Subtle interventions: How ambient displays influence route choice in buildings.

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Abstract. *Ambient displays allow physical space to be transformed into a dynamic and ever-changing environment in which boundaries are dissolved. However, it is likely that the incorporation of such digital elements affects people's perception and understanding of space. In this particular study, a series of experiments were conducted to examine how a skewed perspective projection via an ambient display influences people's navigation in public spaces. The findings are then presented showing how the participants' responded to the presence of the skewed projection and the effects on the movement patterns. This study discusses the ability of an ambient display to influence navigation paths and suggests that a projection with skewed perspective can determine the creation of new movement patterns.*
Keywords. *Ambient displays; human navigation; built environment; visual perception; isovist.*

INTRODUCTION

Space can no longer be seen as a simple composition of static elements. The introduction of ambient displays that simply augment walls causes the boundaries to unfold and reveal hybrid spaces. These interfaces can be considered as digital openings in a form of virtual windows that extend architectural space and widen the vision of users in a given space. Like a window that connects two physical spaces and transfers information between them, an ambient display can be seen as a link between physical and virtual worlds, where the virtual world can be for example the projection of another physical world or a computer generated space. Drawing on this approach, ambient displays can maintain a subtle but highly informative connection with humans and create dynamic and ever-changing environments.

When a virtual space is introduced into the physical environment, the spatial properties are redefined. For instance, an ambient display can transform a static wall to a more transparent and fluid element that dissolves the boundaries between virtual and physical space. During 'out of bounds' interactive installation, Chris O' Shea [1] effectively challenged the relation between physical and virtual space. By projecting previously captured spaces onto the wall, he enabled people to 'see' through the physical boundaries of space. As he stated, this interaction allowed people to enter the 'prohibited'

areas of the museum while encouraging their child-like curiosity [1]. But how can ambient displays affect people's movement in space? The ability of ambient displays to project views of one space from another and create hybrid information space might alter our perception of space. If so, can the use of hybrid space create behavioural changes related to people's navigation in space?

The aim of this research was to analyse how digital information projected with skewed perspective through ambient displays affects people's movement in the interior of public spaces. The research's interest is in how the manipulation of the projection angle of an ambient display at a given position can alter people's navigation. In order to answer this, a series of experiments were designed to explore the effects of ambient displays on people's movement inside public spaces.

BACKGROUND

Research from two fields is relevant to the work. First, this research examines work investigating the use of ambient technology in architectural spaces. Second, there is a brief outline of research studying perception and movement in architectural spaces, where ambient displays are not considered as elements that augment vision.

Ambient Displays: Transforming Architectural Spaces

Ambient displays have received considerable attention by architects who try to construct buildings with embedded digital technologies. For example, the Porsche Museum by Delugan Meissl [2] (see Figure 1) and the BMW Museum in Munich, Germany by ART+COM [3] include large ambient displays that have augmented the interior surfaces of walls. In addition to this, when they designed Digital Pavilion, Kas Oosterhuis and Ilona Lénárd [4] transformed concrete interior walls into interfaces able to display readable information or create atmospheric lighting effects. Taking the idea of placing ambient displays instead of walls further, Ataman et al. (2006) proposed the use of large display 'materials' as construction surfaces in architectural design. They envisioned movement through space in the future to be more dynamic, incorporating different levels of transparency and space that could be described by the fluidity of the walls that surround people.

As indicated by previous studies (Wisneski et al, 1998; Mathew et al, 2008; Tomitsch et al, 2008), the presence of an ambient display in architectural space can ensure more pleasant environments; while at the same time can be informative and socially engaging. For example, Mathew and Taylor (2008) with their project AuralScapes try, with the use of sound and sky projections, to create a virtual connection from the outside to the inside, where information is abstracted and delivered at the periphery of human attention. By developing this link, they create a pleasant indoor environment and partially dissolved the static notion of the surrounding walls.

In fact, the use of digital technologies in architecture goes beyond the simple modification and transformation of space into a pleasant and informative environment, influencing people's behaviour in it. With his work Röcker et al. (2004) states that ambient display installations that promote awareness and presence produce positive effects and behavioural changes on office teams.

