Nordkraft 360 - A Collaborative Public Display Using Proxemic Interactions

JAN SUNDGAARD SCHULTZ and SIMON CHRISTIAN MUNK SØRENSEN, Aalborg University

In this paper we present our findings concerning the use of explicit proxemic interactions for navigating a panoramic images displayed on a collaborative public display in Nordkraft, a cultural center in Aalborg, Denmark. We look into existing literature regarding interactive public displays as well as proxemic interaction in HCI. We created four distinct proxemic interactions to navigate a set of three high resolution panoramas, and implemented them on a public display, which was deployed for a month at Nordkraft. In total we recorded 1336 sessions of interaction above 20 seconds of length, during which we made 95 observations and 20 interviews. We found that some people found the display confusing to used, but also that the majority of people we interviewed were able to explain how the interactions they had used worked. Based on the findings we discuss how the feedback may be a contributing factor to some people finding the display confusing to use, but that in overall, explicit proxemic interactions may be a viable form of interaction for future interactive displays.

1. INTRODUCTION

Public displays are becoming more and more common as they are beginning to appear in everyday life. They are becoming alternatives to old technologies such as the poster and billboard, because they allow for dynamic content that can be easily replaced. In recent times the use of interactive public displays have gained momentum due to their ability to let the users directly manipulate the content on the screen. Technologies such as gestures and touch interfaces allow for this kind of explicit interaction, and are widely used in console technologies such as the Xbox Kinect, and in smartphones, respectively.

In another area Saul Greenberg created the five proxemic dimensions Location, Orientation, Distance, Movement, and Identity for use in ubiquitous computing. As these two areas of interaction are coming together several examples of public displays that use both implicit and explicit interactions are appearing.[Ju et al. 2008][Wang et al. 2012].

An explicit interaction allow people to directly manipulate content on the display through, for instance, touch interfaces. Implicit interactions are hidden away from plain sight, they are described as a part of ubiquitous computing. They for example allow public displays to adjust their content in relation to how many people are looking at it. In current literature it appears that most interactive public displays that makes use of proxemics does so for use in implicit interactions, and also that little in-situ tests have been performed that lasted for extended periods of time.

We propose to use the five proxemic dimensions for explicit interaction in interplay with public displays, and to test these interactions in a real-world collaborative environment for an extended period of time.

We have created Nordkraft 360, a collaborative public display that allow up to four people to navigate high-resolution 360 degrees panoramas. The display was deployed at Nordkraft, a cultural center placed in the heart of Aalborg, Denmark.

The goal of this research is to provide investigate if users are able to learn these interactions, and provide insight into using explicit proxemic interactions as a viable solution for controlling interactive public displays.

Following this section we discuss other examples of public displays, as well as basic theory concerning the use of proxemics as interactions.

2. RELATED WORK

Our work builds on two research areas namely interactive public displays and proxemics in HCI. In order to get an insight into these areas we will outline some of the previous work that has been done. In the following three sections we will discuss existing literature concerning interactive public displays, proxemics as they were defined by Edward Hall, and finally proxemics in HCI.

2.1 Interactive Public Displays

In the following section we will clarify some of the work that has been done within the field of interactive public displays and some of the challenges that have been encountered.

Two of the research areas within public displays are semi-public and public displays, furthermore these displays can be either non-interactive or interactive. Non-interactive public displays can be things like information boards, billboards or advertisements [Brignull and Rogers 2003] where multimedia information can be looped on the screen [Wang et al. 2012]. In Huang and Mynatt [2003] they defined *Semi-Public* as a display where its information is "*Intended to support members of a small, co-located group within a confined physical space, and not general passers-by.*". They also claim that Notification Collage by Greenberg and Rounding [2001] is a *Semi-Public* display. The Notification Collage was a large public display were co-located colleagues could post different multimedia from a desktop computer onto the display [Greenberg and Rounding 2001].

In opposition to semi-public displays, public displays can be used by anyone and Peltonen et al. [2008] defines it as: "*... for anyone to interact in a walk-up-and-use manner.*". In order to clarify what an interactive public display is we will give some examples of the systems that have already been created. One example is Brignull and Rogers [2003] that build the *Opinionizer* system which aimed at encouraging socialization and interaction. Users would make comments on a given subject using a laptop, and the comments would then appear on an interface projected onto a large wall i.e. the public display. The system was used at two social gatherings, once during a book launch party held at a conference, and once during a welcome party. At both events the same setup was used: a 6 ft. wide and 4.5 ft. tall screen which was legible at a distance of five meters. Another example is Peltonen et al. [2008] who created *CityWall*, a large public display on which people, using multi touch, could move around, scale and rotate images on the screen. The display was placed in a shop window in Helsinki which was placed between the main bus station and train stations, and therefore had a lot of pedestrian traffic. Lastly Müller et al. [2012] created a public display by which passers-by in front of a shop window would be able to bounce around a ball on the display. This was also placed in a shop window, by a well-frequented sidewalk in the city center of Berlin.

Even though a public display is placed along a busy sidewalk a potential problem is that it can be overlooked. Like banner adds on web pages, people think they have no relevance to them, and so they disregard them. As public displays becomes more and more common in everyday life, they can suffer some of the same issues. In Müller et al. [2009] they expressed that: "*Expectations of uninteresting content leads to a tendency to ignore displays.*" and defined the effect as *Display Blindness*. If people expect content on a display to be uninteresting, they will simply ignore it. They suggest that in order for a display to receive a lot of attention from an audience, it should meet their expectations.

Attention is important for public displays, without it the display would not get used. One way to get attention is mentioned in Brignull and Rogers [2003] who created the *Opinionizer* system. As a part of their findings they found that as the system was being used a "*...progressive increase in the number of people in the immediate vicinity of the Opinionizer...*" would occur, an effect they dubbed the "Honey

Pot" effect. Meaning that, as people were using the display their presence would further attract other people. They also discovered three distinct activity spaces; *Peripheral awareness activities* which were activities unrelated to the display, *Focal awareness activities* which were related to the display like socialising and *Direct interaction activities* which were activities directed towards interacting with the display. They also identified two thresholds, one from peripheral awareness to focal awareness where the person needs to be tempted by the display in order to cross the threshold. The other is between focal awareness and direct interaction, called the participation threshold. To cross this threshold the display needs to maintain the users attention, and the user needs to be assured that the chance of being embarrassed is low, and he also needs to be aware of the effort required to interact before crossing the threshold. [Brignull and Rogers 2003]

2.2 Proxemics Zones

In 1966 Edward T. Hall described *Proxemics* as a part of non-verbal communication, which described a breakdown of the area around a person into four distinct zones. These zones define the distances people have between each other in different contexts, all zones have a close and a far phase. It is important to note that the following zones are culturally dependant, and are likely to vary between different parts of the world, and that the zones also vary depending on the person you are interacting with, e.g. if it is a stranger, a friend, or a family member. The *Intimate Distance* spans from 0 - 0.45 m, this zone is used for physical contact such as kissing, protecting, and comforting. In the close phase body parts can touch and visually focusing on the other person may be difficult. In the far phase a persons hands can reach another person's body, and the eyes are able to focus on the other person. The *Personal Distance* ranges from 0.45 - 1.2 m and is the distance a person keeps to others, it acts like a "bubble" around this person. In the close phase a person is able to reach out and touch another person. In the far phase a person will be out of touch. The *Social Distance* spans from 1.2 - 3.65 m, at this distance it is no longer possible to reach other people. In the close phase the head size of the person you are looking at is perceived as normal, this phase is commonly used for business and social gatherings. The far phase is also used for business and social gatherings, but of a more formal character. The *Public Distance* ranges from 3.65 - 7.6 m or more, and is used when in the presence of important public figures. In the close phase people loose the fine-grained details of a persons face. In the far phase you have to overdo nonverbal as well as verbal communication in order for the other person to perceive it. This zone ends when you are no longer able to recognize an entity as a person. Hall also described how spatial features could affect people's interactions, he categorized them into *Fixed* features and *Semi-Fixed* features. Fixed features describes things such as entrances into rooms. Semi-fixed features describe objects whose position in a space can affect whether a room brings people together or separates them, such as the arrangement of furniture. [Hall 1966]

2.3 Proxemics in HCI

Greenberg et al. [2011] have used the proxemic zones defined by Hall [1966] to created five proxemic dimensions for use in HCI: *Distance*, *Orientation*, *Movement*, *Identity*, and *Location*. Proxemics in HCI are different from those defined by Hall, as they concern the distance, not only between people, but between all objects such as people, electronic devices, and analogue objects. The five dimensions are measures that define either a continuous or discrete value of proximity between two entities. *Distance* signifies the distance between two entities, e.g. a person and a TV. Its measure can be continuous e.g. the number of meters the person is from the TV, or it can be discrete, which is similar to Hall's *Proxemic Zones*, e.g. if a person is within *close distance*, *viewing distance*, or is *far away*. *Orientation* specifies the orientation between two entities, again we use the example of a person in front of a TV. The measure can be continuous e.g. the number of degrees a persons face is oriented in relation to the

TV, or it can be discrete e.g. if the person is *looking at* or *looking away* from the TV. *Movement* captures the distance and orientation of an entity over time. An example of a continuous value could be the speed at which a person moves, a discrete value could be the direction in which the person is moving, e.g. *towards* or *away* from something. *Identity* is a measure which describes an entity, this measure can be of high or low fidelity, e.g. the measure can describe an entity as a smartphone, or it can describe it as an *HTC One with the Android operating system and a Quallcomm quad-core CPU*. *Location* describes the environment or physical context of an entity, e.g. a room with large open spaces, it is important because it may affect the meaning of the other four dimensions. This measure can also capture contextual information, e.g. when a person crosses the threshold to a room. UbiComp is described as technologies which "*...weave themselves into the fabric of everyday life until they are indistinguishable from it.*"[Weiser 1991]. The five proxemic dimensions can help UbiComp devices recognize their current context, their distance to other devices, people, etc. and can help creating interconnectivity between entities.

