Mirror, Mirror on the Wall: Attracting Passers-by to Public Touch Displays With User Representations

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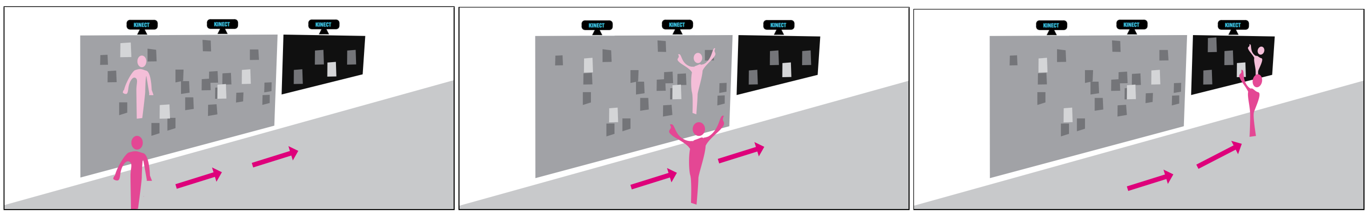

Figure 1. We investigate the effectiveness of user representations to entice interaction with *touch-sensitive information* displays. In particular, we show that augmenting the vicinity of touch displays with screens showing mirror images of the user (1) attracts passers-by, (2) entices playful interaction with user representations and (3) ultimately encourages interaction with informative content.

ABSTRACT
In this paper, we investigate how effectively users' representations convey interactivity and foster interaction on large information touch displays. This research is motivated by the fact that user representations have been shown to be very efficient in playful applications that support mid-air interaction. At the same time, little is known about the effects of applying this approach to settings with a different primary mode of interaction, e.g. touch. It is also unclear how the playfulness of user representations influences the interest of users in the displayed information. To close this gap, we combine a touch display with screens showing life-sized video representations of passers-by. In a deployment, we compare different spatial arrangements to understand how passers-by are *attracted* and *enticed* to interact, how they *explore* the application, and how they *socially behave*. Findings reveal that (a) opposing displays foster interaction, but (b) may also reduce interaction at the main display; (c) a large intersection between focus and nimbus helps to notice interactivity; (d) using playful elements at information displays is not counterproductive; (e) mixed interaction modalities are hard to understand.

Author Keywords
Public Displays; User Representations; Touch Interaction.

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INTRODUCTION
Interactive public displays are increasingly deployed in public places, such as airports, subway stations, or shopping centers [12]. However, the number of people engaging with such displays is still rather small [5, 18, 20]. Previous work identified a number of challenges to be overcome for passers-by to ultimately engage – (1) passers-by need to notice the display [23], (2) realize its interactivity [18, 22], (3) be motivated to interact [5, 18] and (4) be taught what can be done with the display and how [1] – addressing which has shown to increase conversion rates, and thus interaction numbers [20].

To do so, prior work identified a number of helpful strategies, in particular for displays employing mid-air gesture or whole-body interaction [1, 4, 19, 21, 22, 30, 33, 34]. At the same time, relatively little is known about how to support interaction with public *touch* displays [18], despite its popularity and advantages: Touch is the preferred interaction technique for accurate close-up interaction [32] and multiple users can simultaneously view and interact with the display [22, 25], fostering social learning, social experience and the honeypot effect [14]. On the other hand, the occlusion of content by the user's body allows for more private interaction in public [32].

At the same time, using touch interaction at public displays poses challenges: As touch sensitivity is not visible and therefore hard to recognize [18, 25], public displays are often regarded as pure information presenters that should not be touched [18]. Consequently, designers of public touch displays have to find ways to attract the attention of passers-by, communicate touch-interactivity and entice touch interaction. Previous work [18, 25] showed that textual hints are more effective than graphical hints but both do not attract attention.

For gesture-based applications, it has been shown that user representations attract the attention of passers-by, arouse curiosity [4, 7, 19, 27] and are more effective for enticing interaction than calls-to-action [22]. Many applications successfully made use of this method [1, 3, 6, 21, 33]. While this works well in gesture-based applications, it remains unclear whether this approach can easily be applied to applications using other modalities, in particular touch. On one hand, user representations can attract the attention of passers-by, spark interest, and communicate interactivity of a public installation in general. On the other hand, user representations do not indicate the opportunity to touch-interact. Thus, one goal of our work is to understand, whether user representations can easily be applied to other modalities, in particular touch.

In addition, we explore the effect of user representations on the behaviour of passers-by at public *information* displays. In related work, user representations were mainly used in playful applications which users interact with just for fun. At information displays, users typically interact with the displayed informative content to gain knowledge. If user representations are added, users can playfully interact with their user representations without caring about the informative content of the application. So, the question arises how the playfulness of user representations influences the interest of users in the informative content. User representations could either attract passers-by and thus entice interaction with informative content or distract users and keep them from interacting with informative content.

To answer these questions, we setup a touch-based information display in a public space and augmented the user interface with a user representation. Motivated by existing work, showing that recognizing the user representation takes about 1.2 s [22], we experimented with placing additional screens in the touch display's vicinity using different spatial arrangements: (a) one screen in a row with the touch display, (b) two screens in a row with the touch display and (c) two screens facing each other next to the display.

