Chained Displays: Configurations of Public Displays Can Be Used to Influence Actor-, Audience-, and Passer-By Behavior

Maurice ten Koppel **Gilles Bailly** **Jörg Müller** **Robert Walter**

Quality and Usability Lab, Telekom Innovation Laboratories, TU Berlin, Germany
Firstname.Lastname@tu-berlin.de

ABSTRACT

Most interactive public displays currently rely on flat screens. This form factor impacts how users (1) notice the public display (2) develop motivation and (3) (socially) interact with the public display. In this paper, we present *Chained Displays*, a combination of several screens to create different form factors for interactive public displays. We also present a design space based on two complementary concepts, *Focus* and *Nimbus*, to describe and compare chained display configurations. Finally, we performed a field study comparing three chained displays: *Flat*, *Concave,* and *Hexagonal*. Results show that *Flat* triggers the strongest honeypot effect, *Hexagonal* causes low social learning, and *Concave* triggers the smallest amount of simultaneously interacting users among other findings.

Author Keywords

Public displays; Form factor; Chained displays; Field study.

ACM Classification Keywords

H.5.m [Information Interfaces And Presentation]: Miscellaneous.

INTRODUCTION

Interactive public displays are increasingly becoming prevalent within public spaces such as airports, fares, public transit stations, and shopping areas. For instance, users can use them to get information, watch multimedia content, or to play games. However, several studies reported three widespread problems: (1) noticing the public displays, (2) developing motivation to interact and (3) designing for parallel or collaborative interaction. While most public displays rely on one single *flat* screen, we argue that different form factors impact user behavior and can alleviate the previous limitations.

We propose *Chained Displays* (Figure 1) as alternative to the widespread flat public displays. Chained displays consist of a combination of several screens to create a large non-flat continuous display surface. Thereby they provide designers the opportunity to create novel display configurations by changing the quantity of and the angularity between the displays.

In order to analyze the large variety of chained displays configurations, we propose a design space based on two complementary concepts: *Nimbus and Focus* [2]. *Nimbus* refers to a sub-space within which a person projects their presence. *Focus* is its counterpart and represents a sub-space within which a person focuses their attention. We use these two concepts to describe and compare two promising chained displays configurations: *Concave* and *Hexagonal.* We also compare them to the traditional *Flat* configuration (see Figure 1). We discuss these different configurations in regard to actor- (people interacting with the displays), audience- (by-standers observing actors), and passer-by (people passing by the installation) behavior as well as five commonly observed effects on public displays.

We conducted a field study to compare the three chained display configurations within the entrance hall of a university canteen. In particular, we examined how the angularity between the displays impacted actor-, audience- and passer-by behavior. As motivation for people to interact with the chained displays, we designed an engaging but simple gestural version of the classical *space invaders* game. Our findings, based on observation, questionnaires and interviews, reveal how the three chained displays were unique in terms of social learning, group approach, the strength of the honeypot effect, the amount of simultaneous interaction, and where individuals position themselves in front of the displays.

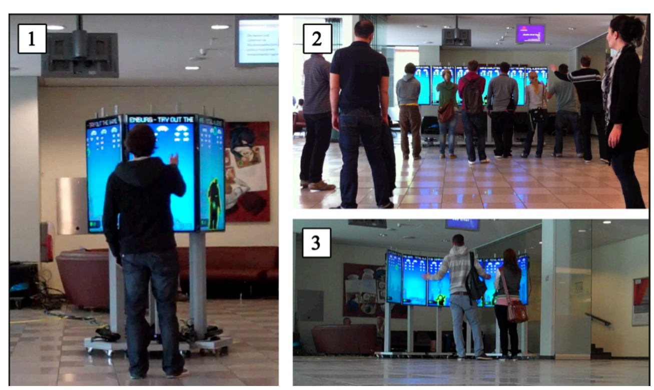

Figure 1: *Chained Displays*: (1)*Hexagonal*: actors can limitedly see other screens resulting in low social learning (2) *Flat* attracts more people (Honeypot) because actions and their effects can be observed (3) *Concave*: actors have a limited interaction space resulting in few simultaneously interacting users.

The primary contributions of the paper are:

- A novel class of generic non-flat public displays.
- A design space based on two complementary concepts: Nimbus and Focus.
- A field study comparing 3 public display configurations.

RELATED WORK

Non-flat public displays

Non-flat displays have been proposed within the context of augmented reality [17], immersive environments [12] and handheld devices [32]. In the context of public displays, most displays are based on horizontal [21] or vertical [18] *flat* screens. The orientation of public displays can impact users' behavior [31]: Rogers et al. showed that people collaborate more effectively when situated around the tabletop than in front of a wall display [31]. We argue that non-flat displays can also impact the behavior of users.

Few spherical displays have been proposed [3, 8, 20], but their medium size (16"-24") limits their practical application for public displays. Beyer et al. investigated cylindrical displays in [4]. A lab study involving single users indicated that the cylindrical shaped displays invited users to actively move around the display. This study demonstrates that non-flat public displays can impact the behavior of users, however fails to capture the social complexities that are inherent to public spaces such as performative interaction [10]. For this reason, we conducted a field study comparing three display configurations.

Field studies on public displays

Several field studies [6,7,9,21,25,26] have been conducted to capture "natural" user practices with public displays. For instance, Peltonen *et al*. installed a wide multi-touch display in Helsinki [26]. They observed and highlighted several social effects such as social learning, performative interaction and issues related to the intrusion of virtual spaces. Cao *et al.* [7] deployed a collaborative multiplayer game and reported on the playing, spectating and social experience of the game. These studies shed light on social phenomena emerging around public displays. What remains unknown is how the form factor of the public display contributed to the observed effects.

We now review five main effects related to public displays that are used to guide our analysis on the impact of the form factors on user behavior. Moreover, we will explicitly report on these effects based on our own observations during the field study.

