INTERACTIVE ADVERTISING DISPLAYS

Audience Behavior around Interactive Advertising Columns, Life-size Screens and Banner Displays

Gilbert Beyer

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Abstract

Interactive public displays are the latest development in the field of out-of-home advertising. Throughout history characteristic shapes for billboards evolved such as flat rectangular displays, long displays or cylindrical advertising columns. This work presents novel interactive display designs that are based on these historical role models and allow passers-by to interact with them in a natural, touchless manner. It further pursues a vision where interactive public displays become more active themselves and actively influence passer-by behavior in order to increase their effectiveness, better attract attention and improve public interaction in front of them. First, to overcome the challenge that passers-by often do not expect public displays to be interactive and thus pay no attention to them, this work presents a solution called unaware initial interaction that surprises passers-by and communicates interactivity by giving visual feedback to their initial movements. To be effective, the visual feedback has to be designed considering the specific display shapes, their requirements to contents and the typical approaching trajectories. Second, to overcome the challenge that larger groups of passers-by often crowd together in front of wide public displays or do not take optimal positions for interaction, this work presents a solution to subtly and actively guide users by dynamic and interactive visual cues on the screen in order to better distribute them. To explore these concepts and following an initial analysis of the out-of-home domain and of typical display qualities, interactive counterparts to the classical display shapes are designed such as interactive advertising columns, long banner displays and life-size screens. Then interactive contents and visual feedbacks are designed which implement the presented interactivity concepts, and audience behavior around them is analyzed in several long-term field studies in public space. Finally the observed passer-by and user behavior and the effectiveness of the display and content designs are discussed and takeaways given that are useful for practitioners and researchers in the field of public interaction with out-of-home displays.

Zusammenfassung

Interaktive öffentliche Displays sind die neueste Entwicklung im Bereich der Außenwerbung. Im Laufe der Geschichte bildeten sich charakteristische Formen für Werbetafeln heraus wie flache rechteckige Displays, lange Displays oder zylindrische Werbesäulen. Die vorliegende Arbeit stellt neuartige Designs für Displays vor, die auf diesen historischen Vorbildern aufbauen und den Passanten erlauben, mit ihnen auf eine natürliche, berührungslose Art und Weise zu interagieren. Darüber hinaus verfolgt sie eine Vision, in der interaktive öffentliche Displays aktiver werden und entsprechend das Passantenverhalten beeinflussen, um ihre Wirksamkeit zu erhöhen, mehr Aufmerksamkeit auf sich zu ziehen und die öffentliche Interaktion mit ihnen zu verbessern. Zunächst stellt diese Arbeit eine als Unbewusste Initialinteraktion bezeichnete Lösung vor, welche die Passanten überrascht und mittels visuellem Feedback auf ihre anfänglichen Bewegungen Interaktivität übermittelt, um die Herausforderung zu bewältigen, dass Passanten oft nicht erwarten, dass öffentliche Displays interaktiv sind und sie ihnen somit keine Aufmerksamkeit schenken. Um effektiv zu sein, muss das visuelle Feedback dabei so gestaltet werden, dass es die spezifischen Displayformen, ihre Anforderungen an die dargestellten Inhalte und ihre typischen Annäherungswege berücksichtigt. Zweitens stellt sie eine Lösung vor, bei der die Nutzer auf subtile Weise und durch auf dem Bildschirm dargestellte dynamische und interaktive visuelle Reize aktiv geführt werden, um sie besser vor dem Display zu verteilen, um die Herausforderung zu bewältigen, dass größere Gruppen von Passanten sich oft vor breiten öffentlichen Displays zusammendrängen oder keine optimalen Positionen für die Interaktion einnehmen. Zur Erforschung dieser Konzepte werden im Anschluss an eine einführende Analyse von Außenwerbedisplays und ihrer typischen Eigenschaften interaktive Entsprechungen der klassischen Displayformen entwickelt wie interaktive Litfaßsäulen, lange Bannerdisplays und Life-size Screens. Weiter werden für diese Displays interaktive Inhalte und visuelle Feedbacks entwickelt, welche die vorgestellten Interaktivitätskonzepte umsetzen und das Verhalten des anwesenden Publikums in mehreren Langzeit-Feldstudien im öffentlichen Raum untersucht. Schließlich werden das beobachtete Passanten- und Nutzerverhalten und die Effektivität der entwickelten Display-Designs und Inhalte bewertet und nützliche Empfehlungen für Praktiker und Forscher auf dem Gebiet der öffentlichen Interaktion mit Außenwerbedisplays gegeben.

Acknowledgements

This work was done with the advices, help and encouragement of many people. I want to thank you all for your support. Special thanks to **Andreas Butz** for the continuous support, motivation and advising until this final written thesis. Thank you for supporting me in accomplishing this research work and in conducting the single field studies, but also for giving advices in many topics far beyond that. Many thanks to **Martin Wirsing** for the helpful scientific advising, the opportunity to discuss this topic on the mountain hut and for sponsoring this often expensive research, as well as to **Harald Reiterer** for joining the committee and for the helpful advices during my visit in Konstanz. Thanks especially to **Nikola Serbedzija** for introducing me to research and the associated projects and to writing research papers. I also want to thank **Ivo Haulsen**, **Manuel Schiewe**, **Karsten Isakovic**, **Stefan Klose** and the whole team at Fraunhofer FIRST and FOKUS for their great support and the productive cooperation on the advertising column over several years. Many thanks also to all students who contributed to this work. Thank you **Florian Köttner** for the outstanding software engineering and our common work on the Interactive Advertising Column, and also for driving it together with me between Berlin and Munich over midnight. Thank you **Jens Fakesch** for the well-considered concepts and sophisticated visual and hardware designs in the context of the studies with the door display and the Life-size Display, **Nina Jäger** for the sidewalk study with the Interactive Banner Display and the nicely designed interactive fish which brought a lot of fun to the passers-by in Maxvorstadt, and **Vincent Binder** not only for the interesting framing concepts on the same display but also for helping me with extensive filming sessions. Thanks also to all students who were involved in the video coding. Further thanks to all my colleagues at the PST team and the HCI group for their advices, as well as the admins and technical staff at LMU Munich for their technical support. Special thanks also to my parents for their continuous support and patience and my sister **Conny** for her encouraging words.

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CHAPTER 1

INTRODUCTION

Research Theme,
Questions, Methodology,
Context

1.1 Research Theme

Interactive Advertising Displays
are subject to their own domain-specific requirements, appear in characteristic shapes, and require novel interaction paradigms that work in public space.

1.1.1 Future Interactive Public Displays

This work explores new opportunities for large interactive advertising displays. Public displays have been used since ancient times for cultural information and proclamations by the authorities, yet advertising for products and services soon became their main purpose. Throughout history, characteristic display shapes for such billboards evolved such as flat rectangular displays, long sidewalk displays or cylindrical advertising columns. While the used display materials were subject to evolution, these distinct shapes prevailed. In the last century public advertising displays, or out-of-home displays as they now are called, became dynamic when illuminated, electronic and digital screen technologies emerged that allowed to display moving images. Still, these displays remained widely passive, and beyond conveying visual-textual messages did not interact with passers-by in any visual-motoric way. One reason was that the available interaction technologies such as touch screens are not effective in public space as passers-by do not expect them to be interactive and thus do not discover their interactivity. This work presents new interactive display formats based on the historical display shapes, investigates new interactive contents based on natural, touchless interaction technologies that allow to overcome the existing limitations, and describes how passers-by behave around these display designs. It pursues a vision where interactive displays become more active themselves by using interactive feedback to attract passers-by and influence their behavior. Beyond presenting novel theories, display designs and interactive contents, this work provides takeaways and practical insights from the conducted field studies.

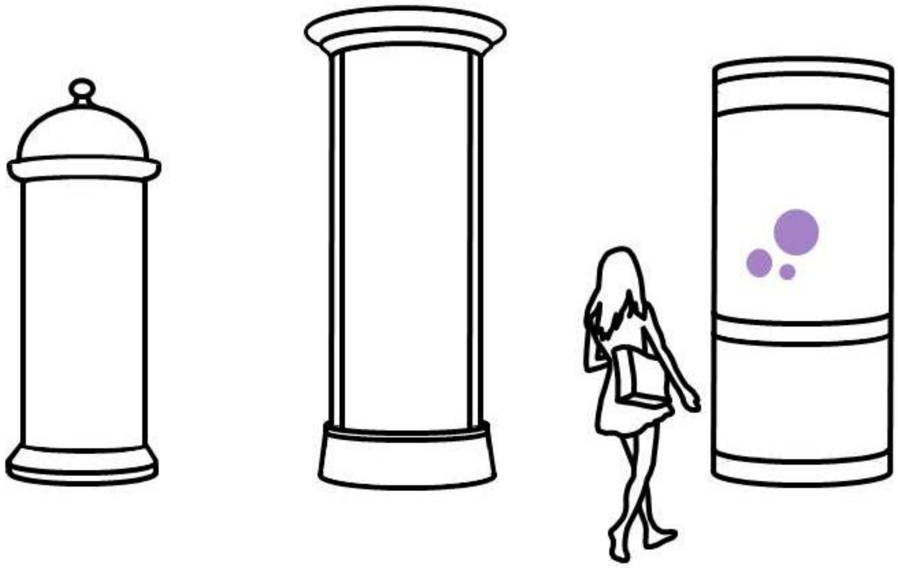


Figure 1.1: Evolution from historical to interactive advertising columns.

1.1.2 Novel Interaction Paradigms

In particular, this work introduces two novel interaction paradigms that make use of touchless interaction and computer vision technologies to make interactive public displays more effective: First, a solution to the challenge that passers-by do not expect that a public display is interactive and therefore pay no attention to it is an *unaware initial interaction* that surprises passers-by and communicates interactivity by giving visual feedback to their initial movements when they are walking by. This can for example be achieved by displaying real or stylized mirror images in which passers-by can recognize themselves and thus notice that the display reacts to them [Beyer 2008]. Also further visual feedbacks can fullfill this purpose if they are effectively recognized as being interactive. To be effective, the feedback has to be designed considering the specific display shape, the individual approaching trajectories towards the display, and the requirements of the specific content. Second, a solution to the challenge that larger groups of passers-by often crowd together in front of wide public displays or do not take optimal positions for interaction is to actively guide users by dynamic and interactive visual cues on the screen in order to better distribute them. This envisioned interaction principle is called *visual audience moderation* [Beyer 2014], and preferably should rely on visual mechanisms that subtly influence user behavior in order to not disturb the flow of interaction with the display. At the beginning of this research, we did not know if this would work at all.

1.1.3 New Display Shapes

This work further presents interactive counterparts to classical display shapes in out-of-home advertising that have not been addressed in research so far, such as round interactive advertising columns, long interactive banner displays and large interactive life-size screens. In HCI research on public displays, so far mostly only industry-standard flat rectangular displays have been used which were originally intended for indoor office or working environments and have no tradition in public space. Yet the common flat and non-flat display shapes that are employed in paper-based or illuminated out-of-home advertising such as Litfaß or Morris columns or wide banner displays have a long history of use and are the result of a continuous evolution. These shapes prevailed because they conveniently integrate with urban architecture and comply with the requirements of long distance visibility and perceptibility. This work explores how the next development stage of these classical display shapes can look like and how they can be enhanced with state-of-the-art screen and sensor devices in order to enable natural, touchless interaction techniques around them.

1.1.4 Audience Behavior

Finally, this work investigates the audience behavior around the domain-specific display shapes that make use of the developed interactive visual feedbacks and cues. The performance and practicability of the developed interaction paradigms in public space has to be tested, as well as how single and multiple users notice, understand, accept and interact with these novel shapes. Further it has to be found out how passer-by and user behavior around such advanced, shaped and interactive displays in public space can be recorded and analyzed. At last, at the beginning of this work audience behavior with interactive displays in outdoor public settings was a very new field of research. While there have been only a few studies with a practical orientation on the side of academic HCI research, the out-of-home industry has developed manifold and sophisticated user research methods over the years but on the other hand has not put much effort into the exploration of new interactive technologies for a long time. This is why issues such as passer-by attention and common behavior, understanding of interactivity and social interaction between multiple users as well as the action possibilities of public displays offer a broad field of research opportunities.

1.2 Research Questions

The key research issues
of this work are how novel interactive display shapes and effective content solutions for them can be designed, and how audience behavior around them can be evaluated.

1.2.1 Research Focus

Pursuing this vision of interactive public displays that continue characteristics of traditional display shapes in out-of-home advertising and use state-of-the-art natural interaction techniques to become more active themselves, this work concentrates on three fields of activity, the design of novel displays, the design of effective interactive contents, and finally the evaluation of audience behavior around these designs in public space in order to prove their effectiveness:

Key Issues		
Novel Displays	Effective Contents	Audience Behavior

This work aims to develop interactive displays and contents which come as close as possible to real operating scenarios of the out-of-home domain. In general, three types of desired effects can be distinguished in advertising: the immediate reactions of the audience upon contact with an advert, the permanent recall of the advertising message, and finally the changes of attitudes and the decising making [Kroeber-Riel 2013]. As this research explores interactive contents which actively influence passer-by attention, unterstanding of interactivity or user positions and social constellations, on the side of behavioral user research it also focuses on the immediate reactions and experiences of passers-by on site. The single research questions within the three fields of activity are:

1.2.2 Designing Novel Interactive Displays

The first set of research questions addresses (1) how interactive counterparts of historically successful role models such as round advertising columns, flat rectangular poster screens or wide banner displays can be designed, including suited and state-of-the-art sensor and display technologies which enable seamless interaction spaces and a seamless perception around them, then (2) which qualities of such different public display shapes can be distinguished, including issues such as which benefits and challenges they imply, how they affect the design of interactive contents and how they interact with other qualities and the surrounding environment, and (3) what the specific potentials and opportunities of the designed individual display types are in regard to visual attention, user and social interaction as well as the display location.

Novel Interactive Displays		
Interactive Counterparts	Display Qualities	Individual Potentials

1.2.3 Designing Novel Interactive Contents

The second set of questions addresses (1) how interactive public displays with different shapes and preconditions in regard to visibility and user trajectories can initially attract the attention of passers-by by suited physical intense, dynamic and interactive stimuli, (2) how novel display types can communicate their interactivity to passers-by who do not expect that they are interactive, by providing effective visual feedbacks and applying appropriate techniques for sensing passer-by movement, positions and directions, and (3) how interactive public displays can actively shape their audience and actively and subtly guide passers-by in front of the display by dynamic visual cues or stimuli on the screen in order to dissolve crowds, users interfering with each other or inactive social constellations, and thus improve parallel usage in front of the display.

Effective Interactive Contents		
Attracting Attention	Conveying Interactivity	Subtly Directing Users

1.2.4 Evaluating Audience Behavior

The third set of questions addresses (1) how arbitrary passers-by behave in public space, in front of interactive public displays and with new touchless interaction techniques in general and which patterns can be identified, (2) how effective the developed display designs and interactive contents are, as there is no prior knowledge in how far passers-by will accept, understand and interact with them and as specific assumptions on standard flat displays such as frontal body orientations and trajectories cannot be simply transferred to novel shapes of interactive displays, (3) how the identified single display qualities influence audience behavior in front of the interactive displays and support or interfere with the primary interaction with the content or the social interaction between users, and (4) what suitable research methods to accurately collect and analyze complex behavioral data are (subtle changes of passer-by attention, positions or movement patterns) around different shapes of displays, and in public settings with large numbers of subjects and their social and environmental complexities.

Audience Behavior	
General Behavior	Effectiveness of Contents
Effects of Display Qualities	Evaluation Techniques

1.3 Research Project

This research work
primarily aims to inform experts in the field of out-of-home advertising about novel interactive opportunities for public displays, and follows a consistent methodology.

1.3.1 Research Objectives

The objective of this work is to introduce novel interactive public display types based on historical role models of out-of-home advertising, and explore the inherent qualities and opportunities of these designs for interactive contents and public user interaction. This research documentation thus primarily addresses practitioners and researchers in the field of interactive out-of-home advertising who work on interactive public displays and contents, as well as other experts from HCI, interaction design, human factors and urban architecture who work on similar problems where unwitting people, crowds or audiences in public space have to be encouraged to perform certain actions by subtly stimulating them.

1.3.2 Research Methodology

To address the research questions formulated above, at first interactive display prototypes were designed and deployed and tested in ecologically valid settings in the wild. Then the natural and uninfluenced behavior of arbitrary passers-by around these display designs was observed, analyzed and interpreted based on the formulated interactivity conceptions and other existing theories on user behavior. From the findings of these evaluations finally recommendations for researchers and practitioners in the field were derived, which we present as takeaways at the end of each study. The single projects presented in this work follow the following consecutive stages of initial field analysis, conception and design, empirical evaluation and interpretation that build upon each other:

Stage 1: Initial Field Analysis

In the first step, the specific domain of out-of-home displays is analyzed. In this context, historical role models for novel interactive display types are identified and their evolution, requirements and formal aspects such as typical shapes and sizes, integration with architecture or deployment analyzed. For this purpose, field overviews are conducted and the domain-specific literature is reviewed.

Stage 2: Designing Interactive Displays

In the second step, based on the initial findings from the field analysis interactive display prototypes that adopt qualities of historical role models such as shapes, sizes and ratios are designed and touchless sensor techniques integrated which enable interactivity. A design goal is to build prototypes which are robust enough for public settings and not immediately recognizable as research prototypes.

Stage 3: Designing Interactive Contents

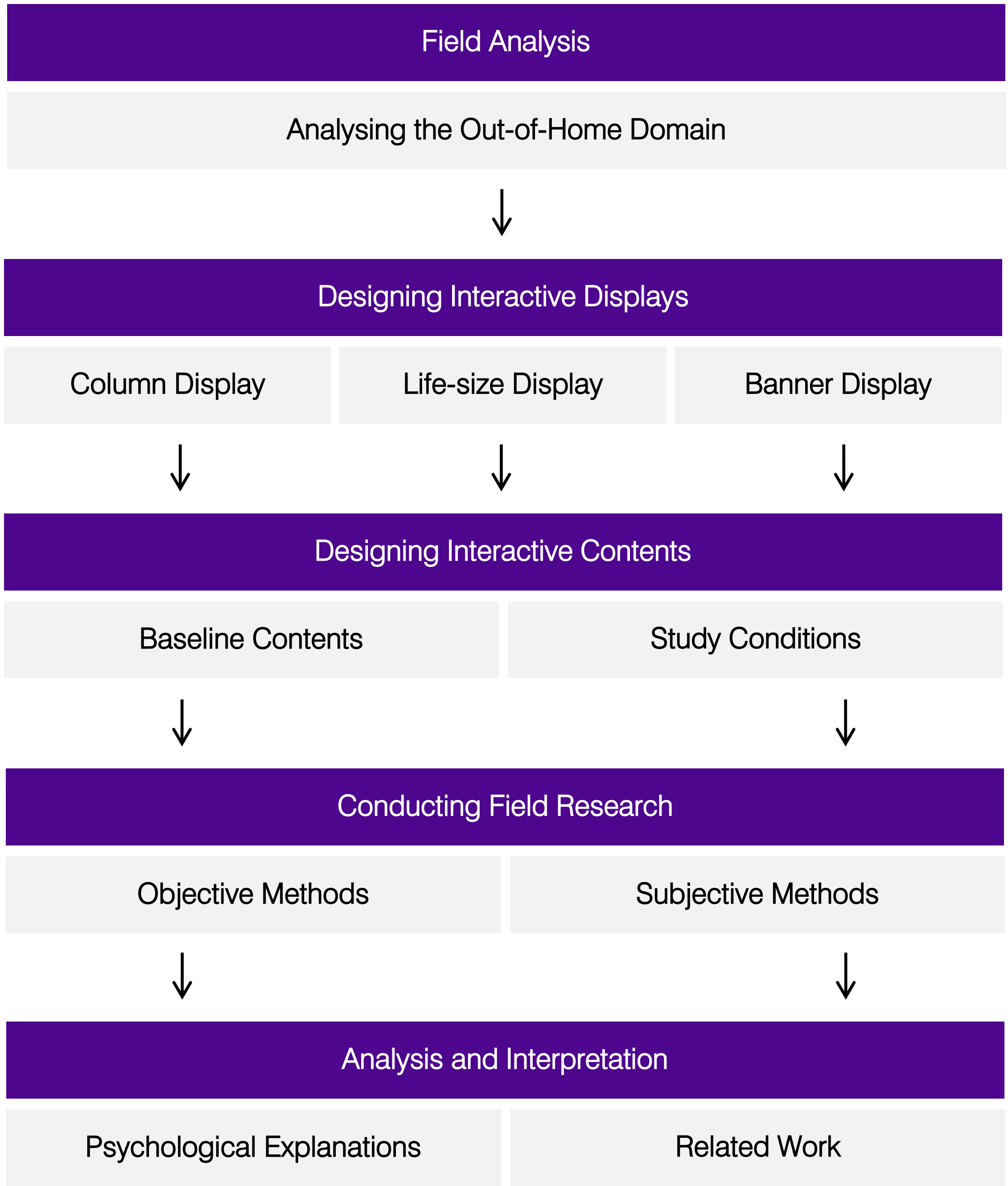
Based on the presented concepts on effective interaction with public displays, interactive contents for the display prototypes are designed. In some studies similar contents are used on different display shapes in order to compare them, for others format-specific contents are designed which exploit unique qualities of the displays such as shape, screen size or typical trajectories. The interactive contents are tested and refined iteratively before being used in field studies.

Stage 4: Conducting Field Research

The prototypes are deployed at locations where also their historical counterparts could be found. To assess detailed audience behavior in public space, objective methods such as field observations are employed in order to obtain accurate measurements on viewing behaviors, reactions, positions, body orientations or trajectories by computer-aided video analysis, and numerical data that can be statistically analyzed. Further, subjective methods such as post-hoc interviews and questionnaires allow to understand the individual experiences of users.

Stage 5: Analysis and Interpretation

Finally, the collected data is systematically analyzed and the results from the objective and subjective methods interrelated with each other. Found effects of the tested display or content conditions on passer-by behavior are interpreted referring to the related literature. From the gained findings and practical insights design recommendations for follow-up research and practitioners are derived.