Our results show that (1) enhancing a public display by additional screens at both sides of the walking path can attract attention and prepare more in-depth interaction with the interactive installation, but (2) may also distract users from and prevent interaction with the main display; (3) a large intersection between the focus and the nimbus of a public display arrangement is crucial for noticing interactivity; (4) promoting playful interaction helps to entice interaction and does not keep users away from interaction with informative content; (5) the use of different interaction modalities within a public display installation may lead to confusion among users.

The primary contributions of our work are: new insights into (I) how people understand competing interaction modes (mid-air gestures and direct-touch) at public displays, (II) the effects of the promotion of playful interaction at information displays and (III) how audience behavior is influenced by different spatial arrangements of additional screens enhancing an original display into a pathway.

RELATED WORK

Our work draws from several strands of prior research – most notably the use of the mirror metaphor, the use of multiple displays as well as previous work on proxemic interaction.

The Mirror Metaphors

The mirror metaphor is commonly used as mental model in public display applications [20]. These applications display reflections of the scene in front of the display like a mirror [8, 19], or extracted reflections of users in the form of videos [22, 27], silhouettes [7, 21, 30, 33], shadows [9, 28, 29] or skeletons [1]. These user representations can be presented in realistic [27] or artificial [9, 21, 22, 33] virtual environments. The shape [8, 9, 35] or the movement [19] of user representations can be used for interaction. Furthermore, user representations can be used to interact with virtual objects, for example, using the contour of the user representation to kick virtual elements [22, 30, 33] or by using the hands of the user representations for selecting virtual elements [28, 34]. User representations can also be used as personal workspaces within a multi-user scenario [29] or for communicating with remote users [21]. In gesture-based applications, user representations can help users to understand how the system interprets their actions and support them in learning how to interact [1, 33].

Multiple Displays

Noticing user representations takes some time (about 1.2 s) [22]. Hence, prior work suggest the use of multiple displays.

The *MagicalMirrors* [19] consist of four large public displays showing a mirror image of the environment in front of them. When people pass by, optical effects are triggered by movements of the users, for example, flowers growing towards the movement center. The displays were installed along a sidewalk behind a storefront window. Users noticed and interacted with the first display while passing by and then interacted with one display after the other. They even walked back to interact with the first display in case they had walked by. We learn from this that people are interested in and actually explore each single display of public multi-display applications, even if they are not directly on their walking path.

Müller et al. [22] investigated how passers-by notice interactivity of public displays. In their field study, three interactive displays were deployed in shop windows on a sidewalk. Passers-by could play with a simple ball game using their user representations. They observed that many passers-by realized interactivity not before they had passed a display – referring to this as the *landing effect*. Some users walked back to the display to interact. Others moved on and interacted with the next display. The landing effect shows that noticing interactivity takes some time. Consequently, there is a risk to lose potential users as not all passers-by are willing to walk back to interact with the display. Like in [19], people often interacted with further displays after having interacted with one.

To explore the impact of the form factor of public displays on audience behaviour, Koppel et al. [30] evaluated different arrangements of six displays in a field study: building (1) a straight row, (2) a semicircle with the content facing inwards and (3) a hexagonal with the content facing outwards. Passers-by could play a shooting game using their user representations. Koppel et al. came up with the concepts of *nimbus* (sub-space from which the content can be perceived) and *focus* (sub-space for which interaction is enabled) of public displays. They found that configurations with a large system nimbus get better noticed, systems with a large focus better communicate interactivity. From that we learn, that the intersection of the walking path and the interaction space is crucial for noticing interactivity. Furthermore, the form factor of a public display installation impacts positioning of users and group behaviour: the row of displays caused the strongest honeypot effect, the hexagonal did not allow for social learning, and the semicircle had least simultaneous interactions.

In the *EMDialog* of Hinrichs et al. [13], users could interactively explore visualizations of the discourse of a Canadian artist at a single-user touch display. To make the content of the application visible in a larger area, it was cloned and presented also at a large projection surface next to the display. They found that the additional projections evoked curiosity and faciliated social learning, but also increased the awareness of interacting in a public place and being observed – sometimes leading to social embarassment. This shows that interaction with one main public display can be influenced by assistive displays with reduced or no interactivity.

Proxemics
Finally, the notion of proxemics, as introduced by psychologist Edward T. Hall [11] and applied to the field of large display applications by Greenberg et al. [10], plays an important role. Prior work focused on describing audience behaviour in the vicinity of displays in the form of spatial models. These models classify the area in front of displays into multiple zones. For example, Prante et al. [26] identify an ambient zone, a notification zone, and a cell interaction zone. Vogel et al. [32] refined the original zone model by further dividing the cell interaction zone into subtle and personal interaction zones and by generalizing the idea of a notification zone into an implicit interaction zone. Our approach is also related to this notion – yet, our approach introduces a second interaction zone, supporting a different modality. In addition, the zones in our case expand along the trajectory of the user rather than concentrically around the touch display.