It has been observed that changes to the digital environment have led to behavioural changes such as the movement of people through that space. Indeed, Schieck et al. (2007) in an attempt to

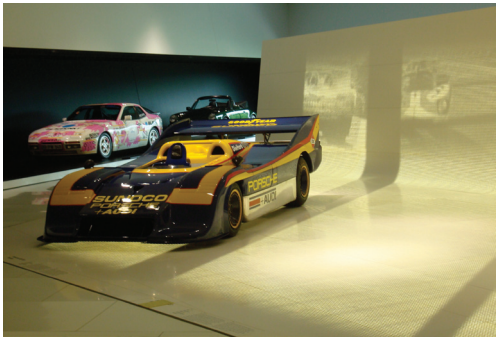

Figure 1
Porsche Museum, Stuttgart, Germany

analyse the influence of an interactive floor installation in people's social engagement in urban environments, reports that she recorded unexpected and diverse changes in movement patterns around the installation. But what are the changes in movement patterns resulting from the presence of ambient technology?

For architects wanting to incorporate ambient interfaces it is essential to acknowledge the effects of their design proposals on people's navigation in space. With analysis and visualization of these effects, ambient display components will be incorporated in designs efficiently and activate or transform existing spaces. Relevant studies (Ishii and Ulmer, 1997; Ishii et al, 1998; Prante et al, 2003; Jafarinaimi et al, 2005) on ambient technology place the centre of attention on human-computer interaction without considering the visual and spatial perception that link people and technology.

Perception and Movement in Architectural Spaces

It is generally accepted in architecture that the structure and configuration of space affect people's navigation and movement. Gibson's research, which was primarily developed for visual perception, suggests that our senses provide us with direct awareness of the external world and its properties (Gibson, 1979). People perceive space through their senses and act accordingly, thus there is a tight relation between perception and movement.

Based on this theory, architect and virtual reality pioneer Benedikt (1979) proposed that space is perceived as a collection of visible surfaces that are not obstructed by physical boundaries and he defined 'isovists' to describe the area in the environment that is directly visible from a location within space. A single isovist is the area of space directly visible from a given location in space, together with the location of that point. For example, in a convex space or a rectangular space with partitions the isovist area of a given point may not include the full area of that space and some parts of the space will not be directly visible from other points in space.

Another urban and architectural theory that is relevant to this study is 'Space Syntax'. Hillier and Hanson (1984) proposed 'Space Syntax' to describe and analyse the character of a space and its effects on human behaviour. 'Space Syntax' research shows that the majority of human movement occurs along the longest lines of sight, and that the more open visible space we have in front of us the more we tend to move towards that direction (Hillier et al, 1993). However, the complexity of the spatial elements that are taken into consideration is limited. 'Space Syntax' sees space as a set of solid walls and empty openings and does not examine transparent elements. In addition to the lack of consideration of transparent materials, there is also a lack in understanding the effects of ambient technologies and 'digital' transparencies. Both physical and 'digital' transparencies extend and sometimes distort the depth of field or the perspective angle and thus may have important effects on people's perception of space and movement.

Existing spatial analysis theories do not take into consideration complex architectural components such as ambient displays. Despite the fact that there are some studies that deal with pervasive systems in urban environments, they focus on social behaviour and do not consider the influence of ambient displays on human movement (Schieck et al, 2007; Schieck et al, 2005). Additionally, such research is limited in considering ambient technology as a layer that is placed over existing urban infrastructures or simply replaces building facades. As we move into a world where a fusion of virtual and physical is going to be prevalent (Spiller, 2002), studying and analysing people's behaviour in relation to the use of embedded ambient displays can offer important knowledge.

AIMS AND OBJECTIVES

The study starts with the assumption that the topological and visual relations between physical spaces are two important factors that determine the distribution of people's movement in space (Hillier , 2004).

This research intends to analyse the changes in movement patterns when ambient displays are used as a virtual extension of the visual boundaries inside public spaces. The hypothesis of this study is that an ambient display able to extend the visual field through a skewed perspective projection towards another space (see Figure 2), which is near but not directly accessible, will influence the topological and visual relations between spaces. As a result it is expected that the distribution of people's movement will be affected.

In contrast to current stable physical spaces, the introduction of new responsive and ever-changing materials will impose new fully adaptive architecture. Therefore, extending current knowledge and theories to involve digital transparencies as a crucial element of spatial configurations is inevitable.

