chose direct technique as a preference (see Fig. 9).

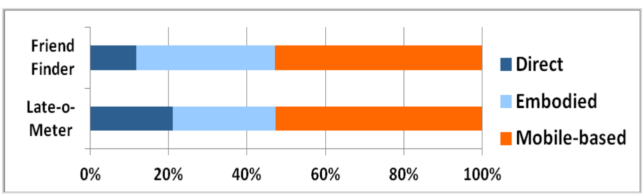

Figure 9. Distribution of preferences: Identification phase.

Mobile-based interaction was perceived more controllable than bodily interaction (FF: t = -3.1, df = 16, p = 0.0069; LoM: t = 3.85, df = 16, p = 0.0014). Mobile-based technique was also found more privacy protective than the direct technique (FF: t = -1.77, df = 16, p = 0.095, LoM: t = -1.95, df = 16, p = 0.069). Mobile-based interaction was also found more reliable (FF: t = -1.9, df = 16, p = 0.028) and more trustworthy (FF: t = -2.4, df = 16, p = 0.029) than bodily interaction.

6.2 Navigation Phase

In the navigation phase, 65% of the preferences were given to direct technique, 26% to bodily technique, and only 9% to mobile-based technique (see Fig. 10).

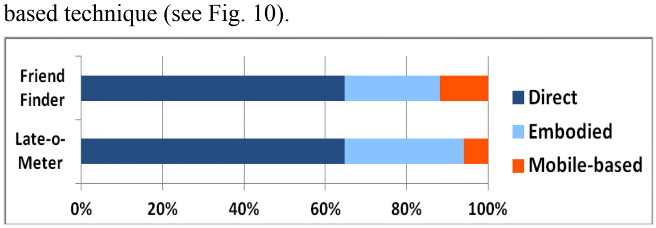

Figure 10. Distribution of preferences: Navigation phase.

Direct interaction was perceived more controllable than bodily (LoM: t=-3.77, df = 16, p = 0.0017) and mobile-based (FF: t = 4.24, df = 16, p = 0.0006; LoM: t = -3.77, df = 16, p = 0.0017) techniques. Moreover, the navigation was seen equally easy, precise, and reliable to browse through linearly arranged objects (LoM) as well as irregularly arranged objects (FF). This quality was seen important since many interfaces contain a mix of linear and arbitrary arrangements. Therefore, the user can keep the same interaction style while browsing through differently arranged items.

Bodily technique was also found equally easy and comfortable for browsing through linearly and arbitrary arranged items. The main disadvantage of the technique, however, was its perceived unreliability. Although MS Kinect recognition worked precisely, the participants mentioned they would not trust the system. Bodily navigation was perceived less trustworthy than mobile-based (LoM: t = -2.1, df = 16, p = 0.056) and direct navigation (FF: t = 1.8, df = 16, p = 0.089).

Mobile-based interaction was found more controllable than bodily navigation (FF: t = 3.27, df = 16, p = 0.0048; LoM: t = -3.4, df = 16, p = 0.003). Mobile-based technique was also found more privacy protective than direct technique (LoM: t = -2.3, df = 16, p = 0.034).

6.3 Collecting Results Phase

The preferences of 62% of the participants in saving results phase were given to mobile-based interaction, 24% of participants gave their preferences to bodily technique, and 14% preferred direct interaction (see Fig. 11).

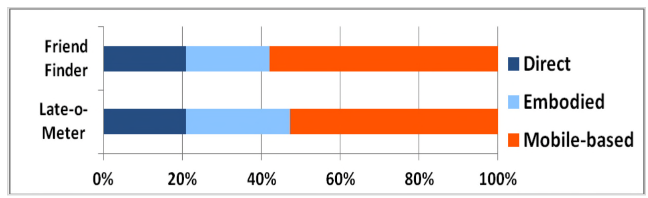

Figure 11. Distribution of preferences: Collecting Results.

Mobile-based interaction was found more controllable (FF: t = -2.1, df = 16, p = 0.046; LoM: t = -4.2, df = 16, p = 0.0006) and more reliable (FF: t = -2.07, df = 16, p = 0.05; LoM: t = -2.5, df = 16, p = 0.024) than bodily interaction. Moreover, it was also found more reliable than direct technique (LoM: t = 2.3, df = 16, p = 0.03). The participants emphasized the perceived control, trust, and security of the mobile-based technique: "*I have to be sure I am saving the right thing… I don't want to save something else*".

Bodily interaction was found less comfortable than mobile-based interaction (FF: t = 2.1, df = 16, p = 0.05; LoM: t = 2.1, df = 16, p = 0.05) and direct interaction (LoM: t = -2.5, df = 16, p = 0.05).

7. DESIGN FOR INTERACTION WITH PERSONALIZED DISPLAY

Below we summarize our observations and the participants' comments into a set of recommendations for interaction design on personalized displays.