Summary
In summary, findings from prior work motivated us to explore the application of the user representation concept to displays using modalities beyond mid-air gestures. In particular, we decided to investigate the use of multiple displays, since prior work showed that people are indeed willing to interact with multiple displays after each other.

APPARATUS
To answer our research question, we implemented an apparatus consisting of (1) a *direct-touch information display*, where users could interact using touch, as well as (2) larger projected screens, which in the following are called *hallway displays*. The term *interactive installation* is used to refer to the whole apparatus including both the direct-touch display and (up to two) hallway displays.

The interactive installation is built alongside a pathway. The section of the pathway, where the hallway displays are, is called *hallway* and the part, where the direct-touch display is standing, is called *display area* (see Figure 3).

Figure 2. The *CommunityMirror* application shows information about the alumni of a university in floating information particles.

Application
We use the *CommunityMirror* application [24] for our study. The *CommunityMirror* is a touch-based information display, presenting information about the members of a community. In the application, information particles horizontally flow across the display. If a particle is touched, it stopps moving and a more detailed view is presented and related information is displayed in a graph structure (see Figure 2). The position of particles on the screen can easily be changed by dragging. Multiple users can simultaneously interact with the application and explore the information space using touch. In our study, the *CommunityMirror* was running on the direct-touch display, presenting information about the university alumni. We assumed this information to be interesting for people interacting for they are mostly university members.

Interactive Hallway
The objective of the interactive hallway is to attract the attention of passers-by, communicate interactivity of the installation and lead them to the direct-touch display for interaction with informative content. To attract attention and communicate interactivity, life-sized user representations are displayed on the hallway displays [21, 22, 30]. In addition, the particles of the *CommunityMirror* are shown on the hallway displays to spark interest in the presented information space among passers-by. Interaction with information particles is not supported at the hallway displays. Instead, the particles flow from the hallway displays to the direct-touch display where users can interact with it using touch.

To realize the interactive hallway we built two moveable self-standing walls (2 × 2.20 m), constructed from a plugged wooden frame, two triangular feet, and a projection screen with a roller blinder system. On top of each frame, a Kinect camera is mounted. The camera is positioned 25 cm above and behind the top edge of the frame, using an L-shaped extension. It is tilted downwards by 30 degrees. This alignment results in a satisfactory horizontal and vertical coverage of the area in front of the wall. The camera is connected to a computer standing on the floor next to the wall.

Images on these hallway displays are created by projectors standing behind the walls on a pedestal. We chose rear projection, since passers-by walking in front of the walls would

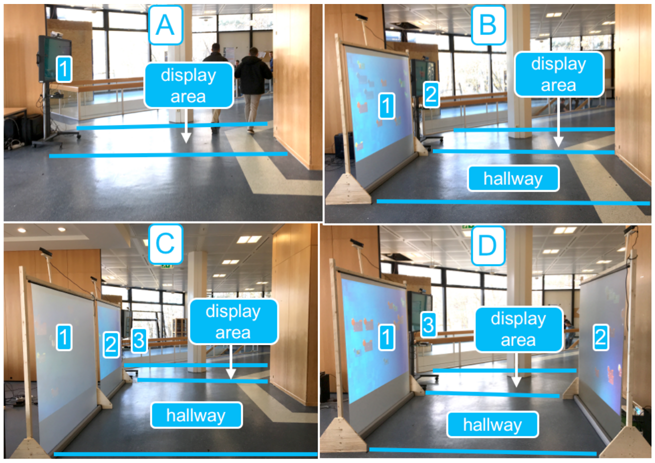

Figure 3. Different display arrangements in the study: direct-touch display only (A), short one-sided hallway (B), long one-sided hallway (C), short two-sided hallway (D). Borders of the interaction space (hallway & display area) are depicted by blue lines.

disturb front projection. The image is displayed in a 4:3 format on the upper area of the screen leaving an unused area of 50 cm height between the floor and the image (see Figure 3).

Display Arrangements

The built hallway displays can be arranged in different ways, hence allowing multiple forms of the interactive hallway to be created. In our study, we used four different display arrangements, which are depicted in Figure 3: Arrangement (A) consisted only of the direct-touch display and no hallway displays were used. In arrangement (B), a *short one-sided* hallway was added to the direct-touch display by positioning one hallway display next to it. In arrangement (C), both hallway displays are placed in a row with the direct-touch display, building a *long one-sided* hallway. In arrangement (D), one hallway display is positioned next to the direct-touch display and the second one is situated opposite of the first one. The cameras on top of the two hallway displays face each other. That way, a *short two-sided* hallway is created, leaving a space of about 3 m for passers-by in between the two hallway displays. In all arrangements using an interactive hallway, the hallway displays are positioned in such a way, that passers-by pass those before they reach the direct-touch display.

User Representations

User representations are created using Microsoft Kinect One's cameras, Kinect for Windows SDK, Processing and JavaFX. The depth data provided by the Kinect Framework is used to cut single persons from the video image. The extracted images are scaled up to match the real size of the person to maximize the realistic picture of the user representation as this helps passers-by to more quickly notice interactivity [22]. Due to the smaller size of the direct-touch display, only the upper body of passers-by is visible (see Figure 4 C). The scaling factor is calculated based on the real-world distance between two joints of the person, considering the size and resolution of the projection image.