Field Analysis
Analysing the Out-of-Home Domain
Designing Interactive Displays
Column Display
Life-size Display
Banner Display
Designing Interactive Contents
Baseline Contents
Study Conditions
Conducting Field Research
Objective Methods
Subjective Methods
Analysis and Interpretation
Psychological Explanations
Related Work

1.3.3 Research Context

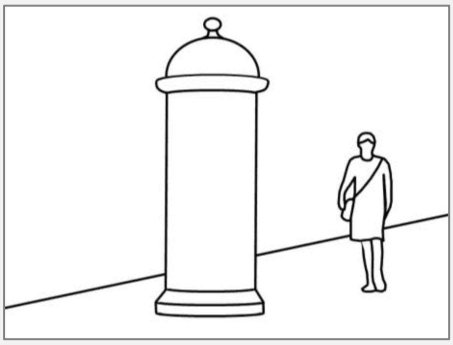
Prior work: Digital Advertising Column

This work extends prior research and concepts on interactivity of public displays and prior work on display prototypes such as the *Digital Advertising Column*. In my diploma thesis [Beyer 2008] the applicability of this cylindrical column display, which was originally developed by Fraunhofer FIRST [Haulsen 2005], as interactive advertising medium was explored. In the context of that work, the column was equipped with a fisheye camera sensor to enable touchless interaction, and several interactive contents were designed that react to the unaware movements of approaching passers-by to attract attention and communicate interactivity. This interactive advertising column and its contents have been reused in parts of this work, such as in the lab study presented in Chapter 6 as well as in [Beyer 2011].

Common Research

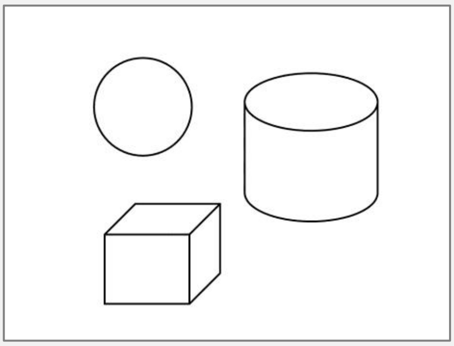
This work has been conducted in cooperation with researchers and students of the University of Munich (LMU) and other institutions. All studies with the Digital Advertising Column as presented in [Beyer 2011] and [Beyer 2013] have been conducted in cooperation with researchers from Fraunhofer FIRST (since 2012 Fraunhofer FOKUS) in Berlin, notably Ivo Haulsen, Manuel Schiewe, Karsten Isakovic and Stefan Klose. In addition, the research on the comparative lab study between the advertising column and a flat display which we presented in [Beyer 2011] has also been done together with Florian Alt and with support by Albrecht Schmidt from the University of Duisburg-Essen as well as Jörg Müller from the Deutsche Telekom Laboratories Berlin. This dissertation further builds on concepts and results of diploma and bachelor's theses of students at the University of Munich whom I supervised, notably Florian Köttner [Köttner 2012] in the context of the field study with the Interactive Advertising Column, Jens Fakesch [Fakesch 2013] in the context of the two field studies with the Interactive Life-size Display and the Door Display, Nina Jäger [Jäger 2013] in the context of the field study on attracting attention and conveying interactivity with the Interactive Banner Display, and Vincent Binder [Binder 2013] in the context of the field study on subtly directing users in front of the same banner display. Finally, the research presented in this dissertation has been conducted under the advisement of and in collaboration with my supervisor Andreas Butz. The individual contributions of these researchers to this dissertation appear in more detail in the corresponding chapters of this work and in the appendix.

1.4 Overview



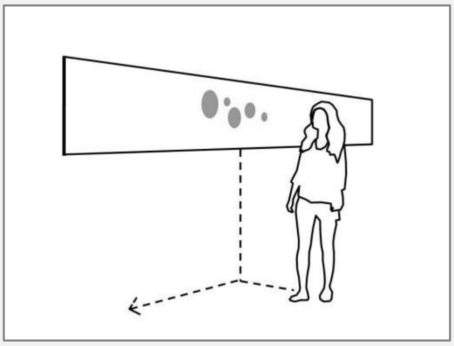
CHAPTER 2 – THE DOMAIN:

Overview on Large Out-of-Home Displays
This chapter analyzes the out-of-home domain and its requirements, historical examples as well as the state-of-the art of large advertising displays in public space.



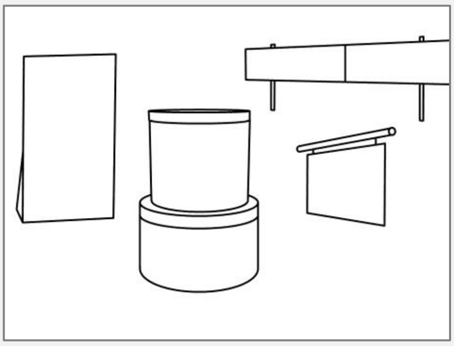
CHAPTER 3 – INTERACTIVITY:

Conceptions for Novel Interactive Contents
This chapter presents conceptual solutions for typical problems with public displays, such as interactive contents which attract users, convey interactivity or subtly influence user positions.



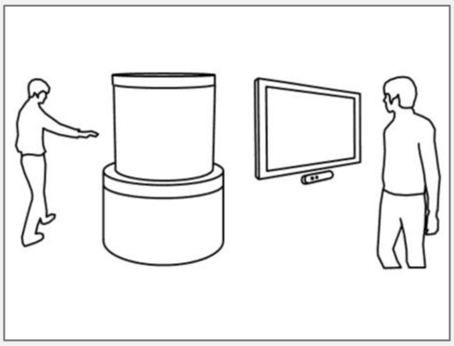
CHAPTER 4 – DISPLAY QUALITIES:

Factors that Influence Passer-By Behavior
This chapter examines the formal qualities of different public display shapes such as form factor, curvature, framedness or materiality and possible effects on passer-by and user behavior.



CHAPTER 5 – PROTOTYPES:

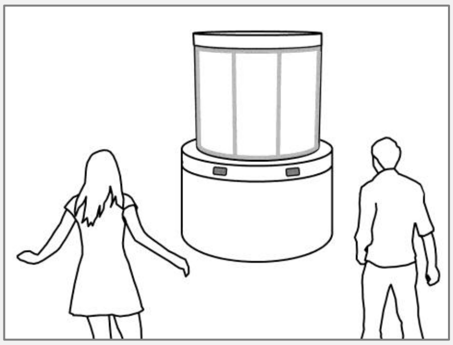
Novel Interactive Display Designs
This chapter presents the envisioned interactive display designs based on historical role models such as interactive advertising columns, wide banner displays and large life-size screens.



CHAPTER 6 – LAB STUDY 1:

Interactive Advertising Column vs. Flat Display

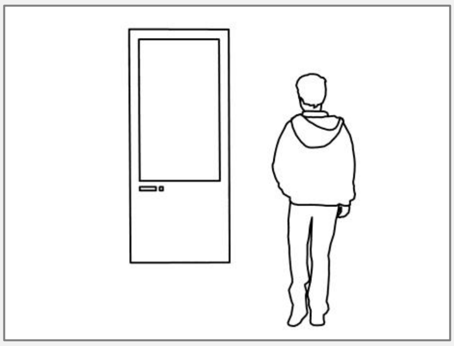
This chapter reports on a comparative lab study between the Interactive Advertising Column and a flat rectangular display with a similar visible screen surface and the same content.



CHAPTER 7 – FIELD STUDY 1:

Seamless Column vs. Framed Column

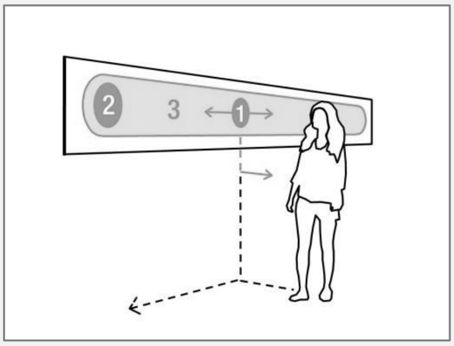
This chapter reports on a comparative field study between the Interactive Advertising Column and the same interactive column in a condition with added visual frames.



CHAPTER 8 – FIELD STUDY 3 & 4:

Approaching Displays Frontally

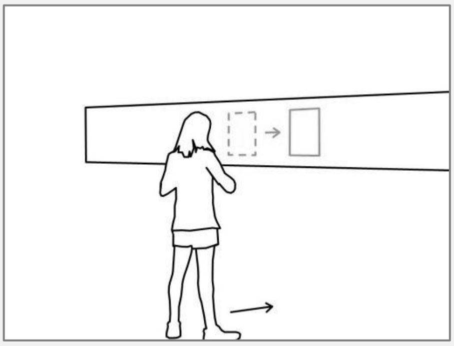
This chapter reports on two field studies with flat Interactive Life-size Displays and how they can attract attention and communicate their interactivity when they are approached frontally.



CHAPTER 9 – FIELD STUDY 5:

Passing-By Displays Sideways

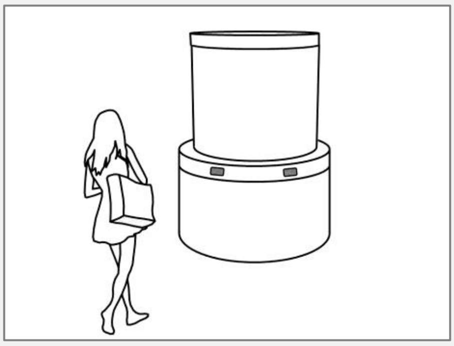
This chapter reports on a field study with the wide Interactive Banner Display and how it can attract attention and communicate its interactivity when it is approached sideways.



CHAPTER 10 – FIELD STUDY 6:

Subtly Directing Users

This chapter reports on a field study with the wide Interactive Banner Display where it subtly guides its users by visual cues on the screen and thus actively shapes audience constellations.



CONCLUSION

Summing up the Findings

While each chapter discusses the findings of the respective studies in detail and provides design recommendations, the general insights from this reseach are finally summarized.

CHAPTER 2

THE DOMAIN

Large Public
Out-of-Home Displays

2.1 Out-of-Home Displays

The Out-of-Home Domain has its own requirements to digital displays
so we conducted a field analysis of the characteristics of the common display types that are used in this industry.

2.1.1 Classifying Public Displays

In order to describe large digital displays, a variety of technical terms are used that cover different aspects. Some typical terms are (compare with Figure 2.1):

Terminology		
Public Displays	Urban Screens[1]	Digital Signage
OOH Displays[3]	Corporate Displays[5]	POS Displays[6]
Billboards[1]	Kiosk Terminals[4]	Media Facades[2]

In HCI research, the common term is public displays, refering to displays that address public audiences. As they are mostly found in inner-city areas, urban screens is used interchangeably. Digital signage describes display networks where content is updated by digital content management systems [Kelsen 2010]. Out-of-home displays (OOH) are a specific range of outdoor and indoor media such as classical poster-size displays which address people on the go and are let via intermediaries to third parties. Corporate displays promote companies on their own property. POS displays are installed at the point-of-sale, and billboards or kiosk systems stand for specific technical solutions. Media facades are, other than the scalable OOH media, usually bound to an individual architectural body.

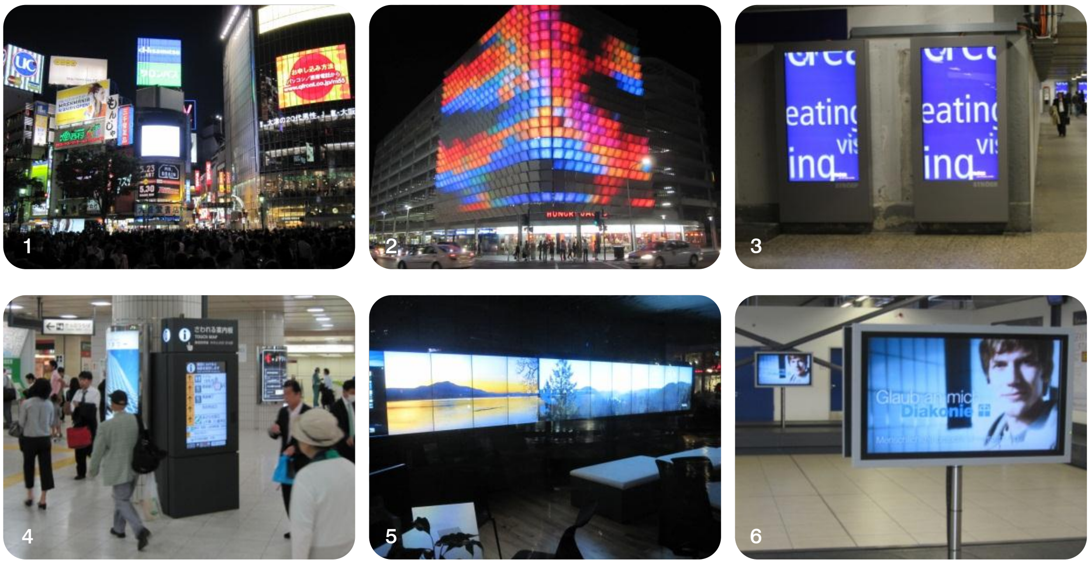


Figure 2.1: Different types of public displays from out-of-home media to media facades.

2.1.2 Out-of-Home Media

Industry

Lots of globally, nationally or regionally acting out-of-home providers exist. The currently largest one is JCDecaux, which is active in more than 4000 cities in 75 countries, operates more than a million advertising panels, and generates a yearly revenue of billions [JCDecaux 2018]. The companies are organized in national associations such as the Outdoor Advertising Association of America with about 900 members [OAAA 2018] or the German Fachverband Außenwerbung [FAW 2018]. In 2016, out-of-home had a market share of 4.3% in the US (Germany/DE: 7%), compared to 11.7% newspapers and magazines (DE: 43%), 40.6% online media (DE: 10%), and 43.5% television and radio (DE: 35%) [OAAA 2018, ZAW 2018].

Advantages

Benefits of out-of-home media are [Schloßbauer 1998, Wall 2012]: an increasingly mobile population, high contact opportunities and coverage, repeated contacts leading to high advertising pressure, and geographical controllability. They allow to selectively address young, active target groups that spend much time out of home while on the go, and are the last medium encountered before the POS. The greatest benefit is the high acceptance of outdoor advertising, resulting from the revival of public space, the entertaining value, and the fact that people do not perceive posters, in contrast to TV breaks or online pop-ups, as disturbing.

2.1.3 Out-of-Home Subdomains

The out-of-home market can be divided into two dominating media segments: classical poster or billboard advertising, and transport media advertising on moved facilities such as public busses, trains and taxis. A third field are so-called place-based or ambient media reaching target groups in their natural ambience such as malls, cinemas, gastronomy or sport arenas [Hofe 2005, P.284]. Billboard advertising can itself be subdivided in stand-alone posters on streets or buildings, and freestanding street furniture (e.g. bus shelters or phone kiosks) which is provided to the cities free of charge in exchange for advertising space. Further, very similar forms to such street media formats are also used indoors in train stations, airports and shopping malls [Schloßbauer 1998, Hofe 2005, OAAA 2018]:

Out-of-Home Media Sites		
Street	Station	Airport
Mall	Transport	Ambient

2.1.4 Historical Evolution

Ancient Public Displays

While wall grafitti and stone boards can be seen as the oldest form of displays, in early civilizations columns became a popular shape, as they provided more screen real estate on the same floor space, but also as freestanding columns such as Trajan’s Column in Rome with their concise, elevated shape were visible from afar. Later cantilever signboards were installed in orthogonal orientation to shops and taverns, such that passers-by would notice them better [Kreutzer 1995].

Organized Out-of-Home Advertising

The problem of wild billposting is reported as early as for ancient Pompeji. To release cities from defacement by paper posters, in 1855 Ernst Litfaß deployed the first network of 150 advertising columns holding standardized poster sizes in Berlin, which is usually seen as the birth of organized out-of-home advertising. Yet George Harris had already patented a mobile column in London in 1824, and columns made of stone decorated Paris since 1842 [Reichwein 1980, Kreutzer 1995].

2.1.5 Technical Evolution

Reflective Displays

Media that are only visible at daylight or by indirect lighting constitute the most ancient form of advertising displays. Early signboards were made of stone, wood or iron. The first posters made of papyrus can be traced back to 2000 B.C. They were later replaced by vellum, paper and synthetic poster materials [Kreutzer 1995].

Illuminated Displays

Light advertising is a requirement for visual attention at night and has emotional and psychological effects [Gut 1974]. The first illuminated signboards were lamps enclosed by oil-impregnated transparent paper. Since 1898 light bulp advertising formed names and shapes of brands and products on buildings and rooftops. The invention of neon tubes in 1910 soon brought colored neon lighting to urban squares and streets. The signboard for *Kupferberg Gold* in Berlin of 1912, where 2500 light bulbs followed a complex program and showed an animation of the lettering and a bottle pouring out brisk champagne, is one of the first dynamic adverts. In the 1920s scrolling marquees and projection-based systems which screened advertisements onto the sidewalk followed [Gut 1974, Kreutzer 1995].

Electronic Displays

Video screens provide more dynamic experiences and a better resolution than light bulb advertising. The first video walls where the image was split to CRT monitors emerged in the 1980s. They were followed by luminous LED video boards in the 1990s which were also effective at daylight, but in the early years suffered from the aesthetical decline (dead pixels) and a low resolution. Thus, on the pedestrian level for a long time screen technologies with a higher resolution were used such as DLP cubes [Mitsubishi 2018], high-contrast plasma display panels (PDP) [Orion 2018], or LED-backlighted LCDs [Samsung 2018]. Currently, the out-of-home industry is interested in high-contrast OLED solutions [Invidis 2017].

Interactive Displays

Info kiosks often used keyboard- and trackball-interfaces, but since the 1990s increasingly touchscreens. Bluetooth posters emerged around the year 2000. Cameras and live video had been used with public displays since *Hole-In-Space* of 1980 [Galloway 1980], while vision- and depth-based sensor systems emerged in this field in the early 2000s [Reactrix 2002] respectively the early 2010s [Invidis 2012].

2.2 Display Media

Several distinct display types such as columns, posters and long walls
appear across all out-of-home pricing segments, but in stores and at landmark sites also individual formats are used.

2.2.1 Out-of-Home Segments

In out of-home advertising, the following display segments can be distinguished depending on the used technology:

Display Segments			
Classical	CLP	DOOH	IOOH

Classical poster advertising means all printed, paper-based display media which become visible only by reflection of light and thus require frontal lighting at night. They constitute the most cost-saving pricing segment. City light poster (CLP), which first emerged in France in the 1980s, are printed posters which are protected by glass and backlit by LED or neon tubes. Due to their high visual quality, they are considered as a premium segment of OOH [Schloßbauer 1998, P.35]. Even more exclusive are digital out-of-home media (DOOH), networks of dynamic and high-contrast electronic screens which are controllable in real-time and thus highly adaptable to the audience and their environment [Kelsen 2010]. They increasingly replace city light media at premium indoor and outdoor sites. The next step are interactive out-of-home media (IOOH), which use sensor input for dynamic feedback to make the content more effective. Across these technical categories a convergency of the display formats can be observed, which means that printed, CLP and DOOH media often appear in very similar spatial shapes.

Figure 2.2: City light column, city light poster and long poster wall.

2.2.2 Ground-Level Displays

Posters

On the pedestrian level, printed posters, city light posters and digital screens often appear in very similar or even standardized spatial formats. Some types can be found worldwide, such as the portrait-ratio displays which are often installed at sidewalks and bus shelters and are oriented such that they are approached frontally (see Figure 2.2, top right). Such specific display formats use different technologies such as CLP or LED, but still have the same size and ratio. They are also not only used on the street, but equally indoors in shopping malls and train stations. Yet, many paper-based posters still have individual sizes in different countries due to national sheet standards. Beyond the portrait-ratio pedestrian poster, some countries also have landscape-ratio posters or wide formats such as the swiss F12 [APG 2018]. Such wide panels are mostly installed at thoroughfares and sidewalks where passers-by are passing them sideways. The spatial formats of printed posters are usually chosen such that large posters can be created by combining multiple units of the basic format [Schloßbauer 1998]. The pedestrian poster, especially its city light variant, is currently one of the most high-selling out-of-home media formats in several countries [OAAA 2018, Wall 2018].

Columns

The advertising column is another street medium that appears either as billboard for classical glued posters, as backlit city light column (see Figure 2.2, left), or as cylindrical digital screen. There is a wide variety of column shapes across different countries, while some modern CLP columns can be found globally. Paper-based columns usually hold a predefined number of single sheets, for example 18 glued posters or 6 city light posters. City light columns are framed in order to hold single posters, and rotate around their own axis in order to attract attention and equalize the perception chances of all posters. Advertisers can book single sheets, sides or even full posters using the entire column surface. Columns are deployed close to the street such that they can be seen from all sides and address both pedestrian and motorized traffic, and preferably at places with high frequency such as traffic junctions. They can also be found indoors in malls or cinemas, either freestanding or as structural component of a building. In some cities such as Berlin thousands of units can be found.

Large Poster Boards

Large poster boards are as well available in printed, city light and digital variants, but on the pedestrian level often still paper-based boards are used. In European countries rectangular or nearly squared formats prevail, while in the US wider formats are used. Paper boards are also composed of multiple single sheets, in Germany for example by 18 such as columns. Thus they offer the same visual surface, but still require more floor space. Ground-level boards are installed parallel to the pedestrian and motorized traffic, often in streets where they cover wasteland. Traditionally they were the most widespread medium, but have been outrun by the smaller city light posters and columns in many countries [Wall 2018].

Long Walls and Banners

Some display panels cover a very long distance along street sidewalks. There are three main types: Signage banners, which are made out of vinyl and up to 10 meters long, are installed along fences and inform about the shortest way to the point-of-sale. Long backlit city light boards are installed at the side of walkways in airports. The longest displays are yet long wall murals which are used to cover construction sites (see Figure 2.2, bottom right). Similar to wide posters, such long walls and banners address people passing by sideways, but the advantage in comparison to posters which are put side by side is that they are not interrupted and thus can stimulate passers-by and tell a story along the whole trajectory.

2.2.3 Elevated Displays

Large Freestanding Boards

The most widespread type of elevated displays stand on one single footing and are installed at the sides of streets in frontal orientation towards the traffic. They appear in the same size as pedestrian poster boards and are either realized as printed, backlit or LED panel. Depending on the chosen technology, these displays are called *Mega Poster*, *Mega Light*, *(Digital) City Light Board*, *Roadside screen* or just digital billboard. City light boards are equipped with a computer-controlled motiv changer for showing up to 7 posters and attracting attention by the resulting dynamic. They are often deployed at highly-frequented arterial roads nearby traffic lights, and primarily address motorized traffic [Hofe 2005, P.49]. In many countries tens of thousands of units of such elevated street panels exist.

Building-Integrated Boards

In contrast to freestanding boards, boards attached to building facades also appear in larger, less standardized sizes. Larger front-illuminated panels are often called *Super Poster*, and digital screens, which are mostly realized by very luminous LED multi display panels, *Video Board* or *LED Billboard*. The larger such screens are, the more elevated is usually their position. They are often installed below the top of buildings and can cover hundreds of square meters. Even larger are *Wall Murals*, *Blow-ups* or *City Key Visuals,* adverts printed on vinyl that use large parts of building facades. These displays are available in various formats and also can address motorized and pedestrian traffic in the distance.