Stages of interaction

Several models have been proposed to describe the different stages of interacting with a public display [13, 24, 33, 36]. For instance, the *audience funnel* [24] describes 6 stages of interaction. First, people are unaware of the public display (*passing-by*). Then, after *viewing and reacting* to the public display, users test the interactivity of the screen with *subtle interaction* (e.g. they might wave their hand). They come closer to the screen to perform *direct interaction* with the device. In the context of multiple displays, users might start interacting with other screens (*multiple interaction*). Finally, they can perform *follow-up actions* such as taking a photo of the device. This model is especially relevant for our setup as it focuses on both multiple displays and gestural interaction.

Performative interaction

Users of public displays are simultaneously in three different relationships [29]: (1) the interaction with the public display; (2) the perception of oneself within the situation and (3) acting out a role for others to observe [10]. The experience people have with public displays is determined by the interaction between these roles. This can for instance result in social embarrassment [27], but it can also lead to users showing off [29].

Reeves *et al.* differentiated two ways in which users can be observed [29]: *manipulations* and *effects*. *Manipulations* refer to the performer's gestures while *effects* refer to the visible result of the interaction on the display. Installations making manipulations highly visible might trigger hesitance to interact but can favor social learning and foster the social experience around the display [27]. We argue that the form factor of public displays contributes strongly to the visibility of manipulations and effects, yet its impact is poorly understood.

Personal space

Personal space is the "invisible bubble" around the self used as mechanism to control the desired state of privacy [1]. The proxemics between people depends on many factors such as the social relationship [1]. In the context of public displays, we differentiate between the intrusion of *personal* and *virtual* space. Both intrusions lead to social discomfort and could result in people leaving the display [21,26]. Modifying the form factor of a public display changes the size of the interaction space. This can impact the number of simultaneous users or the level of social comfort.

F-Formations

F-formations is a tool to analyze how the organization of space supports or blocks social interactions [22]. It refers to the specific spatial arrangement people persist during social interaction in which people maintain a shared attention area referred to as the *shared transactional segment* [19]. While social interaction typically structures these spatial arrangements, spatial structures can in return also influence the f-formation and thereby the resulting social interaction [19]. The form factor of a public display is an example of such a spatial structure and thus plays a crucial role in influencing the user experience. However, this effect has only been investigated within lab studies (e.g. [31, 34]).

Honeypot effect

The *honeypot effect* [6] is the social effect of people being attracted to the public display by other people standing in close vicinity to it. It creates a social atmosphere around the public display in which people do not only signal their interest towards the display but also express that they are open for social interaction. Several field studies on public displays [24, 26] reveal that the honeypot effect is powerful in attracting users: once there is an initial crowd, people will be attracted by it and thereby again attract others [16]. Except for the location of the public display [6], it is not clear how this effect can be catered for and whether the form factor of the public display can influence this effect.

In summary, only few studies proposed different form factors for public displays and never compared them in a field study. While several effects have been observed during field studies, it is unsure how the form factor contributed. For these reasons, we conducted a field study contrasting form factors and report on the five described effects (*stages of interaction*, *performative interaction*, *personal space*, *f-formations* and *honeypot effect*).

CHAINED DISPLAYS

Chained displays consist of a combination of several screens to create large non-flat display surfaces (Figure 2). Each screen is linked to its neighbor screens in order to maintain a "global continuity". By changing the angularity between displays, we can easily modify the form factor of the display surface. Our chained displays also include a depth sensor (e.g. Microsoft Kinect) to allow users to perform mid-air gestures in front of the displays.

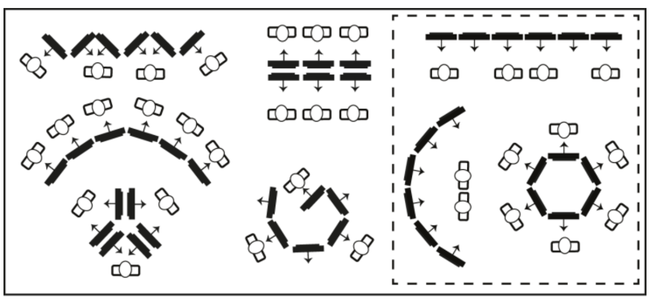

Figure 2: An overview of possible 6-chained display configurations. In dashed lines: the chained displays we tested

We used 40" LCD displays to build our chained displays. They were chosen for their wide viewing angles and thin bezel. We also built specific stands designed for this setup in order to (1) guarantee a high level of stability, (2) easily transport the displays and (3) have the screens close to each other whatever the angularity. While the minimal chained display configuration relies on 2 screens, our setup is based on 6 screens. This is a good compromise between (1) the number of users it can support (2) the number of possible configurations and (3) practicalities to run the experiment.

DESIGN SPACE

We propose a design space to describe and compare chained display configurations. This is followed by an analysis of the three tested chained displays according to our design space. Finally, we discuss how the design space helps in understanding how the configurations impact the five aforementioned effects.

Scope and Definition

To precisely understand the interaction between users and the system as well as interaction between users many factors need to be considered such as location of the display, the architecture of the hall/room, the flow of people, the type of population around, the form factor of the displays, etc. Some tools such as proxemic interactions [15] can help to reason about social interaction around public displays. In this article, we use the concepts of *Nimbus* and *Focus* [2, 30] to analyze how chained displays configurations influence *actors*, *audience* and *passers-by*.

The *Nimbus and Focus* concepts [2] have been applied in other contexts such as virtual reality [2], privacy [5, 23] or multimedia streams [14]. *Nimbus* is defined as a sub-space within which a person projects their presence. *Focus* is its counterpart and represents a sub-space within which a person focuses their attention. While Nimbus is related to the question "*Where can I be perceived?*". Focus is more related to the question "*What can I observe?*", We argue that these two concepts can help to reason about the behavior of individuals around public displays. Although they are insufficient to precisely describe the complex environment of public displays, they form a basis on which more complex concepts can be described.