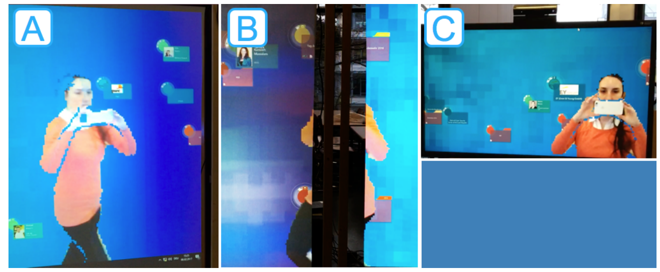

Figure 4. Life-sized user representations on the hallway (A), between two hallway displays (B) and on the direct-touch display (C).

User representations are displayed of all people located within an interaction space, defined by imaginary orthogonal lines on the sides of the displays (see Figure 3). The user representation follows the user as if walking in front of a mirror. Representations are only shown on the display in front of which the user currently is, even if tracked by the cameras of two adjacent displays. If a user is standing between two displays, the corresponding part of the representation is displayed on both displays (see Figure 4 B). To calculate the position of the user representation, the 3D coordinates of the user's head are mapped to the 2D space of the projection area considering size and resolution of the projection image, the position of the camera on the display, the position of the user's head in the image and the scaling factor of the image.

On the direct-touch display, user representations are displayed behind information particles to enable touch interaction. On the hallway displays, user representations are displayed in front of particles, serving as signifiers here.

FIELD STUDY

To obtain an in-depth understanding of how showing a user representation can aid to entice interaction with direct-touch displays, we compare different architectural variants of the hallway to using the display only with or without user representations. This comparison was regarding (1) the effectivity of the variants in making passers-by stop and interact with the installation as well as the (2) social behaviour of the audience.

A field study was chosen as interaction rate and audience behaviour are hard to evaluate in the lab and evaluation in a public setting contributes to a high ecologic validity [2].

Deployment

The interactive installation described in the previous section was deployed in a university canteen during lunch time (11am–1pm) for six weekdays (Tuesday to Thursday) during two consecutive weeks. The deployment was limited to this time slots as there are the most visitors in the canteen.

A 46" direct-touch display was positioned on the left side of a 3.5 m wide passage to the stairwell, parallel to the walking path of visitors leaving the canteen after lunch. This position was chosen because (1) it is frequently visited, (2) visitors have finished their lunch and therefore no urgency to get, pay for, or eat their meals, (3) are not in a waiting situation, (4) walk only in one direction, and (5) there is enough space to place the installation without blocking the way of visitors or disturbances of the rear projection.

Figure 5. Embedding of the installation into the canteen from the perspective of visitors (left) and the opposite direction (right): visitors first passed the hallway, then the display when leaving the dining room.

The interactive hallway was positioned in such a way that visitors passed it before they reached the display. In the two-sided arrangement of the hallway, the wall on the right side had to be close to the wall of the dining hall so as to leave enough space for passers-by in the hallway. To create a sufficiently large projection, a short-throw projector was used. The projectors on the other side of the hallway were positioned at a distance of approximately 3 m to create an image of the desired size. Figure 5 illustrates, how the installation was integrated with the canteen and its furniture.

Variants

In the field study, five different variants (v_1-v_5) were evaluated (see Table 1). Four of these variants (v_2-v_5) differ in the arrangement of displays (A-D). In these four variants, user representations are shown at all displays of the interactive installation. In variant v_1, the same display arrangement (A, *display only*) as in v_4 is used, but no user representations are displayed. So, v_1 represents the baseline setting, in which the direct-touch information display is deployed without additional displays and interaction modalities.

Study Design

During the six days of our deployment, the setup was changed on a daily basis. This was done, since rearranging required significant time and effort and would have likely influenced results by attracting the attention of visitors of the canteen.

To minimize the novelty effect, we decided to deploy one of the variants including the hallway displays (v_5) twice – once at the beginning and once at the end of the deployment – and subsequently exclude data from the first deployment from further analyses. Note, that the canteen is the main location to have lunch on campus. Hence it can be assumed that many students and staff members visit daily, hence having passed the long one-sided hallway during the first deployment. Our results indicate that this was a reasonable approach, as the novelty effect indeed played a role in the study: The percentage of passers-by that stopped at the installation decreased from 24.7% at the first day to 14.2% on the last day. As a consequence, the interaction rate decreased from 17.1% to 9.9%. Also the average duration of interaction was higher (31 s) on the first than on the last day (23 s).

After the introductory deployment of the long one-sided hallway on the first day (v_5), the five variants were evaluated in the following randomized order (see Table 1): v_1 (baseline), v_2 (short one-sided hallway), v_3 (short two-sided hallway), v_4 (display only) and v_5 (long one-sided hallway).

day	week day	week	variant	hallway	user rep.
1	*Tues.*	*week 1*	v_5	*long one-sided*	*yes*
2	Wed.	week 1	v_1	no (baseline)	no
3	Thurs.	week 1	v_2	short one-sided	yes
4	Tues.	week 2	v_3	short two-sided	yes
5	Wed.	week 2	v_4	no (display only)	yes
6	Thurs.	week 2	v_5	long one-sided	yes

Table 1. Order of deployment of each variant within two weeks.