METHODOLOGY

To achieve the aims of this research, a series of experiments were developed in order to observe and analyse how the presence of an ambient display and the perspective angle of its projection affect people's movement (see Figure 2). The experiments are focused on the use of ambient displays in the interior of public spaces by placing them near an area of common interest. Public spaces offer great opportunities for experimenting with ambient technology and the analysis of movement. From a methodological perspective, such places allow observing the movement behaviour of a significant amount of people providing a larger sample for experimentation and analysis.

A fundamental form of space, in which it is simple to examine the flow and direction of people between discrete routes, is corridor-like settings. Based in this setting, two distinguished routes are needed, from which the users can choose in order to access the target space. 'Target space' is considered as a space with common interest for the participants of the experiment such as a coffee area or a common room that they can prepare and eat their lunch.

This type of experiment gives the opportunity to examine a single 'decision making' point providing clear and unbiased experimental conditions. It is essential that the routes need to be symmetrical in order not to influence the users' choice by producing different visual triggers. Moreover, having the 'T' shaped corridors as the setting, where people can go left or right, gives symmetrical visual characteristics. Therefore, the addition of an ambient display that distort the visual perspective at the wall in front of the end of the corridor as depicted in Figure 3 is expected to act as a visual trigger. The display's presence and the different skewed projections will potentially introduce a digital opening in the visual field and will influence people's movement.

Intuition and a simplistic interpretation of 'Space Syntax' suggest that the presence of an ambient display in a corridor should not influence the route decision-making choices of occupants going down this corridor. In the condition when both routes are equidistant from the objective, one might well expect a 50/50 left-right split of occupants. Alternatively, the hybrid space hypothesis suggests that a digital ambient display that functions like a virtual window, when distorting the visual field with a skewed projection, will alter spatial morphology and so will result in an observable behavioural change in movement patterns (see Figure 3). To test this, a set of corridors as a 'T-shaped' arrangement was constructed with the upper part of the 'T' near the target space. As the 'target space', a room for coffee providence was used. The research's interest is

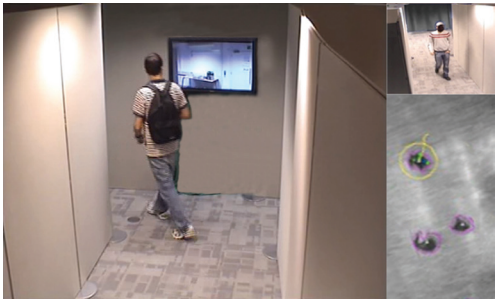

Figure 2
Example of an experiment setting ('left' skewed projection).

to examine how the addition of a skewed perspective view would affect this distribution, a case that currently is not predictable by relevant theories like 'Space Syntax'.

Deriving from the background research and the hypothesis, the display's main function was to act as a live video link providing a one-way video from the 'target space' and introducing an augmented opening that digitally distorts the visual perspective. In addition, a series of 'null-tests' were introduced as part of the experiment using the ambient display with: no content, random static images and random animated content. The 'null-tests' were critical for establishing the content of the display as the only source of influence.

Experimental Set-Up

The space used was the Ambient Technology Lab, an approximately 144 m2 area free of internal walls, at the Open University UK. For the construction of the corridor-like setting, full-height lightweight solid partitions were used producing a symmetrical space. The remaining space at the end of the corridor-like setting was designed as a small coffee area, where free coffee, tea and biscuits were available to everyone during the course of the experiment.

For the data gathering, a multi-camera set-up was used for synchronized recording of every corner of the lab. The cameras were positioned in the ceiling and configured to track multiple angles of the decision-point area as well as the full length of the corridor and coffee area.

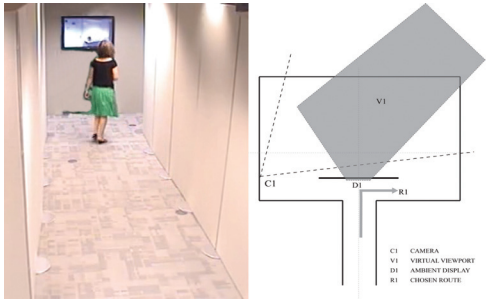

Figure 3
Influencing direction of movement. Experiment setup.