The *Proxemic Peddler* [Wang et al. 2012] is a prototype display which made use of three proxemic dimensions to capture a single persons attention. Using this persons *Identity*, his location in front of the display, and his orientation the Proxemic Peddler would decide what to display to the person in order to get the his attention. Once this was achieved, the person would be able to interact with the display via a touch interface. Their intent was to draw a persons attention in a subtle way using the proxemic dimensions. Another example is Ju et al. [2008], they created *Range* which is a public interactive whiteboard which supports co-located meetings between colleagues. The area in front of the display is divided into four zones, named after the proxemic zones defined by Edward T. Hall. The *Intimate* zone spanned from 0 - 38 cm, the *Personal* zone spanned from 38 - 64 cm, the *Social* zone spanned from 64 - 101 cm and the *Public* zone from 101 cm and out. Using these zones, the display would make a choice of what content to show. If the user was for example in the intimate zone he would be able to write on the whiteboard with a marker. If no users were present in the social, personal or intimate zones the display would switch to ambient mode overlaying the current whiteboard contents with a transparent backdrop.

A similarity between *Range* and *Proxemic Peddler* is that both of them used the proxemic dimensions in order to attract peoples attention to the display. For example, *Range* achieved this by sensing peoples distance to the display, and accordingly change what content to show on the screen, e.g. if no one was near the display it would overlay existing content with a blue backdrop and a stream of images. We found that much existing literature have used proxemic interactions implicitly.

Designing a system that makes use of proxemic dimensions to create either implicit or explicit interactivity is subject to a series of challenges. Marquardt and Greenberg [2012] establishes six core challenges related to designing UbiComp interactions. *Challenge 1: Revealing Interaction Possibilities* describes how ordinary physical objects communicate their interactiveness by their physical appearance, this is also known as *affordances*. In UbiComp it is however not possible to visually describe a systems affordances, instead it is necessary to determine how a technology can reveal its interaction possibilities only when needed. *Challenge 2: Directing Actions* points to the issue of how to determine if a users actions are pointed towards the system, or directed towards something else. An example is an ordinary PC with a mouse and keyboard, all input happens through these two devices, and the computer is at no point in doubt of whether or not the input is directed towards it. In proxemics on the other hand, a TV that can sense when a user is close and then turn itself on can result in a problem of it turning on even though a person is just dusting it off. *Challenge 3: Establishing Connections* defines the issue of device interconnectivity while still safeguarding privacy. Take for instance two devices, a TV and a smartphone that are able to automatically connect when in close proximity to each other and upload pictures which then gets displayed on the screen. This may not be a desirable interaction when you are, for instance, visiting a business affiliate at his home. It is important to be able to determine when to enable this feature, and when not to, depending on the location and context. *Challenge 4: Providing feedback* describes the necessity of providing feedback to a user. It is important to let the user know that the input given has been interpreted correctly, or if an error occurred and the input was discarded. *Challenge 5: Avoiding and Correcting Mistakes* is important because often a proxemic UbiComp system makes use of sensors for input. This makes it more likely that the input will contain an error. This is why it is important to provide feedback to the users when an error occurred, and provide them with options on how to correct the mistake. *Challenge 6: Managing Privacy and Security* is the last of the six challenges and is concerned with how a Proxemic UbiComp system can maintain privacy and security without blocking the intended features of a Proxemic Ubicomp system.

3. NORDKRAFT 360

Much of the prior research on the use of proxemics together with public displays have been focused on using these proxemics for implicit interactions[Wang et al. 2012][Greenberg et al. 2011]. An example of an implicit proxemic interaction could be a display sensing the distance between itself and a person. Depending on this distance, the display adapts its content, for example if no one are close to the display it will display public information, and as people come closer the more personal the information will become. They have also had a focus on performing small tests with few empirical studies.

The motivation for our work originates in the desire to test the learnability of explicit proxemic interactions in the context of a collaborative public display. That is, we wish to see if and how people are able to learn to use these interactions. We wish to create a system that is able to gather data on this subject for an extended period of time in a real-world situation. For this purpose we created Nordkraft 360, a collaborative public display which is deployed in a real-world setting at a cultural center in the city of Aalborg. This display allows people to view a 360 degree panorama through three proxemic interactions, and a fourth interaction which can change the panorama being displayed on the screen. These interactions are based on the *proxemic dimensions* defined by Saul Greenberg[Greenberg et al. 2011]. The following sections will describe the technical details regarding the displays implementation.

3.1 Physical setup

The physical setup of Nordkraft 360 included a 50” 1080p flatscreen TV, a powerfull desktop PC with an available wireless connection, and an XBox Kinect. These items were mounted onto a large rigid metal stand with wheels on it, allowing it to be easily moved around, see Figure 1. The Kinect was attached above the TV in order to minimize the possibility of people blocking other players from the Kinect’s line of sight. The PC was hidden on the back of the metal stand and the cabling was arranged so it was hidden from view in order to give the setup a ”nice” look and improve its overall impression, see Figure 1 (B). Apart from the display and PC the setup also included a dark blue 2.5 x 2.4 m floor mat with an imprinted compass on it which was placed 1.2 m from the display, see Figure 4. This distance was chosen partially based on the Kinect’s minimum distance of operation which is 80 cm, and also on the TV’s size, going any closer than this would make it possible to see each distinct pixel on the TV. Apart from a minimum distance, the Kinect also has a maximum distance of 400 cm, a horizontal field-of-view of 57 degrees and a vertical field-of-view of 43 degrees. The sensor is also able to tilt its head 27 degrees up and down.

3.2 Participation zone

Based on the Kinect’s field-of-view, we define the participation zone as the area in which users are able to interact with the display. This zone has a 1-to-1 relationship with the floor mat in order to let people get a clear understanding of when they are expected to interact and when they are not. For

Fig. 1. To the left an image of Nordkraft 360, showing the four interaction illustrations beneath the display, along with the interaction and information poster hanging to the right of the system. To the right the back of the system is shown, with the computer and cables attached to the metal stand.

technical reasons the participation zone is 50 cm wider than the mat, see Figure 2. This is done in order to counter both the small imprecision in the Kinect, but also to create the effect that if a person is standing just off the edge of them mat but some of his torso is still above it, he will retain his player status and still be able to interact with the display. The Kinect field-of-view seen on the figure is based on theoretical numbers, in reality the two blind spots seen in the two top corners of the participation zone are not that large because the Kinect is placed high above the ground and tilted about 25 degrees downward. Trough tests we found that a person that is already recognized by the display can move around in these blind spots without getting lost, and retain his status as a player.

3.3 Interaction Design

Nordkraft 360 supports up to four simultaneous users which are identified as player 1, 2, 3 and 4. People are assigned player numbers according to the order in which they entered the participation zone. People outside the zone receives the number 0, as does any person inside the zone who entered after the fourth person. Each player is assigned a distinct interaction according to their player number. There are a total of four different interactions: *Panning the panorama*, *Pitching the panorama*, *Zoom*, and *Changing panorama*, which are described in the following sections. Each interaction has a corresponding illustration, see Figure 3, designed to teach how the interactions work. All illustrations have been drawn in perspective to better reflect how the interactions work. Each illustration has a very short text designed to let the players know what it does. In the corner of each illustration are four small men which denominate players 1 to 4 respectively, the number of men whose center has been filled with a colour signifies the number of people required for this interaction. If for instance three men are filled with colour, see Figure 3 (C), that interaction requires three players on the mat. The men that are coloured green denotes the players who are able to use this interaction, Figure 3 (D) shows that four players are required and that it is player 4 that is able to use this interaction.

3.3.1 *Panning the panorama.* Player 1 has the ability to pan the image in a horizontal direction by moving relatively to the centre of the participation zone, shown in Figure 2. This means that if player 1 is standing north of the mats center, depicted in Figure 4 (A), the panorama will also be shown in a northern direction.

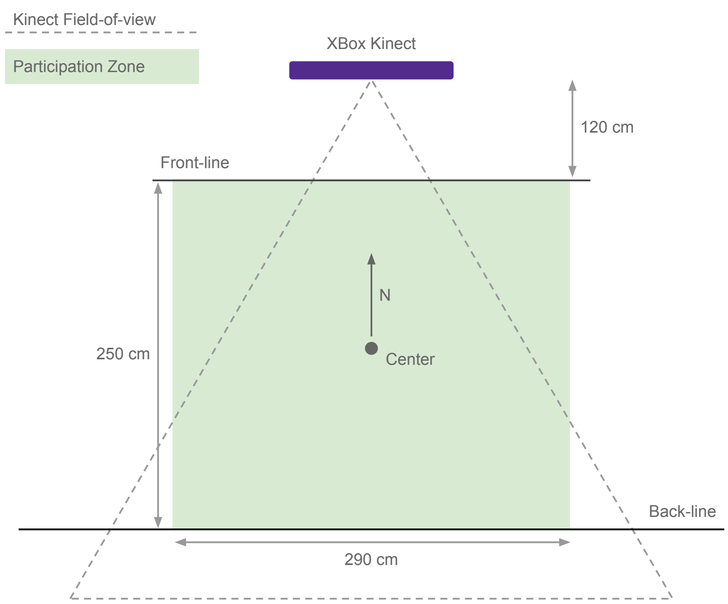

Fig. 2. The area in front of Nordkraft 360 is divided into different zones. The interaction zone is a 250x290 cm rectangle, in which users are allowed to interact with the panoramic image. If a user is outside of this zone, he is given the player number 0.