7.1 Keep Interaction Discrete

The users of personalized displays prefer not to demonstrate their interaction on public. This recommendation to personalized displays is in line with existing design recommendations to public displays in passing-by situations as in [23].

The *mobile-based technique* gives users the opportunity to remain discrete. In our experiment, participants mentioned that they do appreciate to remain unnoticed. Mobile interaction enabled users to control the display from any distance, thus letting the users choose any "safe" place.

The *direct interaction*, on the contrary, reveals the fact of interaction. The necessity to interact standing right in front of the public screen made interaction completely noticeable, whereas the users preferred to keep it discrete.

These findings deviate from the user preferences identified for the scenarios that don't involve personalized data. For instance, where people interact with real-life physical objects, they prefer direct and bodily techniques [1]. Therefore, mobile interaction is perceived much less comfortable due to the indirect way of addressing physical objects.

In our experiment, the desire to stay unnoticed was emphasized mostly for the identification phase. However, in the other phases (navigation and collecting results) the discrete interaction did not seem to be that critical. Once the personalized data is put onto the large screen, the users tend to be less concerned about the protection of their identity.

In the navigation phase, the *bodily interaction* was also criticized for making users too noticeable. However, the participants were rather concerned to look ridiculous in public, when using gestural interaction. The concerns were mostly expressed by the people unconfident of the Kinect gestural interaction. They were afraid of confusion, especially in public, if the gestures were not recognized correctly.

7.2 Minimize Physical Effort

The users of personalized displays generally prefer to minimize physical motion. This recommendation repeats the guidelines for other interaction scenarios, such as mobile interaction with physical objects [1].

Projected onto the domain of personalized displays, this requirement additionally mimics the users' privacy concerns. Active physical interaction not only attracts attention of the public, but also may slow down the control over the displayed private information. The control, however, is required to be prompt and easy to perform, in the case of potential privacy threat.

The excess in physical motion refers to bodily and direct techniques. Mobile interaction, in all phases, required almost no physical effort.

The *direct interaction* presumed user position next to the large screen. Such position unavoidably caused some physical effort: in order to reach the markers, the users had to move in front of the screen and stretch their arms.

The *bodily interaction* technique, in all phases, presumed some physical motion: crossing the proximity zone for identification, hand gestures for navigation and collecting results. Some participants indeed appreciated such intuitive physical interaction style. Apart from the fun factor, they found it advantageous to be able to interact on the spot without a need in any assisting devices. However, many participants have seen the physical motion rather negatively.

Important to mention, many participants commented that bodily interaction is more entertaining than the other techniques. For example, a female participant noticed: "*I have never tried it, but it's really fun!*" We suppose that the ratio of supporters of the bodily technique may vary depending on the application character. The applications used in the experiment are rather aimed at *utility* and quick and efficient usage. Therefore, the entertaining nature of the bodily technique might be unnecessary. However, in the applications aimed to be a *toy* for the public the bodily technique might fit better than the other techniques [31, 32].

7.3 Provide Position Freedom

The users prefer to be flexible in the choice of their position. Generally, they want to keep some distance to the large screen. This recommendation is specific to the scenario of a personalized display: it addresses the user necessity to stay unnoticed and assures a sufficient overview of the screen.

Participants mentioned that the main advantage of the *mobile technique* is the possibility to control the public display from any distance. Such freedom enabled the users to choose a comfortable position in a given public place; it gave them a chance to have an unnoticeable interaction and also not to move a lot.

Navigation with the *bodily interaction* technique, using hand pointing, was also appreciated for giving participants a relatively flexible choice to position themselves. Unlike the direct interaction the users could choose a comfortable distance from the large screen to ease the browsing process.

7.4 Enable Sufficient Display Overview

The users require a constant visual control over the entire surface of a personalized screen. The recommendation maps to the visibility guidelines that are generally applicable to interactive systems [33]. However, in a scenario with personalized displays; it additionally maps to the need of easy and comfortable screen control.

The *direct interaction* technique was often criticized for the necessity to stay too close to the large screen. Apart from already mentioned disadvantages (making interaction noticeable, causing physical effort), such position also hindered the overview of the entire screen. This inconvenience was especially critical in the navigation phase. The participants often had to step back in order to see where the necessary item is located.

The *bodily interaction* technique, on the contrary, made the users interact from some distance, staying centred in front of the display. Such position though made users noticeable, but at the same time maintained a sufficient overview of the entire content. The participants, however, were suspicious about using the bodily interactions in public places. The Kinect recognition is not resistant to occlusions, which often occur in crowded public places.

The *mobile technique* enabled interaction from any position. Thus the user could take care of a comfortable place providing sufficient screen overview.

7.5 Exclude Unintended Log-In

The system must initialize the personalization (log-in) only by an explicit command of the user. This recommendation may be mapped to the general usability guidelines, informing designers to avoid erroneous system behavior [34]. However, in the domain of personalized displays the need to avoid an erroneous log-in becomes especially critical. Log-in is a highly sensitive moment in the process of interaction with personalized display. Therefore, users need to be familiar and confident with the technique that triggers the log-in. The *mobile* and *direct interaction* techniques assured that the log-in process entirely controlled by the user's input.