Indoor Displays

Elevated displays are not only found on the street, but also inside malls, airports and train station concourses. In shopping malls large displays are often found in the atriums suspended from the ceiling (see Figure 2.3, top right). In this case, they often rotate or have a round shape such that they can be seen from all sides. In hallways often also large banner displays are found in top positions or in mid-air.

Steles

Another elevated format are steles or pylons. Similar to mega lights they are installed close to boulevards and oriented frontally towards the passing traffic such that they can be seen from afar (see Figure 2.3, bottom right). Their purpose is to announce large buildings in front of which they are standing such as casinos.

Figure 2.3: Elevated multi display panel, hanging indoor display, and large display stele.

2.2.4 Spectaculars

Individual Solutions for Maximum Attention

Beyond the common standardized or convergent display formats, out-of-home providers often also offer individual, custom-designed solutions marketed as *Spectaculars*, *Iconic Displays* or *Landmark Displays* for advertisers who want to attract maximum attention through eye-catching attributes such as display size, shape or technology. Often elevated displays are chosen for this purpose, as they are better visible and allow for more flexibility than the pedestrian panels.

Shaped Displays

Especially shaped digital displays have been used to create such spectacular advertisements as they are an unusual experience for our eyes. Digital displays in convex, concave or complex three-dimensional shapes can be found indoors where they integrate with the surrounding architecture (see Figure 2.3, top right), or outdoors in major cities where they cover the bulding facades of landmark sites such as Times Square in New York. The market of shaped out-of-home displays is currently dominated by modular and flexible LED solutions as for example offered by [Barco 2018] or [Orion 2018]. But also classical curved street media such as digital columns have been realized by companies such as [Dynascan 2018] and [Kinoton 2018]. Bendable OLED displays or flexible displays based on electronic paper (E-Ink) are often predicted to replace these technologies in the future.

2.2.5 Store and Fashion Displays

Life-size Displays

Fashion advertising is a branch that has its very own requirements to displays set up in stores and shop windows, and thus uses a range of recurring display shapes that differ from classical out-of-home advertisements in streets and mall precincts. Due to the needs of the fashion industry, fashion displays usually appear in a very tall *Life-size* portrait-ratio format that allows to show the images of complete humans in life size. The used technologies include high-quality print, backlit and digital displays, but in recent years high-resolution LED screens that are suited for the pedestrian level dominate this segment. Life-size displays set up on the ground level in store windows are already taller than CLP posters, but on building facades of big stores the display size further rises with the installation height and can even cover up to multiple storeys. This ensures that the pictures showing faces and persons are also perceived in life-size from the distance.

Wide Shop Window Displays

In order to display whole groups of fashion models, also wider formats are used on building facades and in shop windows. Fashion and other stores often use large video walls in shop windows, either stand-alone or in combination with real products and mannequins, in order to attract maximum attention in shopping streets and malls with high pedestrian traffic. Often also very individual and spectacular shapes of LED screens are used.

2.2.6 Interactive Displays

Interactive Street Furniture

The most traditional interactive out-of-home (IOOH) media are street furniture such as city information terminals, often summarized by the term *Digital Urban Furniture*. An early example are the *bluespot* e-info terminals by Wall which were installed in bus shelters and multi-functional columns in German cities such as Berlin since the year 2000 [londesign 2000]. These terminals were already equipped with a selfie camera, a keyboard- and trackball-interface and a phone, and were part of an online plattform. Since the 1990s such robust input interfaces were steadily replaced by touch, and modern terminals use touchscreens in CLP-size or larger to promote the point-of-interest or point-of-sale (see Figure 2.4, right).

Figure 2.4: Digital advertising column equipped with sensors and touchable information kiosk.

Interactive Posters, Columns and Walls

The first interactive classical billboards were city light posters equipped with Bluetooth, NFC or QR-codes that offered young, technology-affine target groups to download songs, promotional videos or flyers directly to the mobile phone. Another classical type are context-aware poster screens that provide tactical contents, for example adverts for ice cream when the temperature exceeds a certain level [Wall 2018]. Since the mid 2000s the out-of-home industry offers touchable posters, touch terminals in poster size and large multi-touch media walls [JCDecaux 2011]. In 2012, Infoscreen presented a depth-sensitive out-of-home display, where users could interact touchlessly and fit shoes virtually [Invidis 2012]. In 2014, augmented reality posters were installed at bus shelters and enabled by vision sensors [BBDO 2014]. Also digital columns have been equipped with camera sensors in order to adapt contents to the surrounding traffic (see Figure 2.4, left).

Interactive Shop Window Displays

Since the 2000s, interactive advertising displays have also been used behind the glass of shop windows and inside stores. Vision-based shop window adverts, which use a camera to give visual feedback to the movement of passers-by, have been realized by Trytes in 2005 [Trytes 2005]. In this case festival logos or products such as cars followed the passers-by while walking along the stores. In 2006, four large life-size diplays installed behind the office window of SAP in Berlin displayed the mirror feedback of passers-by and interactive visual effects in order to attract them [Michelis 2007]. In 2010, Benneton installed shop window advertisements in Barcelona, Milan and Munich where users could draw onto the screen, control virtual textiles or their mirror image with their hands [Fabrica 2018].

Interactive Ground Poster

The earliest vision-based advertisements that have been used worldwide in larger numbers are interactive ground posters, which are the modern successors of classical floor graphics, a special form of place-based out-of-home media [Hofe 2005]. Since 2002 the company Reactrix Systems sold such interactive floor advertisements, where passers-by who incidentally cross interactive areas in shopping malls or cinemas are caught by surprise that virtual products, logos or animals on the floor react to their movement. The platform, which was marketed under the name *StepScape Media Network*, is based on a projector installed at the ceiling that projects the advertisement down to the floor, and an infrared camera for tracking user motion and position [Takahashi 2004, Rae-Dupree 2005]. The platform was distributed to more than 186 locations within the US [Reactrix 2002].

2.3 Mediatecture

Out-of-Home Displays are not placed arbitrarily within public space
but in typical orientations and configurations that take account of the surrounding cityscape, architecture and trajectories.

2.3.1 Space and Situation

Geographically, out-of-home displays appear either at a single spot, as a cluster of multiple screens at a single site such as a town square, or as a complete net across a city. Such spots and nets then can be booked for several days, weeks or even permanently [Schloßbauer 1998, Hofe 2005]. Out-of-home displays are usually perceived *en passant* within three different perception spaces [HGKL 2004, P.22]:

Perception Spaces		
Transit Zone	Circulation Zone	Waiting Zone

Transit zones are areas where people perceive the displays just for seconds when passing by, such as on the sidewalk or in pedestrian subways. Circulation zones are areas where a display can be perceived repeatedly, such as in malls. Waiting zones are areas with longer perception times such as railway platforms. While passers-by move, the distance and the angle towards a display change constantly, and the actual perception time and quality determines if contents will be successful. Still, out-of-home displays can be distinguished according to several ordering factors such as: display location (top or low, left or right, central or at the side, freestanding or integrated), display orientation, typical trajectories and traffic streams, distance to buildings and other signage, display quantity, and similarity with or contrast to their architectural environment [Kreutzer 1995, P.86f].

Figure 2.5: Parallel shop window display, frontal display in a mall, diagonal street display.

2.3.2 Display Orientation

The viewing angle towards an out-of-home display determines how many details can be perceived and how much competitive information has to be processed. The main trajectories of pedestrians and motorized traffic are predetermined by the urban architecture, and the follwing typical display orientations can be found:

Display Orientation			
Frontal	Diagonal	Parallel	Omnidirectional

Displays which are oriented frontally towards passer-by trajectories can be found on wide sidewalks, inside shopping malls (see Figure 2.5, middle), and preferably at the end of the long trajectories of aisles or passages such that the viewing time is maximized. An orthogonal, frontal orientation of displays can not only be found where people are approaching or passing by, but also in waiting situations nearby traffic lights or across from railway platforms. A diagonal orientation can be found at large boulevards (see Figure 2.5, right), where the displays are installed freestanding or integrated with bus shelters at 45° such that they address both the pedestrian and the motorized traffic. While approaching frontally is the ideal condition from a perception perspective, passing-by situations are much more common in narrow city streets. In the typical street window situation, displays are installed behind shopping windows in a parallel orientation towards the traffic (see Figure 2.5, left) such that they are only perceived in the periphery and among a high density of other information. The omnidirectional orientation, where people approach from all sides, applies to columns which are deployed freestanding and centrally at intersections, on city squares or also indoors (see Figure 2.4, left).

Figure 2.6: Frontally oriented display row, parallel display row, displays at an intersection.

2.3.3 Display Configurations

Frontal Display Rows

Out-of-home displays do not only appear as solitaire, but are often deployed in groups and effective configurations. The most common configuration on street sidewalks are frontal displays rows, sequences of single orthogonally oriented panels which are installed along the passer-by trajectory (see Figure 2.6, left). Digital forms of such frontal rows, also called *Ad Walk* by the industry [Ströer 2018], are also found inside train stations and shopping malls. Advantages of display rows are the longer perception times when passers-by are walking alongside them, and that the single panels can also show chronological sequences of static or dynamic images which are synchronized with the walking speed.

Parallel Display Rows

Parallel display rows are usuallly installed where the limited space does not allow to install freestanding frontal rows, such as in passageways of public transport or in narrow streets (see Figure 2.6, middle). If the street is straight, parallel displays are less effective than frontal panels as the limited space prevents to view them fully, but in curved streets they are perceived and integrate better [Kreutzer 1995, P.105]. The gaps between the single units of parallel rows also disrupt the content, such that long continuous walls and banners constitute an alternative to them.

Other Configurations

Further display installations are often found indoors where they are determined by the surrounding architecture. For example, structural pillars at intersections can be encompassed by four displays which are aligned to the main trajectories (see Figure 2.6, right), but also a seamless column display can be used in this case.

2.3.4 Architectural Integration

Visual Integration to the Cityscape

From a semiotics perspective out-of-home displays are, just as traffic signs or street furniture, secondary signs of the cityscape that have to orient themselves to some degree by the primary signs of the cityscape (the built environment), but also have to follow a contrast function in order to attract attention. As furnishing components of the city they take in a communication role that cannot be fulfilled by the permanent buildings or the dynamic street life, and should represent a balanced compromise between unobtrusive integration by optical similarity and defacing contrast to the city environment. From a Gestalt psychology point of view, displays can integrate with or distinguish themselves from the surrounding architecture and other signs by principles such as grouping, conciseness or figure-ground [Kreutzer 1995, P.74f]. Their design has to consider urban-architectural requirements such as the structure and age of a city quarter, the course of the street, the dimensions, facade ornamentation and architectural style of single buildings, and social-spatial requirements which are related to the residential, recreational or commercial function of the area. Out-of-home displays are also a means for urban enhancement [Kreutzer 1995, P.127]. For example, at prominent sites such as Market Street in San Francisco advertising columns are decorated with ornaments to reinforce the impression of a historical quarter. In contrast, modern-looking columns and other freestanding displays are used to revive monotonous areas and compensate overdimensioned streets [Kreutzer 1995, P.106]. Digital displays convey the impression of modernity inside airports and malls and also have become the symbols of entertainment districts in large cities.

Architecture-bound vs. architecture-related Displays

Out-of-home displays can be distinguished into architecture-bound or -related ones [Kreutzer 1995, P.106f]. Architecture-bound displays are installed directly at a building and thus have to be related to other elements of the facade and other advertisements in regard to criteria such as form, brightness, color, material, location, direction, distance, amount, dimension or modernity [Kreutzer 1995, P.126f]. Architecture-related displays are solitary structures that are placed further away from buildings and thus have more architectural freedoms, such as freestanding posters, advertising columns, bus shelters and other street furniture. Where the surrounding architectural space allows it, principally also all available surfaces and building structures can be used for placing advertisements (see Figure 2.7).

Figure 2.7: Usage of the architectural space and integration of adverts in a subway station.

2.3.5 Illuminated Advertising

Illuminated advertising, also referred to as light advertising, is dominant at night and often superimposes the architectural cityscape by becoming itself the visible city structure (see Figure 2.8). From a semiotics perspective, at night the conditions of daytime are reversed, and light advertisements become the primary signs, while the architecture retreats [Kreutzer 1995, P.114f]. In contrast, at daytime the perception quality of light advertisements is reduced [Gut 1974, P.182]. The main advantage of light advertising is that it attracts attention more effectively than reflective media. Because of the human need for light it also has emotional and psychosomatic effects [Gut 1974, P.14f]. Further, illuminated displays provide an orientation function for both passers-by and drivers at night, and thus are largely welcomed by the urban population [Gut 1974, P.15, Kreutzer 1995, P.114]. City squares or quarters which are strongly illuminated by light advertisements and digital screens have a certain appeal for people searching for entertainment or nightlife, and thus places such as Times Square in New York, Picadilly Circus in London or Shinjuku in Tokyo are the main centers of attraction within these cities at night. The strong attention-grabbing effect of light also implies that passers-by in many cases can notice illuminated displays long before the planned attraction cues of the shown contents take effect. In order to not distort the perceived city structure too excessively at night, the luminosity of displays can be dimmed down, and vice versa the architectural surroundings be slightly lighted [Kreutzer 1995, P.130].

Figure 2.8: Light advertising superimposing the architectural city structure.

2.3.6 Practical Issues

Site Acquisition and Building Laws

In order to acquire an advertising site, a lease contract with the property owner has to be concluded. Even before, permissions at the local building authorities have to be obtained. There are usually a number of public building laws, state laws and local laws that have to be observed. Also traffic laws, laws for the protection of historic monuments and the protection of nature can restrict the acquisition of sites. In particular, the display installation must not deface its architectural environment or the surrounding cityscape. Further, disturbing accumulations of units have to be avoided, the traffic must not be endangered, and safety must be guaranteed [Schloßbauer 1998, P.54f, Kreutzer 1995, P.132f].

Weather, Vandalism and Obstacles

Outdoor displays must be sufficiently stable during all weather conditions. If the displays are not installed above the pedestrian level or behind shop windows they must be optimized for robustness in order to protect them from vandalism. Sometimes also measures have to be taken to prevent people from accidentally bumping into freestanding displays. Another issue on the street level is that deployed obstacles can prevent passer-by interaction with the displays, such as bikes that are parked around freestanding displays or in front of shop windows.

2.4 Out-of-Home Research

Market research concentrates on evaluating the quality of single display sites as well as the quality of individual media contents, and the collected media data are later used for media planning.

2.4.1 Audience Measurement

In market research person- and site-related evaluations on the performance of out-of-home media can be distinguished. The first focuses on the experiences of single persons and allows to correlate data with demographic characteristics and specific target groups, while site-related methods compare the performance of different sites by rather counting categories of passer-by on a sample basis. The single measures for the performance of a display are [Schloßbauer 1998, P.124f]:

Measures for Media Contact		
Passage of a Site	Passage Recall	Key Visual Recall
Eye Contact	Site Recall	Visual+Site Recall

The passage of a site counts the passer-by frequency by either observation or interviews, and the number of eye contacts with a site can be analyzed as well by video observation or mobile eye-tracking tools. The recall of the passage of a site, of the specific site itself, or the more valid measures recall of a key visual or even recall of a key visual at a specific site are evaluated by detailed questions. Such analyses on media contact are conducted by outdoor media associations such as FAW in Germany and consumer research institutes such as Geopath in the US and later published such that the media planning can build upon them.

2.4.2 Evaluating the Site Quality

The performance of a specific site arises from the passer-by frequency, i.e. the amount of people who walked by the display, and the contact opportunities, also referred to as *opportunities to see*, the actual number of people who had eye contact with the display. Out-of-home media providers and consumer research institutes offer various rating systems (such as OSCAR, the G-Value by GfK or its successor PpS in Germany [Schwarz 2018]), which beyond the frequency, recall and duration of eye contacts also consider aspects of the display such as distance, angle, side or floor clearance and situational and perceptual factors such as distractions by traffic signs, competing advertisements or dense traffic or positive effects by waiting situations at intersections [Schloßbauer 1998, P.144f]:

Measures for Site Quality		
Display Visibility	Lighting Conditions	Traffic Density
Display Amount	Degree of Occlusion	Traffic Signs
Display Angle	Distractions	Distance to Traffic
Clearance	Environment	Angle to Traffic
Gross Contacts	Neighborhood	Waiting Situations
Contact Durations	Seasonal Effects	Obstructions

The contact values PpS and G-Value are based on mobility and partly realtime data of the frequency atlas by Fraunhofer IAIS which covers more than 150.000 sites and distinguishes between traffic streams of pedestrians, cars and public transit, different contact opportunities for drivers and pedestrians, and local infrastructures and income structures [FAW 2018]. Also temporal factors are taken into account such as the traffic and commuter behavior at different daytimes. Another important factor is the media coverage reached by whole nets of display units in regard to a target group, expressed by the measure gross rating point (GRP). The costs of displays are described by the measure cost per mille (CPM).

2.4.3 Validating the Content Quality

Another field of research is the validation of media contents for outdoor displays. The performance of designed advertising contents is evaluated in pre-tests. Procedures where the cognition of competing key visuals is analyzed include constrained stimulus tests where the perception conditions are impeded, tests on the shape strength where key visuals are deliberately distorted or presented only partially to the test persons, as well as eye motion tests analyzing which elements of the content people fixate when passing by a display site. Further standardized treatments followed by interviews analyze the attitude, emotions and social distance towards the key visual, recall and recognition tests how well it is learned, and reading tests the readability of text [Schloßbauer 1998, P.109f]:

Validation Methods for Contents		
Tachistoscope	Size and Acuity Test	Video Observation
Perimeter Test	Distance Test	Recall +Recognition
Viewing Angle Test	Distortion Test	Attitude Tests
Nytoscope	Eye Tracking	Reading Tests

The constrained stimulus and partial presentation tests simulate the range of perception conditions that really occur in public space. For example, with the tachiscope test a key visual is only displayed for fractions of a second, as is the case when driving by an outdoor display. With the nytoscope test dawn and night light conditions are simulated, and viewing angle tests and perimeter tests acquire data on the peripheral detection and performance of visual stimuli at different viewing positions such as the brink of the subjects field of view. Some of the methods such as video observation are also conducted at real poster sites.

2.5 Conclusion

The street level provides recurring display formats such as freestanding columns, frontally approached poster displays or long sidewalk displays that are suited well for one-to-one interaction with users.

2.5.1 Display Convergency

Summing up the analysis of out-of-home displays, it can be concluded that, apart from special and customized formats, a range of recurring display shapes exists. Especially displays on the street level are consistently subject to similar requirements of perception, pedestrian traffic and architecture. Typical shapes on the walking level are flat portrait-ratio displays that passers-by often approach frontally such as classical posters or life-size screens, wide landscape-ratio displays and long banners where people and cars are passing by sideways, and cylindrical advertising columns that are deployed freestanding and can be seen from all sides. These characteristic shapes appear across many historical and technical formats from paper-based panels to digital screens. In contrast, on the elevated level displays sizes and formats are more diverse (see Figure 2.9).

2.5.2 Implications for Interactive Screens

Interaction on the Pedestrian Level

On the pedestrian level, a moving environment can be found which is suited for user interaction. In contrast, elevated displays communicate their messages over longer distances such that a one-to-one interaction cannot be realized easily. Here the passers-by, and possibly multiple of them at the same time, might falsely relate the displayed visual feedback on the distant screen to themselves if no clear relationship to the individual users on the street can be communicated.

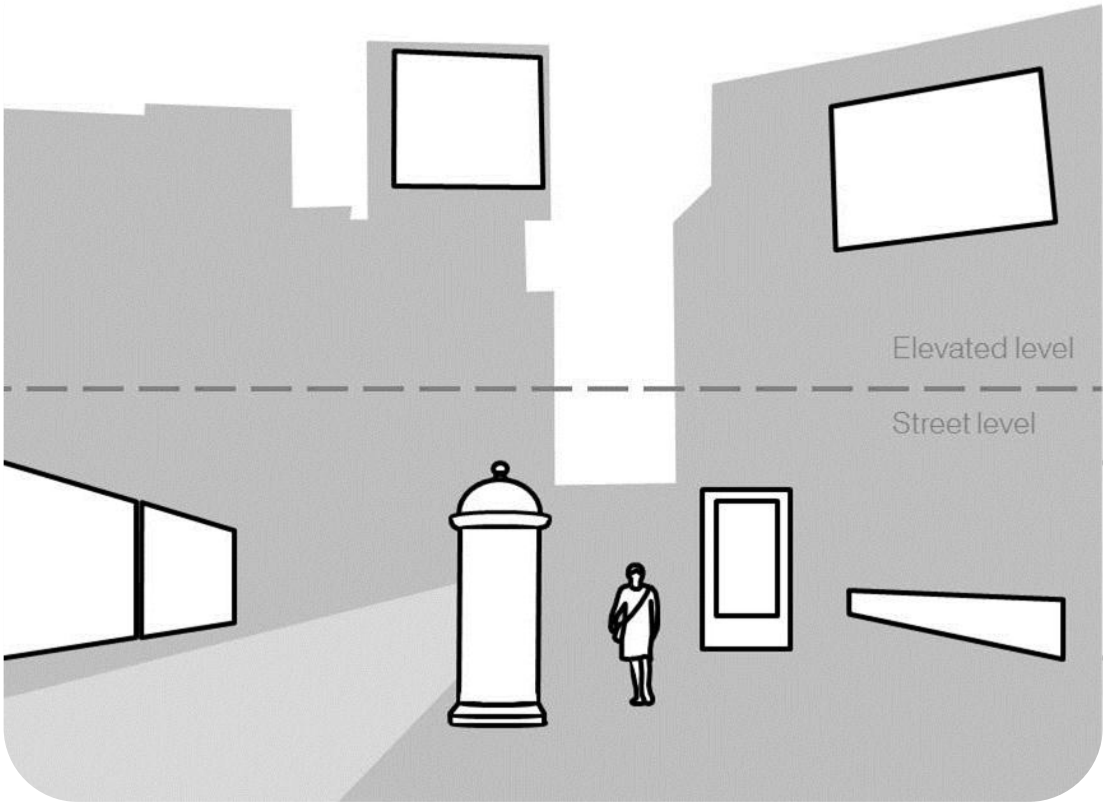


Figure 2.9: Different preconditions for interaction with street level and elevated displays.

Approaching Frontally vs. Passing by Sideways

In regard to the situational preconditions on the street level, interactive public displays have to take into account the site-specific distances, the perception zones, the traffic velocity and density, as well as the typical walking trajectories. The analysis showed that street displays are mostly deployed in transit and circulation zones, and that the approaching trajectories of passers-by and the display orientations are often predetermined by the urban architecture. The offered interaction principles must be adjusted to and make use of the existing typical pedestrian flows, such as passers-by approaching frontally, passing by sideways or, as in the case of the advertising column, potentially approaching from many directions. Further, suitable methods for evaluating passer-by, user and audience behavior in these specific situations have to be found.