Due to the huge size of possible chained displays configurations, we decided to mainly focus on "curved" configurations: configurations where the angularity between each pair of screens is similar. In particular, we distinguish *Concave* and *Hexagonal* (the latter as an example of a Convex configuration) as well as *Flat* (as baseline) to systematically illustrate our analysis. These three configurations (Figure 2) are both simple and sufficiently different to highlight the differences between chained display configurations in regard to our two concepts.

To understand the experience people will have with chained displays, we apply the Nimbus and Focus concepts to the four main components of the public display: The *public display* itself, its *actors*, its *audience* and its *passers-by.*

Public display

The concepts of Nimbus and Focus are originally defined for persons. We argue that the same terms can be used to describe from where a display can be perceived and what it can 'perceive', i.e. what its interaction area is.

Nimbus: Inspired by the concept of Isovist [11, 35], the nimbus of a public display refers to a sub-space from which the content of the system's displays can be perceived. Figure 3 illustrates strong differences in terms of Nimbus of the system. Whereas the content presented on *Flat* can only be perceived from one side, *Hexagonal* can be perceived from all around it. Finally, *Concave* has the lowest nimbus.

Focus: Inspired by the concept of aura [2], the Focus of a public displays includes the sub-part within space for which the interaction is enabled. Figure 4 shows that the interaction space decreases when the curvature increases.

Actors

Nimbus: The nimbus of actors can be described in relation to their physical body (manipulations) or their representation on the screen (effects). Because the public display itself blocks visibility, increasing the curvature increases the physical nimbus of the actor (Figure 5). In addition, *Hexagonal* favors the nimbus of manipulations rather than effects. Indeed, certain audience members (D2) and actors (A2) can see the face of actors (dotted line) and the subtle interaction performed in front of them but cannot see their screens (*effects*). Notice that the distance of the actor from the screen in *Hexagonal* (to a lesser extent in *Concave*) impacts the nimbus area of the actor. For instance, direct touch interaction reduces the nimbus of the actor.

Focus: Only *Hexagonal* limits the number of screens (1-3) that actors can see simultaneously. However, it offers the opportunity for actors to see other actors (A2) and audience members (D2) in their peripheral vision during interaction (Figure 6). Once again, the distance of the actor from the screen modifies the observable area.

Audience members and passers-by

As passers-by and audience members share a lot of similarities in regard to their nimbus and focus, they are discussed together.

Nimbus: Whatever the configuration (Figure 7), an audience member can be seen by other audience members (or passers-by) from the back (D4) or the side (D2). Moreover, in *Hexagonal*, an audience member can be perceived from the front (D2) but only by some actors (A2).

Focus: In *Flat* and *Concave*, audience members can simultaneously see *manipulations* and *effects* performed by all actors. This in contrast to *Hexagonal*, where only the *manipulations* of up to 4 actors and the *effects* of up to 2 actors can be observed. They can in return see other audience members from the front (D1).

Discussion

The concepts of Nimbus and Focus provide a tool to analyze the differences between chained displays in a systematic way. We also derived five main effects of public displays from literature: *Stages of interaction*, *Performative interaction*, *Personal space*, *f-formations* and *Honeypot effect*. Equipped with these concepts, we can now revise our original research question: How does the shape of chained displays influence actor, bystander and passer-by behavior? A more specific version would be: How do different focus and nimbus of chained displays influence stages of interaction, performative interaction, personal space, f-formation and the honeypot effect? In order to address this research question we conducted a field study.

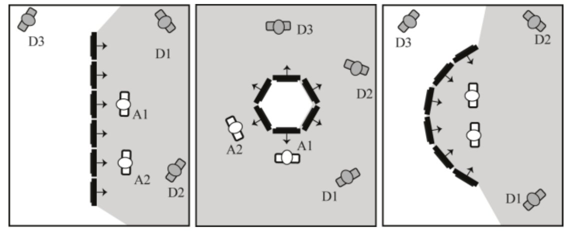

Figure 3: Public display Nimbus for each configuration: Flat, Hexagonal and Concave (in white actor, in gray audience member).

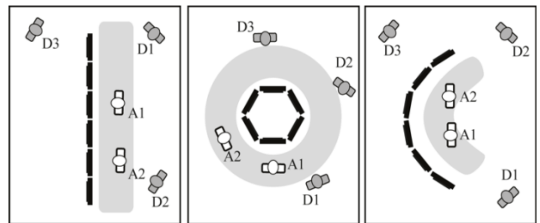

Figure 4: Focus of three chained displays configurations: Flat, Hexagonal, Concave.

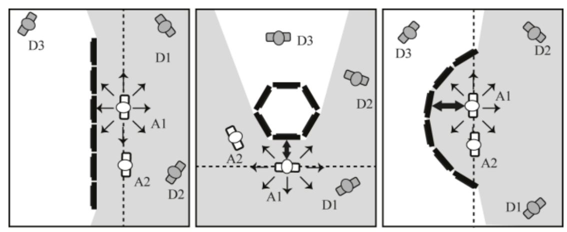

Figure 5: Actor nimbus depending on the configuration.

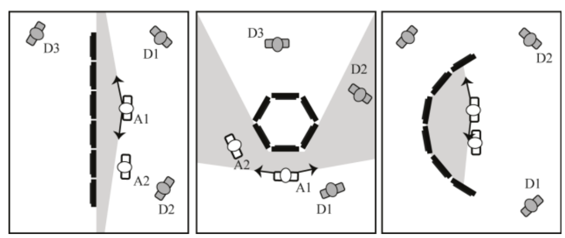

Figure 6: Actor focus for each configuration.