Data Collection and Analysis

Our findings are based on observations, interviews, recording of depth data and automated logging. An observer was seated at a lunch table between other visitors of the canteen, where the behaviour of passers-by could be well perceived. He made notes about any noteworthy events in front of the installation. The interviewer was hidden behind the direct-touch display and stepped forward when users were leaving the installation. He asked users what made them stop and what they expected to be able to do with the installation and why. Furthermore, he asked why they did or did not interact with informative content. To get a feeling about how many users came back to interact a second time, he asked them, if they had already seen and interacted with the installation before.

For privacy reasons, we were not allowed to record users on video for data analysis. Instead we recorded the depth images from the Kinect framework, which shows anonymized silhouettes of the users. We used the recorded depth data to analyze (1) how many passers-by stopped in front of the installation, (2) how many users played with their user representations, (3) tried to interact with informative content using their user representations and (4) interacted using touch. In addition, the position of passers-by and users was tracked every 100 ms and touch interaction was logged. From these loggings, we were able to deduce how many people passed the installation and how many touch interactions occurred.

Interviews and observations were collected in the form of field notes. Two researchers then extracted interesting findings and identified recurring patterns. Finally we related these patterns to the different interaction phases.

Limitations

We are aware of several limitations of our study. Firstly, the installation may still have been subject to the novelty effect, in particular for first-time passers-by. Secondly, there may have been an influence of the week-day. However, since most of the students live on campus it can be assumed that most of them visit the canteen daily.

FINDINGS

During the six days of the field study 4538 people passed our installation. Each variant had individual effects on the audience behaviour. We observed differences in noticing interactivity, arousing interest, playful interaction, interaction with informative content, positioning and group behaviour and the duration of stay based on the applied variant.

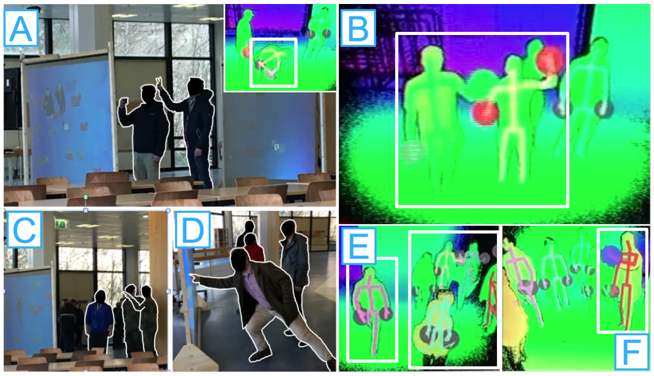

Figure 6. Audience behaviour in the interactive hallway: playful interaction with user representations (A), interaction with informative content using gesture (C) or touch (D) and different group behaviours (B, E, F).

interaction phase	v_5	v_1	v_2	v_3	v_4	v_5
passing-by	*881*	717	855	773	501	811
stopping	*24.7%*	13%	13.2%	23%	14.4%	14.2%
any interaction	*17.1%*	5.4%	8.9%	14.9%	10.8%	9.9%
playful interaction	*12.9%*	-/-	4.3%	6.3%	6.2%	6.5%
with informative content	*8.6%*	5.4%	5.8%	10%	7.4%	5.7%
using gesture	*6.7%*	1%	4.8%	7.8%	4%	4.6%
using touch	*2.7%*	4.9%	1.4%	2.6%	3.8%	1.1%

Table 2. Numbers of passers-by for each variant and percentages of passers-by that (a) stopped, interacted (b) playfully with user representations and/or with informative content, (c) playfully with user representations, (d) with informative content, (e) using gesture or (f) touch.

Phases of Interaction

At our installation, we observed four phases of interaction (not necessarily in that order): (1) Noticing interactivity of the installation, (2) showing interest in the application by stopping in front of the installation, (3) playful interaction with user representations that do not involve informative content and (4) interaction with informative content.

We regard any (successful and unsuccessful) trials of users to select or drag information particles of the application using mid-air gestures or touch as *interaction with informative content*. All other movements of users in front of the interactive installation that do not belong to independent activities (for example, passing by or talking to others) and do not involve interaction with informative content are referred to as *playful interactions*.

We do not provide any quantitative data for noticing interactivity as this is difficult to measure in a field study. For all other phases, the percentages of passers-by that transitioned to these phases are reported in Table 2. The average time passers-by stayed at the installation are shown in Table 3. To investigate significant effects of variant on the transition rates we performed a one-way analysis of variance (ANOVA) for each phase. The results of that analysis are shown in Table 4.