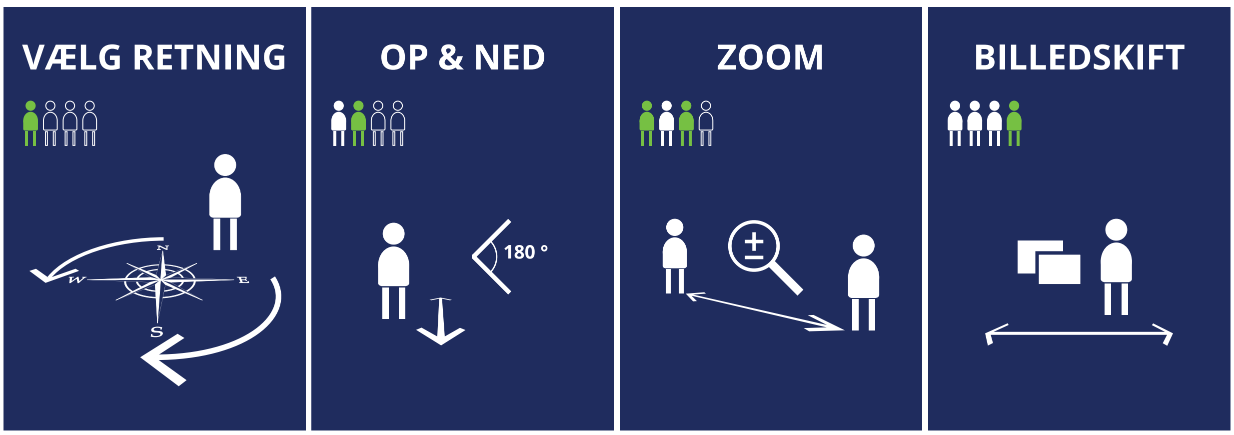

Fig. 3. The four illustrations the were posted below the display. From left to right: Vlg Retning (Choose Direction), Op & Ned (Up and down), Zoom (Zoom), and Billedskift (picture change)

This interaction is based on the proxemic dimension *Orientation*, and is defined as the absolute angle between the player and a the fixed center point on the mat. To calculate the absolute angle we use the players position relative to the centers front which is the direction of the display. The angle is a continuous measure meaning that no matter where on the mat the player is standing, that angle will be depicted accordingly on the display. If the player decides to move south of the center, he will be standing at 180 degrees relatively to 'N' on the mat, then the panorama will shift correspondingly to

Fig. 4. A person standing in northern, western, southern, and eastern direction. On each image the panorama is shown a corresponding direction.

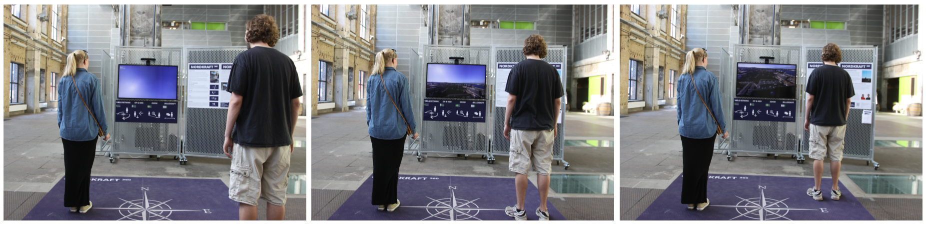

Fig. 5. Player 2 (person on the right) controls the pitch, when he walks forwards the image tilts downwards.

a 180 degree direction, i.e. due south. This can also be seen in Figure 4 which depicts the panorama when player 1 is standing in northern, western, southern, and eastern direction respectively.

The illustration associated with this interaction shows that it is possible to move around the center of the mat to pan the image, in Figure 3 (A).

3.3.2 *Pitching the image.* Player 2 has the ability to pitch the image in a vertical direction by moving towards or away from the display with the front- and back-line shown in Figure 2 as boundaries. This means that if player 2 is standing near the front- or back-line the panorama will be shown directly downwards or upwards respectively.

This interactions is based on the proxemic dimension *Distance*, and is defined as the absolute orthogonal distance between the player and the display. This measure is continuous meaning that depending on the players distance to the display, the panorama will be pitched correspondingly, see Figure 5.

The illustration associated with this interaction shows that it is possible to move forwards or backwards to pitch the image up or down 180 degrees, seen in Figure 3 (B).

3.3.3 *Zooming.* Zooming in on the panorama is a special interaction in that it requires player 1 and player 3 to collaborate. It is based on the proxemic dimension *Distance* as a continuous measure between player 1 and 3. The closer the two players are two each other, the further the panorama is zoomed in, see Figure 6. To achieve a maximum zoom the two players have to be within *intimate distance* of each other, meaning their bodies have to touch. Reaching the minimum zoom is achieved when the two players are at a 188 cm distance from each other. Keeping this distance well below the smallest side of the participation zone allows the players to move more freely, which is important if player 1 is to pan the panorama while also zooming.

The illustration associated with this interaction shows that it is possible to move two players closer or further apart in order to zoom, see Figure 3 (C). The two green men in the figure indicates that the interaction is used by player 1 and 3.

Fig. 6. Player 1 (left woman) and 3 (right woman) controls the zoom by moving farther away or closer to each other. A through C shows the two players zooming in on the white church.

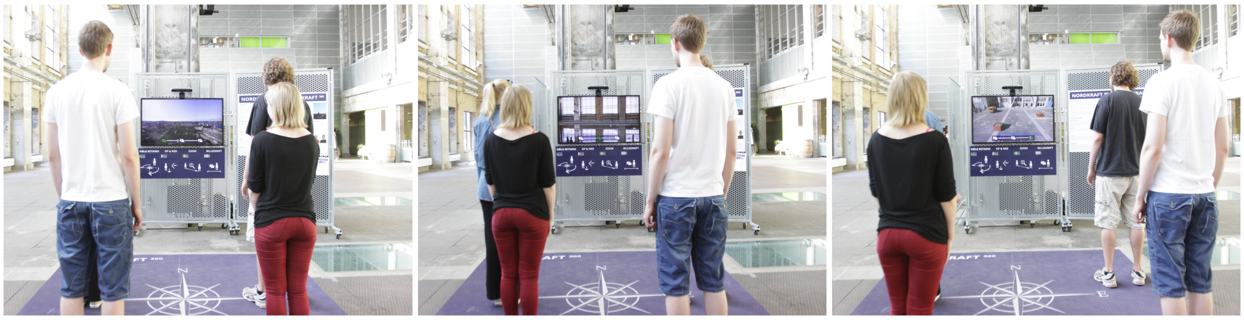

Fig. 7. Player 4 (man in white T-shirt) controls the image change, this is done by moving from the left side of the mat to the right side.

3.3.4 *Changing panorama.* The last interaction allows player 4 to control which panorama, from a total of three different panoramas, is showed on the display. This interaction is based on the *Distance* dimension and is a discrete measure in order to prevent excessive switching of the panoramas. The floor mat is divided into three narrow zones roughly 33 cm in width which are evenly spaced on the floor mat, see Figure 9. Whenever the player enters one of these zones, the panorama will change accordingly, see Figure 7. This also means that whenever the player is between two zones nothing will happen. Because this interaction is based on a discrete measure, the player will not receive the same feedback as with the other interactions which are based on continuous measures. To counter potential issues with using a discrete measure, an extra interface element will appear in the bottom of the display every time player 4 is present on the mat, see Figure 8. This interface will continually show the players position on the mat, and how close he is to changing the panorama.

The illustration associated with this interaction shows that it is possible to move sideways on the mat in order to change the panorama, see Figure 3 (D).

3.4 Player Shifting

Because the Kinect is situated about 2m from the ground, above the TV, it has a relatively clear view of everyone located on the floor mat. It is however possible if a person steps directly in front of another to block the Kinects line-of-sight to that user, we will refer to this as *blocking* another player. When this occurs, the display will think that the player has left the mat and reset his interaction. When the player then steps away from behind the other person he will be treated as a new player and assigned an interaction accordingly. This is an undesirable behaviour which we try to counter by introducing *player*

Fig. 8. The interface showing up on the screen when there is a fourth user.

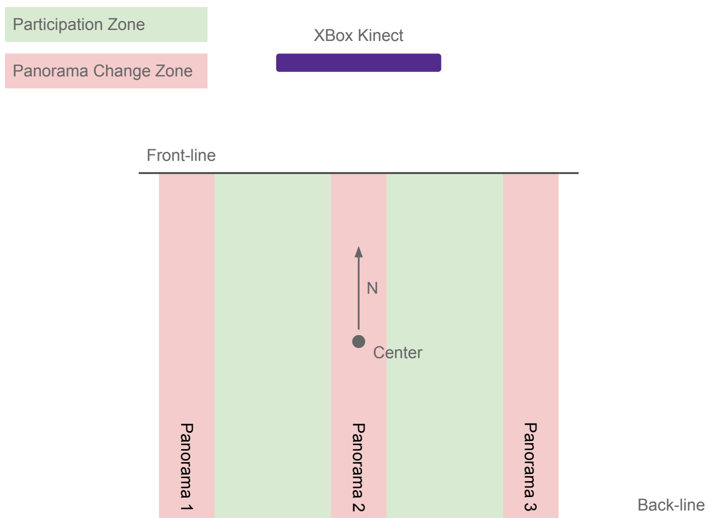

Fig. 9. The mat was divided into three zones, when a player enter one of the zones the panorama is changed accordingly.

shifting. What this means is that when a player leaves, his player number is reserved for 10 seconds. If the person becomes unblocked or another person steps onto the mat within those 10 seconds, he will receive this interaction. If 10 seconds pass, the players present on the mat will be rearranged, and their player numbers will be lowered according to the number of missing players. As an example Brian (player 1), Mia (player 2), and Dom (player 3) are interacting on the mat, see Figure 10 (A). Brian then permanently leaves the mat, see Figure 10 (B). When 10 seconds have passed, Mia and Dom are reassigned as player 1 and 2 respectively, see Figure 10 (C). If Brian had re-entered the mat within 10 seconds he would have been assigned his old player number, i.e. player 1.