CHAPTER 3

INTERACTIVITY

Attracting Attention,
Communicating Interactivity,
Subtly Directing Users

3.1 Perceiving Displays

Passers-by notice public displays
in walking situations while scanning the environment for salient stimuli that are shortly fixated by the eyes and further inspected in the case of sufficient activation.

3.1.1 Perceptual Foundations

Visual Field

The binocular visual field (the combined visual field of both eyes) can be described as roughly oval, with upper and lower embayments by facial features such as the nose and the eyebrows [Ware 2013, P.52]. It extends to beyond 180° (newer studies suggest 214°) horizontally and to about 140 degrees vertically [Gibson 1979, P.206]. Humans have a schematizing vision within this area, but sharp vision is only possible within a tiny spot called fovea centralis, outside of which it falls off rapidly. For example, at a deviation of 5 percent from the fovea sharp vision has already decreased by 50%, and at a deviation of 10 percent only one tenth of the details can be resolved [Kreutzer 1995, P.72, Ware 2013, P.52f]. While in the periphery of the retina also the color perception falls off [Wyszecki 1982], peripheral vision is especially sensible to movement. A study found that while the ability of participants to detect static objects fell off rapidly beyond 4 degrees from the line of sight, they responded quickly to moving visuals which where up to 20 degrees away from it [Petersen 1972]. Beyond physiological abilities also the visual processing determines how much information can be absorbed. For example, the area around the fovea from where information can be extracted at a single glance (the useful field of view: UFOV) depends on individual factors such as age and situational factors such as the stress level [Ware 2013, P.173f]. Figure 3.1 left illustrates the visual field of a passer-by within a city setting.

Figure 3.1: Illustration of the visual field (left) and possible fixations and saccades (right).

Fixations and Saccades

Human eyes are yet not staring rigidly forward, but scanning the environment by unsteady movements that consist of fixations and saccades. During a fixation the eye is targeting a visual stimulus (or *tracking* a moving one), while a saccadic movement is a very quick jump of the eye from one fixation to another. Yet even during a fixation the eye is not completely at rest but still underlying a range of micro-saccades [Gibson 1979, P.212]. Fixations can overlap, for example when a fixation that tracks a moving person also includes several short fixations for scanning the person's gaze and facial expressions [Gibson 1966, P.260]. This shows that a single fixation cannot be equated with selective attention. Instead the scanning of a target region involves a series of fixations, while no information is absorbed during the saccades. A study found that fixations on ads last on average 0.27s, with 0.2s being the most frequent value [Leven 1991 P.94]. Thus 3–5 fixations can occur per second, but fewer image elements are absorbed if parts are fixated repeatedly. For scanning an image the eye movements proceed as follows: 1–2 shorter fixations are needed to get an overview and understand the topic, then several longer fixations follow that allow the viewer to inspect details. The topic of an image can already be recognized in the range of 1/100 seconds, for recalling it 1–2 seconds are required [Kroeber-Riel 1993, P.53f].

Seeing with the Head-Eyes-System

Further, one does not only see with the eyes but with the interrelated head-eyes-system [Gibson 1979, P.205]. For example, when one enters a new room, the head can turn 90° to the left and right, while simultaneously the eye movements serve for exploration and compensation [Gibson 1966, P.259]. The positions of eyes and head include the information where we are looking: Humans can determine the direction to which others are looking with high reliability [Gibson 1963].

Subjective and Subconscious Perception

Research on viewing behavior has to bear in mind that perception is a process of information processing which underlies the viewer's subjective impressions and which is selective to avoid information overload. The information reception can further be active (conscious) or passive (unconcious) [Kroeber-Riel 2013, P.363f]. In regard to subconscious perception, all the information received from the environment is at first processed pre-attentively, but most of it will be filtered out and only the stimuli which are most salient or relevant for the individual will be analyzed further by the conscious, attentive processing [Neisser 1967, Treisman 1985]. On the level of gaze motion, many eye movements are also not consciously controlled, but instead follow learned patterns or biological stimulus-response mechanisms, for example when viewers fixate the eyes and mouth first when looking at advertisements with human faces [Kroeber-Riel 2013, P.345f].

3.1.2 Perception of Public Displays

Scanning the Urban Environment

In the context of urban architecture visual perception has its own requirements relevant to out-of-home advertising [Kreutzer 1995, P.72f]: When taking the typical sight relations in urban streets with distances of about 10 meters as a basis, a visual focus with a radius of 5 percent around the fixation axis results in a circular area of about 90 cm for relatively sharp viewing. To perceive a larger area of the environment, viewers have to scan their environment by gaze movements, which follow salient stimuli such as sudden changes or strong color and light contrasts in the unsharp periphery, and guide them towards the central visual field. The overall perception process can be structured into three phases [Kreutzer 1995, P.73]:

First, viewers try to orient themselves and establish an overview by short and long-span eye movements of less than 0.25 seconds to fixate contrasts in the environment. In the second phase, the stimuli which attracted attention are inspected in more detail for smaller stimuli (for example the concrete design details of an advertising display) and for a longer timespan. In the last phase, all seen stimuli are combined to a consistent and understandable overall image.

Subjective and Temporal Factors

However, this three-stage perception process is yet just a simplification that at best applies to a non-local walking along streets with no concrete purpose, but in practice the sensitivity for different stimuli is affected by individual, subjective factors such as experiences, attitudes and expectations about the environment [Kreutzer 1995, P.73f]: For example, a non-local who is actively looking for a certain shop may tend to fixate stimuli which help to identify this shop even if they are not eye-catching. Differently, a local resident who knows the street well may blind out the majority of the well-known stimuli to the subconsciousness. The perception can also be influenced by the time factor, which for example is different for a car driver who perceives a larger distance than a pedestrian during the same time period, while he still has only the same reception capacity.

Role of the Context for Perception

One characteristic of perception is that single stimuli are not perceived alone, but interpreted in the context of their environment and together with other stimuli as a whole [Kloss 2007, P.60]. The capabilities of the perceptual system are limited, such that it strives for efficient information reception. The summarizing principle of Gestalt psychology that "the whole is more than the sum of its parts" thus also plays an important role for how structures and forms of urban architecture are initially recognized [Wienands 1985, P.17f]. The single Gestalt laws then describe the patterns how the gaze can orient itself by contrasts and contexts when scanning the environment. Especially relevant for visual orientation within cities are the Gestalt principles of wholeness, prägnanz, and figure ground [Kreutzer 1995, P.74]:

Relevant Gestalt laws		
Wholeness	Prägnanz	Figure-Ground

First, the principle of wholeness means that single stimuli are interpreted together with other stimuli and coordinated to a whole impression. For example, an advertising display may be only recognized as such in the context of its integration with the built environment. Second, the law of Prägnanz means that a display and its environment are identified by their distinctive design features. Third, the figure-ground principle means that the identifiability of an advertising display depends on its similarities and contrasts to the local environment.

3.2 Attracting Attention

Attracting attention of passers-by is the primary objective of out-of-home advertising that is classically achieved by using physically intense, dynamic, affective and surprising visual stimuli.

3.2.1 Applied Model of Attention

Types of Attention

Four subtypes of attention can be distinguished [Coull 1998, Kroeber-Riel 2013, P.62]: orienting attention, selective attention, divided attention and sustained attention:

Types of Attention			
Orienting	Selective	Divided	Sustained

Orienting attention or attentional orienting means the guidance of one's attention towards a certain direction for a certain timespan. It is closely linked to the so-called orientation reaction [Sokolov 1963] that often reveals itself by a rotation of the head. Focused or *selective attention* means that attention focuses on a defined location or stimulus, while other stimuli are ignored. Selective attention is closely linked to the phasic (short-term) activation of an individual by certain stimuli. *Divided attention* stands for the simultaneous processing of multiple stimuli when one is performing multiple tasks. *Sustained attention* is the maintenance of attention towards a stimulus for some seconds or minutes, for example when a passer-by observes a shopping window. Further an active search for information (e.g. when one is looking for a certain shop) can be distinguished from passive perception where one is just reacting to activating stimuli [Kroeber-Riel 2013, P.349f].

Salience of Stimuli

So-called salient stimuli within the perceived visual scene can attract and hold one's attention if they are intensive enough [Goldstein 2015, P.130f]. Thereby the eye fixations fall onto stimuli with a high intensity (e.g. by color or lightness) in regard to their environment. The sum of such high-contrast stimuli can be visualized by a saliency map. Yet visual attention is additionally determined by the subjective expectations and interpretation of the surrounding scene as well as by one's interests and socialisation, such that the visual focus can also fall onto novel and surprising stimuli or stimuli which only have a relevance to the individual.

3.2.2 Classical Attraction Cues

Types of Stimuli

In general, three types of stimuli for activating attention can be distinguished [Berlyne 1960]: physically intense stimuli, affective (emotional) stimuli, and collative (novel and surprising) stimuli. In advertising practice these stimuli are usually not used in isolation but combined with each other.

Types of Stimuli		
Physically Intense	Affective	Collative

Physically Intense Stimuli

Intensive stimuli are salient information which is effective by physical qualities such as colorfulness, lightness or size [Kroeber-Riel 2013, P.81f]: In advertising often light and chromatic signal colors with a high contrast to their background are used to activate strongly. Advertising research has shown that colorful shopping windows can lead to a significant increase of attention. Equally the size of an advertisement is an important factor in advertising. For example, doubling the size of an ad can multiply its attraction performance [Kroeber-Riel 2013, P.85]. Due to the higher distances in out-of-home advertising that entail that people can only distinguish fewer colors, only one or maximally two distinct colors should be used and emphasis instead be put on concise shapes and high contrast values [Schloßbauer 1998, P.102]. Thereby it should also be considered that shape and color can mutually draw off their effect [Gut 1974, P.197].

While the strongest contrast can be found between black and yellow and in second place black and white, the overall picture that includes the surrounding context determines the actual contrast. Further, changing light conditions affect the perceived intensity. In light advertising, darkness can entirely extinguish the display context and thus support the stimulus intensity, but high luminance can also quickly lead to glare effects during night conditions [Gut 1974, P.197f].

Physically Intense Stimuli				
Color	Light	Contrast	Size	Form

Moving and Dynamic Stimuli

Moving and dynamic physical intense stimuli gained importance when light and digital screen advertising emerged. Such stimuli have the advantage that they also attract attention in the periphery of the visual field and thus force humans to an orientation reaction [Bartram 2003]. The earliest dynamic stimuli were blinking light bulbs which used periodic impulses similar to warning signals and animated light bulps which used stroboskopic movement, while modern digital screens rely on salient animations and a fast montage of images. The most prevalent techniques in advertising are blinking stimuli, looming stimuli and simulated biomotion [Schönhammer 2013, P.167f]:

Dynamic Stimuli		
Blinking	Looming	Biomotion

Looming stimuli [Franconeri 2003] describe the quick concentric increase of a visual, which is interpreted by viewers as the threatening collision with an approaching object. Already babies react to such stimuli with a preattentive defensive reaction [Sokolov 1963]. Characteristic movement and biological motion make humans and animals recognizable, but animate motion can also be interpreted as hazard (such as spiders) and cause startle responses [Schönhammer 2013, P.170]. Motion effects can effectively delineate a screen from competing stimuli, but also impair the information reception. Preferably, motion effects should be coordinated with the pace of the traffic at the display site [Gut 1974, P.161, HGKL 2004, P.23].

Affective Stimuli: Schema Images

Affective stimuli trigger pleasant or unpleasant emotions due to inborn stimulus-response mechanisms or due to conditioning and belong to the classic toolset of advertising to attract attention [Kroeber-Riel 2013, P.81f]. Positive affective stimuli include key stimuli such as the baby schema, eroticism, images of humans, animals and nature, and stimuli which have a special meaning for the individual. Affective stimuli are very effective by the rapid and reliable recognition process whereby visual patterns of the perceived image are matched with *schema images* in one's memory [Kroeber-Riel 1993, P.166f]. Adverts with highly emotional stimuli can even then be perceived and recalled if they are not within the focus of attention [Nielsen 2010]. Especially effective are schemas that trigger biologically preprogrammed reactions such as the baby schema, eye schema and facial schema, facial expressions, erotic features or body language. Such key stimuli provoke automatic orientation reactions towards them [Kroeber-Riel 1993, P.171f].

Inborn Visual Key Stimuli				
Baby	Face	Eyes	Facial Expression	Eroticism

Especially quickly fixated are the eyes, which because of their orientation reveal the intention of the glancing person [Schönhammer 2013, P.173f]. Figure 3.2 shows a popular format in fashion advertising: the *balcony girl* who effectively attracts passer-by attention by making eye contact with passers-by and by being placed within a situational context. Next to the eyes, the mouth and the eyebrows are the most significant features for face and emotion recognition [Weinberg 1986, Sadr 2003]. Erotic stimuli are also very popular as they never wear off and are barely affected by individual, cultural and sociodemographic factors. Artificial and illusive imitations of affective stimuli such as graphical illustrations of facial features can be equally effective or even be more effective as the natural stimuli if key features are exaggerated. Professionally edited fashion photos, cartoons or caricatures make use of the effect of such *superstimuli*. Individually conditioned affective stimuli are images of pop stars, movie heroes, pets (cats or dogs), a football during the World Cup, symbols for personal hobbies (e.g. sailing ships) or preferred brands [Kroeber-Riel 2013, P.81f]. Culturally conditioned emotional schemas include motives of remote landscapes, such as the Mediterranean schema or the tropical schema in colder northern countries [Kroeber-Riel 1993, P.168].

Figure 3.2: Balcony girl: Subtly activating attention by eye contact and situational placement.

Collative Stimuli: Novelty, Contradictions and Surprise

The third category of stimuli for attracting attention are collative, that is, novel and surprising stimuli. Here cognitive activation is triggered by mental conflicts, contraditions or surprises which confront the perception with an unexpected task and thus stimulate the information processing [Kroeber-Riel 2013, P.83]. This can be achieved by either alienating schema images or avoiding them altogether, by deviating from verbal, visual, social or cultural norms and values [Gaede 2002], by presenting unusually combined or contradicting stimuli which lead to cognitive dissonances [Kloss 2007, P.62], by ambiguous stimuli that allow more than one distinct interpretation and thus encourage people to look twice [Mahon 2010, P.40f], by any form of surprise that results from humor [Mahon 2011, P.128] and, closely related to this, by shifting different levels of meaning as proposed by the framework of visual rhetoric [Urban 1995]. Collative stimuli initiate mental activity and improve the recall of an advert very effectively, yet also involve some risks such as that they can wear off over time, quickly hit the wrong note if they are perceived as trivial, surreal or exaggerated, or that they pose an unintelligible riddle that cannot be decoded in a few seconds [Kroeber-Riel 2013, P.83f].

3.2.3 Surprising Stimuli

Advertising as Play with Expectations

Due to their strong activation and recall effect collative stimuli gained importance in advertising over the years. A common characteristic of effective solutions is that they consciously play with audience expectations and surprise people where they do not expect it [Mahon 2010, P.126]. Human thinking is activated by impulses that are either completely diametral to or consistent with one's expectations [Urban 1995, P.9]. In this regard collative stimuli work contrary to schema images: they are perceived because they go against common logic and experiences [Kloss 2007, P.201]. For example, outdoor advertisements can confront passer-by expectations in regard to the surroundings which determine their attention.

Surprise: Decoding Inconclusive Messages

Surprising messages work by stimulating mental activity until they are decoded and the perceived contradiction is resolved, which results in a surprise reaction:

Dieter Urban describes this functional principle as follows [Urban 1995, P.9]:

> „**Messages** that are visually coded in the image and **that have to be decoded** by the observer – this is the requirement. Images in target-group specific language are equipped with a key element which rips them out of their routine everyday perception. […] Strong solutions substitute the reality, i.e. present entirely natural elements in an unnatural manner to irritate the observer – and thus stimulate him to reflect about it. […] The recipient is better reached by an impulse, which at first appears curious, paradox, suspect to him. Consequently a permanent **thinking process is provoked**. […] He classifies things **until the overall picture has build up**. Each offered image is processed as long until it becomes imaginable."

This process is comparable to the decoding of the punchline of a classical joke, where finally the penny drops and the listener or reader reacts with laughing [Urban 1995, P.11]. It is also similar to the general concept of the human strive for consonance in the case of a presented cognitive dissonance [Kloss 2007, P.201].

Visual Rhetoric

The systematic application of this effect mechanism in visual-textual advertising is subsumed under the term *visual-rhetoric*. Dieter Urban presents a framework of five visual-rhetoric categories as a systematic approach to generate surprise. These categories are all based, similar to many jokes, on the shift of different levels of meaning: the meaning of one level is set into another surprising context by the meaning of the second level [Urban 1995, P.214, Barowski 2003, P.85]. The single categories are the shift of word levels (cacography), the shift of text levels (puns), the shift of image levels (analogies), the shift of image-text levels (dialectic), and the shift of color levels (paradoxes):

Visual-Rhetoric Categories				
Word	Text	Image	Image/Text	Color

Reframing

The technique of reframing is a supplementary strategy of playing with viewer expectations in order to even intensify the effect of surprise [Mahon 2011, P.126]: Here the thoughts of the audience are at first deliberately diverted towards another direction by the given information – usually a common and expectable context, the so-called reference frame – to then suddenly supply little additional information that changes the context and thereby the initially suggested meaning of the message completely.

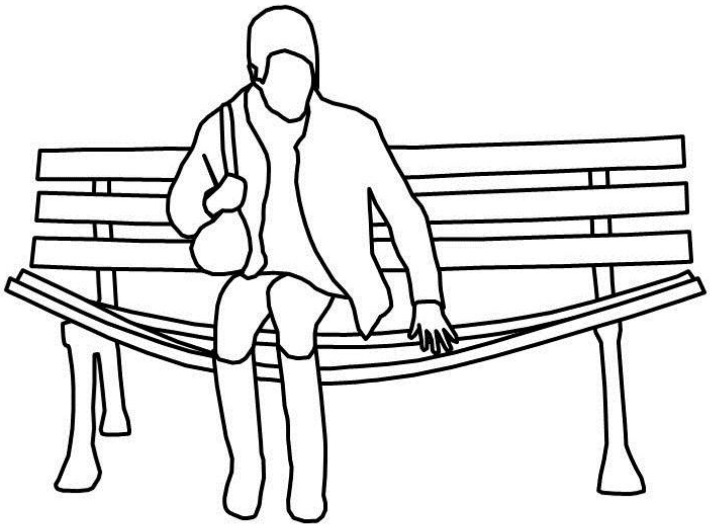


Figure 3.3: Ambient media surprise people in situations where they expect it least.

Expectations in Ambient Media

Ambient media use a strategy to play with passer-by expectations which is similar to reframing: they are at first not recognizable as being an advertisement, but then catch their audience flat-footed [Mahon 2010, P.126]: Therefor common and unsuspicious sites are integrated to the advertising message where passers-by would expect advertising least. One example is a park bench that bends itself as soon as people sit themselves down: as a result they look around with irritation, and discover an unobtrusive sign at the backrest which reads: "Its time for Kellogg's Special K – 99% fat-free". When they realize the advertising character of the bench at this moment, they have already received the message.

Risks of Irritation

Surprising stimuli involve a particular risk of irritating the audience and thus require a sensitive use. According to [Urban 1995, P.11], the methodical patterns of visual rhetoric have to be used very pointedly and well-dosed in order to avoid that experience-based convergence is just substituted by divergence and uncontrolled fantasy. While irritation also generates attention and cognitive processing, it can lead to a negative attitude towards the advertisement. Irritation can for example occur if collative stimuli hit the wrong note or are perceived as trivial, surreal, tasteless or exaggerated. Advertisements can be testet in advance on possible irritation by observing and listening to test persons and using so-called acceptance and irritation profiles [Kroeber-Riel 2013, P.83f].

3.2.4 Measuring Attentional Reactions

In field research with public displays, measuring attention requires suitable methods and knowledge of the attentional reactions passers-by show. Methods which involve user contact, such as physiological measurements on electrodermal activity or head-mounted eye tracking, are unsuitable due to the strong bias. Subjective methods such as post-hoc interviews involve the risks of biased answers and of affecting the attention of non-involved passers-by. Most suited are thus external measurements on the motoric or sensoric level such as remote observations of head and eye movements, gaze motion, facial expressions, movement patterns, and other sudden behavioral changes. Passers-by can show the following observable attentional reactions to a public display:

Attentional Reactions		
Orientation Reaction	Surprise Reaction	Motion Response
Direction Change	Eye Fixation	Active Engagement

The sudden change of oriented attention towards the new stimulus is often indicated by a so-called *orientation reaction* which expresses itself by a sudden, reflexive rotation of the head and by dilation of the pupils [Kroeber-Riel 2013, P.63f]. Beginning attention towards a sudden, unexpected stimulus can also be revealed by a *surprise reaction*. On the emotional level surprise expresses itself by typical facial expressions such as raised eyebrows, wide eyes and an open mouth or jaw drop which are described in detail by the Facial Action Coding System (FACS) [Kroeber-Riel 2013, P.141]. On the level of bodily motorics, a surprise reaction can reveal itself by a sudden interruption or delay of movements such as when passers-by are slowing down or suddenly stopping in front of an advertising display, or in an extreme case even by a defensive startle response. Beyond such initial reflexive reactions, constantly focusing the display indicates sustained attention towards the given stimuli, and emotional reactions such as smiling can indicate mental activity and result from the cognitive engagement with a collative stimulus. If people discover the display from the distance, they can further react by changing their walking direction and approaching it. The most reliable indicator for attention is active and social engagement in front of the display, such as passers-by hinting to or talking about the screen contents.

3.3 Conveying Interactivity

Interactive Out-of-Home Displays
are often not expected to be interactive and thus have to surprise passers-by and communicate their interactivity by an unaware initial interaction.

3.3.1 Challenge: Passer-by Expectations

Expectations on Interactivity in Public Space

A challenge in public space is that passers-by often do not expect that a display is interactive: With touch screens and kiosk terminals passers-by need to know about the possibility that one can interact by touching the screen with one's hands, and have to turn actively and purposefully towards the display in order to engage with it [Beyer 2008, P.42]. Beyond the expectation that one can interact, there must also be an incentive to use the display before approaching it, such as buying a ticket or gathering information at a city information terminal. In other words, also in public space the initial interaction with the display usually has to happen awarely. If passers-by do not know that they can interact by touch, the display can explain itself by text, three-dimensional button designs or animations which exemplarily play back the possible interaction one time and where viewers can recognize themselves and the intendend actions [Beyer 2008, P.101]. Yet also in this case, potential users need to have turned towards the display before and already pay selective attention to the visual explanations on the screen.