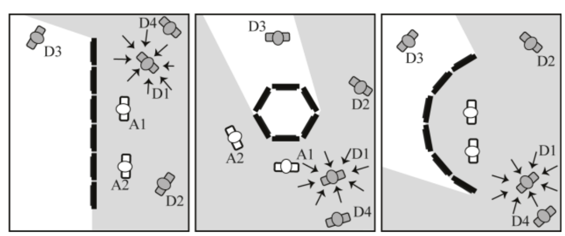

Figure 7: Audience nimbus for each configuration.

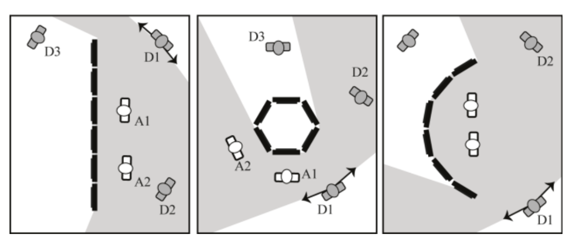

Figure 8: Audience focus for each configuration.

FIELD STUDY: COMPARING CHAINED DISPLAYS

The goal of the field study was 1) to qualitatively compare three chained displays configurations (*Flat*, *Hexagonal* and *Concave),* 2) to investigate the impact of form factor on actor-, audience- and passer-by behavior 3) to understand the influence of Nimbus and Focus on stages of interaction, performative interaction, personal space, f-formations and the Honeypot effect.

Game content as motivation

To motivate people to interact with the chained displays we designed a simple gestural version of the classical *space invaders* game (Figure 9). It was implemented in Flash and used the OpenNI framework to capture depth images and the OpenCV library for processing depth images. The design of the game was guided by 5 principles:

Immediate usability. Users interacted as soon as they entered in the interaction space: Their body contour appeared on the screen and they started to shoot projectiles immediately. So, novice users only required a minimum amount of knowledge to start playing the game.

Ad-hoc gaming. The game was designed to let people join and leave when they want to (no need to wait for the next round or to achieve a specific goal after which the round is ended). Users could engage in short interactions but could also play for a long time as aliens were regenerated.

Gestural interaction. The game is based on body gesture interaction to reward demonstrative interaction. For instance, users need to move their hands in order to define the direction of projectiles. Moreover, users have to move their body to avoid aliens' projectiles.

Advanced control and difficulty. We created advanced controls to invite intermediate users to actively explore the possibilities and to keep expert users motivated. Spreading the arms increases the shooting frequency while moving the arms up increases the shooting power. Finally, the difficulty increases over time by aliens shooting faster.

Deployment

The three chained display configurations were deployed for three days in the entrance hall of a university canteen in Berlin. Figure 10 provides an overview of the space: People mainly come from two entries (A & B) and move towards the canteen (C). After lunch, they leave the canteen (points D & E) by exiting through the entrance hall. This hall has several advantages: it is big, has a strong flow of people and is indoors. However, the population is not heterogeneous: It is mainly composed of students (and personnel of the University) and a high proportion of large groups (>5). The displays were positioned in the area F, directly besides the main walking path for users. People walked parallel to the flat or concave displays, while passing on one side of the hexagonal display (people could still circulate around the configuration). One alternative placement would have been to position the hexagonal display directly on the main walking path, so that people would circulate to both sides.

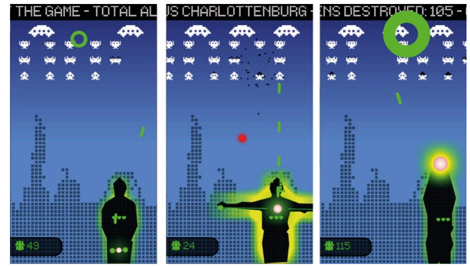

Figure 9: Left: users standing in front of the displays immediately started interacting. Middle: By spreading the arms the shooting frequency is increased. Right: By moving the arms up the shooting power is increased.

The side position was chosen because (1) the position was the same for all three displays, eliminating confounding effects of position (2) positioning on the side of the walking path is more realistic. Indeed, positioning of public displays is strongly regulated. For example, the OSHA standard [28] explicitly mentions "Exit routes must be free and unobstructed". Thus, the majority of all advertising columns are placed to the side of the main walking path.

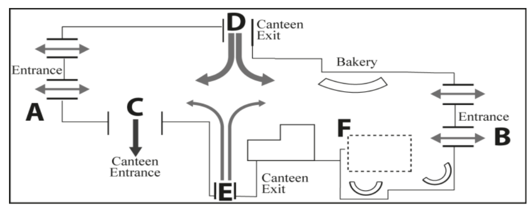

Figure 10: Overview of entrance hall. A and B are the entrances of the space. The chained displays were installed in area F

Data collection and Analysis

We used two methods to collect data:

Direct observations and videos. Our primary data collection method was direct observation. Three researchers observed the displays and kept field notes. We also deployed several cameras capturing how users approached and interacted with the chained displays. Videos were used to review situations from the field notes in more detail.

Interviews. We approached those who played for at least 10 seconds to fill in the survey right after they stopped playing. The survey had 24 questions (inspired by [18]) and covered items related to the user and social experience, personal space and f-formations. We also conducted semi-structured interviews with actors and audience members.

The data was analyzed qualitatively by two researchers. As a guide for analysis, the concepts of stages of interaction, performative interaction, personal space, f-formations and the Honeypot effect were used. Qualitative and explorative analysis was chosen because of the early stage of research regarding interactive public displays, which does not yet provide accepted theories that lend themselves to hypothesis formulation. Because of the social nature of the research question, we emphasize ecological validity over a controlled setting.

Design

Each configuration was tested for a single day (3 days in total) during lunch time (from 11:00 am to 2:00 pm). The first day we tested *Flat*, followed by *Hexagonal* and finally *Concave*. To understand to what extent a novelty factor was present, we included an item in the survey asking whether actors had just seen the installation for the first time (day 1: 93.8%, day 2: 73.1%, day 3: 59.1%). The results indicate that a global awareness of the presence of the game was developed over the test days. While it is a limitation of our study, it was impossible to test the 3 configurations at the same time. Moreover, the questionnaire showed that still a large number of users playing the game on the third day were still new users (72.7%).