In order to notify the players of which interactions are currently available, four icons denoting the number of current players are shown in the upper left corner of the display, see Figure 11. The four

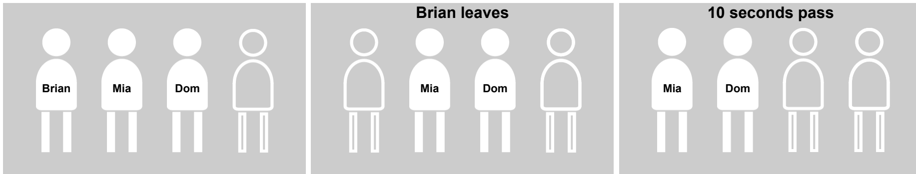

Fig. 10. The four icons showing how it looks when three players are present(A). Brian then leaves the mat (B), and doesn't return within the 10 seconds which causes Mia and Dom to be shifted down one place (C).

Fig. 11. A screenshot of Nordkraft 360 in its "idle" mode, displaying the peephole.

icons are by default empty, but if a player steps onto the mat, the associated icon is filled with a white colour.

3.5 Peephole

Communicating to people that a display is interactive and entice them to approach the system and interact has been done in various ways. Müller et al. [2012] describes methods such as *call-to-action*, *attract sequence* and constantly moving objects on the screen which allows a display to convey its interactiveness. *Call-to-action* usually involves a short message on the display reading something like "Touch screen to start", and an *attract sequence* is a short video showing how to interact with the display. Similar to Peltonen et al. [2008] we use a constantly moving object, a peephole, to attain peoples attention and let them know that the display is interactive.

We chose using a peephole, see Figure 11, because it creates a sharp contrast between the black border and the underlying image.

The peephole is displayed whenever the display has not been used in five seconds, as soon as a person steps onto the mat the peephole fades away and he is able to interact. This behavior is based on the proxemic dimension *Location* which allows the display to detect when a person crosses the participation threshold, i.e. enters the mat.

3.6 Software setup

The display was controlled using three custom built applications: A native C# application for controlling the Kinect, a PHP/HTML5 web application for controlling the GUI including the panorama, and another native C# application for making continuous backups of logged data.

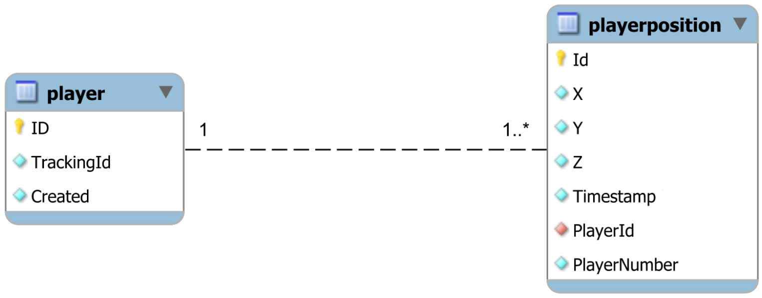

Fig. 12. The underlying data model to which the log data is save

The C# application controlling the Kinect was built using the Kinect for Windows API. This application managed the input coming from the Kinect regarding a persons position in front of the display. It kept track of people, their current and past positions, and their player number. This application also implemented the *Player Shift* feature, and made sure all data was sent to the web application and also saved as log data to a local database. The data logged to the database consisted of a player entry, and all his positions inside the Kinect's field-of-view, including those outside of the participation zone. These positions included an x, y ,z coordinates and the persons current player number, see Figure 12.

The second application was the web application that was written using PHP and HTML5 technologies. It ran on a local web server, and was responsible for displaying the different UI elements such as the player counter in the corner of the screen, which can be seen in the top left corner of Figure 11, the panorama changer UI, and it controlled krPano, the software rendering the panorama.

The application controlling the kinect, and the web application both transmitted a status message at a 20 second interval. This status message was sent to an online status server which recorded these messages. The status server could be accessed through an online web page. The purpose of this status page was to keep track of when the display crashed, so that we were able to act accordingly, e.g. restart the display.

The last application running on the setup was a native C# application which managed all database backups. Once every night the windows task scheduler would run this application which created a backup of all logged data and uploaded it to an online resource. This allowed us to perform ongoing data analysis on new data every day.

4. DEPLOYMENT

4.1 Nordkraft

Nordkraft was originally a power station, but it has since been rebuild as a cultural center which is located in the city center of Aalborg, Denmark.

As a cultural center Nordkraft is host for many different activities. In Kedelhallen (the kettle hall), where Nordkraft 360 was located during the deployment, there are two restaurants, two small shops, a culture house for young people and a tourist information kiosk. Furthermore there is a staircase leading up to a sports center/gym and an art gallery. In the adjacent Turbinehal (turbine hall) there is also a movie theater, music venue, two restaurants and a theater. Additionally some of Aalborg Universities educations are situated on the upper floors. This means that Nordkraft is visited by different audiences, but also that the many activities attracts a lot of people. Nordkraft is open to the public all weekdays from 7:00-23:00 o'clock and from 7:00-24:00 o'clock in the weekends.

Nordkraft 360 was placed in the middle of Kedelhallen between the main entrance and a frequently visited restaurant, see Figure 13, with the main entrance being just left of the image and the restau-

Fig. 13. To the left an overview of where the display was situated in Kedelhallen between the main entrance just to the left of this image and a restaurant in the top right corner. To the right an image taken from the main entrance of Nordkraft towards the system and the information poster situated on a metal board near this entrance.

rant can be seen in the top right corner. After entering Nordkraft from the main entrance, and looking to the left a metal board with a information poster about the display and the display itself can be seen in the background, see Figure 13.

The information poster stated different facts about how the panorama pictures were made, how the system worked and who had created the system, see Appendix A. There were two information posters in total, one at the entrance and the other by the display. At the display there was also an interaction poster that stated the idea behind Nordkraft 360 but also explained how the four interactions worked, see Appendix B. Just under the poster there were leaflets containing some of the same information as the two posters, which people could take with them, see Appendix C.

4.2 Creating the 360 Degree Panoramas

The 360 degree images were created by the help of an amateur photographer who owned equipment specific for this sort of images. They were all taken on a day with a clear sky in order to get the best lighting conditions possible. The three images were taken from three different locations around Nordkraft. One was taken from the Kedelhal, one from Teglgårds plads behind Nordkraft and one from the roof of Nordkraft.

4.2.1 *Kedelhal.* Large boilers used to occupy the space of the Kedelhal, the boilers were used to create steam for the power stations turbines. Today the Kedelhal is the main hall of Nordkraft.

The pictures taken within the kedelhal was produced using a Canon EOS 5D Mark II camera with a 14 mm fisheye lens. The camera was raised several meters into the air using a tripod with a telescopic pole. There was taken in total six images horizontally, four images in a downwards position, and one image towards zenit (the sky). The last image was taken towards nadir (the ground) just beneath where the tripod had been, this was done in order to remove the tripod and any shadows when creating the panorama. The size of the final image was 14,000 x 7,000 pixels or 98 megapixels. Two images from the panorama can be seen in Figure 14

4.2.2 *Teglgårds Plads.* Teglgårds plads is used as a large outdoor activity space, which people can use as they please, furthermore there is a stage that can be used for music etc. The panorama from teglgårds plads is taken in the same fashion as the panorama from the Kedelhal. Two images from the panorama can be seen in Figure 15.

Fig. 14. Images taken from the Kedelhal panorama. On the left a view in the northern direction and on the right a view of the southern direction.

Fig. 15. Images taken from the Teglgårds plads panorama. On the left a view in the western direction, showing the back of Nordkraft and on the right a view of the eastern direction of the activity space and stage.

4.2.3 *Roof.* The roof of Nordkraft is not normally accessible to the public, and can only be accessed through a small smoke hatch. The image from the roof of Nordkraft was taken using a 50 mm lens. The camera was once again raised into the air in order to take the pictures, see Figure 16.

A total six rows of 30 pictures were taken from a horizontal position to nadir. The sky was shot with 7 images using the fish eye and a couple of extra photos was shot of the ground in order to remove any shadows. After the images had been taken they were imported into a panorama image tool called PTgui. The tools were used to stitch the images together and create the final panoramic images. A total of 146 of the images from the roof was chosen in order to create the panorama. Since not all the images were taken at one time some photo editing was required in order to remove any mistakes in the images. An example would be that on one image there is half a bus, but if this is stitched together with an image that does not have the the other half on it only half a bus will be shown in the final panorama. The final size of the image from the roof was 75,676 x 37,838 pixels or 2.86 gigapixels. Two images from the roof can be seen in Figure 17, one showing an overview and one zoomed in at the same spot showing the highest magnification possible.

Fig. 16. Images taken from the roof panorama. On the left an overview of the western direction and on the right the same spot zoomed in.

Fig. 17. Images taken from the roof panorama. On the left an overview of the western direction and on the right the same spot zoomed in.