Noticing Interactivity

Interviewees pointed out that without user representations (v_1) interactivity was hard to notice. Those that stopped at the direct-touch display said they deduced from the constant movement of the information particles that those were interactive. Some mentioned that they had already seen the installation before in one of the variants using a hallway. We assume that using the hallway displays the days before led to an increased awareness of the interactivity of the direct-touch display. While this reduces the comparability of our variants, it also shows that the interactive hallway had long-term effects on the awareness of passers-by, that continue even after the hallway is removed from the direct-touch display (v_4).

If user representations were used, those were the primary indicator for the interactivity of the application. In the variant with display only & user representations (v_4), the landing effect [22] could be observed quite often: People realized interactivity late and walked back to the direct-touch display in order to explore it. In variants with hallway (v_2, v_3, v_5), the landing effect did not occur: Passers-by stopped at the installation before they passed by. Accompanying passers-by on their walking path for about 2 m (= length of one hallway display) by user representations seems to be sufficient in order to make passers-by notice interactivity before leaving the interactive surface. This confirms the results of [22] that realizing user representations takes about 1.2 s. Considering an average walking speed of 1.4 m/s passers-by cover a distance of 1.68 m until they notice interactivity.

Some passers-by noticed the user representations but did not stop. They turned their heads towards the installation while walking by and sometimes even looked back. Their facial expressions and comments showed pleasant surprise. Some were so immersed into watching their representation that they almost ran into a column on their walking path.

Passers-by following others often realized interactivity before reaching the interaction space, as they saw the representations of those people walking in front of them. This was apparent as those passers-by immediately started to interact when entering the interaction space. In the variant without hallway (v_4), this counteracted the landing effect. If they knew the people walking in front of them they told them to come back to look at the user representations. In contrast to the honeypot effect [5], this pattern can be caused by passers-by even if those do not pay attention to the display. We refer to this as the *forerunner effect* and think that it is an important factor for increasing the attraction power of interactive public displays.

If no hallway but user representations were used (v_4), the nimbus of the application was larger than its focus. This led to another interesting effect: Passers-by often took a first glimpse on the direct-touch display when they were still outside the interaction space and their representations were not yet visible. Some people realized their user representation when they had passed the display, but many never did. They seemed to have already decided from their first impression that the display is not interesting and subsequently ignored it. This is consistent with the findings of Huang et al. that passers-by spend only a few seconds to determine if a display is of interest [16]. Hence, not only the intersection between the interaction space and the walking path [30] but also between the focus and the nimbus of the display is crucial for

duration of stay	v_5	v_1	v_2	v_3	v_4	v_5
avg. (total)	*18*	22	10	10	36	12
avg. (visited hallway & display)	*31*	-/-	22	23	-/-	23
avg. (stopped only once)	*13*	22	7	8	36	9
time in the hallway	*55%*	-/-	58%	64%	-/-	52%
time at the display	*45%*	100%	42%	36%	100%	48%

Table 3. Average duration of stay in seconds of passers-by that (a) stopped at least once, (b) at the hallway and the display, (c) either at the display or at the hallway. Percentage of time users spent at the hallway and at the display.

noticing interactivity. As passers-by have to be attracted at first glance, the visibility of the attracting stimuli at that moment has to be ensured.

Showing Interest

From the interviews we know, that curiosity of passers-by was aroused by the displayed information particles, if no user representations were displayed (v_1). Passers-by were in particular interested in information of persons they knew.

If user representations were added (v_2-v_5), those attracted the attention and caught the interest of passers-by. People said that they stopped because it was strange to see themselves at the installation. They wanted to explore how the videos came into the application, how large the interactive space was or what could be done with the displays. Some passers-by were just interested in seeing themselves. For example, a man used the installation to correct his ducked posture. The attraction power of user representations could also be deduced from the facial expressions and verbal comments of passers-by: After a short moment of astonishment almost all passers-by reacted with a pleasant smile to seeing themselves on the installation, sometimes even laughing aloud. Mainly when belonging to a group, people also made exclamations of positive surprise like "Wow!' or "How cool is that!".

For the quantitative analysis, we regarded the stopping of passers-by in front of the installation as indicator for their interest in the application. A one-way analysis of variance (ANOVA) revealed an effect of variant, $F = 10.51$, $MSE = 0.13$, $p < 0.0001$. A post-hoc Turkey HSD test revealed that the percentage of passers-by that stopped at the installation was significantly higher if the short two-sided hallway (v_3) was used, compared to all other variants. No other significant differences were found between variants.

From this we learn that adding user representations to the information display alone (v_1) does not increase the interest of passers-by, nor does the enhancement by a one-sided hallway (v_2, v_5). But positioning hallway displays at both sides of the pathway (v_3) helps to arouse their curiosity in the application.

Playful Interaction

Once passers-by had realized their user representations, many performed playful gestures (see Figure 6 A). Other elements on the displays (for example, information particles) were ignored in the first instance. This is in line with Tomitsch et al. [31] who observed playful interactions with a skeleton user representation at a public, gesture-based information display prior to interaction with informative content.