Role of the Context

The location and situative context in which passers-by encounter public displays crucially affect their expectations. For example, a check-in terminal at an airport, a ticket machine in a train station or an information terminal at an entertainment venue (see Figure 3.4) will be more likely expected to be interactive than a touchless advertising display system which is installed behind a shopping window.

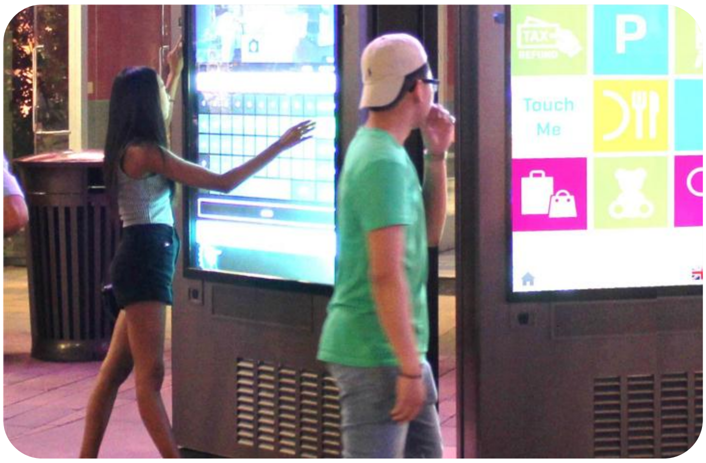


Figure 3.4: People have to know that touch displays are interactive and approach them actively.

Evolving Knowledge

In particular in the case of novel interaction technologies with public displays such as for example touchless interaction first of all also a learning effect by the audience has to occur that one can interact with the screen in this specific way. Over time recurring users can learn that a certain type of display is interactive and other people can learn about the interactivity by hearsay, by someone showing them the system or by media coverage. But before people implicitly assume that any display in the public environment may potentially be interactive, first a broader dissemination of the technology has to take place.

3.3.2 Solution: Unaware Initial Interaction

Solution for Communicating Interactivity

The solution for the challenge that passers-by do not expect that a public display is interactive and therefore pay no attention to it is an *unaware initial interaction that surprises passers-by and communicates that there is a possibility to interact* by giving visual feedback to the initial movements of passers-by [Beyer 2008, P.41]. Practically this can be realized with the help of computer vision techniques which allow a display reaction also to unaware movements, such that – in contrast to touch – the approaching user does neither have to know about the displays interactive capabilities nor to actively turn towards the display [Beyer 2008, P.42].

Mirror Images and Visual Feedback to the Initial Movements

The concept *unaware initial interaction* originated from a expert interview in 2007 with Tomas Sommer of DEON, the company who designed the four Magical Mirrors displays in Berlin (↺ Chapter 2.2.6). According to them, the initial interaction should be unware at first to turn out to be an interaction at all [Beyer 2008, P.99]:

> „One can distinguish between unaware and aware interaction. According to our experience the **initial interaction** should be **unaware at first**, to then **turn out to be an interaction at all**"

Sommer further describes the process of communicating interactivity by using mirror images (or stylized ones) as visual feedback as follows [Beyer 2008, P.102]:

> „The user has to be **made aware** by any means that the interactive application **reacts** to him at all, that this is about an **interactive system**. We at DEON have found out that the connection of the **self-perception** with the visual representation can be best achieved with the **mirror image** respectively camera image of the viewer, this also works better than to **stylize this image**. Here man is still too much animal: as soon as he sees himself he stops and dedicates oneself to it."

He also outlines the importance of passer-by movement in this process:

> „The displays are thus set up in an area where people pass by, and this passing-by then contains the **movement** that **has an effect on the image**. Other attractors are not required in this case."

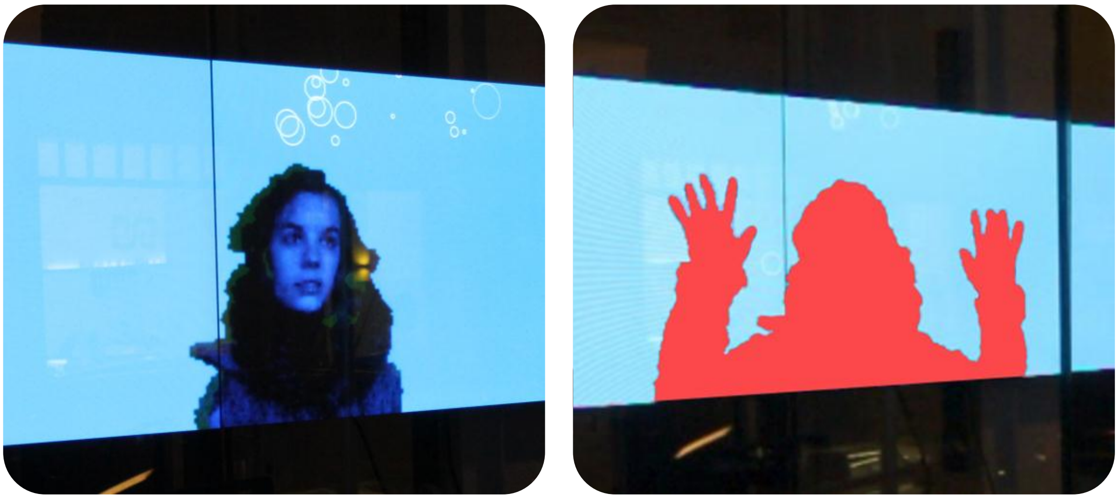


Figure 3.5: Recognizing oneself in a mirror image or stylized mirror image on a public screen.

Cognitive-Perceptual Mechanisms

Two mechanisms for an unaware initial interaction are addressed in the above statements of the interview: the *mental connection of the self-perception with a mirror image or stylized mirror image* (self-recognition), and the principle that the *passing-by movement has an effect on the image* (the principle of cause and effect, which is also known as the principle of action and reaction):

Mechanisms for Communicating Interactivity	
Mirror Image: Self-Recognition	Movement: Cause and Effect

Surprising Feedback

This solution for conveying interactivity to passers-by is again characterized by surprise which violates people's expectations. Surprising stimuli are an effective means to attract attention in visual advertising (↺ Chapter 3.2.3). If one surprises passers-by now with an unaware initial interaction, the interactivity signaled by the visual feedback itself is the surprising stimulus. In the context of his research on the Magical Mirrors, Daniel Michelis used the term *surprising feedback* when he observed that *passers-by stopped beeing surprised when they discovered the reaction of the interactive effects to their own movement and the representation of their own mirror image* [Michelis 2009, P. 160f]. In other words, passers-by who didn't expect the display to be interactive were surprised when they became aware of the correlation between their movements or their self with the visual feedback.

Reframing: Increasing the Surprise

Similar to the way surprise can be amplyfied in ambient media (↺ Chapter 3.2.3), a subtle *reframing* of passer-by expectations may also increase the surprising effect of the initial visual feedback. For an effective unaware initial interaction the interactive interface thus should be preferably unobtrusive [Beyer 2008, P.41]. This is similar to startling someone: this becomes more effective if one is initially hiding around a corner. In the moment when people become aware of the interactivity they may, once again, suddenly stop or show a surprise reaction (↺ Chapter 3.2.4):

Interrelation with Attention

The principle of unaware initial interaction fullfills two purposes at one time: first, it communicates the interactivity of the display to passers-by. But second, the discovery of interactivity also serves as another *attractor* that makes passers-by who only incidentally noticed the visual feedback through peripheral or oriented attention pay *selective attention* to it, stop and engage with the display. As this process of *attracting attention by communicating interactivity* relies, as discussed, on surprise it is in fact another collative attraction stimulus (↺ Chapter 3.2.3).

Stages of Understanding Interactivity

The process of unaware initial interaction thus can be classified into the stages attention, awareness and success of interaction: first people notice and focus the visual feedback, then they become aware of the interactivity, and once they interact explicitly with the feedback they can either interact correctly or wrong with it. In [Serbedzija 2008] and [Beyer 2010] we related the initial interaction also to the concept of *implicit interaction*: when becoming aware of the feedback, people first only implicitly interact with it before they start to explicitly engage with it:

Attention	Awareness	Interaction	Success
Ignoring	Unaware	Implicit	Correct
Focusing	Aware	Explicit	Wrong

Communicating Interactivity vs. Interactive Capabilities

One can distinguish between communicating interactivity at all and conveying the scope of the interactive capabilities (functionality) of a display. Unaware initial interaction just means the initial discovery of functions that react to the passer-by movement or appearance. Its main purpose is to attract and stop people and entice them to interact. Sommer notes that the mirror image used therefor does not leave much room for other content and thus a design solution is essential which uses this effect as initial interaction, but then subtly integrates it to the further interaction [Beyer 2008, P.102]. Once users understand the basic interactivity, more complex functions which are not self-explaining can be conveyed. For this, better than textual explanations are animations where viewers can recognize themselves and which exemplarily demonstrate the interaction [Beyer 2008, P.101].

RW ↗

Conveying Interactivity by Mirror Images

As proposed above, in order to convey interactivity of a public display to passers-by who do not expect it to be interactive, mirror images or their stylizations can be used in which people can recognize themselves, as well as the visual effects which the passing-by movement causes to the screen. In regard to the mechanism of recognizing oneself by self-perception or by the effects of one's movement to the screen, [Müller 2012] discuss several psychological foundations (↺ Chapter 3.3.4) and compare the effectiveness of different stylizations or abstractions of mirror images.

Terminology

We called the solution for conveying interactivity unaware initial interaction [Beyer 2008] and related it to the concept of implicit interaction. [Müller 2012] argue that implicit interaction means that users are not aware of the visual effect, and use the term inadvertent interaction for the same process of passers-by becoming aware of the effect. They further add to the discussed distinction between aware and unaware interaction that one could likewise also speak of intentional and unintentional manipulation of the screen. But on the other hand, an unaware initial interaction is, as discussed above, an unexpected but not evidentially unwanted event, and other works such as [Vogel 2004, P.3] do also argue that the implicit interaction phase involves user awareness of the visual feedback.

3.3.3 Cues for Signaling Interactivity

In general, everything that is not expectable in the current public context and can be decoded within seconds as being caused by or controlled by, as actively or passively reacting to onself or as specificially relating to individual characteristics of the self such as one's appearance can potentially communicate interactivity, if it can be clearly recognized and surprises beyond a certain treshold:

Self- Recognition: Mirror Images

Mirror images are effective by the recognition of oneself and of the surroundings such as the street or buildings. The Magical Mirrors displayed a full-screen mirror image which led to an increase of display usage of 500% compared to baseline contents that just provided interactive virtual effects [Michelis 2007, P.4]. In contrast to such classical mirror images often also cropped greenscreen images such as in [Beyer 2014] are used, where the virtual context gets more apparent through the virtual background. Mirror images are not equally suited for all situations and display formats. For example, a 360° mirror image around an advertising column can only be displayed distorted due to the projection angle [Beyer 2008, P.45]. When passing a display sideways, mirror images show a person only from the side and are only perceived in the periphery until people turn towards them. Mirror images often are also not clearly recognizable due to the distortion by the tilted camera angle, insufficient size, low luminance or poor contour quality.

Silhouettes and other Stylizations

DEON reported that stylized mirror images are not as effective as photo-realistic ones [Beyer 2008, P.102]. The most typical stylization or abstraction of mirror images are color-filled silhouettes. In theory, silhouettes reduce an image to its most basic expression and can be very effective by the fast recognition of the distinct contour that is emphasized by the color contrast [Gautier 2010, P.84, Ware 2013, P.299]. Yet in practice the displayed silhouettes of passers-by frequently suffer from the arbitrary, distorted perspective and poor contour quality such that they are often hardly recognizable. [Trytes 2005] avoid this problem by using pregiven silhouettes which are more concise than real silhouettes of passers-by. Silhouettes have been compared with other interactivity cues in field studies such as for example in [Müller 2012] and [Beyer 2014]. Even more abstracting reductions of mirror images than silhouettes can be used to convey the interactivity of public displays, such as for example the stick-figure-like Kinect skeleton representation [Beyer 2013B].

Figure 3.6: Recognizing oneself in an augmented mirror image or greenscreen image.

Augmented Mirror Images

If mirror images are augmented with interactive effects this puts them into a virtual context and makes interactivity more obvious than with classical mirror images, which are in fact not more than plain camera images and could also be mistaken for the common reflections in shop windows. Mirror images which are enriched with virtual effects have been used by [Michelis 2009, P.62f]. In fact, greenscreen images also already constitute a simple form of augmented mirror images as their virtual background makes clear that the image is processed (see Figure 3.6).

Reacting Humans

Some systems give interactive feedback by autonomously acting virtual human characters that react to passers-by. The Interactive Catwalk Display showed the human silhouettes of the Apple iPod campaign which began dancing as soon as someone passed by [Trytes 2005]. More active and complex human behavior was used in a promotion for the Disney Side ad campaign [Mazza 2015]: in a shopping mall the interactive silhouettes of famous Disney characters such as Mickey Mouse, Goofy or Donald Duck were shadowed on an opaque shop window and surprised unsuspecting shoppers by reacting to, mimicing or dancing with them. To attract attention, [Reitberger 2009] displayed an interactive mannequin on a shop window display that reacted to passers-by by looking towards their direction, a principle that has also been investigated for an avatar displayed on a kiosk system [Christian 2000]. Such interactive shop window mannequins and avatars should be designed such that they avoid the *uncanny valley* [Mori 1970].

Reacting Animals

While human characters are mostly displayed on vertical screens and reveal their interactivity by directly addressing passers-by by looking at or mimicing them, reacting animals make more sense when the feedback must be displayed on the ground or at the side, or when a more flexible behavior is needed. The interactive floor advertisement system Reactrix [Takahashi 2004] provided an interactive content where fish projected on the floor did not only show their typical biological motion, but to communicate interactivity also an *escape reaction* as soon as passers-by walked with their feet over the projected image of a koi pond. In [Beyer 2014] we used fish that swam along with passers-by who were approaching sideways in order to convey the reaction of the system to the passer-by movement.

Reacting Objects and Surfaces

Another possibility to communicate interactivity to passers-by when they are walking over an interactive floor advertisement or passing by a sidewalk display are reacting objects and surfaces. Differently from human and animal characters who usually *react actively* to passers-by, inanimate objects and surfaces *react* according to the principle of *cause and effect*. Reactrix developed diverse contents where passers-by “do a double take when they gaze at the floor” when they incidentally collide with virtual store logos, product images or footballs that are bouncing off their feet according to real world physics [Takahashi 2004]. In another content water-like ripples appear around passers’-by footsteps as a perceived reaction to their movement of the feet [Rae-Dupree 2005]. On a sidewalk display [Trytes 2005] used a content where passers-by could slow down cars when approaching sideways. In [Beyer 2008], [Beyer 2013] and [Beyer 2014] we used balls as objects that reacted to passer-by movement and that could be kicked around a cylindrical advertising column or along a long sidewalk display.

Abstract Reactive Feedback

To communicate interactivity of the display also very abstract reactive visual feedbacks can be used. The Magical Mirrors of [Michelis 2007] provided four basic virtual effects called aura, progression, luminary and flexibility that reacted to the movements of people or their hands and that were played back both with and without mirror images of the passers-by. In [Beyer 2013] we used particle clouds that were equally attached to the body parts of people who were passing by.

3.3.4 Non-interactive Interactivity Cues

Animations and Call-to-Action

Visual animations on the start screen of touchable kiosk systems where viewers can recognize themselves and which exemplarily demonstrate the interaction are often used to explain the interactive capabilities of a display [Beyer 2008, P.101], but they can hardly attract and communicate interactivity to inattentive passers-by. The same is true for so-called call-to-actions (CTA), imperative texts such as “Touch to start” or “To select your language, tap on the flag” on graphical buttons, banners or labels of such kiosk touch screens. In contrast to an unaware initial interaction, they require that users have already turned towards the display and pay selective attention to the text. [Müller 2012] compare the performance of such a call-to-action with other interactivity cues.

Disclosing Hardware: Interaction Sensor

The process of surprising passers-by by an unaware initial interaction can be undermined if they notice disclosing hardware like interaction sensors before receiving the visual feedback. Visible sensors can communicate interactivity to experts, but also lead to false assumptions on the interaction principle by non-expert users. For this reason interaction sensors should preferably be hidden or integrated as unobtrusively as possible [Beyer 2013B].

Passers-by as Cues: Seeing Others Interact

Passersby themselves can reveal interactivity in two ways: Several works describe that users who already interact with the display can attract the attention of other people, and the term honeypot effect by [Brignull 2003] describes such an progressive increase of interested people [Michelis 2007, Müller 2012]. In the context of passers-by understanding interactivity by seeing others interact, a more precise conception is *Stellvertreterinteraktion* (proxy interaction) by [Sauter 2004], which means that passive observers who watch interacting users are involved in the communication and experience process.

Getting Notified by Others

Passers-by who already noticed interactivity can also make others aware of their discovery, or the knowledge that a spectacular display installation is interactive can be spread by hearsay or media coverage about the system.

3.3.5 Psychological Background

Self-Recognition: Recognizing Oneself in a Mirror Image

In regard to understanding interactivity by recognizing oneself in a plain or stylized mirror image (↺ Chapter 3.3.2), [Müller 2012, P. 3] refer to the two mechanisms of mirror-self-recognition distinguished by [Mitchell 1993]: visual appearance matching which means that passers-by compare the seen mirror image with the mental image they have of how they look like, and kinesthetic-visual matching which means that they recognize themselves by the correlation between the felt motion and extent of the own body parts (proprioception) with the perceived visual feedback in the mirror image. Further, they mention the example for perceiving biological motion by [Cutting 1977]: due to the rapid and effective recognition of the congruence of the biological motion in the mirror image and the proprioceptively felt own body schema with that motion, also very abstracted mirror representations such as an array of point lights are effective for recognizing oneself. Silhouettes are recognized in early processing stages of object recognition on the basis of their contour. Most easily recognizable are canonical silhouettes where the shape is viewed from the most distinct and simplified perspective, such as when human body parts like hands, arms or legs are clearly identifiable when one is facing the display frontally [Ware 2013, P.299f].

Perception of Cause and Effect

The principle of cause and effect is another important mechanism for recognizing interactivity (↺ Chapter 3.3.2). A popular example for human perception of causality is, as [Müller 2012, P.3] also mention, the problem in physical collision simulation in computer graphics of correctly synchronizing visual events. This is similar to the typical contents of the Reactrix system where one billard ball strikes another to set it in motion (↺ Chapter 3.3.2). In order to achieve perceived causality a precise timing is required, which means that the launching delay of the hit object should not exceed an interval of 70 milliseconds [Ware 2013, P.233f]. Yet there are also further examples of causality in nature where the effect does not follow that immediately on the cause and a certain delay or development of the reaction is natural, for example when brushing a branch of a tree when walking, when blowing away leaves on the ground by one's movement, or when causing waves when walking over shallow water surfaces. In general, for perceived causality it is just important that passers-by can correlate the effect with their own behavior according to their experiences with the natural world.

Active or Passive Correlation with the Feedback: Causality vs. Reaction

Physical causality where the passing-by movement has a force effect on things is an example for an active correlation of one's behavior with visual feedback. Yet interactivity of a display can also be communicated by a passive correlation of one's presence with the screen content, when an object or living being shows an action or behavioral reaction towards one's presence. If for example a virtual avatar on the screen actively approaches and speaks to passers-by, a mouse on the screen flees from them or a school of fish shows a reflex action when walking by, or if a virtual shark actively attacks people walking by such as depicted in the movie *Back to the Future*, interactivity is not conveyed by causality, but by an *active response* of the screen content to one's presence. In sum, every animate or inanimate being or entity which conveys a recognizable active or passive correlation to the passer-by appearance, presence or behavior and which is unexpected and surprising in the current context can communicate interactivity:

Passerby-Feedback Correlations		
Appearance	Presence	Behavior

Reaction of Animals vs. Animacy

Human perception is highly sensitive to motion that appears to have a biological origin such as in the known studies where viewers were able to recognize human motion just by points of lights which were attached to the limb joints of human actors [Johansson 1973]. Further, humans can even attribute human characteristics such as anger or fear to very simple moving geometric shapes [Ware 2013, P.235f]. [Müller 2012, P.3] discuss biological motion as a possible psychological cue in the context of noticing interactivity. However, biological motion alone and the animacy it conveys do not communicate interactivity: passers-by are used to animations of animals and humans which they perceive on non-interactive video screens every day and they usually do not consider them to be interactive. Only if the displayed animals really show a noticable behavioral reaction to passers-by and thereby surprise them they convey interactivity in the sense of an unaware initial interaction. Of course, animacy can still surprise viewers and make them stop even if no interactivity is present, but then as a classical attraction cue similar to looming or hazardous stimuli which trigger startle responses.

Understanding Control

When passers-by recognize the cause and effect relationship with the screen, they have a subjective feeling of control which can motivate them to interact [Michelis 2009, P.90]. Understanding one's control of the visual feedback thus can be seen as a specific and advanced form of recognizing causality. In regard to recognizing mirror images, [Müller 2012, P.3] compare the understanding of control of a user representation with the experiences of ownership and agency which are main constituents of the mechanism of self-recognition in humans [Jeannerod 2003].

3.3.6 Practical Needs

When designing visual feedbacks for communicating the interactivity of public displays, also several practical considerations have to be taken into account:

Practical Needs	
Interplay with other Cues	Attention vs. Interactivity
Needs of Advertising Industry	Integration with Contents
Display Formats	Risks of Wearing Off

First, visual feedbacks should be compatible with multiple user scenarios in front of the screen as well as with other attraction and interactivity cues. Many visual feedbacks may also not accomplish the purposes of attracting attention and communicating interactivity equally well. For example, a mirror image may better convey interactivity than a colorful abstract cue, but on the other hand be less physically intense and salient. Then, visual feedbacks have to make sense in the context of the basic content and be integrated with it usefully. They also must be suited for the used display format. For example, mirror images fit perfectly onto life-size displays, but not entirely onto horizontal banners. The visuals must also fullfill the needs of the advertising industry. While mirror images of random passers-by produce funny results, they may not be compatible with the smooth photographic illusions needed in fashion advertising. Finally, feedbacks that do not rely on inborn stimulus-response mechanisms may wear off over time.