FINDINGS

Over the three days, on the order of 250 people interacted with the game ranging from relatively short interactions (a couple of seconds) to long interactions of around 5 minutes.

Findings from the survey

We compared the responses of the 66 collected surveys about configurations but our analysis returned no significant differences. In general, people responded they had a positive experience with the game. People who played the game reported that they only had few worries of social embarrassment. Moreover, none to few issues of personal space were experienced. In terms of the social experience created by the game, few people felt they created new contacts but judged the social experience more towards natural as unnatural. Players responded that they did not change their behavior towards others. In response to whether they observed other players using the screens, and whether they observed the actions, respondents were neutral: not declining but also not fully agreeing.

Observation and video analysis

In this section we report on our observations. Our observations are organized according to the process how an individual approaches the display. After the approach, we describe how individuals and groups position themselves in front of each configuration and the impact on the number of simultaneously interacting users. We also report on social embarrassment and social learning. Finally, we mention the size of the audience.

Individual approaching

We observed two distinct ways in how people approached the displays:

(1) Many people started out as part of the audience and after brief observation of the game, directly approached the displays having a sense of what actions to perform. This process looked similarly for the three tested configurations.

(2) Passers-by passed through the interaction space, noticed the interactivity and were intrigued to interact. In *Flat*, passers-by only made a small detour when they noticed the display as the chained display was positioned in parallel and not far from the natural walking path (Figure 11-top). In *Concave*, they performed the same detour, however, many showed a hesitance to enter the shape and thereby did not notice the interactive component (Figure 11-bottom). We argue this is due to the shape of the chained display that affords a clear entry point.

Finally, *Hexagonal* triggers different passing-by behavior. Here passers-by only have the front screen to get a reaction of the system as the other screens were too far from the natural walking path. As a consequence, many noticed the interactivity of the setup too late and did not stop. For those passers-by who did notice it in time, we observed that they followed the curved path around the displays, almost as if the displays had a gravitational pull (Figure11-middle).

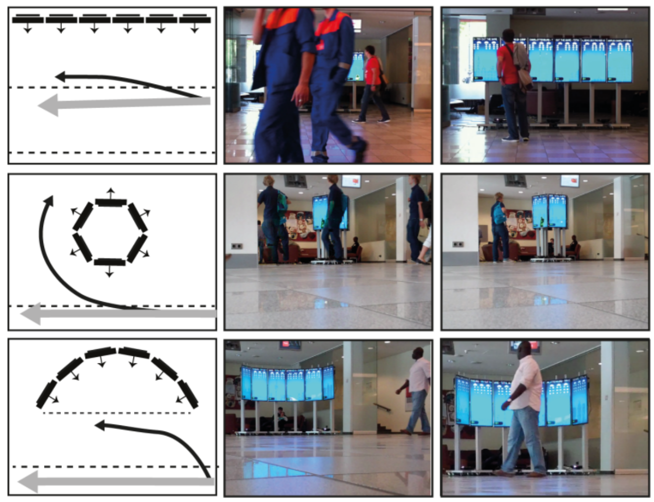

Figure 11: Top: A user noticing interactivity while passing by *Flat*. Middle: A user orbiting around the Hexagonal (several instances of the *same* user are displayed to describe the path. Bottom: a user avoiding the inner space of the Concave.

Individual positioning

We observed that the configurations influence where individuals position themselves in front of chained displays (Figure 12) especially in the case of few actors being present (up to 2 persons).

In *Flat*, we observed that individuals frequently approached one extremity of the public display even if no other actors were present. Individuals seemed to maintain a rule to maximize the amount of personal space with others, anticipating where joining strangers could position themselves (Figure 12-top). This is in contrast to *Hexagonal*, where individuals generally annexed the neighboring screen of an actor (Figure 12-middle). Probably, the physical distance between them was large enough for people to feel comfortable. Finally, in *Concave*, the first user generally positioned himself/herself in the middle of the setup. When a second individual approached, s/he frequently waited for the actor to leave or positioned himself/herself at one extremity (at the limit of the interaction space) as shown in figure 12-bottom.

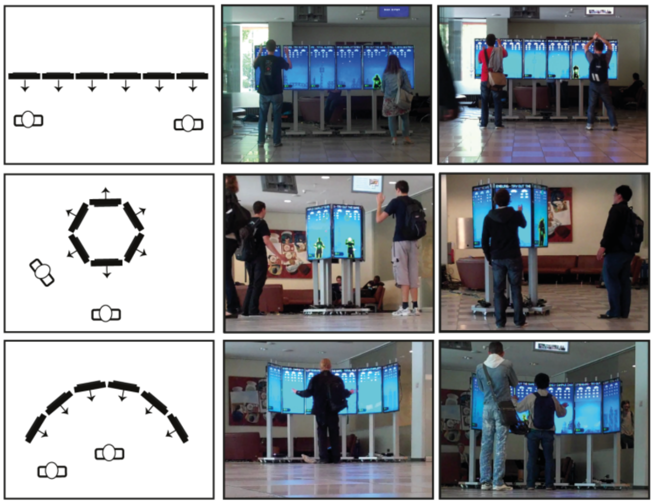

Figure 12: Top: people maintained a *safe* distance in *Flat.* Middle: strangers occupying neighbor screens in Hexagonal. Bottom: *Concave* afforded 1 to 2 players simultaneously

Our findings contrast with [4] who found that actors are generally positioned in the middle of a flat display. This might be explained by the fact that the user study tested single user interaction where users did not have to anticipate other users.

Group approaching

We observed that within all conditions, groups generally followed one "brave" member who initiated the interaction. The group quickly followed, but the members positioned themselves differently within the conditions.