4.3 Pilot Study

In order to see if people would be able to understand and use the different interactions a small pilot study was performed. Nordkraft 360 was set up at the computer science depart of Aalborg University, see Figure 18, and passers-by was invited to try it. Furthermore it was tested with one person and a group of two, three and four people respectively. This was done in order to determine if people would be able to figure out the interactions and use them. The order of the interactions in the pilot study were panning the panorama, changing panorama, zoom and pitch. It was found that people were able to understand and use the interactions, but based on a comment from one person stating that the change image interaction was a bit boring, it was switched with the pitch interaction. It should be noted that the system was not tested with the final panoramas, but rather a 98 megapixel image from the roof of Nordkraft and a 40 and 28 megapixel panorama found on the internet.

Fig. 18. The test setup used in the pilot test.

4.4 Field Study

The objective of the field study was to observe how people would interact with the display, and if they would be able to use the proxemic interactions.

Nordkraft 360 was deployed for a total of 30 days during the period April 29 to May 31. On occasion the system would be taken down and hidden away because the space it occupied was needed for something else. This happened on May 2 the system was temporarily taken down for the weekend, and was put up again on May 6. This was also the case from May 24 until May 26.

4.5 Data Collection and Data Analysis

During the deployment we spent nine days observing people using the display, in total we collected 95 observations, see Appendix E, and 20 interviews with 37 people, see Appendix D. Based on demographic data gathered during the interviews, see Appendix F for questionnaire and Appendix G for results, there were 17 men and 20 women with an average age of 34 years, with the youngest being 9 and the oldest being 69. 15 of them had a 5 year further education (FE), four had a 1-3 year FE, seven had a high school degree, five had a vocational education and six had a grade school education. 17 people were still studying, two was looking for work, six people were employed in the public sector, two were employed in the private sector, three were salaried employees in the public sector, four were salaried employees in the private sector, one was self-employed, one was retired and one did not answer. 32 of the 37 people had not used a Kinect before.

Furthermore a timelapse video was taken on May 23 between 17:00 and 18:45. An image was taken every second resulting in a video of 4 minutes and 21 seconds. The timelapse video was taken from the top of the stairs looking down on the display. It has been used to support some of the findings with real footage.

During the data analysis the 95 observations was divided into groups of similar interactions. For example a person fetching another person to help with the interaction. The groups were then divided into five themes, the themes described in Section 5. Following this the interviews were transcribed and matched with the five themes in order to support the observations. As previously described the display also collected log data about each interaction, which was saved to a local database. Using a custom built tool which we programmed, we were able to view these log data as playbacks, essentially showing a video of how people moved around on the floor mat.

	Interaction	No interaction
10 to 20 seconds	10	22
21 to 30 seconds	14	3
31-40 seconds	9	3
41-50 seconds	6	0
51-60 seconds	10	0
Above 60 seconds	38	0

Table I.

5. FINDINGS

In this section we will present our findings based on observations, interviews, and logged data. We will focus on five themes: *Engaging with the display*: How the system attracted the attention of people in the surrounding area and passers-by, and convinced them to interact with the system. *Using the Different Interactions*: An overview of how people used the display. *Recruiting help*: How people tried to get other people to help them perform use Nordkraft 360. *Collaboration among users*: How people worked together when using Nordkraft 360. *Staying outside the participation zone*: How people would be attentive to the display, but not engage in interaction with it.

5.1 Nordkraft 360 in use

Nordkraft was used 1336 times based on session for sessions of 20 seconds or longer. Its use would peak around 18:00 o'clock, and on days with special events in Nordkraft its use would be higher than normal.

The amount of time people spent in front of the display varied greatly. Sessions with a length between 10 and 20 seconds was the most common with a count of 395. The number os sessions declined progressively as the length became longer.

We chose May 23, a day with a high amount of activity, and coded all logged replays according to their length, and based on our assessment if it contained any interaction. We found that sessions with a length from 10 to 20 seconds 10 replays contained interaction, 22 did not. In sessions between 20 and 30 seconds we found that 14 contained interaction and 3 did not. And in sessions between 30 and 40 seconds 9 contained interaction, 3 did not. All sessions longer than 40 seconds contained interaction, see also Table I. Based on this we have chosen to focus on sessions with a length of more than 20 seconds in the following text.

The number of people who used the display peaked during the late afternoon and evening hours around 18:00 o'clock, see Figure 19. This pattern is similar to the one in Peltonen et al. [2008], where they also noted an increased amount of activity during the late afternoon and evening hours. Figure 19 shows the total dispersion of sessions throughout a day, over the entire period of deployment.

When looking at the entire period the system was used, we found that May 11 and May 23 were the two days with the highest amount of activity, see also Figure 20. On both of these days Nordkraft had organized large events, which is what contributed to a much greater amount of people visiting the building.

In general 39% of users were individuals, whereas 40% of sessions consisted of pairs of users. 13% were groups of three, and 8% were groups of four. This pattern is similar with Peltonen et al. [2008] where they saw a majority of sessions being with groups of 2 users. Only 5 sessions were of people who did not step onto the mat, but came close enough for the system to log their data. These numbers are also shown in Table II. Due to a technical issue, it was not possible to reliably determine which person had which player number at any given time, this glitch was however fixed by May 7. Due to this error Table II only shows data recorded after May 6.

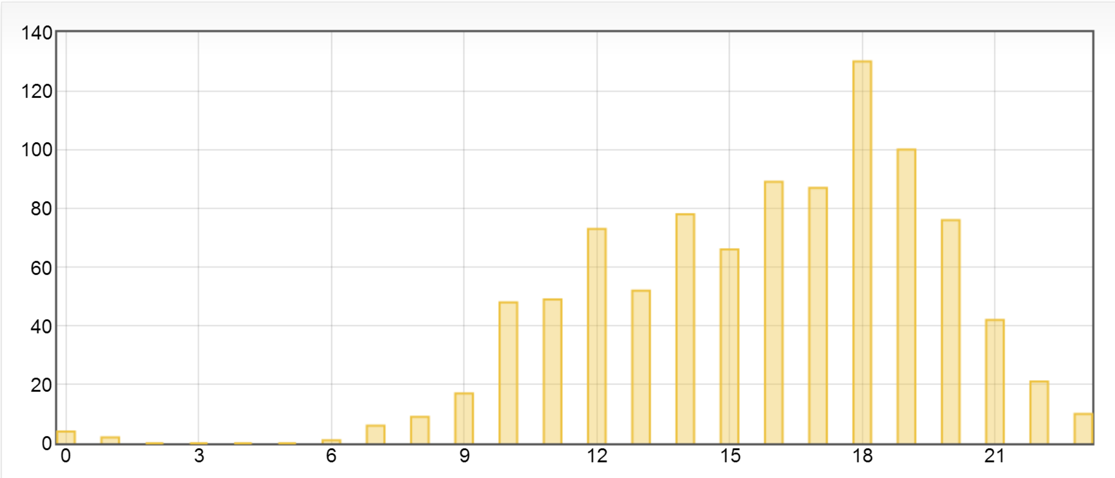

Fig. 19. Shows the time of day and how many sessions have been recorded in total at the given time.

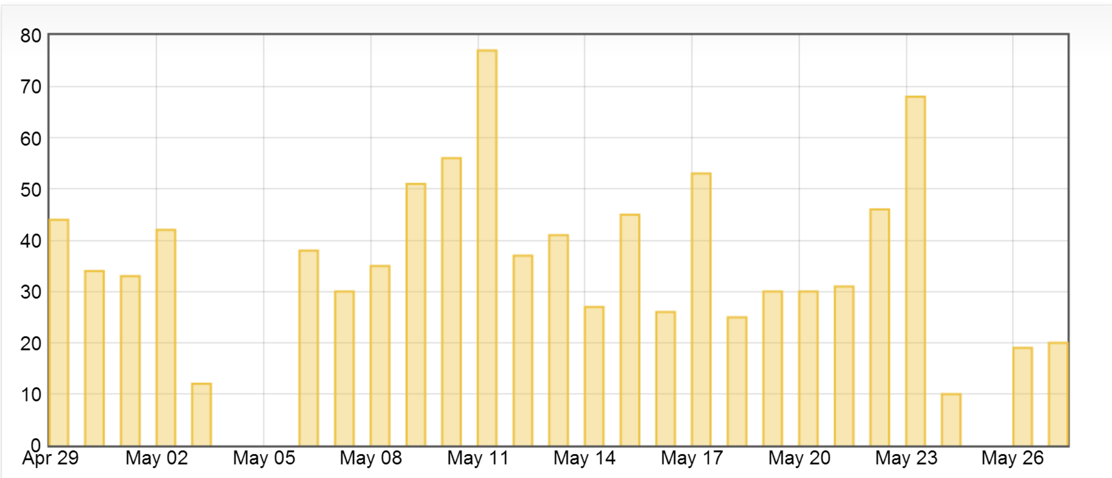

Fig. 20. Shows the number of sessions for each day the system has been active.

Total sessions	0 players	1 player	2 players	3 players	4 players
1093	0%	39%	40%	13%	8%

Table II.

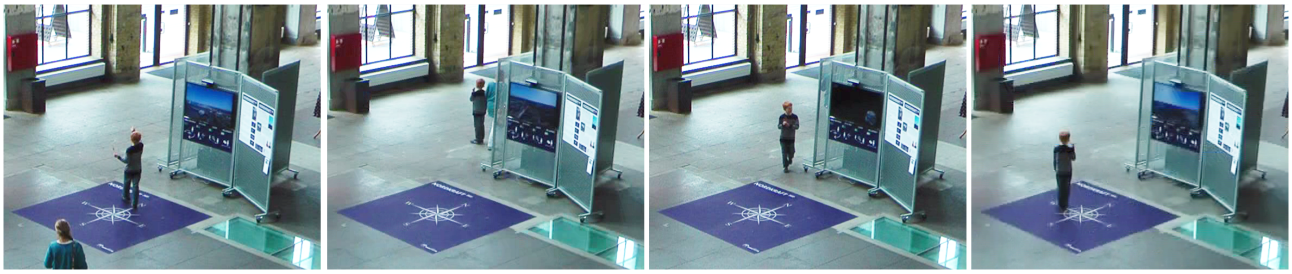

Fig. 21. A young boy walking past the display with his mother. After having passed, they stop, and the boy walks back to the display.