The *bodily interaction* technique, however, exploited rather unusual technique: proximity-based identification inspired by the metaphor of coming closer [19]. Although the idea was generally appreciated by the participants, they saw its main drawback in insufficient visibility. The proximity-based identification assumes that the user remembers how the system works, and where the proximity border lies. Such an invisible or barely notable border may easily cause an unintended identification: the user just comes closer to the display and suddenly the data is shown! In the narrow places, such as office passages, the user may personalize the screen without intention just by passing by the display. Therefore, the proximity border should be clearly indicated, for instance, explicitly drawn on the floor.

7.6 Avoid Forgetting to Log-Off

The system must provide the means to remind the user about logging-off or perform the log-off automatically. This recommendation reflects the specific need for users when interacting with personalized data. The users need to be sure to remove the personalized data from the public display when interaction is finished.

The positive side of the *proximity-based identification* was the convenient and intuitive way to log-off. The participants emphasized that the bodily interaction technique was especially beneficial for logging-off. The automatic removal of the personal data is logical and desired when the user abandons the display. It could also secure the cases when the user forgets to log-off.

7.7 Allow Quick Exit

This recommendation, specific to personalized displays scenario, supports the user feeling of secure interaction. In order to feel secure, the user needs a leverage to remove the personal data from the public display as quickly as possible.

The *mobile-based interaction* technique enabled the users to react quickly to the surrounding context, and hide the personal data with a single tap. The participants mentioned it as an important aspect. For example, one of them commented: "*I can immediately say: on or off*".

The identification phase of the *bodily interaction* also allowed a quick reaction to the situation: in case of an observation danger the user can quickly step back from the display. However, the participants emphasized that they need to sufficiently trust the system in order to be sure the system will react in an appropriate way. Since the technique was rather unusual for the majority of the participants, they were suspicious about its reliability.

In the collecting results phase, the participants also appreciated the quick completion of the final action. The *bodily technique* in this phase had a certain disadvantage: the performance of a gesture made the saving slower compared to the other techniques.

7.8 Exploit Well-Known Metaphors

The usage of well-known or real-life metaphors can be considered as a general recommendation to interactive systems [33]. The metaphors are widely applied in different scenarios, for instance, in the design of gestural interactions between multiple displays [34].

In our experiment, *mobile-based interaction* with the personalized screen was understood and mastered quickly due to the replication of learnt metaphors from the everyday life. A mobile device was often associated with a joystick or a remote control. The employment of the metaphor enabled people to easily learn and understand the technique: "*It reminds me of a TV remote control*".

Due to the employed metaphors, *bodily interaction*, for identification and navigation, was also found intuitive. To initialize the interaction people had to come closer, just as the proximity-based log-in. The conversation is closed once the person leaves the counterpart (proximity-based log-out). To highlight a distant object, we point at it (gestural pointing).

In collecting results phase, participants also emphasized the importance of metaphors. Thus, the mobile-based saving supported the real-life metaphor of "taking it with me", by saving the result to the mobile "depot" which always accompanies the user.

In the direct interaction technique, the metaphor of "taking it with me" was even stronger, since it was supplemented with the physical action: the user took the object directly from the screen.

7.9 Ease "Search and Act" Process

During navigation, the "search" part of the selection process and the selection "act" itself should be supported on the same screen (in case of multiple screens). Moreover, the "search" and "act" parts should be performed within the same interaction flow, e.g. with finger pointing.

This recommendation can also be met in other interaction scenarios that involve several heterogeneous displays. The main interaction issue refers to the uncomfortable focus switch between two screens [1, 17].

In our experiment, *bodily interaction* in navigation phase, was appreciated by participants for the possibility to interact from a distance. Apart from a good overview of the screen, such position eased the selection process. Indeed, with the pointing technique, the "search" part of the selection process and the selection "act" itself can be done simultaneously, focusing on the same screen.

Although *mobile-based interaction* was mentioned to be the quickest way to navigate through the content, its main disadvantage was the inconvenient control switch between the small and the large screens. Indeed, the "search" component of the selection process had to be accomplished on the large screen, whereas the "act" component – selection command – using the mobile screen.

8. CONCLUSION

In this work we explored direct, bodily, and mobile-based techniques for interaction with personalized public displays. Three phases of interaction were examined: identification, navigation, and collecting results. By means of an experiment we compared the techniques direct, bodily and mobile-based interaction in each phase. The experimental results give an insight into the particularities required for each of the interaction techniques when used for with personalized public displays. The results show that the requirements to the interaction with personalized displays differ from other interaction domains. The paper is rounded up with design recommendations derived from the experimental results. The recommendations summarize critical aspects that should be considered when designing interaction for personalized displays.

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