The experiment ran over a period of several weeks during working hours and employees and visitors were able to use this setting for taking their morning or afternoon coffee. None of the participants were aware of the research's nature but were informed that they were taking part in an experiment and were being recorded. The experiment area was clearly marked to the effect that they were entering a video monitored zone and emails were sent out to ask for participants. The emails explained that the purpose of the experiment will be revealed after its compilations and the whole process was ethically approved. While participants were asked to use a specific entrance and exit door in order to avoid passing through the corridor in both directions, it was felt that this did not bias participants' response of direction choice.

As discussed before, the measurements had to be compared with a 'base model' of this space with no ambient displays installed. On that account, the experiment started by collecting data about people's movement within the T-shape configuration with no ambient display present. After having sufficient data to serve as the basis of the experiment, the second phase started, in which a large display was carefully embedded into the wall in front of the end (see Figure 3) of the constructed corridor (decision point). The display, a large anti-glare display with a 15 mm black casing, was linked with a high-definition professional camera and depicted the coffee area as seen from a centred 'perspective' in relation to the depicted area. This 'perspective' view was used in order to emulate the actual perspective of the coffee area that an opening at this position would have revealed. In the third phase the display's placement did not change and a skewed perspective projection was used (off-centre vanishing point) in order to emulate the same effect of a virtual window but as seen from the right side (Figures 2, 3). Similarly, in the forth phase the skewed projection change a symmetrical effect to 'phase 3' but towards the left side. Everything else in the experimental setting remained unchanged for the course of the experiment.

At the end of the study all video streams were examined regarding the movement, choice of direction and the reactions of the people. All data were treated with confidentiality and not shared with anyone outside the limits of this research.

In total, more than 900 individuals took part in the experiment, which gives us a clear evaluation of the hypothesis. The number of participants doesn't include people passing multiple times but the observations are kept in order to later check their potential contribution on the overall hypothesis.

RESULTS

To analyse the movement patterns in the experimental setting the number of individuals and groups walking through the corridor were counted in relation to their decision to follow the right or left direction in the particular setting. The data were categorized according to the experimental phase (without display, with the display depicting a centred perspective, with the display depicting a 'right perspective' and with the display depicting a 'left perspective') and whether it was individuals or groups. The analysis conducted by grouping the data into two categories in order to eliminate any signs of internal influence within the groups of people ('groups' have more than one person and all subjects follow the first person in the group): 1) for 'all groups and individuals' without taking into account if a person was alone or a part of the group and 2) 'only individuals' counting all 'individuals' and each of the 'groups' as one subject unaffected by the number of people in the group. These categories were analysed using a chi-squared test and logistic regression analysis (modelling of binomial proportions).

In the first phase (no display), which took place over a period of four weeks, the findings revealed that combining groups and individuals, 55% of the people turned left in the specific setting and 45% turned right, while counting only the individuals the distribution was 54.8% left and 45.2% right (see Figure 4).

In the second phase where the display produced a centred projection of the 'target area', the distribution was 55.1% turning left and 44.9% turning right for the combined test subjects and 53.7% left and 46.3% right for only the individuals (see Figure 4). Those results showed no significant 'shift', as expected, in people's distribution along the two alternative directions in view of the fact that there was no distortion of the visual field or the 'virtual' spatial topology.

In the third phase where the display produced an off-centred projection with a skewed perspective to the right, the distribution was 37.1% turning left and 62.9% turning right for the combined test subjects and 38.5% left and 61.5% right for only the individuals (see Figure 4). Those results showed a significant 'shift' in people's distribution along the two alternative directions. The shift towards the right side was 17.9% combining all test subjects together and 16.3% counting only the individuals.

Finally, in the forth phase where the display produced an off-centred projection with a skewed perspective to the left, the distribution was 65.3% turning left and 34.6% turning right for the combined test subjects and 65.6% left and 34.4% right for only the individuals. Those results also showed a significant 'shift' in people's distribution (see Figure 4). The shift towards the left side was 10.3% combining all test subjects together and 10.8% when counting only the individuals.

Furthermore, for validation of the significance of the results from the three unmatched groups a chi-square statistical test was used. The p-value of this test was 0.0018.