5.2 Engaging with the display

On some occasions we observed cases where people would walk past the display without interacting with it, but would subsequently turn around and return and begin interacting with it, also known as the landing effect. During one evening with an unusual high amount of activity we also observed that people already using Nordkraft 360 would attract others to engage with the system, this is also known as the *Honey Pot* effect.

From our observations and interviews, we found that some people would walk past the display, and only once they had gone by would they perceive that it was possible to interact with it and walk back. An example of this was a young boy and his mother walking towards the display and across the mat, the boy in front of the mother, also depicted in Figure 21(a). They pass the left side of the display and the boy comes to a halt, moments later the mother also stops besides him, see Figure 21(b). The boy turns around and begins walking back to the mat while looking towards the display setup, the mother continues onwards, see Figure 21(c). The boy reaches the mat and begins interacting with the display, see Figure 21(d).

Similar behaviour was observed in Müller et al. [2012], where they also experienced that people walking past their display would not notice its interactivity until after they had gone by. This resulted in two scenarios, either people would stop and walk back to the display, also known as the ”Landing Effect”, or they would ignore the display and continue walking. In another observation similar to the previous one, a man and a woman crossed the mat and walked past the left side of the display. They then came to a halt and walked back onto the mat, and began interacting with it. In a later interview we asked why they walked past the display but then came back, to which they replied:

> ***Man***: *I think it is just a reflex you know, you walk past and notice something, and then you walk back because it might be something interesting.*
> ***Woman***: *I think I had to subconsciously reflect upon on it, that you noticed something and that it might be interesting, you then return in order to explore it a bit.*

People often observed and read the instruction on the posters before they would engage with the display. As previously mentioned a poster advertising the system was placed near the entrance to Nordkraft. The following describes how people who encountered that poster would sometimes engage the system. This occurred in four of our observations and interviews. During an interview with a couple we asked what made them walk over and use the system, the man replied:

> *I think it was, that I saw something by the entrance, it was a poster that said something about 360 and some images taken from the roof, or something in that major. I didn't look at it any more than that, but i was headed in that direction, and then i saw the system and had to try it.*

An example we observed was a young male who left his backpack by the windows and walked over to the poster by the entrance. After he had spent some time looking at it, he then walked over to Nordkraft 360 and began interacting.

During one evening there were multiple events in Nordkraft, one of which took place in a cafe inside Kedelhallen. This lead to an increased amount of activity inside Kedelhallen compared to what we had previously experienced. During this evening we observed a number of consecutive sessions, where people would leave the system and new ones would take over almost immediately afterwards. Over a period of about 20 minutes three waves of these consecutive sessions occurred which amounted to 19 people (at least). One of the occasions began with a boy and his father trying out the system. While they were using the system they were given instructions by another man. As they were getting instructions a group of onlookers formed behind them. When they walked away two women that had been standing behind them engaged the system. As they were using the system an elderly couple walked up behind them, looking at them from just outside the mat. At one point the elderly couple stepped onto the mat with the girls still on it. Similar observations have been described as the 'Honey-pot' effect in Brignull and Rogers [2003], they observed that people were being attracted to a public display already in use by others.

It was not always directly noticeable how people were attracted to the system. In seven of our observations we noted that people would walk directly towards the system and begin interacting. It was not observed that these people had looked at the poster by the entrance, nor did we know if they had used the system before.

During 14 of our interviews we asked what made people walk over to the system. Six of them replied that they walked over because it looked interesting and that they were curious: "*I felt like it in some way, i had to see what it was all about.*", another person replied "*It was simply out of common curiosity.*", and a third replied: "*It looked like fun, when you have a Wii at home and stuff like that, the ones with a camera. Curiosity.*" Another six of them said that is was because of the moving peephole when the system was idle, one replied:

> *Well i saw that circle moving around, and then I thought that there had to be something that could somehow be activated. I had not noticed what was on the floor, well i saw the compass...*

When we asked a couple what made them go over to the system, the woman answered: "*It was the screen, I noticed something was there.*" and the man elaborated: "*There was something that was moving.*". Three people stated they were attracted to the system because of the mat or the entire setup, one replied: "*I think it was all of it, but i noticed the mat first ... and then i thought if i went over and stood on the mat, maybe something would happen.*". During a single interview when asked why she had walked over to the system and begun using it she stated: "*It was by accident.*".

5.3 Using the Different Interactions

We found that people who had used the first interaction seemed to frequent the 'N', 'S', 'E', 'W', and center of the mat the most. We also found that some people would find the system confusing to use, however through 13 out of 20 interviews we also found that people were able to explain the interaction(s) they had used. In this section we will outline some of the more prevalent scenarios that would unfold when one or more people used the display.

People using the panning interaction would generally visit the same areas of the mat. An example of this was a woman who began by stepping onto the middle of the mat, see Figure 22(A). Then she slowly walked over to "W", see Figure 22(B). She steps back onto the middle of the mat, see Figure 22(C) and walks down to 'S', see Figure 22(D).

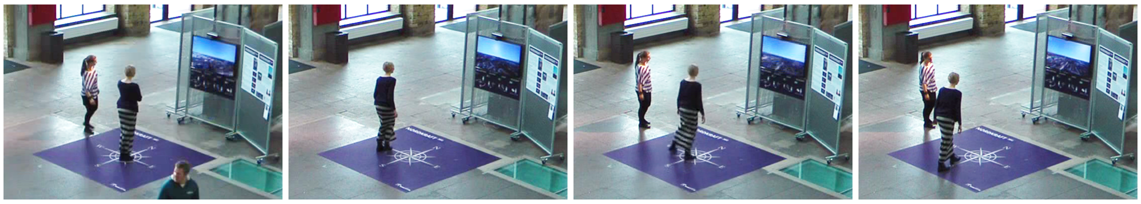

Fig. 22. A woman learns how to use the first interaction.

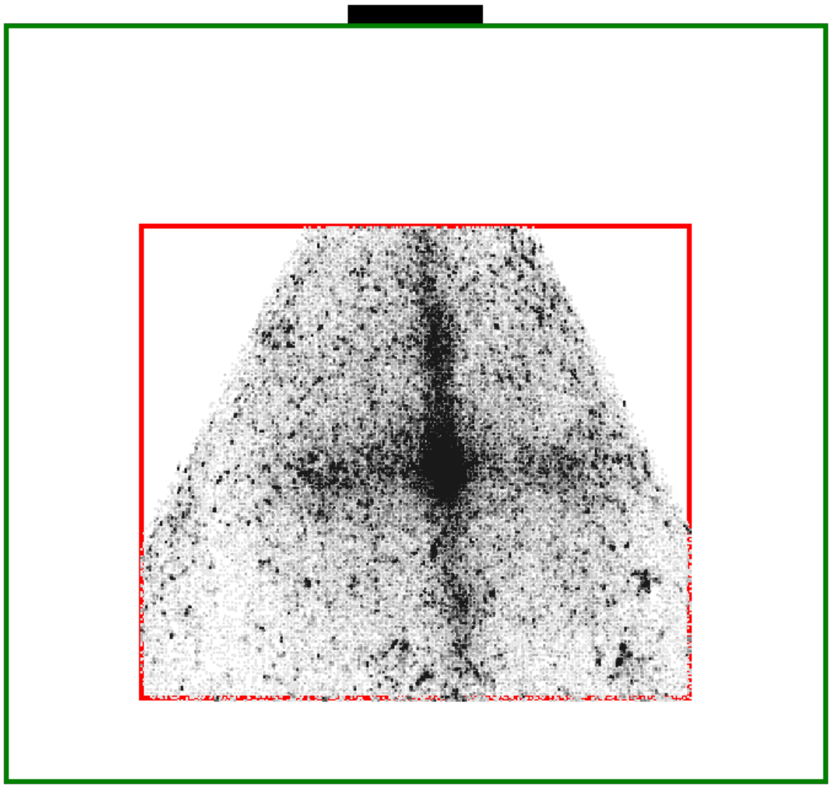

Fig. 23. Based on the log data from people using the panning interaction we can see a pattern formed by the most frequented areas of the mat. A pixel is stepwise colored from white to black according to the amount of data for that location. The participation area is defined by the red box and the small black box signifies the Kinect.

From the log data we can see that this is a common pattern for people using the panning interaction. The data shows that the most frequently used areas on the mat formed a cross between 'N', 'S', 'E', and 'W', with the center being the most frequented area. Figure 23 shows this pattern, every pixel on the figure signifies a location on the mat, according to the number of times a user has been recorded at a location a pixel goes from white to black.