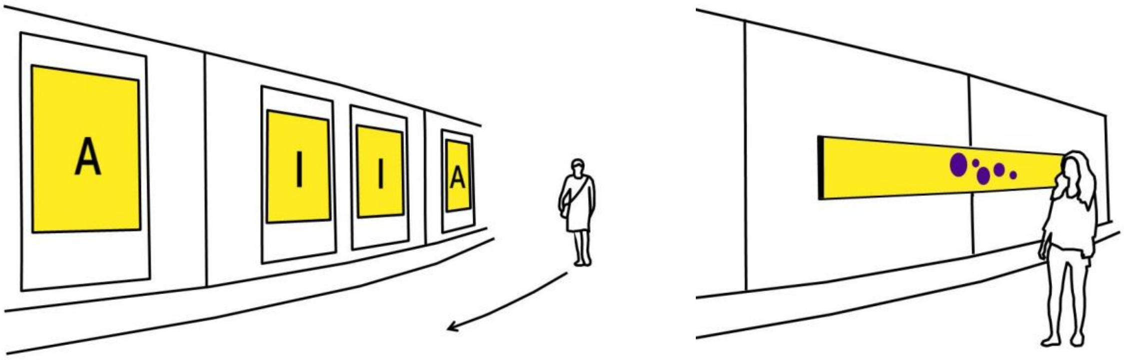


Figure 3.7: Instead of a display row such as by [Michelis 2009] also a long display can be used.

3.3.7 Noticing Interactivity while Passing Displays

Unaware Initial Interaction along Display Rows

When walking along sidewalks, people may often look towards the movement direction and not pay any attention to interactive displays which are installed within shop windows and thus only appear in the periphery at an angle of 90°. The following observation that passers-by miss out the first unit of a display row which consists of the four interactive *Magical Mirror* displays installed in parallel configuration along a sidewalk trajectory were made by [Michelis 2009, P.161]:

> „In regard to the initiation of the interaction it could be further observed that passers-by often just noticed the first display when passing by and **stopped only at the second or third display** to start interaction. For the experimental setup with four displays this meant that the middle displays would be perceived more intensely. As first of all the outer screens have assumed an activation function, surprising elements could be predominantly displayed on them."

Instead of letting passers-by just pass the outer interactive displays along a row of separated displays, also a long continuous banner display could be used for the unaware initial interaction that constantly provides visual feedback without any disruptions (compare Figure 3.7). The observation by Michelis that passers-by stop late and just notice the first display when passing by to then stop and interact only at a second screen has also been confirmed by [Müller 2012, P.7f].

3.3.8 Measuring Reactions to Interactivity

Similar to measuring passer-by initial attention towards classical attention cues (↺ Chapter 3.3.2), for measuring how people notice and become aware of interactivity one can analyze the same properties such as orientation reactions, surprise and other emotional reactions, startle responses, stopping reactions and movement patterns as well as the visual focus (eye fixation patterns) of passers-by. In addition to these properties, correct or wrong explicit interaction of the passers-by with the given visual feedback indicates if and in how far they already have understood interactivity at a certain point in time:

Reactions when Noticing Interactivity		
Orientation Reaction	Surprise Reaction	Motion Response
Direction Change	Eye Fixation	Explicit Interaction

As not every passer-by who has understood interactivity might also show a visible reaction, such objective measurements have to be complemented with subjective data obtained by semi-structured interviews. Yet if the interviews are conducted nearby the investigated displays, this public situation particularly involves the risk of social desirability bias of the respondents and further can reveal the display’s purpose and the research context to non-involved people.

3.4 Subtly Directing Users

Public displays may actively shape their audience by subtly influencing user positions by dynamic and interactive visual cues on the screen, in order to dissolve crowds and improve parallel usage in front of them.

3.4.1 Active Behavior Shaping

Actively and Subtly Directing Users in Front of Displays

Out-of-home displays may actively influence their audience by subtly directing users to certain positions in front of displays by displaying dynamic and interactive visual cues on the screen [Beyer 2014]. Such active behavior shaping is most useful in front of wide displays which provide no standard user position and allow multiple users to interact in parallel. It can be used to help users to position correctly in front of interaction sensors, to dissolve crowds by guiding users to empty spots in front of the display, or to establish specific audience constellations that encourage users to start playing with each other. For this, effective visual mechanisms that trigger behavioral responses have to be found.

Reversing the Notion of Adaptive Displays

The notion of displays that actively shape or adapt the audience reverses the classical notion of displays that just adapt the content to users. Classical adaptive displays such as that by [Vogel 2004] adapt the content in response to explicit actions or implicit contextual cues of users such as their proximity, positions or body orientations. Proxemic interactions [Ballendat 2010] is a similar concept to describe how data on the relations of multiple people and devices in front of the display can be used to provide appropriate content and to mediate conflictive needs. But in contrast to such systems that adapt to users, also the positions, orientations and constellations of the people themselves could be actively manipulated to establish preferable conditions in front of large displays.

3.4.2 Challenge: Managing Audience Constellations

Positioning within the Sensor Space

The most classical field of application of visual positioning cues is the correct positioning of users in front of interaction sensors [Beyer 2014B, P.2]: In the context of expert and habitual use of touchless devices, for example when playing Kinect games in the living room, one or two active users know from experience how to position and orient themselves to be correctly detected, or otherwise can follow the instructions on the screen. Yet for novice users in public who are not aware of the positioning needs of such devices, the optimal standing position has to be communicated as intuitively as possible. A common solution in consumer electronics stores are floor markers or spotlights that signal the optimal position for being correcly detected by sensors such as the Kinect (see Figure 3.8).

Dissolving Crowds in front of Displays

Large out-of-home displays offer extended interaction spaces that allow multiple users to interact in parallel, but in practice passers-by often will crowd together in front of one region of the display instead of using the whole space. One reason for this is that if a group of people arrives, its members stand by the first user in order to watch him or her interacting [Michelis 2007]. Such close bystanders may ignore and interfere with each other when interacting [Peltonen 2008], block the way of others when standing behind each other in rows [Müller 2012], and prevent new arrivers from taking an active part. Such crowding effects may be resolved by actively guiding users to the still uncrowded areas in front of the display where they have sufficient space to interact and do not impede each other [Beyer 2014].

Social Constellations and F-Formations

The situations emerging in public space are at all more incidental and complex than in the living room. Singles, pairs or larger groups of passers-by arrive at the display at different points in time, stop at various positions, and assume different body orientations, user roles and social constellations. The spatial arrangements between multiple users in front of a display are called f-formations [Kendon 1990]. For example, in the case of an L-shaped formation usually an active performer and a passive bystander are standing close and orthogonal to each other. Close bystanding can also result from social behaviors such as embracing each other. Such social constellations may prevent that the available interaction space is fully used and interactive applications for multiple users function as intended.

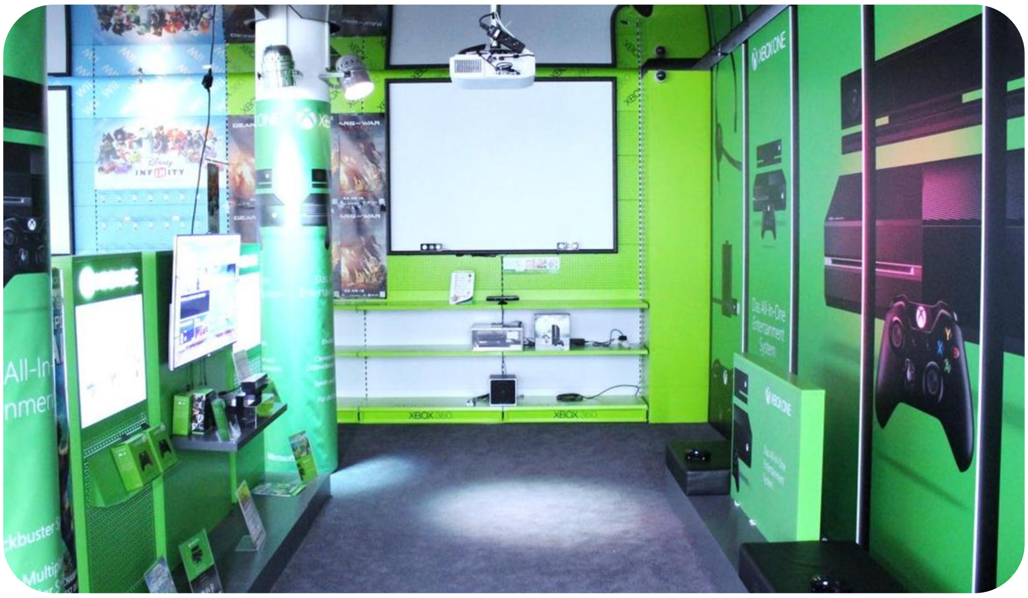


Figure 3.8: In stores floor graphics or spotlights are used to indicate the optimal user position.

Ideal User Positions in Games

In addition to the inherent social complexities in public space, certain touchless contents require specific user constellations that are not evident to all passers-by. For example, we observed that pairs playing interactive ball games in front of public displays first have to adjust the distance between each other before they can comfortably pass the ball. Some cooperative applications may also require a close distance between users, while others may need space for detached users performing wide-reaching gestures. Further applications may require a minimum number of users to work properly. Also, user positions and user roles may have to be changed if further potential players are arriving. If such conditions do not emerge spontaneously, the display itself may become active to establish them.

Initiation of Games

To carry this thought even further, the display may also help users to find starting positions for certain multi-player games that are still unknown to arbitrary passers-by and thus lead them to active engagement. Once users have been subtly guided by the display to the required starting positions of a game, they may suddenly discover and intuitively understand the intended game principle or interaction possibility of which they were unaware before, and consequently be encouraged to start playing. By such a subtle assistance the display may for example stimulate users to start a completely new ball game.

3.4.3 Solution: Visual Audience Moderation

Subtly Directing Users by Dynamic and Interactive Visual Cues on the Screen

If the ideal conditions for convenient simultaneous interaction or start conditions for cooperative applications do not emerge spontaneously, the display itself may become active to increase its effectiveness. We propose that this could be accomplished by the use of dynamic and interactive visual cues on the screen, with which the display subtly manipulates user positions. Such positioning cues may react to current user positions, social constellations or crowds in front of the screen and appear right in front of users in order to actively guide them to more preferable positions. If crowds can be distributed more evenly this way, the percentage of active users may increase and groups may stay longer at last.

Basic Problems

We call the idea of actively influencing user positions and regulating audience constellations in front of public displays by visual cues and dynamic strategies for displaying them *visual audience moderation* [Beyer 2014], as the system acts like a moderator here who assigns the optimal positions to individual users. This process of active behavior management poses the following basic problems:

Visual Audience Moderation		
User Positioning	User Repositioning	Audience Distribution

First, visual positioning cues on the screen must be able to effectively draw arriving users to arbitrary positions they would not have chosen themselves (*user positioning*). For this, they must be wittingly or unwittingly understood and immediately accepted by users. Further, when a user already interacts with the display, it might become necessary to reposition him in order to free space for new arrivers, and visual cues thus should be able to make users step aside and clear the needed space (*user re-positioning*). Finally, visual cues should manage to dissolve crowds caused by passive group members gathering around an active user, and distribute users more evenly (*audience distribution*). This may be achieved by guiding single users towards empty spots, or by undirected signals that address the entire crowd. If interactive visual cues accomplish these basic goals, they might also be used to shape specific audience constellations.

3.4.4 Subtly Influencing User Positions

Subtle Stimulation vs. Explicit Instructions

At the first glance, an apparent alternative to subtly influencing user positions by dynamic and interactive visual positioning cues seems to be to explicitly instruct passers-by what to do. Yet as public interaction is characterized by spontaneous and constantly changing situations with multiple users, explicit instructions such as text messages which have to be read and interpreted first are not an adequate way to address individual users and bring them to adjust their positions and distances. Instead, subtle mechanisms such as dynamic visual stimuli on the screen seamlessly integrate into the flow of play and are immediately and intuitively understandable by users. Interactive stimuli are also superior to the classical static and inflexible floor graphics, which cannot adapt to manifold situations and user numbers in front of the display [Beyer 2014B].

Preattentive Control of Behavior

As the goal is to actively and subtly guide users in front of the screen, questions arise such as in how far such a subtle stimulation can work at all, and which subliminal stimuli are effective. As discussed, the information reception can be distinguished into conscious and unconscious perception, and all information that is received from the environment is processed preattentively at first before most of it is filtered out and only the relevant information is analyzed further by attentive processing (↺ Chapter 3.1.1). Preattentive processing accomplishes some initial tasks of perceptual grouping and segregation with which phenomenons from Gestalt psychology such as figure-ground organization or the law of closure can be understood [Treisman 1986, Wertheimer 1923]. According to Ulric Neisser the preattentive processes represent, in some conformity with the central rationale of Gestalt theory that “the whole is more than the sum of its parts” (↺ Chapter 3.1.2), a preliminary stage to focal attention where “the whole is prior to its parts”. This means that figures and objects are separated from others in their entirety before selective attention analyzes them in detail [Neisser 1967, P.89f]. Neisser states that much cognitive activity in daily live is preattentive and identifies two classes of movements that are under preattentive control: the direction of attention itself (i.e. head and eye movements), and the guidance of body movements. He gives the example of a busy boss, who arrives at his office in the morning and only recognizes the familiar environment and his secretary “out of the corner of his eye” without focal attention, but still is aware of their presence and does not collide with co-workers or furniture when moving. Another example that most drivers know from personal experience is when they suddenly realize that they have been steering the car for a longer timespan but not been paying attention to the road, as they were lost in thought or distracted by conversation. According to Neisser, this behavior was entirely steered by preattentive pattern analysis. If the preattentive processes extract a relevant (e.g. potentially threatening) motion cue in the periphery, the driver's focal attention is directed back to the road immediately. Similarily, phylogenetically threatening stimuli such as spiders or snakes are processed preattentively in order to enable a quick and appropriate reaction [Öhman 2001]. Yet [Wolfe 2003] warns that it would be a mistake to think of a "self-sufficient preattentive vision" that can directly trigger "a motor response without also engaging attention-demanding processes" or that its "output can directly control behavior". At last, preattentive processing is an integral part of the attentional process and just represents a prestage which, in the case of strong (threatening or positive) stimuli, passes the selected features on to the attentive processing. It is followed by selective attention towards the stimulus and by a conscious attentional reaction (e.g. a startle or defensive response). If focal attention concentrates on (or is distracted by) interactive content on a large display, preattentive processes may also affect certain aspects of user behavior in response to visual cues on the screen, similar to the examples given above.

Subliminal Stimuli

In marketing research, further also continuous forms of subliminal perception are discussed, where the viewer does not become aware of presented stimuli at all. But these theories only make assumptions such as that repeatedly presented subliminal stimuli can influence attitudes or create preferences for certain brands or products, such as with the mere-exposure effect [Kloss 2007, P.63f]. They also do not assume that they could control viewer behavior in any way. In this context, some works also speak more carefully of stimuli or messages, which have implicit effects, but cannot be recalled consciously [Scheier 2012, P.167f]. In regard to visual stimuli on the screen that are designed to subtly influence user positions in front of the display it would also be thinkable that the stimuli are processed attentively, but only at such a low level that they are only hold in short-term memory and then quickly forgotten. Attention strongly depends on the viewers expectations [Ware 2013, P.156], and the positioning cues might be designed in such a typical and expectable way that they are taken for granted and viewers can focus their attention on other aspects of the content.

CHAPTER 4

DISPLAY QUALITIES

Factors that Influence Passer-by Behavior

4.1 Formal Qualities

Possible influences of display qualities such as the form factor, framedness, seamlessness or materiality on user behavior have to be considered when designing interactions for out-of-home displays.

4.1.1 The Form Factor

The most basic distinguishing feature between different out-of-home displays is their form factor, which is influenced by architectural and communicative, but also technical needs. The form factor can be subclassified into the dimensions shape, size, planarity, curvature and ratio (see [Rümelin 2012] and [Beyer 2013, P.2f]):

Form Factor				
Shape	Size	Planarity	Curvature	Ratio

Basic Shape

The basic shape means the rough geometrical form of an out-of-home display. It has to integrate well with the environment and predetermines the visibility and interaction space of the display. For reasons such as architectural integration, conciseness, simple perception and uptake of standardized content primitive geometric shapes are preferred to complex shapes for out-of-home displays. Common basic display shapes range from flat or curved surfaces to geometric primitives such as cylinders, semi-cylinders, cubes, spheres or domes, and are either free-standing or integrated with a building façade. Display shapes further can support certain metaphors if they resemble common objects from real life. For example, the cylindrical shape of advertising columns is often used as a kind of sculpture when displaying cola cans, tyre stacks or humans [Beyer 2008, P.10].

Size

The display shape can vary in size. The size of an out-of-home display depends on factors such as the sight relations (visibility and readability from the distance), velocity of the surrounding traffic, and content. The display dimensions increase with the installation height, i.e. elevated displays are larger than displays on the pedestrian level such that they are still noticed and perceived well (↺ Chapter 2.3.3).

Ratio

Flat rectangular displays are available in the horizontal landscape ratio or the vertical portrait ratio, which brings along different preconditions for content layout and perception [Beyer 2010, P.3]. Rarely the aspect ratio is also almost squared. While basic display units are often available in classical ratios such as 16:9, for out-of-home displays visibility, passer-by trajectories and architectural integration are more relevant issues than accomodation to the proportions of the visual field.

Planarity

Out-of-home displays can also be distinguished in regard to their planarity and classified into planar, flat displays and non-flat, shaped displays (↺ Chapter 2.3.4). While flat displays are clearly oriented towards a direction and ideally positioned such that they are approached frontally (↺ Chapter 2.3.1), non-flat displays often are approached from different sides, display visual information towards various directions, and involve complex non-rectangular interaction spaces.

Curvature

The majority of non-flat out-of-home displays are curved instead of squared, and the curvature can be convex or concave or the display can even be multi-curved:

Curvature		
Convex	Concave	Multi-curved

Outdoors most non-flat displays are convexly curved due to increased viewing angle and thus visibilty. For optimal perception out-of-home displays are further usually curved in a steady, homogenous way. The convex or concave bending of the display in relation to the user can influence how far the screen covers the visual field [Beyer 2010]. Convex displays involve larger interaction spaces than concave ones, for example columns have a 360° circular interaction space.

4.1.2 Framedness

Beyond the rough form factor, also the framedness or framing of a digital display should be taken into account as a factor influencing user behavior. All flat and non-flat displays can be classified into framed, semi-framed or unframed displays depending on how many boundaries they have [Beyer 2013, P.2]:

Framedness		
Framed	Semi-Framed	Unframed

Framed Displays

Flat rectangular displays are typically framed as they are embedded in a frame with four boundaries and often bezels limiting the display towards the top and bottom, left and right. The four boundaries function as reference lines for aligning content within the screen layout. Framed out-of-home displays can appear either in the narrow portrait format, the wide landscape format or the squared format. Beyond real physical frames, also virtual or implicit frames can be created, for example by the white background light of projected displays [Pinhanez 2005, P.8].

Semi-framed Displays

In contrast to framed displays, semi-framed displays only have top and bottom boundaries – but no left and right ones. Thus designers can only draw on the top and bottom boundaries as reference points for aligning content on the screen, but the lack of the left and right boundaries can be compensated by the spatial organisation of elements and their decoration by size, color, shape, or animation [Beyer 2010, P.6]. In the out-of-home context, round advertising columns are an example for *semi-framed and curved* displays. As they have no left and no right, no beginning and no end [Reichwein 1980, P.68f] they allow users to endlessly move along the screen surface. If one “unrolls” such a column one gets a *semi-framed and flat* display or long banner format (↺ Chapter 2.2) which distinguishes itself from columns by having no bending where the content can disappear from view.

Unframed Displays

Unframed displays are characterized by the total absence of any boundaries, such as with spherical displays hanging from the ceilings in shopping malls, or by having a boundary only at one side, such as with hemispheres.

4.1.3 Surface Structure

Closely connected to the form factor is also the structure or *surface roughness* [Beyer 2013, P.2] of shaped displays: Two non-planar displays can have a similar basic form factor, yet still a different surface structure depending on their larger deviations. One can distinguish between curved and polygonal shaped displays:

Surface Structure	
Curved	Polygonal

For example, a cylindrical display can be realized as truly round, circular cylinder or as a polygon made of flat faces just approximating this cylindrical shape. In practice for cost reasons often industry-standard digital flat rectangular displays have been used as components for building polygonal non-planar displays. Figure 4.1 shows a round cylindrical display surface and a polygonal configuration of multiple flat displays on the same building façade. Comparably, a digital advertising column can be realized as real round column made from one mould, or as hexagonal or octagonal prism which is composed of multiple subareas.

4.1.4 Seamlessness

Another quality we propose is seamlessness [Beyer 2013, P.2]: Any flat or non-flat display is seamless if its screen surface is not interrupted by any visible bezel, frame or edge. According to this definition the round cylindrical screen in Figure 4.1 is seamless, any polygonal display is not just alone because of its bends. But also flat displays can be non-seamless if they are composed of single units which are divided by frame bezels. Seen historically, most non-planar displays in architecture such as columns, arches or domes are curved and seamless and not made of polygons or flat rectangles. Also curved out-of-home displays such as advertising columns have continuous, unstructured surfaces, apart from a few exceptions such as citylight columns (↺ Chapter 2.2.2). While to some extent a rough common form factor of different displays might trigger similar behaviors, qualities such as the surface structure and seamlessness should always also be considered, as displays with a smooth seamless surface might elicit different audience behavior than arrays of flat and framed displays with discontinuations.

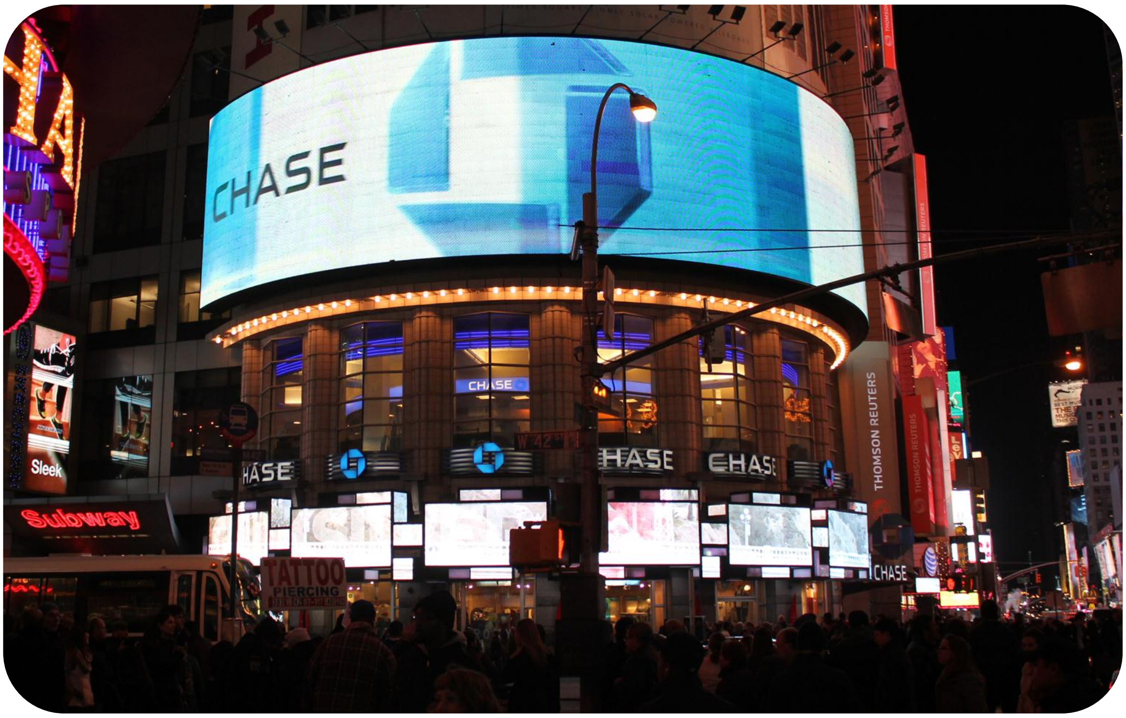


Figure 4.1: Seamless and round cylindrical display above a polygonal display configuration.