ANOVA	SS	df	MSE	F	p
stopping	5.48	4	0.13	10.51	< 0.0001
any interaction	3.47	4	0.09	9.76	< 0.0001
playful interaction	0.26	3	0.05	1.59	0.1897
with informative content	1.10	4	0.06	4.36	0.0016
using gesture	1.73	4	0.04	10.16	< 0.0001
using touch	0.33	4	0.02	3.96	0.0033

Table 4. Summary of results of one-way analysis of variance looking for effects of variant on the percentage of passers-by that (a) stopped, interacted (b) in some way, (c) playfully with user representations, (d) with informative content, (e) using gesture or (f) touch.

The quantitative analysis revealed that 5.8% of passers-by played with their user representations. There was no significant difference between variants. Most of these playful interactions occurred while standing (71%) and some while passing by. In variants with hallway (v_2, v_3, v_5), the majority (70%) of all playful interactions were performed there.

Typical playful gestures were waving, moving arms, lifting hats, performing a short dance, or kickboxing. Furthermore, playing with the boundaries of the interaction space was observed: People positioned themselves outside of the interaction space and stuck a single body part into it so that only an arm or head was visible on the installation. Also playful multi-user interactions were observed: Couples or friends were standing side by side, holding hands, embracing each other or making dog-ears as if they were posing for a photograph. User representations that were showing the backs of users from the opposite hallway display in v_3 were completely ignored and did not foster social interaction.

Playful actions were apparently performed just for fun. In the interviews, actors confirmed that they wanted to create funny pictures and did not expect anything else to happen within the application. Some users took pictures from their representations with their smartphones to take them home. Interviewees complained about the low resolution (caused by the immense enlargement) and the inaccurate border of the user representation. This shows how important their visual impression is.

Interaction with Informative Content

Depending on the applied variant, 5.4% to 10% of all passers-by interacted with informative content. Interaction with informative content often occurred after playful interaction. Some users skipped playing and directly started to interact with informative content, sometimes showing playful behaviour later. A one-way analysis of variance (ANOVA) revealed an effect of variant, $F = 4.36$, $MSE = 0.06$, $p = 0.0016$. A post-hoc Turkey HSD test revealed that the percentage of passers-by that interacted with informative content was significantly higher if the short two-sided hallway (v_3) was used compared to the baseline (v_1) and other variants using a hallway (v_2, v_5), but not the variant with display only (v_4).

However, the attempts of users to interact with informative content were not always successful. If user representations were displayed (v_2-v_5), one hurdle was to figure out the modality of interaction: The majority of interactions with informative content was done using mid-air gestures (72%):

Users tried to select informative content by moving a hand of their user representations onto it. Thereby they pointed with one finger, spread their fingers, or made a grabbing gesture with their active hand (see Figure 6 C).

If no user representations were used (v_1), only very few passers-by (1%) tried to interact using mid-air gestures. The interviews revealed that those passers-by recognized the Kinect camera on top of the direct-touch display and therefore supposed that the application would react to their gestures. From the increased number of gesture-interactions we learn that displaying user representations at an information display seems to be a strong indicator for gesture-based interaction.

In variants with hallway (v_2, v_3, v_5), not only the number of gesture-interactions increased but also the number of touch-interactions decreased from 4.4% without hallway to 1.7%. Hence, which modality of interaction is assumed, seems to be influenced by the hardware of the displays (thin piece of fabric vs. tv screen). This is confirmed by the fact that touch-interaction mainly occurred at the direct-touch display and only few passers-by (0.66%) tried to touch the hallway display (see Figure 6 D). Furthermore, passers-by did not regard the hallway as mere guidance to the direct-touch display, but expected that they could interact with informative content there: 56% of all trials to interact with informative content occurred in the hallway and 44% at the direct-touch display.

Other Findings

Willingness to Interact

In the previous section, we have already discussed the effect of user representations on the interest of passers-by in the informative content of the application: While displaying user representation caused a high number of playful interactions, the number of interactions with informative content did not suffer from it. On the contrary, the percentage of passers-by that interacted with informative content was higher if user representations were used (v_2-v_5), particularly in the variant with the short two-sided hallway (v_3).

Also the general willingness to engage with the application (playfully or with informative content) was increased by adding user representations: A one-way analysis of variance (ANOVA) revealed an effect of variant on the percentage of passers-by that interacted with the installation, $F = 9.76$, $MSE = 0.09$, $p < 0.0001$. A post-hoc Turkey HSD test revealed that the percentage (5.4%) was significantly lower in the baseline variant (v_1) compared to all variants with user representations except the short one-sided hallway (v_2). Furthermore, the test showed that the percentage was significantly higher (14.9%) if the short two-sided hallway (v_3) was used compared to all other variants.

Approaching the Display

Although the interactive hallway was intended to attract the attention of passers-by and subsequently lead them to the direct-touch display, the actual behaviour of passers-by was different: They stopped, played with their user representations, and tried to interact with informative content not only at the direct-touch display but also in the hallway. The allocation of actions of passers-by among the hallway displays and the direct-touch display is reported in the following.

12% of all passers-by stopped in the hallway and 7% at the direct-touch display. Only 21% of passers-by that stopped in the hallway also stopped at the direct-touch display. In total, 3% of all passers-by stopped in the hallway as well as at the direct-touch display. If two hallway displays were used (v_3, v_5), only 0.2% of passers-by stopped at both hallway displays and the direct-touch display.