Flat: Once a brave member had initiated the interaction, the rest of the group approached the display and divided up in front of the display in order to have one screen per group member as shown Figure 13-top.

Hexagonal: After a member initiated the interaction, the rest of the group usually formed an audience around the player (figure 13-middle). At many occasions, we observed that a member of the group tried to play at a neighboring screen, but returned quite quickly to re-join the audience of the other player. It seemed the relatively large distance from the group signaled detachment of the group and as a result he/she returned to the group.

Concave: The group also formed an audience around the first player but at a larger distance. Moreover, we sometimes observed that the brave individual returned to the group and someone else would take his place (Figure 13-bottom).

Simultaneous interaction

We observed that the form factor impacts the number of simultaneous actors (Figure 14). While we frequently observed 5 simultaneous actors in *Flat*, it was generally limited to 2 or 3 in *Hexagonal* and 1 or 2 in *Concave*.

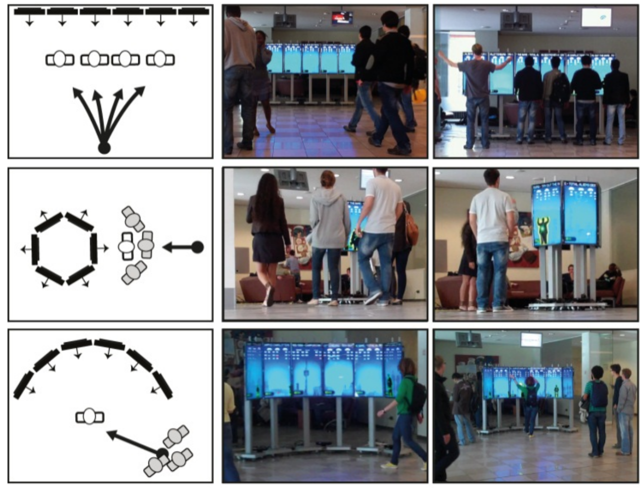

Figure 13: Top: a group approaching and dividing in front of the screens. Middle: A group approaching and centering around one screen. Bottom: A group member detaching to play.

Surprisingly, in the case of *Hexagonal*, people did not interact with the screens that were not oriented in the direction of the pathway: people seem to interact with screens only if it does not force them to diverge from their initial pathway. We expect that moving *Hexagonal* to a location directly in the pathway (i.e. towards the center of the large hall) would increase the number of simultaneous actors. Finally, as mentioned above, *Concave* affords interaction for only 1 or 2 actors due to the lack of personal space.

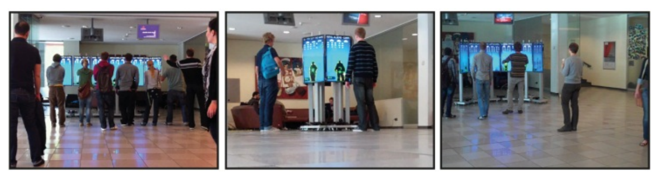

Figure 14: Left: multiple people playing simultaneously. Middle: Only the 2 front displays are occupied. Right: *Concave* afforded 1 to 2 users.

Social learning

Our game supports novice users (intuitive gestures) and lets more experienced users discover advanced gestures. We observed that many people discovered these advanced gestures and often learned them by mimicking successful other users. We frequently observed in *Flat* and *Concave* that actors copy (Figure 15) each other's gestures even if these gestures were not correct. Surprisingly, mimicking happened to a lesser extent in *Hexagonal* although actors could easily observe manipulations of other actors. This may be explained by the fact that for social learning to occur, it is important that actors can see both *manipulations* and the *effects* of other (successful) actors as opposed to seeing only the *manipulations.*

Figure 15: Example of social learning for *Flat.* The user with the black shirt stayed a long time without performing advanced gestures. He starts performing them by mimicking the two students.

Social embarrassment

Most actors had no worries of social embarrassment (most of passers-by were students) whatever the configuration. They frequently performed very expressive gestures as soon as they discovered them. Some of them even took the opportunity to make a small spectacle for their groups or other audience members (Figure 16-middle and -right). However, we also observed some audience members anxiously standing in the proximity of the display (Figure 16-left). It seems that social embarrassment is more likely to manifest itself in a hesitance to interact as opposed to non-expressive behavior.

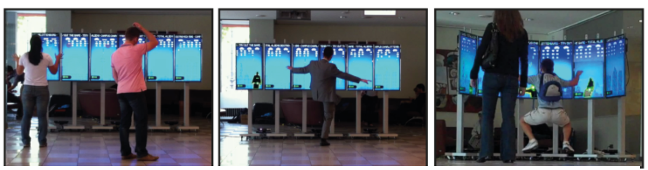

Figure 16: Left: Hesitance to interact. Middle and right: Example of performative interaction

Size of the audience

We observed that *Flat* triggered more audience than the two other configurations. At occasions, different rows of people were formed to observe what was happening. *Hexagonal* triggered less audience than expected.

DISCUSSION

We now revisit the five effects derived from the literature according to the findings of the field study and the concepts of Nimbus and Focus.

Stages of interaction

Configurations with a large system nimbus get noticed better. Given our deployment location, the flat configuration was noticed by most people, followed by the cylindrical and the concave display. This can be explained by the fact that flat configuration had the largest system nimbus given the deployment location, followed by the cylindrical and the concave configuration. Note that the nimbus not only depends on the configuration itself but also on the environment. Had the cylindrical configuration been installed directly in the walking path, it would probably have had a larger nimbus and been noticed by more people.

Configurations with a large system focus (interaction space) better communicate interactivity. We observed that the most important factor for passers-by noticing interactivity is the intersection between the interaction space and the walking path. We argue that the directions of the natural walking paths are an important factor for creating interaction. This directionality is not directly reflected in the design space, but needs to be considered in particular regarding Nimbus.