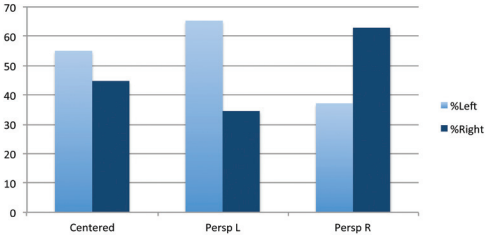

Figure 4
Distribution (%) between routes.

Following the tests about the general significance of the measured data and the influence of the skewed projections, a logistic regression analysis was conducted ('modelling of binomial proportions'). For this test a value denoting the direction of the skewed projection of the ambient display was introduced (direction of influence): '-1' when the perspective's vanishing point is at the opposite side than the one testing, '0' when there is centred and '1' when the vanishing point is on the same side, as well as a value denoting the presence of an ambient display regardless of projection (encoded as '0' for not present and '1' for present). The 'direction of influence' matches the direction of the significant change in movement as measured in the experiment, with a p-value (t pr.) less than 0.001. The result of this analysis further confirms the hypothesis that the ambient display produces a significant change in the direction of movement, when using skewed projection, towards the side at which the vanishing point of the perspective is located. Additionally, combining the 'direction of influence' and the 'presence' variables evinces that the resulted distortion is not based on the location of the vanishing point (skewed perspective towards right or left), and thus for both 'right' and 'left' cases the change was equally significant.

Null-Tests Results

In relation to the above, there was a need for extracting whether the ambient display itself (the device) or its content were responsible for the findings. For that reason, using the same equipment and spatial setting a follow-up experiment was conducted positioning the display in the same place as the first experiments but without the video link. Instead of the video feed, several scenarios were tested: no image is used in order to test the ambient display as a device while static images, animated images and short video clips used to explore the effects of diverse content that could affect the users.

The results were treated in the same way as the first experiment and showed that the shift in direction between the phase without a display (base model) and each of the null-test phases is less than 2% in all cases and not statistically significant.

In detail, from more than 350 individuals who took part in the null-test experiments, the majority of people continue to use the left route more (the same way as before the application of the ambient display), with the percentage varying from 56.5% to 53.8% in favour of the left route. What is clearly visible from the results is that the ambient display blends in the environment and becomes an unobtrusive object that without the added visual perspective it does not influence people's behaviour and movement in space.

CONCLUSION

The results of this study reveal that, an ambient display that shows typical information has, as one might expect, no change on pedestrian route choice behaviour. On the contrary, a non-centred perspective projection of a space influences route choice behaviour towards the side of the projected vanishing point. This has a number of ramifications in terms of both the design of ambient displays in architectural settings and the use of augmented/hybrid spaces in research conditions.

This study also demonstrates that a skewed projection has the effect of increasing awareness about the "target" space giving a subliminal direction towards the side where the vanishing point of the projection is situated. In some cases the ambient display unconsciously nudged people to pass through the corridor setting and go to the coffee area. As the video revealed, most of the users took decisions quickly. However, there were cases of individuals changing their initial decision and adapting their route towards the side of the 'influence'. It is speculated that raising awareness of this decision may have increased the likelihood that these individuals recalculated the new augmented layout of space against the old and moved accordingly.

Accepting that people's visual perception of space becomes influenced by the virtual augmentation and extension of space that ambient displays

produce, this research can contribute in two main areas. One area deals with the architectural space design featuring ambient displays, as well as navigation in space. The second area is the content and interface design for ambient media. In the fast-growing field of digital augmentation in architecture, understanding and acknowledging people's movement, proximity and navigation in space can give new ways of managing and directing movement towards desired places or interfaces. Examples within this area include subliminal nudges for accessibility of remote or 'hidden' spaces as well as alternative and more efficient methods to assist way-finding. In addition, ambient information systems can be made and positioned in a way able to enhance interactivity and social engagement.

The findings of this research enable the need for further analysis and understanding of the fusion between physical and virtual spaces. Exploring in depth the hybrid spaces that emerge through the use of ambient displays will provide more generic insights and allow the effective use of digital augmentation in architecture. Currently, a research that explores the spatial properties of such hybrid spaces is under development in order to bridge this gap.

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