4.1.5 Materiality

Beyond the spatial attributes of a display such as shape, size or curvature also its materiality is an important visual and haptical information carrier. In the context of digital out-of-home displays, materiality of the display is primarily determined by the factors technology, luminance and resolution:

Materiality		
Technology	Luminance	Resolution

The used materials can convey information about the display's input and output technologies as well as characteristics such as its current state, intactness, modernity, quality and value. Especially the perceived luminance, which is affected by the surrounding light conditions and the daytime, reveals information about the visual state of the display [HGKL 2004, P.39]. Nowadays the screen resolution is chosen depending on the installation's height and distance to passers-by (↺ Chapter 2.3.3). It also plays a key role in conveying the quality and function of the display, and can influence expectations about screen interactivity.

4.2 Behavioral Effects

The manifold qualities of public displays such as shape, curvature or framing may affect passer-by perception and behavior, provoke motoric responses, and even interact with and either reinforce or neutralize each other.

4.2.1 Visibility and Perception of Displays

Visibility of Content on Shaped Displays

Displaying content on shaped displays involves, compared to classical flat ones, more complex issues in connection with the passer-by viewpoint, partial visibility and non-directionality of the display, and the deformation of the content:

Visibility			
Viewpoint	Partial Visibility	Non-Directionality	Deformation

The viewer position and viewpoint in the vicinity of shaped displays are not as predefined as in front of classical flat rectangular displays, which are intended for frontal viewing [Manovich 2001, P.99] and, in the case of out-of-home displays, are positioned such that they are approached frontally. Instead, non-flat shapes can be approached from different sides and at various angles. Partial visibility means that especially with convex and complex display shapes only a section of the whole screen is visible at a time, such that contents should be displayed within the part of the screen currently visible to the user. While flat displays clearly indicate a direction, non-flat displays are further non- or multi-directional and contents may have to be aligned to the viewer position first. If contents designed for flat displays are transferred to shaped displays they may also not be properly mapped or even deformed and in this case can be perceived quite differently.

Understanding Interactivity of Shaped Displays

In regard to noticing and understanding visual feedback which is displayed to communicate interactivity, for each display shape the mentioned visibility issues, content-to-user mapping and seamlessness should be considered [Beyer 2013B]:

Interactivity		
Visibility	Content-to-User Mapping	Seamlessness

Partial visibility means in this context that around shaped displays passers-by can only notice visual feedback to their movements which is displayed on their side of the screen. But if the feedback is also displayed beyond the visible part, it can also attract the attention of and signal interactivity to uninvolved passers-by on the other sides of the display. Due to the *non-directionality* and the deviating *viewing angles* of curved displays the optimal screen position for visual feeback where passers-by can clearly attribute it to the person who triggered it is also hard to determine: If the visual effect is displayed ahead of passers-by such that they still can notice it at the brink of their visual field, it may be wrongly attributed by other close-by viewers to themselves. *Deformed visual feedback* on curved displays can appear unfamiliar or lose its effect: If mirror images are squeezed on convex displays or stretched on concave ones viewers may perceive them as in hall of mirrors [Beyer 2008, P.45]. Also a *constant mapping* of individual feedback to the users around the screen has to be ensured. For example, around convex column screens the virtual space assignable to a single user is smaller than the physical space around the display, and if all users shall be treated equally mirror feedback has to be squeezed. For displays that do not have a *seamless surface* but bezels and edges, the resulting visual discontinuities might make it difficult to understand that the feedback relates to one's own movements when passing by.

Media Suitability

The stated issues demonstrate that contents for out-of-home displays should suit the medium, i.e. function on the specific display shape and make use of it. Yet often contents designed for standard flat displays are simply transferred to shaped displays without any adaptation to the media-specific demands. Figure 4.2 shows contents for flat displays which are only partially visible, deformed or not aligned to viewers when displayed on a column, and thus are not well perceived and may irritate viewers. For how to display text on a column see [Beyer 2008, P.31].

Figure 4.2: Visual-textual contents for flat displays mapped to a column without any adaptation.

Curvature and Immersion

In principle, the convex or concave bending of the display in relation to a viewer who is standing right in front of it influences how far the screen covers the visual field (↺ Chapter 4.1.1). Thus, next to factors such as the screen size, the curvature determines whether a non-flat display can support immersive or non-immersive experiences. For example, concavely curved cinema screens or spherical dome theatres enclose their viewers in order to create immersion respectively total immersion. In contrast, inversely curved advertising columns are non-immersive as their convex shape is warped away from the viewer, and thus rather support metaphors where virtual things emerge out of the screen [Beyer 2010, P.6] or move around it. Yet in general, out-of-home displays are not suited for immersive experiences due to the rough environmental conditions anyway [Beyer 2008, P.100].

Perceived Materiality

From the display's materiality (↺ Chapter 4.1.5) people can draw conclusions on its state of the art, operation and functionality. For example, viewers can associate a display with touch functionality if they had the respective prior experience with the used material before [Beyer 2008, P.28]. The display's state may also reveal its purpose, i.e. is it just a research prototype or a serious commercial display.

4.2.2 Behavioral Effects of Display Qualities

Positioning Effects in Front of Display Frames

Beyond just having effects on attention and perception or triggering orientation reactions, display qualities might even evoke motoric responses of viewers such as movements towards the display, a repositioning or an adaptation of the body orientation. Visual floor markers can affect user positions in front of a display, but also qualities of the display itself such as its frame may be effective stimuli that subtly influence user positions (↺ Chapter 3.4.1). Lev Manovich presents a theory on the relationship between the screen and the viewer that aligns well with this idea [Manovich 2001, P.99f]: First, he describes that a clearly defined rectangular frame induces a *viewing regime*, where the viewer focuses on and indentifies with the screen image while ignoring the physical space outside. The frame acts as a boundary between the space of illusion and what is screened out. Manovich continues with the notion of an *imprisonment of the viewer's body* in a fixed, immobile position by the requirements of the image perspective that promotes such a focused viewing. This imprisonment can be established by the screen apparatus such as in cinema where the body of the viewer is confined to a seat and the head is aligned to forward view in order to provide the best viewpoint. But in other cases viewers have to take action themselves. For example, in order to best perceive a painting in a museum, viewers have to position themselves centrally and frontally at a certain distance in front of it. This significance of the frame as a reference for the image perspective and the need to position oneself correctly in order to orient within the scene is also described by [Pinhanez 2005]. Similarily out-of-home displays may, even when they are not deployed frontally, stimulate users to position themselves frontally and centrally just by their frames.

Curved vs. Polygonal Displays

Such positioning effects may not just occur in front of the frames of single flat displays. Polygonal displays (↺ Chapter 4.1.3) constitute arrays of standard flat rectangular displays and thus are divided into multiple frames again. In contrast to truly round and curved displays with a seamless surface, such multi-display configurations may also show characteristics of the individual flat displays they are composed of such as a frontal and central positioning in front of the frames. Not only shaped but also flat polygonal displays may show such effects of single framed units. To carry the thought even further, also implicit frames [Pinhanez 2005] or virtual frames of the screen content may evoke a central positioning of users.

Stimulation of Movement

Some display shapes may also stimulate passers-by to move around them in a certain way. For example, cylindrical columns which are semi-framed provide more degrees of freedom for users than narrow flat displays [Beyer 2010, P.5]. Herbert Kaufmann, a designer of Litfaß columns, described the cylindrical shape of the column as having no beginning and no end, no left and no right. Thus the viewer would be encouraged to look behind things and be caught in a pull forcing him or her to circulate the column [Reichwein 1980, P.63f]. This gravitational pull which is already inherent in the shape can be further amplified by interactive contents that stimulate users to move along the screen [Beyer 2008, P.53f].

Effects on Social Interaction

Display qualities such as the shape, the associated interaction space or framing may influence social interaction around displays. For example, convex columns with their large circular interaction space allow multiple users to interact at the same time. While in front of narrow flat displays often only one single person is exposed to the public interaction and reaction of the audience and thus might get embarrassed, all people in the vicinity of a column are equally exposed to visual feedback which might reduce barriers to start performing [Beyer 2008, P.24]. The display shape may also affect how multiple users position themselves, which constellations or spatial-orientational arrangements they assume, and how they cooperate with each other. For example, if users can see each other when interacting around a convex column, this may stimulate cooperation between them. The display shape may also encourage users to start social games which are inherent in that specific shape, such as hide and seek around a column.

Interplay of Different Qualities

Often more than one quality may affect audience behavior around displays, and individual behaviors may not always be explained sufficiently by only one factor. For example, a polygonal column might to some extent trigger similar behaviors as a seamless column due to the same rough form factor, such as for instance stimulating users to move around it. But as it is also squared to single flat faces it may also evoke the central positioning effects typical of flat framed displays. Such simultaneous effects may interact with, counteract or reinfore each other, and the stronger stimulus may even override the effect of the weaker quality. For this reason, individual qualities of the display such as the basic shape should not be considered in isolation when designing for new display shapes.

RW ↗

Form Factor of Displays

Few works have systematically classified or discussed formal qualities of large out-of-home displays such as the form factor and possible effects on passer-by behavior. [Benko 2009] address general challenges of non-flat interfaces such as complicated viewpoints, limited visibility or the possible absence of a master user position using the example of a sphere and a dome. [TenKoppel 2012] apply the concepts of awareness subspaces nimbus and focus [Benford 1993] to describe the influence of different curvatures of a polygonal display on passer-by awareness and issues of social interaction such as performativity, embarrassment, personal space and f-formations.

Framing of Displays

In regard to display frames and their possible effects on user behavior, Manovich's conceptions of frontal viewing and the imprisonment of the viewer's body [Manovich 2001, P.100f] and similar notions by Pinhanez and Podlaseck about frames as a reference for perspective and the correct positioning of viewers are most relevant. [Pinhanez 2005] also present usage guidelines for frameless displays, warn of possible influences of implicit frames and propose the technique of real world framing where frame-like elements of the physical environment are used as a substitute for display frames. [Benko 2009] notes that with borderless displays such as spheres no off-screen space exists, impeding classical applications such as zooming.

Further Issues

The impact of factors such as display materials, dimensions, proportions, technology, screen aspect ratio or resolution, as well as the design of the content on the perception of out-of-home displays is addressed by various domain-specific literature such as [HGKL 2004], [Kelsen 2010] or [Schaeffler 2013]. In regard to the effects of light on distant viewers also technical literature on illuminated advertising such as [Gut 1974] or [Fischer 2007] can be useful. In the related field of media facades [Gehring 2013, P.74f] discusses the relations of display, content and input resolution and the viewing distance. In regard to seamlessness, [Bi 2010] investigate how interior bezels of tiled-monitor large displays affect user behavior, while the addressed issues such as visual search and wide bezels are usually less relevant for out-of-home displays.

CHAPTER 5

DISPLAY PROTOTYPES

Advertising Column,
Life-size Screen,
Banner Display

5.1 Approach

We designed interactive successors of classical display shapes
that have prevailed in out-of-home advertising such as round columns, large life-size screens and long banner displays.

5.1.1 Deriving Shapes from Classical Displays

The interactive display prototypes developed in this work are derived from classical out-of-home display formats (↺ Chapter 2) such as cylindrical advertising columns, large portrait-ratio life-size screens, and long banner displays which have become established in out-of-home advertising (see Figure 5.1). When we designed these display prototypes, three questions emerged: First, how can digital and interactive counterparts of classical advertising displays look like, if one aims to design them as similar as possible to their successful predecessors on the one hand, but also has to take account of the requirements of suitable interactive technologies and a prototypical design on the other hand. Second, how can interactive counterparts of classical display shapes such as round columns or long banners with their untypical and complexly formed interaction spaces be made interactive at all, and how can seamless user interaction involving multiple sensors be realized around theses shapes. Third, how can such displays be used in a similar way as or possibly also beyond the classical installation sites of their predecessors. The main issues related to designing the display prototypes can be summarized as follows:

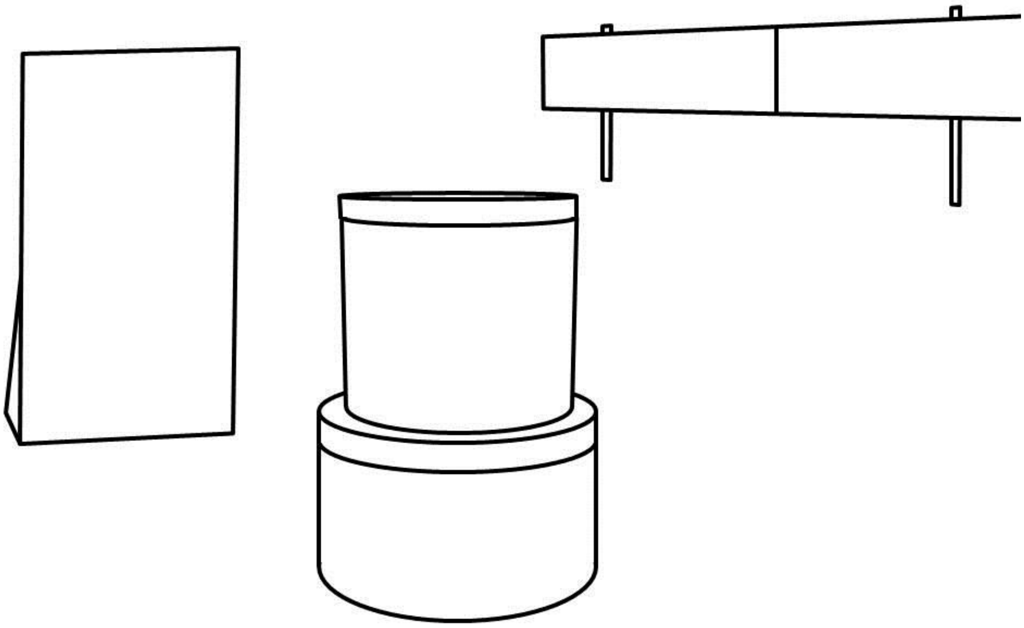


Figure 5.1: Basic shapes of the interactive display prototypes derived in this work.

RQ

Q 5.1 Appearance of Interactive Counterparts

How can digital and interactive counterparts of classical advertising display shapes such as columns or long banners look like?

Q 5.2 Interactivity of New Display Shapes

How can different display shapes such as columns or long banners with their untypical interaction spaces be made interactive?

Q 5.3 Deployment and Application

How can such novel interactive display shapes be used at sites similar to their predecessors or even beyond that?

5.2 Advertising Column

The Interactive Advertising Column is a counterpart to classical columns
but in addition provides dynamic images and touchless interaction within a circular interaction space around it.

5.2.1 Concept

The Interactive Advertising Column is an interactive and digital successor of classical advertising columns which are usually deployed freestanding and there where users walk (↺ Chapter 2.2.2). The cylindrical display provides a round and seamless screen which is surrounded by a 360° interaction space such that user interaction and visual feedback to approaching passers-by is supported towards all directions. Due to this wide circular interaction space the column can serve large numbers of users at the same time. The cylindrical display itself was originally designed by Fraunhofer FIRST in Berlin in 2004 [Haulsen 2005], and its interactive capabilities were further developed over the years. In order to enable touchless interaction, we equipped the column display with a 360° fisheye vision sensor in 2007 [Beyer 2008] and with multiple Kinect sensors in 2012 [Beyer 2013].

FACTS

Design Idea	Interactive and Digital Successor of Classical Advertising Columns
Construction	Column Display by Fraunhofer FIRST in Berlin (2004)
	Extension with 360° Vision Sensor for User Interaction (2007)
	Redesign to Multi-Kinect Column in Munich (2012)
Display	Indirect rear-projection, cluster of 8 or 4 beamers, 4 foil mirrors
Screen	Seamless cylindrical acrylic screen with diffusely scattering surface
Sensors	Fisheye camera OpenCV, Multi-Kinect
h x d	Column: 2.2 m x 1.6 m Base: 1 m x 1.6 m Screen: 1.1 m x 1.3 m
Publications	[Haulsen 2005], [Haulsen 2006], [Beyer 2008], [Köttner 2012], [Beyer 2013]

Figure 5.2: Interactive Advertising Column at one if its deployment locations.

5.2.2 Design and Construction

Column Base

The cylindrical display used for the Interactive Advertising Column was originally designed and constructed in 2004 by Fraunhofer FIRST [Haulsen 2005] and initially also proposed as a VR Object Display. This large digital column consists of a column base and a cylindrical screen on top of it (see Figure 5.2). The base or socket construction of the column consists of a base plate containing a cluster of 4 or 8 Sony Plus Vision U5 beamers (see Figure 5.3). Each beamer is equipped with a cooling fan which is attached to a tunnel to bring out warm air that otherwise would cause heat haze and thus impair the projected image. Above the base plate there is the carrier construction with four inclined foil mirrors which redirect the beamer light to the curved rear-projection screen. Inside the column base all materials are kept in black and it is also well-sealed to keep out daylight and to avoid any unwanted reflections on the column screen. Four removable coverings around the carrier construction protect the mirrors inside and prevent light incidence. Above the mirror component and the coverings there is a heavy middle ring which functions as fixation for the circular rear-projection screen and also contains four speakers for optional sound as well as the interaction sensors.

Figure 5.3: Column base with beamers and deflection mirrors and integration of sensor coves.

Cylindrical Screen

The column display prototype distinguishes itself from other early digital columns by its seamless cylindrical screen which is made from one mould. This acrylic rear projection screen diffusely scatters the incoming beamer light for a smooth image appearance such that from normal viewing distances no pixels are visible. The appearance of the dark gray acrylic screen material is reminiscent of custom materials that are typical for multi-touch tables. At the top there are two further fixation rings for the screen and a covering to avoid any incidence of light.

Image Correction

On its way from the beamers to the screen the light is distorted in two ways, first by the reflection angle of the mirrors and then a second time by the curved screen. In order to equalize the resulting distorted image, we used the calibration software described in [Biehlig 2004]. As the light of each of the four beamers covers about 130° of the cylindrical screen, this software also ensures an edgeless blending of the resulting overlapping partial images. Every time the column was build up and in the case of strong ground vibrations also later from time to time a basic calibration and a subsequent fine calibration of the cylindrical image had to be conducted when starting up the column (see Figure 5.4). During our early research the contents that are displayed on the column had to be available in a cylindrical virtual representation, for example as a VRML scene [Isakovich 2002], while we later used the player descibed in [Dingeldey 2010] which allowed to put two-dimensional graphical applications of 4:1 ratio around the column screen.

Figure 5.4: Unobtrusive integration of Kinect sensors and fine calibration of the cylindrical image.

5.2.3 Sensor Technologies

The Camera-based Column

The column was enhanced with different sensor technologies over the years. In order to convert the cylindrical display to an interactive outdoor advertising medium that can attract users by visual feedback, in the context of [Beyer 2008] a camera-based fisheye-sensor was developed for the column. The vision-based sensor hardware of this first version of the Interactive Advertising Column consisted of a Fire-i Webcam and a 180° fisheye lens installed on top of the column. With this sensor device it was possible to detect any kind of user movement and measure the positions of multiple users within the whole 360° interaction space around the column. Due to the fisheye perspective, the maximum distance of motion detection and user recognition theoretically was only restricted by the used camera's resolution. On the software side the motion tracking was implemented using C++ and the OpenCV computer vision library, using frame differencing to detect motion and calculating the angle, speed and rough distance of moving users around the column. The Kalman filter was used to smooth user trajectories around the column.

The Multi-Kinect Column

Due to technical advancements in depth-based sensing technologies, we modified the column again in 2012 and equipped it with eight Microsoft Kinect for Windows sensors (see Figure 5.2). With the help of the university's carpentry the Kinect sensors were integrated into the column corpus at equal angles and as unobtrusively as possible to avoid that passers-by would notice interactivity just by immediately recognizing the sensors and as a consequence align themselves to them. We were able to reduce the sensor coves to a minimum size of 14 to 8 cm (see Figure 5.4). A direct integration of the small sensor lenses to the column shell was not possible due to the curved shape of the column.

Circular Interaction Space

A main challenge of using Kinect sensors in a circular configuration around a column display is that they were originally designed for single deployment and frontal use within home environments. Our goal was to create a seamless, continuous interaction space around the column, where the sensor technology should not restrict interaction by invisible dead zones. In order to realize a transition-free circular interaction space around the entire column, in total eight Kinect sensors were required to cover the entire surroundings, as well as a high performance hardware and software setup that woud guarantee fluent interaction even if a large number of users would be present.

Software Framework for Seamless Interaction

To realize a continuous interaction space around the column, several issues in regard to the overlapping of the Kinect sensors and a consistent representation of skeletons on the screen had to be resolved [Beyer 2013, P.3]. Florian Köttner developed the corresponding Multi-Kinect software framework that was capable to operate a required number of Kinect sensors as part of his diploma thesis [Köttner 2012]. In preliminary tests we found that there was nearly no relevant interference between two sensors when using the Microsoft Kinect SDK, even when a nearly 100% overlapping of regions was reached. Yet within the overlapping regions doubly recognized skeletons had to be filtered out. The developed software was based on a fixed angular and vertical arrangement of the sensors and by fine-tuning the transition areas we maintained a nearly consistent mapping between user positions and the screen coordinates.

Computing Performance

Running a setup with 8 Kinect sensors in parallel required a substantial amount of computing performance. We used standard office hardware where the fastest Core i7 computers could serve a maximum of 3 Kinects in parallel at an acceptable performance. Thus the distributed application developed by Florian Köttner exchanged skeleton and depth data between several Kinect clients and a server for data aggregation and rendering. The final setup also handled situations properly where large groups of people approached the column at the same time. In such situations a maximum of 16 users could be served with a skeleton representation simultaneously, while all other passers-by were ignored. This framework was programmed using C# and the Microsoft Kinect SDK. For the GUI we used the Windows Presentation Foundation (WPF). The final hardware setup required to run the column included five computers for running the application, four of which were used as Kinect clients, one as the Kinect and rendering server, and two also concurrently for the image correction.