When two or more people would use the display it would sometimes seem confusing to them. Through four of interviews people stated that the display was either confusing to use, or that it seemed broken. An example of this was two girls who stepped onto the mat simultaneously, one from the lower right corner who received the panning interaction (Girl 1), and one from the back of the mat who received

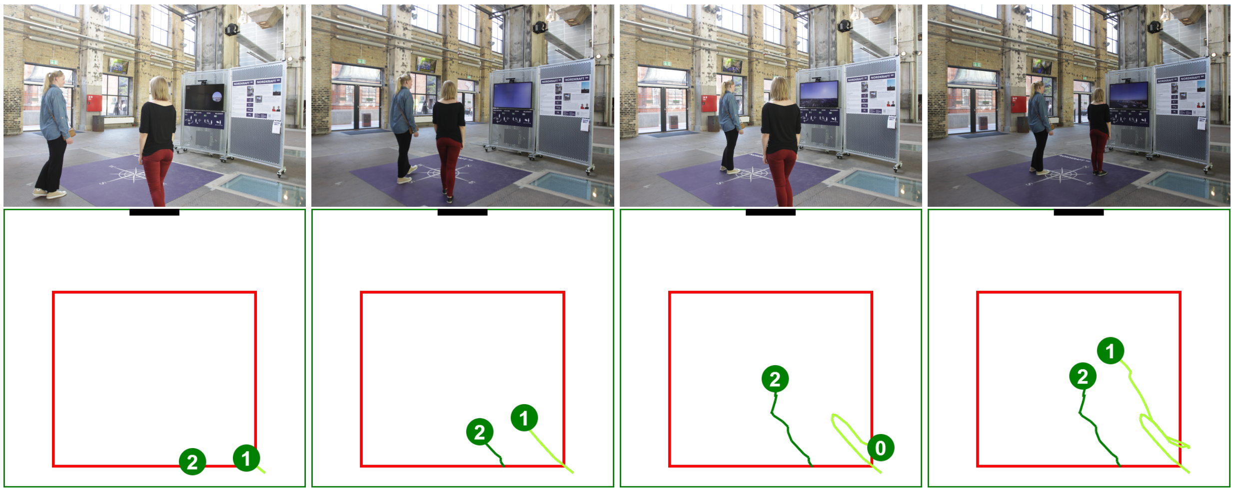

Fig. 24. A set of reconstructed images along with replay screenshots showing two girls stepping onto the mat simultaneously. One girl leaves but re-enters shortly after.

the pitching interaction (Girl 2), see Figure 24(A). As they walk further onto the mat Girl 1 comes to a halt, see Figure 24 (B). She then walks to the right, off the mat, see Figure 24 (C). After some she time re-enters the mat, see Figure 24 (D). When asked why she walked off the mat she replied: "*It looked like it was broken.*", but eventually she stepped back onto the mat stating: "*There was a sign showing that you could be two persons on the mat.*".

Another example was a man who stepped onto the mat and began interacting. After a short while he called over a woman, who entered from the bottom right corner and received the pitching interaction. After only a few seconds she walks off again. At one point a third person steps onto the lower left corner of the mat and receives the pitching interaction, and stays there causing the panorama to pitch up and only show blue sky. After only a few more seconds the man leaves the mat. Afterwards in an interview we asked him what it was like to use the system, he replied:

> ***Interviewer***: *What was it like using it (the display)?*
> ***Man***: *I found it confusing.*
> ***Interviewer***: *You thought it was confusing?*
> ***Man***: *Yes, but i didn't take the time to stand and read (the poster), i just jumped in but i didn't find it easy and then i quickly lost interest. But if I had read it first (the poster) i think it would have been better.*

We coded all replays for a single day of logged data, and found that during 28% of sessions with two or more players, one or more people would be blocked from the display. If a person that is blocked will have difficulty viewing the display, but also the Kinect will be unable to track a person which means his interaction will be reset to its default value. An example of this was a replay where two people are interacting with the display, see Figure 25 (A), at some point player 2 steps in front of player 1 and blocks him which causes the display to lose track of him. The lost player moves to the left, away from player 2 allowing the display to once again track him and he becomes player one, see Figure 25 (B).

During most of our interviews we would ask people to describe how the interactions they used worked. In 13 of the interviews people were able to correctly explain how to use the interaction(s) they had tried.

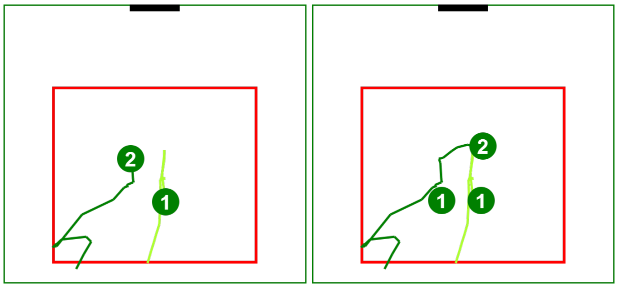

Fig. 25. Screenshots from the replay tool showing player 2 momentarily blocking player one.

In an effort to interact with the display people tried different approaches such as hand gestures, touching the display, and even jumping. For example a larger group of people had walked onto the mat, and in doing so a lot of interaction started and the people noticed that the image zoomed in. In an effort to try and control the zoom, a man that stood at the front held up both his hands, and moved them away from each other and back together again to see if it had any effect. During seven of our observations and interviews we noted others would make hand gestures towards the display, in an interview with a woman she said: ”*I started doing this (waving her arm) with my arms, i know that some TVs can register it, but nothing happened.*”. We also made seven observations that people would walk onto the middle of the compass on the mat, looking at the TV and then turn to either side in order to make the panorama change direction. In one of these observations a woman said to a man: ”*Try turning all the way around, arh, then you cannot see but I can.*”. In three instances we observed people walking directly up to the TV and touching it, discovering that it had no effect. Other actions included bending in the knees, jumping, and bending forwards or backwards in order to affect the system.

People would have different approaches to using the interaction, some would consult the posters either before or after they had tried the display, others seemed to learn from people already using the display by observation, and some would walk directly onto the mat and interact.

As previously mentioned in Section 5.2 we observed that people would walk straight onto the mat and try the system. In an interview a man expressed it like this: ”*I did not want to read the posters so we just gave it a try.*”. However, it sometimes seemed that if people were unsure about what was happening they would consult the posters. Another man with a son and daughter said: ”*We did not really understand it before we started to read, that when we were more people we could do more, and then it suddenly became fun.*”. Another example of people using the poster was a woman who walked onto the mat and moved around a little bit. She then walked over to look at the posters, and when she returned to the mat she began by standing on ”North”, moving towards ”West”, she appeared to be moving around more freely than before she had looked at the posters. We also observed people looking at the posters before stepping onto the mat. For example a woman walked up to the posters and started looking at them, she then proceeded to step onto the mat and used the panning interaction, panning the image. In total we gathered nine observations and interviews where people had at some point looked at the poster. Lastly we observed that people would seem to learn from others before they engaged the display themselves. We made and observation of a man who started by looking at the poster by the entrance, and afterwards walked towards the display. But as it was already in use by another person, he stood and watched while awaiting his turn. Once the display became vacant, the man stepped onto the mat and began using the panning interaction. In a similar observation a boy, sitting in the same café from where the authors was making observations, walked over to the display

Fig. 26. A reconstructed set of images showing a woman fetching her husband to help her interact with the display.

after having looked at another person use it. While on the mat, his father shouted to him: "*Try walking around.*" after which the boy started using the panning interaction. These observations are similar to those in Brignull and Rogers [2003] where they noticed that people appeared to have learned how to interact with the display by looking at others use it.

5.4 Recruiting help

We observed that people would sometimes call over people they knew in order to unlock more interactions. This behaviour was observed seven times, during one of the observations a woman walked onto the mat and began interacting with the display, see Figure 26 (A). Moments later she walked back to her husband, see Figure 26 (B), and he followed her back onto the mat, see Figure 26 (C, D). In a following interview when asked why he had done so he replied: "*Oh she asked me to come and stand there because if two of them are standing there, you get the zoom.*".

In a similar observation, a young girl stepped onto the mat while her mother walked past to look at another exhibition. After some time, the girl walked over to her mother and they both returned to the mat, the girl once again began interacting with the display while the mother watched. After some time the mother also began interacting. When asked afterwards if the girl had asked the mother to come over she responded: "*I fetched my mother, she was too busy looking at the exhibition.*". In none of the observations did a person approach a stranger to ask for assistance. During two of our interviews we asked whether or not people would be inclined to ask a stranger for help, and a woman replied: "*Yes, I'm not very shy.*", whereas in another interview with two young guys, one of them replied: "*I think it depends on what type of person you are, but I would probably not do it.*", and the other one replied: "*It depends on the signals emitted by the stranger, but I think you ought to try it.*". At no point did we observe people trying to recruit strangers, and only one time did we observe strangers stepping onto the mat while the display was already in use.

5.5 Collaboration among users

During our observations we found that people would differ in how they collaborated, either verbally or non-verbally, in order to use multiple interactions. Some people would converse about the interactions in order to identify who was doing what, others would take turns interacting in order to uncover who controlled which interaction.

An example of this was three men who walked onto the mat, see Figure 27 (A), and quickly began talking about which interactions were available. One of the men noticed that they were able to see how many people that were presently registered by the system, he says: "*You can see how many it registers.*", upon which two of the men left the mat, see Figure 27 (B), with one of them telling the remaining person: "*Stay there, then I will walk in as pitch.*", and then walks in, see Figure 27 (C). The third man then said: "*Then I will enter as zoom.*" and stepped onto the mat, see Figure 27 (D). The three men calls for a fourth person who walks over and steps onto the mat. Moments later a fifth man

Fig. 27. A reconstructed set of images showing three men walking onto the mat. Afterwards two of them leave and re-enters one by one.

arrives and says: ”I also want to try.” upon which he tries to step onto the mat, but is held back by one of the other men on the mat.

Another example we observed was a man with his daughter, who was young enough to still be in her stroller. They walked over to the system and stepped onto the mat. The daughter walked to the right side of the mat while the father walked towards ’N’ and then towards ’W’. Both the father and the daughter seemed to realize that the panorama started to turn, and so the daughter told her father: ”*Over here.*” and the father jumped to the spot she pointed to. She then proceeded to command him where to go several more times, and the father moved as he was told. After a while the daughter stepped back onto the mat, and the father saw that the panorama pitched and told her: ”*Now we are looking up.*” and the daughter looked at the screen. He then nudged her forward a little with his hand and the panorama pitched down so they were able to see the city again.