67% of all interactions (playful and with informative content), 84% of all playful interactions and 55% of all interactions with informative contents occurred in the hallway. 16% of passers-by that interacted in the hallway also interacted at the direct-touch display.

Passers-by spent more time in the hallway (58%) than at the touch display (42%), in particular if the short two-sided hallway (v_3) was used. The average duration passers-by stayed at the installation was shorter (9.3 s) in variants with hallway (v_2, v_3, v_5) compared to variants without hallway (v_1, v_4) (29 s). If passers-by stopped both in the hallway and at the direct-touch display, the average duration of stay (22 s) was about the same as in the baseline variant (v_1). The highest average duration of stay (36 s) was achieved if only the direct-touch display and user representations were used (v_4).

Positioning & Group Behaviour

In general, single users seemed to strive for maximal personal room and privacy. They tended to move to an unoccupied screen rather than joining others (see Figure 6 E). This behaviour is similar to people taking a seat in a free row in a bus or train rather than sitting next to a foreign person.

The long one-sided hallway (v_5) held enough space for large groups. If one person stopped to interact, the rest of the group gathered around. After some seconds of watching, group members started to interact from behind and then quickly distributed in front of the installation. In the short two-sided hallway (v_3), all group members faced the same hallway display. They were rather watching others from outside of the interaction space than distributing on both hallway displays. We assume they enjoyed exploring the installation together and that standing back to back would disturb social experience.

As is also reported by [17], groups often cooperatively explored the application in one of two ways: (1) If one person started to interact in some way with the application, others imitated that behaviour. It is already known that social learning occurs at public displays [17, 30]. But people do not only learn from experienced users. They also take in (wrong) ideas from other unknowing users: At our installation, users often tried to interact with information particles using mid-air gestures after they watched others doing so – although this was not supported by the application (see Figure 6 B). (2) Other groups were split into one actor who was actively interacting at a central position and multiple passive observers gathered around the actor watching him (see Figure 6 F).

DISCUSSION & DESIGN RECOMMENDATIONS

In the following we summarize and discuss our findings. Furthermore, we derive some specific design recommendations.

Intersection between Nimbus and Focus

By adding an interactive hallway to our application, we increased both its focus and its nimbus. As a result, the *landing effect* occurred less and the *forerunner effect* more often, as passers-by had more time to realize their own and other people's user representations while walking by the installation. When increasing the focus and the nimbus, also the intersection between those areas becomes larger. It was apparent that the intersection is relevant for noticing interactivity: The interest of passers-by has to be sparked on their first glimpse of the display. If at that time, passers-by are outside of the focus of the display, no user representations are visible that could attract their attention. Consequently, we recommend to strive not only for a large system nimbus and focus, but also for a large intersection between both areas.

Opposing Interactive Surfaces

Among all variants of adding displays to our interactive installation, the two-sided hallway was most effective in sparking interest of passers-by and enticing interaction. Hence, we recommend to expand the interactive surfaces of public display installations to both sides of the pathway of passers-by. Particularly in wider passages, the distribution of interactive surfaces in the room can help passers-by to recognize the user representations and thus the interactivity of the installation.

Assistive Displays

People who were not able to interact with the first display they encountered, subsequently did not try to interact with further displays in the vicinity. Furthermore, the use of more displays counter-intuitively reduced the overall interaction times. From this we learn that display owners need to be careful with augmenting the surrounding environment. In cases where display owners are operating a successful installation, adding another display may indeed negatively influence interaction numbers with the original display as well as interaction times. In order to still benefit from the advantages of enlarged nimbus and focus and opposing interactive surfaces, designers could adapt existing approaches for directing the users position in front of public displays [2,6] to actively guide them to and foster interaction with the main display.

Mixing Interaction Modalities

If user representations were displayed, many users expected that they could interact using mid-air gestures and did not recognize the touch-interactivity of the main display. However, Houben et al. [15] showed that switching between different interaction modes at public displays is possible. They used a physical input device on a table in front of a public display to arouse curiosity of passers-by. When the display then presented its interaction possibilities, many users perform the primary interaction using direct-touch at the display. Hence, a conceivable approach is to use user representations as curiosity objects to arouse the interest of passers-by and then provide further hints revealing the touch-interactivity of the display. This should be further examined in future work.

CONCLUSION

In this work, we described our approach of augmenting the vicinity of public touch-sensitive information displays by screens showing life-sized user representations with the objective of attracting passers-by, communicating interactivity and enticing interaction. From our field study, we learn that (a) providing additional (opposing) screens foster interaction with public display installations, but (b) may also reduce interaction rates at the main display; (c) a large intersection between focus and nimbus helps passers-by to notice interactivity; (d) using playful elements at information displays is not counterproductive; (e) switching interaction modalities within a public display installation is hard to understand.

We deduced design recommendations for increasing interaction rates at public touch-enabled information displays by means of displaying user representations. In future work, we plan to further improve our approach by adding additional signifiers to the user representations in order to clarify the modality of interaction of the touch display.

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