Performative interaction

Configurations making actors' effects and manipulations highly visible favor social learning. *Flat* favors social learning because actors can easily observe other actor's *effects* (*System Nimbus*) and *manipulations (Actor Nimbus)*. This allows actors to mimic other successful actors and thereby learn the system. In the *Hexagonal*, people can better see other actors' *manipulations* but have limited (or no) view on their *effects.* Thereby, social learning is limited.

Configurations do not seem to impact the hesitance to interact or the expressivity of behavior. Social embarrassment is more likely to manifest itself in a hesitance to interact as opposed to non-expressive behavior. Although no clear behavioral difference between the configurations emerged, *Concave* and *Flat* seemed to attract more performative behavior. They had a smaller nimbus considering the person itself, but the overlapping of the nimbus of the actor and the representation of the actor was larger. For these configurations, the space directly in front of the chained display signals a highly observable stage for an actor to perform his actions.

Personal space

Configurations with a large interaction space have the highest amount of simultaneous users. Configurations with a high system Focus seem to afford more simultaneous users. However, for the hexagonal display, this was only true for the interaction areas that intersected with the walking path of users. Therefore, the size of the intersection between the interaction space and the walking path better explains our observations than only considering the size of the interaction space.

Configurations with a small interaction space do not create more social discomfort nor make people leave. We did not observe occasions where people invaded the personal space of another person playing and thereby making the other person leave. It seems that when a display is occupied, people rather observe the actor and wait for their turn. This is particularly true for displays with a rather small interaction space, e.g. the concave display.

F-formations

The maintenance of the shared transactional space is essential for the cohesion of the group. While *Hexagonal* areas allow groups of actors to position themselves in a slight angle towards each other, we observed that isolated group members quickly returned to the screen where the rest of the group focused on. Audience members and actors have the opportunity to monitor the *manipulations* of multiple players but they lose the shared focus because the *effects* can no longer be observed. In contrast, although *Flat* changed the f-formation to a shoulder-to-shoulder interaction it still allowed groups to observe (virtually) what the other group members were doing (effects) and thereby maintained their "shared transactional space" [19]. In conclusion, the maintenance of the *shared transactional space* is of more importance for the cohesion of the group than the increase of monitoring each other's actions.

Concave configurations favor turn-taking. As this configuration only affords space for a single or two users, a group of people split up in an observing and an interacting group. As the observing group tended to observe from a distance, the social communication between the groups necessarily decreased.

Honeypot effect

Judged by the size of the audience, *Flat* triggered the strongest honeypot effect. We argue that *Flat* catalyzed the Honeypot effect more because (1) its position triggered the highest number of simultaneous actors and (2) all passers-by can observe many *manipulations* and *effects* due to the orientation and the location of the setup (parallel to the walking path). Although we observed something different than we anticipated (*Hexagonal* would trigger the strongest honeypot effect), the configuration with high system, actor and audience nimbus (in our test situation *Flat*) triggered the strongest honeypot effect.

CONCLUSION

We proposed chained displays as alternative to the flat form-factor commonly used within the context of public displays. We then proposed a design space based on two static concepts: *Nimbus and Focus*. It serves to describe and compare chained displays as well as to reason about the 5 commonly described effects found within the literature. We performed a field study and qualitatively compared three chained displays (*Flat*, *Hexagonal* and *Concave*) in an "in the wild" situation. Observations show that each configuration (and more generally form factor) impacts actor-, audience- and passer-by behavior.

From the field study, we learned that *Flat* created the highest honeypot effect, triggered individuals to position themselves at the extremities of the display, triggered groups to divide and occupy multiple screens, and fostered social learning. *Hexagonal* allowed strangers to comfortably play on adjacent screens. *Concave* created the lowest amount of simultaneously interacting people, and caused groups to split into actors and audience. These results can help designers to consider different form factors for public displays as they trigger different user behavior.

Importantly, contrary to our first assumption, the concept of Nimbus and Focus must be extended from the persons themselves to their representations on the screen. Social learning, for example, only occurred if users could see the effects of other people actions on the screen and was strongest when they could see both the manipulations and the effect. Similarly, the honeypot effect was strong for the flat display where audiences could see both manipulations and effects of actions, and weak for the cylindrical display, where the manipulations could be seen from a large area, but not the effects.

The field study also highlighted some limitations of our design space, which provides a simplified model based on two *static* concepts (Nimbus and Focus) to describe user behavior around a public display. Our observations from the field suggest that the natural walking path is an important *dynamic* factor that strongly influences the noticing of interactivity and thus impacts user behavior. In future work, we plan to include this dynamic factor in our design space and to perform a field study comparing different locations for our configurations.

ACKNOWLEDGEMENT

This work was supported by the Alexander von Humboldt Foundation and the European Institute of Innovation and Technology. We also wish to thank Sarah Kleideiter and Hossein Maktoufi for their help during the field study.

REFERENCES

1. Altman, I. 1975. The environment and social behavior: Privacy, personal space, territory, crowding. Monterey, Calif.: Brooks/Cole Pub. Co.
2. Benford, S., Bullock, A., Cook, N., Harvey, P., Ingram, R., Lee, O. 1993. From Rooms to Cyberspace: Models of Interaction in Large Virtual Computer Spaces. *Interacting with Computers*. 217-237.
3. Benko, H., Wilson, A. D., and Balakrishnan, R. 2008. Sphere: multi-touch interactions on a spherical display. *ACM UIST '08*, 77-86.
4. Beyer, G., Alt, F., Müller, J., Schmidt, A., Haulsen, I., Klose, S., Isakovic, K., Schiewe, M.: Audience Behavior around Large Interactive Cylindrical Screens. *ACM CHI '11*, 1021-1030.
5. Boyle, M., Greenberg, S. 2005. The Language of Privacy: Learning from Video Media Space Analysis and Design. *ACM ToCHI*, Vol. 12, No 2. P328-370.
6. Brignull, H. and Rogers, Y. 2003. Enticing people to interact with large public displays in public spaces. *IFIP INTERACT 2003*, p. 17–24.
7. Cao, X., Massimi, M., & Balakrishnan, R. 2008. Flashlight jigsaw: an exploratory study of an ad-hoc multi-player game on public displays, *ACM CSCW '08*, 77-86
8. Companje, R., van Dijk, N., Hogenbirk, H. and Mast, D. 2007. Globe4D, Time-Traveling with an Interactive Four- Dimensional Globe. *ACM MULTIMEDIA'06,* 959–960.
9. Coutrix, C., Kuikkaniemi, K., Kurvinen, E., Jacucci, G., Avdouevski, I., Mäkelä, R. 2011. FizzyVis:

Designing for Playful Information Browsing on a Multitouch Public Display. *ACM DPPI'11.*

10. Dalsgaard, P., & Hansen, L. K. 2008. Performing perception - staging aesthetics of interaction. *ACM TOCHI*, 15(3), 1-33.
11. Dalton, S. N., Marshall, P., & Dalton, R. C. 2010. Measuring environments for public displays: A space syntax approach. *ACM CHI EA'10, 3841-3846*
12. Elumen's Vision Dome. www.virtuale3d.com/elumens.html
13. Finke, M., Tang, A., Leung, R., & Blackstock, M. 2008. Lessons learned: Game design for large public displays. *DIMEA '08*, 23-33.
14. Fernado, O., Adach, K., Cohen, M. 2004. Phantom Sources for Separation of Listening and Viewing Positions of Multipresent Avatars in Narrowcasting Collaborative Virtual Environments. IDCSW'04. 170-175.
15. Greenberg, S., Marquardt, N., Ballendat, T., Diaz-Marino, R. and Wang, M. 2011. Proxemic Interactions: The New Ubicomp?. Interactions 18, 1 (2011), 42-50.
16. Hornecker, E., Marshall, P., & Rogers, Y. 2007. From entry to access: How shareability comes about. *ACM DPPI'07,* 328-342
17. Hua, H., Brown, L. D., Gao, C., and Ahuja, N. 2003. A New Collaborative Infrastructure: SCAPE. *IEEE VR'03*, 171–179.
18. Jacucci, G., Morrison, A., Richard, G., Kleimola, J., Peltonen, P., Parisi, L., & Laitinen, T. 2010. Worlds of information: Designing for engagement at a public multi-touch display. ACM *CHI'10*, 2267-2276
19. Kendon, A. 2010. Spacing and orientation in co-present interaction. Development of Multimodal Interfaces: Active Listening and Synchrony, 1-15.
20. Kettner, S., Madden, C. and Ziegler, R. 2004. Direct Rotational Interaction with a Spherical Projection. *Creat. & Cog. Symp. on Int.: Syst., Pract. and Theory*.
21. Marshall, P., Morris, R., Rogers, Y., Kreitmayer, S., & Davies, M. 2011. Rethinking multi-user: An in-the-wild study of how groups approach a walk-up-and-use tabletop interface. *ACM CHI '11*, 3033-3042.
22. Marshall, P., Rogers, Y., & Pantidi, N. 2011. Using f-formations to analyse spatial patterns of interaction in physical environments. *ACM CSCW '11*, 445-454.
23. Mataxas, G. Markopoulos, P. 2008. "Aware of What?" A Formal model of Awarness Systems that Extends the Focus-Nimbus. *Enginnering Interactive Systems*. 429-446.
24. Michelis, D., & Müller, J. 2011. The audience funnel: Observations of gesture based interaction with multiple large displays in a city center. In *International Journal of Human-Computer Interaction*, (1), 1-1.
25. Müller, J. Walter, R., Bailly, G., Nischt, M., Alt, F. 2012. Looking Glass: A Field Study on Noticing Interactivity of a Shop Window. *ACM CHI'12*.
26. Peltonen, P., Kurvinen, E., Salovaara, A., Jacucci, G., Ilmonen, T., Evans, J., Oulasvirta, A., Saarikko, P. 2008. It's mine, don't touch!: Interactions at a large multi-touch display in a city centre. *ACM CHI '08*, 1285-1294
27. Perry, M., Beckett, S., O'Hara, K., & Subramanian, S. 2010. Wavewindow: Public, performative gestural interaction. *ACM ITS '10,* 109-112
28. OSHA. United states Departement of Labor, section regulations, paragraph 1910.37(a) 3. www.dol.gov.
29. Reeves, S., Benford, S., O'Malley, C., & Fraser, M. 2005. Designing the spectator experience. *ACM CHI'05,* 741-750.
30. Rodden, T. 1996. Populating the Application: A Model of Awareness for Cooperative Applications. *ACM CSCW'96*. 87-96
31. Rogers, Y., & Lindley, S. 2004. Collaborating around large interactive displays: Which way is best to meet. *Interacting with Computers*, 16(6), 1133-1152.
32. Roudaut, A., Pohl, H., Baudisch, P. 2011. Touch input on curved surfaces. *ACM CHI'11*, 1011-1020.
33. Russell, D., Drews, C., & Sue, A. 2002. Social aspects of using large public interactive displays for collaboration. *ACM Ubicomp'02*, 663-670.
34. Ryall, K., Forlines, C., Shen, C., & Morris, M. R. 2004. Exploring the effects of group size and table size on interactions with tabletop shared-display groupware. *ACM CSCW '04,* 284-293.
35. Scupelli, P. G., Kiesler, S., & Fussell, S. R. 2007. Using isovist views to study placement of large displays in natural settings. *ACM CHI EA '07*, 2645-2650.
36. Vogel, D. and Balakrishnan, R. Interactive public ambient displays: Transitioning from implicit to explicit, public to personal, interaction with multiple users. *ACM UIST'04*, 137-146.