During an interview with a mother and her daughter, when asked if they could explain how the system worked the mother replied: ”*We noticed that you had to be two persons in order to make it work in another way, and three people to make it work in a third way. You are dependant on others in order to get the additional features.*”. We had noted during our observation, that while the mother was moving around the daughter stood still. We asked if this was done deliberately or unintentionally, to which they replied:

> ***Daughter****: We moved around as we saw fit.*
> ***Mother****: I think we switched automatically. When moving at the same time we would not be able to uncover who controlled what. It was unconsciously deliberate that we took turns moving. Without doing it like this, we would not be able to learn who controlled which interaction...*

5.6 Staying outside the participation zone

We made eight observations when the system would clearly have a persons attention, without the person engaging in interaction. In five of these eight occurrences people would stand near the mat, look directly at the system for a time, and then walk away. In the remaining three people would spend time both looking at the system and the posters.

An example of this behaviour was a man who stopped and looked at the poster placed by the entrance to Nordkraft. Afterwards he proceeded over to the posters next to the display. Soon after he walked away. When asked during an interview, why he didn't step onto the mat despite having spent time looking at the display and the posters, the man replied: ”*It was because you become a little shy when others are looking.*”. In Brignull and Rogers [2003] they observed similar behaviour, they noticed that after acquiring peoples attention towards the public display, people still needed to cross what they called, the *Participation Threshold*.

6. DISCUSSION

We have created and deployed the Nordkraft 360, a collaborative public display, in the cultural center Nordkraft for a period of 30 days. The display demonstrates a possible solution to using four explicit proxemic interactions in order to control several 360 degree panoramic images. The purpose of this display was to test peoples ability to learn and use these interactions. We also observed the landing effect, honey pot effect and recruitment to be some of the ways people would be attracted to the display. We found that people would on some occasions find the interactions confusing to use. During situations were groups of people would interact with the display, they would help each other discover how their respective interactions worked.

One of the concerns we wanted to address was if and how people would be able to learn the four interactions. Through interviews we found that some people who had used the display together with others would find the interactions confusing. We saw through our observations that people would walk onto the mat together, after which one or more people would leave the mat. Having for example three people continuously interacting with the display would potentially cause the panorama to pan, pitch and zoom at the same time. When a single person was on the mat he would only get feedback on the display from his own interaction. However when multiple people were on the mat a person would not only get the feedback from his own interaction but also the other players interactions. This is similar to Ju et al. [2008] where the whiteboard would change *mode* depending on which zone was used. This lead to confusion when a person would cause the system to change mode unexpectedly. One of the ways they attempted to solve this issue was by introducing an extra element on the screen which illustrated which zone people were in. In the case of Nordkraft 360, it would seem the feedback provided on the display when using the interactions was not sufficient in instances with more than one player, which is also a concern raised in Marquardt and Greenberg [2012]. Even though we observed people sometimes being confused, we registered through 13 interviews that people were also able to correctly explain how the interactions they had used worked. This could be an indication that people are able to understand the proxemic interactions, and that it is the combination of these and the associated feedback that may be confusing.

Similar to existing literature we also experienced the *Honey Pot* effect[Brignull and Rogers 2003], and *Landing* effect[Müller et al. 2012]. In accordance with the design recommendations [Müller et al. 2012] on how to avoid the landing effect Nordkraft 360 was placed in such a way that people would walk directly towards it. Despite having placed the display in this way, we still encountered two instances of the landing effect. This suggests that placing the display facing people is not a definitive solution to the landing effect problem. Another downside to this solution is that it is not possible to see the display coming from the opposite direction. On one occasion we observed the *Honey Pot* effect. This was observed on a night with a much higher concentration of people than what we normally experienced. In Müller et al. [2012] they observed many instances of the *Honey Pot* effect, and that in some cases people in the audience would join the interaction. They also described the side walk by which the display was located as well frequented. Contrary to their observations we only observed the honey pot effect once, and also that people that did not know each other would never join the interaction together, instead they would wait until the display was free.

The honey pot and landing effect are examples of how people are attracted to a display. Apart from these, we also saw that people would recruit friends and family to unlock more interactions. According to one person, the reason for this was that she wanted to unlock more of the available interactions.

Similar recruiting has been seen in Cao et al. [2008], where people would form groups in order to gain more points while playing the *Flashlight Jigsaw* game. This is interesting because it could seem that limiting people's ability to interact with a display would give them an incentive to recruit other people in order to get the full experience. It would be interesting to see if rewarding a user for recruiting another user, could be used as a tool to attract more users to the display.

7. CONCLUSION

In this article we have shown how explicit proxemic interactions can be used for interaction with a public display. We did this by creating a public display that would allow people to navigate high resolution panoramic images, using proxemic interactions. This display was deployed for a period of 30 days at a cultural center in order to provide us with in-situ observations of people using it.

We found that a majority of people we asked were able to describe the interactions they had used, but also that some would find them confusing. Through observations we saw that when groups of people stepped into the participation zone to interact, they would seem unable to discern the interactions from each other, causing them to temporarily leave the participation zone allowing the remaining players to figure out their interactions. This suggests a problem with the feedback players receive from their interactions, and not the interactions based on the fact that the majority were able to correctly explain how to use them.

The interactions were made in such a way that people were forced to collaborate with others in order to gain full control of the display. As a result of this we observed people who would recruit their friends and family to help navigating the panorama. We also observed other effects associated with attracting new players to the display, namely the *Honey Pot* and the *Landing* effects. Müller et al. [2012] suggests that in order to prevent the landing effect, the display should be placed at a location which would have people walking towards it, instead of parallel to it. Nordkraft 360 was positioned in a large open space where people would mainly walk towards it, despite of this we still encountered this effect.

REFERENCES

Harry Brignull and Yvonne Rogers. 2003. Enticing people to interact with large public displays in public spaces. In *Proceedings of INTERACT*, Vol. 3. 17–24.

Xiang Cao, Michael Massimi, and Ravin Balakrishnan. 2008. Flashlight jigsaw: an exploratory study of an ad-hoc multi-player game on public displays. In *Proceedings of the 2008 ACM conference on Computer supported cooperative work (CSCW '08)*. ACM, New York, NY, USA, 77–86. DOI:http://dx.doi.org/10.1145/1460563.1460577

Saul Greenberg, Nicolai Marquardt, Till Ballendat, Rob Diaz-Marino, and Miaosen Wang. 2011. Proxemic interactions: the new ubicomp? *interactions* 18, 1 (Jan. 2011), 42–50. DOI:http://dx.doi.org/10.1145/1897239.1897250

Saul Greenberg and Michael Rounding. 2001. The notification collage: posting information to public and personal displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '01)*. ACM, New York, NY, USA, 514–521. DOI:http://dx.doi.org/10.1145/365024.365339

Edward T. Hall. 1966. *The Hidden Dimension* (2nd ed.). Doubleday, New York.

Elaine M. Huang and Elizabeth D. Mynatt. 2003. Semi-public displays for small, co-located groups. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03)*. ACM, New York, NY, USA, 49–56. DOI:http://dx.doi.org/10.1145/642611.642622

Wendy Ju, Brian A. Lee, and Scott R. Klemmer. 2008. Range: exploring implicit interaction through electronic whiteboard design. In *Proceedings of the 2008 ACM conference on Computer supported cooperative work (CSCW '08)*. ACM, New York, NY, USA, 17–26. DOI:http://dx.doi.org/10.1145/1460563.1460569

Nicolai Marquardt and Saul Greenberg. 2012. Informing the Design of Proxemic Interactions. *IEEE Pervasive Computing* 11, 2 (April 2012), 14–23. DOI:http://dx.doi.org/10.1109/MPRV.2012.15

Jörg Müller, Robert Walter, Gilles Bailly, Michael Nischt, and Florian Alt. 2012. Looking glass: a field study on noticing interactivity of a shop window. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. ACM, New York, NY, USA, 297–306. DOI:http://dx.doi.org/10.1145/2207676.2207718

Jörg Müller, Dennis Wilmsmann, Juliane Exeler, Markus Buzeck, Albrecht Schmidt, Tim Jay, and Antonio Krger. 2009. Display Blindness: The Effect of Expectations on Attention towards Digital Signage. In *Pervasive Computing*, Hideyuki Tokuda, Michael Beigl, Adrian Friday, A.J.Bernheim Brush, and Yoshito Tobe (Eds.). Lecture Notes in Computer Science, Vol. 5538. Springer Berlin Heidelberg, 1–8. DOI:http://dx.doi.org/10.1007/978-3-642-01516-8_1

Peter Peltonen, Esko Kurvinen, Antti Salovaara, Giulio Jacucci, Tommi Ilmonen, John Evans, Antti Oulasvirta, and Petri Saarikko. 2008. It's Mine, Don't Touch!: interactions at a large multi-touch display in a city centre. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '08)*. ACM, New York, NY, USA, 1285–1294. DOI:http://dx.doi.org/10.1145/1357054.1357255

Miaosen Wang, Sebastian Boring, and Saul Greenberg. 2012. Proxemic peddler: a public advertising display that captures and preserves the attention of a passerby. In *Proceedings of the 2012 International Symposium on Pervasive Displays (PerDis '12)*. ACM, New York, NY, USA, Article 3, 6 pages. DOI:http://dx.doi.org/10.1145/2307798.2307801

Mark Weiser. 1991. The computer for the 21st century. *Scientific american* 265, 3 (1991), 94–104.