5.2.4 Display Qualities

With regard to the display qualities identified in Chapter 4 the Advertising Column represents a non-planar, convexly curved and semi-framed cylindrical display:

Shape	Curvature	Framing	Ratio
Cylinder	Convex	Semi-Framed	Infinite

From flat, planar displays it distinguishes itself by its curvature and the lack of a left and a right boundary, which allows users to move endlessly along the in horizontal direction infinite screen surface. From concavely bended displays it distinguishes itself in that the virtual space on the screen that can be assigned to the individual user is smaller than the physical space around it. Our column display further provides a seamless cylindrical screen without any disruptions.

RW ↗

Other Interactive Column Displays

Beyond commercial out-of-home products such as offered by Barco, DynaScan or Kinoton (↺ Chapter 2.2.4), only a few large digital and interactive column displays have been presented in academic research. [Kim 2012] presented a cylindrical display for life-size telepresence applications, which is narrower compared to our column. In the context of public displays, [TenKoppel 2013] presented a hexagonal display configuration made out of six chained flat displays each of which was equipped with a Kinect sensor. Our cylindrical column [Beyer 2008] differs from this polygonal display by using a truly round and seamless display screen.

5.3 Life-size Display

The Interactive Life-size Display is a counterpart to classical ones
that can display interactive mannequins or mirror images of passers-by in life-size when they are approaching frontally.

5.3.1 Concept

The Interactive Life-size Display is an interactive successor of classical life-size displays which are often used in fashion advertising and are ideally installed such that they are approached frontally (↺ Chapter 2.2.5). The large portrait-ratio screen allows to display interactive mirror representations of users in life size and thus increases the chance that passers-by recognize themselves, but of course also other contents can be displayed (see Figure 5.5). Similar large screens capable of displaying life-sized mirror images of users have priorly also been used by [Galloway 1980] and [Michelis 2007]. The Interactive Life-size Display was designed to be lightweight and demountable such that it can be easily transported and aligned towards the site-specific approaching trajectories of passers-by in field studies. It was constructed in Munich in 2008.

FACTS

Design Idea	Large Portrait-ratio Screen Suited to Display Humans in Life Size
Construction	Lightweight Display, Munich (2008)
	Vision-based Camera for User Interaction (2008)
	Extension with Kinect Sensor for Depth-based Interaction (2011)
Display	Direct Rear-projection using one Beamer
Screen	Semi-permeable, Milky Opaque Screen Material
Sensors	Camera OpenCV, Kinect Sensor
h x d	Screen: 2.35 m x 1.15 m
Publications	[Serbedzija 2008], [Fakesch 2013]

Figure 5.5: Lightweight Interactive Life-size Display that can display one person in life size.

5.3.2 Design and Construction

The Life-size Display uses a milky opaque rear-projection screen and a high-resolution beamer which displays the image from the back such that it can potentially be seen from both sides. In order to easily align the display to approaching users, it was constructed lightweight and out of wood. It is further self-standing such that it can be deployed in freestanding locations, and for a better transportability can be disassembled. As this flat and narrow display is aligned to one specific direction only, one single vision or depth sensor is sufficient to cover the whole interaction space in front it. To enable user interaction, in the first version a USB camera and later a Kinect sensor were installed at the top of the display, as unobtrusively as possible to not attract user attention. From a technical perspective, sensing techniques that favor a frontal body position such as current Kinect skeleton recognition are suited best with this type of display as users are typically approaching it frontally (↺ Chapter 2.3.2).

5.3.3 Sensor Technology

The first version of the Life-size Display was equipped with a high-resolution USB camera which was installed at its top in 2008. The applications for detecting passer-by movements were programmed using C++ and OpenCV. In 2011, the Life-size Display was upgraded with a Kinect sensor. This was also installed at its top, and to avoid that passers-by notice interactivity by discovering the sensor instead of the visual feedback on the screen, we disguised it with an unobtrusive casing in the same color as the screen and with notches for the lenses and the IR emitter. Interactive applications were written using the Kinect SDK and C#.

5.3.4 Display Qualities

With regard to the display qualities identified in Chapter 4 the Life-size Display can be classified as a planar, framed and rectangular large display in portrait-ratio:

Shape	Curvature	Framing	Ratio
Rectangle	Planar	Framed	Portrait

The rectangular frame with its four boundaries determines the spatial distribution of visual elements displayed on the screen and also limits the suitable contents to such that can make use of its vertical alignment. The interaction space in front of the narrow life-size display can, depending on the contents shown, be limited by its left and right boundaries, and it favors interaction in a frontal body position.

RW ↗

Other Life-size Displays

While Life-size Displays are nowadays one of the most widespread display formats in out-of-home and fashion advertising (↺ Chapter 2.2.5), the potential of such displays has hardly been investigated in academic research. The only known prior work using real life-sized displays is [Michelis 2007]. Mirror representations of users in life size or even larger sizes have also been displayed on other large and mostly horizontal display shapes such as in [Galloway 1980] or [Dalsgaard 2010]. Most other works used smaller portrait-ratio displays for displaying persons, for example [Reitberger 2009] or [Müller 2012].

5.4 Banner Display

The Interactive Banner Display is a counterpart to classical banners
that provides touchless interaction, and also an alternative to display rows when passers-by are approaching sideways.

5.4.1 Concept

The Interactive Banner Display is an interactive successor of classical banner displays which are installed at sidewalks where passers-by pass them sideways (↺ Chapter 2.2.2). We designed it as a solution to overcome the common problem with interactive display rows such as the Magical Mirrors that the discontinuities between single display units make it difficult to understand that the displayed visual feedback correlates to one's own movement (↺ Chapter 3.3.7). Instead, with its long continuous surface the banner exposes passers-by as long as possible to visual feedback when they are passing by, and thus increases the chance to notice the effects in the periphery when looking in walking direction. A further advantage of this long display is that it provides sufficient space so that multiple users can interact in front of it side by side without impeding each other. Other than paper-based banners it can ideally be installed behind shop windows. The Interactive Banner Display was installed behind a shop window in Munich in 2011.

FACTS

Design Idea	Long Shop Window Display to Attract Users Passing-by Sideways
Construction	Outdoor Installation at Amalienstrasse 17, Munich (2011)
	Installed behind a large Shop Window
Display	Cluster of 4 Frameless Plasma Displays Orion MIS-4220
Sensors	Dual-Kinect Configuration with Overlapping Sensor Region
h x d	Screen: 0.52 m x 3.75 m
Publications	[Beyer 2014], [Beyer 2014B]

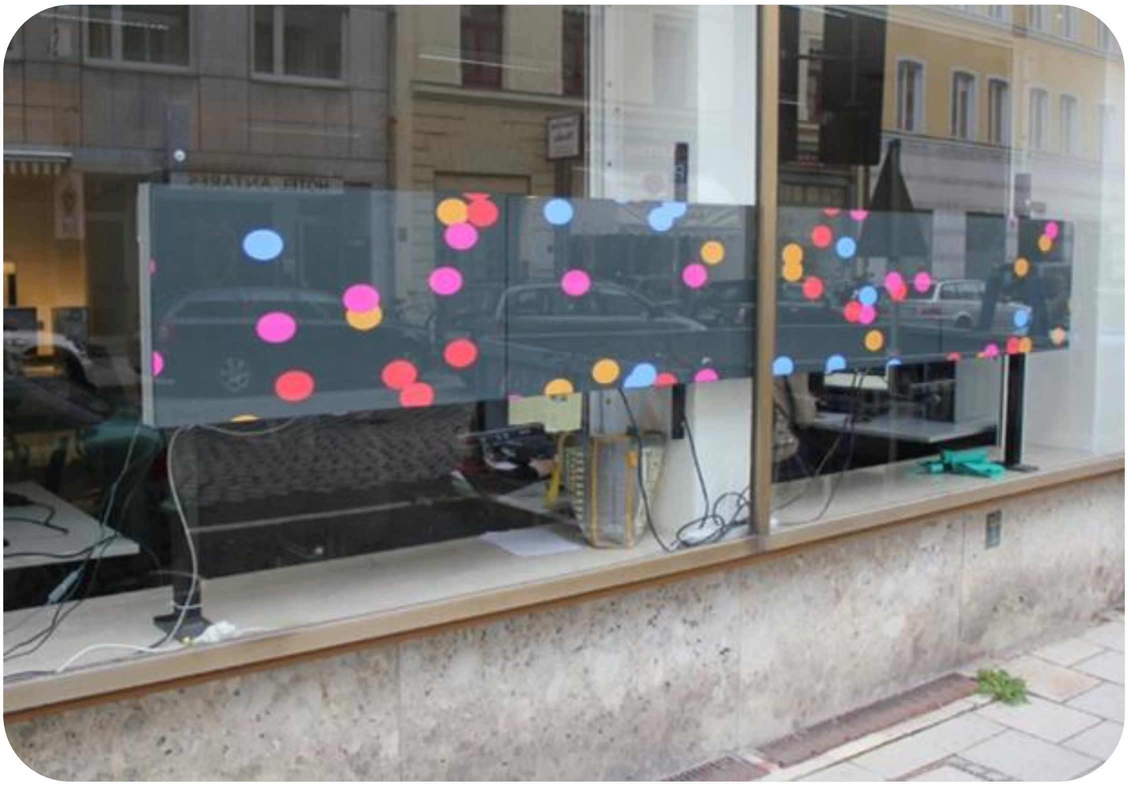


Figure 5.6: Long Interactive Banner Display installed behind a shop window next to a sidewalk.

5.4.2 Design and Construction

Sidewalk Plasma Display Panel

The Interactive Banner Display (see Figure 5.6) is a permanent installation behind a street window in a lively shopping and nightlife city quarter, facing outwards to the sidewalk where passers-by approach the display with a nearly 90° body orientation in relation to the display. The Multi Plasma Display Panel (M-PDP) consists of a cluster of 4 frameless and horizontally aligned plasma display units directly installed behind the street window. It was installed with a metal mounting designed by the university's locksmith. One design goal was a long and seamless interactive screen surface and to avoid any discontinuities as possible. The final solution included a single discontinuity caused by a window sash in the middle of the display, which yet showed to not influence passers'-by positions in our field studies in a particular way. In fact, many people stopped and interacted directly in front of this window sash and ignored it. We had no prior experience in regard to the minimum display length required to attract the attention of people walking by sideways and make them react and stop before they had passed the screen completely, and opted for a length of 3.75 meters for practical reasons, that is, the display should be long enough but still fit within a shop window.

5.4.3 Sensor Technology

To realize a long and seamless interaction space in front of the banner display, two Kinect sensors were installed below it, each sensor covering an interaction space a little wider as two of the frameless display components. Thus there was an overlapping sensor region in the middle requiring a transition similar as with the advertising column (↺ Chapter 5.2.3). User data such as skeletons and depth data were exchanged between client processes and a main application by using memory-mapped files. As most people walked by the banner sideways, the initial lateral recognition of passers-by used for providing visual feedback was based on depth images. As the Dual-Kinect configuration covered the whole interaction zone in front of the display, one high-performance PC was sufficient to handle both the sensor processing and the graphics rendering.

5.4.4 Display Qualities

With regard to the display qualities identified in Chapter 4 the Interactive Banner Display presents a long planar and semi-framed seamless display:

Shape	Curvature	Framing	Ratio
Banner	Planar	Semi-Framed	Long

From other planar displays it distinguishes itself in regard to the aspect ratio which is even wider than landscape ratio and by its semi-framedness: From the perspective of a user in the middle of the display the banner provides no left and no right boundary, i.e. the display is quasi infinite from this perspective. The upper and lower boundaries are still present and can be used by content designers as reference points for user orientation within the screen layout. From the semi-framed advertising column the banner display distinguishes itself in its planarity, i.e. there is no bending behind which the content can disappear from a user's view. Finally, from sequential, parallel-aligned display rows the banner display distinguishes by its seamlessness. No discontinuities between single display units or display bezels can affect the behavior of people passing by. The interaction space in front of the long sidewalk display which is usually passed sideways is determined by its horizontal length, and the possible user distance is limited by the sidewalk width and the lower height of the screen.

RW ↗

Display Rows and Long Display Walls

While we are not aware that any equivalent to the banner display format has been investigated in academic research, passer-by interaction has been investigated in front of other long display shapes as well as rows of multiple displays along sidewalks and long trajectories. The deployment of our display banner is similar to the Magical Mirror display row [Michelis 2009], where four display units are also installed behind a street window and along a sidewalk trajectory (↺ Chapter 3.3.7). Most similar to the screen format are long display walls and media facades that are also passed sideways such as the Climate Wall [Dalsgaard 2010] and Screenfinity [Müller 2013].

CHAPTER 6

FLAT VS. COLUMN DISPLAY

Different User Behavior around Interactive Column Displays and Flat Displays

6.1 Background

Observed audience behavior around the Interactive Advertising Column
indicated the existence of different user positions, body orientations and movement patterns compared to classical flat displays.

6.1.1 Audience Behavior around the Column

When students visited the Interactive Advertising Column at the Fraunhofer lab, we observed patterns different from the typical behavior we knew from classical flat displays [Beyer 2010]: Instead of the immobile positions in front of flat displays, users interacting with the cylindrical display started to walk around it to discover the still unseen sides of the screen. Beyond just moving once to the other side of the column, they also showed a strong movement activity when interacting with the contents. Instead of the frontal positioning with flat displays, users walking around the column also assumed a lateral body orientation to the screen much more often than a frontal orientation. Such different behavioral patterns between columns and flat displays had not been directly compared in a user study so far.

6.1.2 Possible Effects of Display Qualities

The different behaviors around columns and flat displays may be caused by their different action possibilities or behavioral effects of single display qualities such as shape or frame (↺ Chapter 4): The movement around the column is enabled by the degrees of freedom of the semi-framed, infinite screen where no vertical display boundaries limit the user movement to the left or right, and it may also be encouraged by the cylindrical shape. At last, the interactive contents had been designed to actively stimulate users to walk around the column [Beyer 2008, P.52f]. In contrast, the immobile and frontal position in front of flat displays is in line with Manovich's theory on viewer imprisonment in front of rectangular frames.

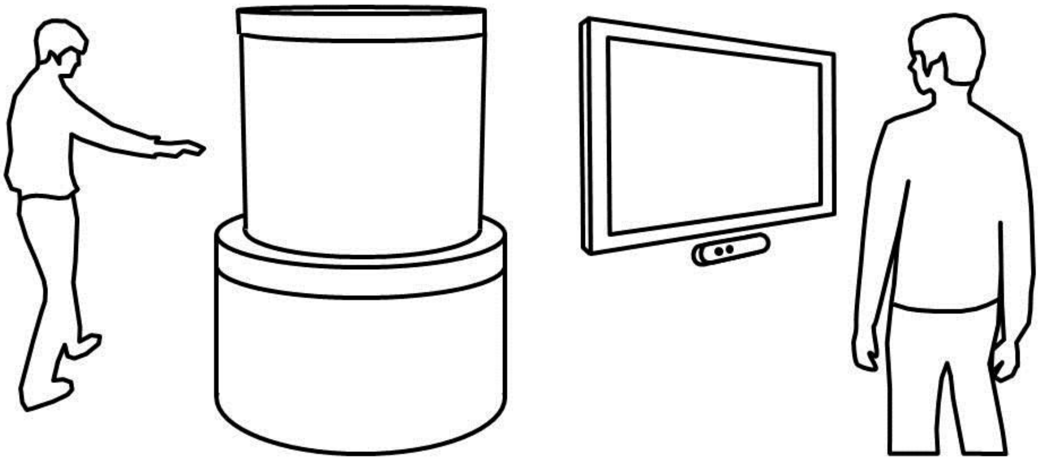


Figure 6.1: Columns may influence user behavior differently than classical flat, framed displays.

6.1.3 Questions and Issues

If user behavior differs between columns and flat displays, it would be helpful for interaction designers to know the single distinctions and responsible display qualities. In fact, interactive gestures and visual layouts often follow implicit assumptions on user positions, movement patterns, body orientations and viewing behaviors. Yet, specific assumptions for classical flat displays cannot be simply generalized to other shapes such as cylindrical columns: In regard to the *user position*, most contents for flat, framed displays are designed for interacting in a central position. This frontal viewing position determines the visual layout and how the interactive elements are arranged in relation to the user. It also implies that the optimal standing position is limited to one or two users. In regard to *user movement*, most applications for flat displays are further designed for standing still in front of them. This allows users to deal with more details, complexity and levels of interaction, but the contents do not work for people walking due to perceptual and bodily limitations. In a *frontal body orientation* in front of flat displays users can also use both arms equally well for gesture-based interaction. In contrast, when walking in a lateral orientation around a column, one arm and in one direction the dominant hand is turned away from the screen, which limits the abilities for lateral movements of the arms against the walking direction (see Figure 6.1). Such different bodily and movement patterns may also affect the *viewing behavior* and how people *notice and understand interactivity*.

RQ

Q 6.1 Noticing Interactivity

How do users notice and understand interactivity when they encounter cylindrical advertising columns or flat rectangular displays?

Q 6.2 User Movement

How much do users walk when interacting with cylindrical advertising screens or flat rectangular displays?

Q 6.3 User Position

Where do users position themselves when interacting with cylindrical advertising columns or flat rectangular displays?

Q 6.4 Body Orientation

Which body orientations do users assume when interacting with cylindrical advertising columns or flat rectangular displays?

Q 6.5 Viewing Behavior

Where do users look at when interacting with cylindrical advertising columns or flat rectangular displays?

Q 6.6 Evaluation

How can two differently shaped large interactive displays such as a column and a flat display be evaluated in a comparative user study?

6.2 Lab Study

We conducted a lab study with the Interactive Advertising Column
and a flat interactive display to explore different user behavior around cylindrical and flat rectangular displays.

6.2.1 Study Context

To explore different user behavior around interactive advertising columns and interactive flat displays, we conducted a comparative lab study. This study was conducted in December 2009 at the Fraunhofer FIRST laboratories in Berlin Adlershof together with Florian Alt, Jörg Müller, Karsten Isakovic, Stefan Klose, Manuel Schiewe and Ivo Haulsen. It involved the camera-based version of the Interactive Advertising Column as described in Chapter 5. Partial results of the study have been published as a paper at the CHI 2011 conference under the title *Audience Behavior around Large Interactive Cylindrical Screens* [Beyer 2011], and at a conjunct workshop under the title *On the Impact of Non-flat Screens on the Interaction with Public Displays* [Beyer 2011B].

FACTS

Idea	Comparing User Behavior between a Cylindrical and a Flat Display
Type	Observational Lab Study
Study	Gilbert Beyer, Florian Alt, Jörg Müller
Hardware	Gilbert Beyer, Karsten Isakovic, Stefan Klose, Manuel Schiewe, Ivo Haulsen
Software	Interactive Content [Beyer 2008], Rendering System [Isakovich 2002]
Date	3th–4th December 2009
Location	Fraunhofer FIRST Laboratories Berlin
Prototype	Interactive Advertising Column and a Flat Display
Publications	CHI 2011 Conference [Beyer 2011], CHI 2011 Workshop [Beyer 2011B]

6.2.2 Hypotheses and Assumptions

Spatial and Bodily Factors

The focus of the study was on the different spatial and bodily factors between both displays such as user positions, movement patterns and body orientations. Our first assumption was that users, instead of assuming an immobile position according to Manovich's theory on viewer imprisonment in front of frames, would show more variable positions around the column compared to a flat and framed display. This can be analyzed by comparing the *variance in locations* and the trajectories of users which form different *interaction spaces*. Second, as semi-framed columns have no display boundaries that limit user movement to the left and right, we assumed that users would walk more around the semi-framed column than in front of the flat display. This can be analyzed by measuring the *distances* users covered and the *time* they spent walking. Third, we assumed that users would interact less time in a frontal body orientation around the column compared to the flat display, and instead often assume a lateral body orientation. This can be operationalized by looking at how much time *shoulders are parallel* to the displays or not. Finally we hypothesized that some of these spatial and bodily factors could depend on active and passive behavior, which can be tested by analyzing the user activity and correlate it with these factors.

Viewing Behavior

In regard to a different viewing behavior between both displays, we assumed that different from the notion of *frontal viewing* in front of flat displays, users who walk around the column in a tangential direction and in a lateral body orientation would not view the whole display frontally most of the time. Instead, users would look at the *display section* that coincides with the walking direction only: the left half of the column when walking clockwise and the right half of the column when walking counterclockwise. Further, they would switch their gaze back and forth to also scan the area in walking direction from time to time, or in other words, look at the column for *shorter intervals*, but *more often* compared to the flat display.

User Engagement

Due to the assumed higher movement activity around the column, the potentially infinite screen surface that invites users to discover it, and not at last because of the novelty factor of this display, one further assumption was that users would *spend more time* when engaging with the column than with the flat display.

User Position	
Variance of Locations	Interaction Spaces

User Movement	
Walking Distance	Walking Time

Body Orientation	
Shoulders while Walking	Shoulders while Standing

Viewing Behavior	
Viewing Direction	Viewing Frequency

User Engagement
Interaction Time

Noticing Interactivity

Prior assumptions on how people would become aware of the two displays and notice interactivity were difficult to make due to the planned lab setting of the comparative study. There were multiple unknown factors such as possible raised expectations of the participants invited to this renowned research lab, or how the study design might affect their knowledge of interactivity. Different from a real public setting also no characteristic baseline behavior would be available that could be used as reference for the analyzed user reactions. Yet, we did not disclose the interactivity of the displays to study participants, which allowed to retrospectively analyze how they noticed and understood interactivity.

RW ↗

Shape and Framing

In regard to behavioral effects of display qualities (↺ Chapter 4), Manovich's theory of frontal viewing and the imprisonment of the viewer's body [Manovich 2001, P.99f] is central to this work, as well as similar notions by [Pinhanez 2005] about frames as a reference for the image perspective and the correct positioning of viewers. In regard to form factors and the cylindrical display shape, this study builds upon our prior work [Beyer 2008, Beyer 2009B, Beyer 2010].

Comparative Studies

Follow-up studies to this work which compare audience behavior around different public display shapes are [TenKoppel 2012], who compare three angled configurations of chained displays, and [Beyer 2013], where we compare a seamless interactive advertising column with one in a framed condition.

Noticing Interactivity

Similar to the visual feedback used in our study is the flower feedback used by [Michelis 2007]. In regard to the quantitative analysis of passer-by reactions, most studies count the number of interactions with the display. In addition, [Michelis 2009] also counts single interaction phases, [Müller 2012] interaction durations, and [Beyer 2014] eye contacts with feedback stimuli. In contrast, in this study we analyze the detailed reactions during the intial movements of users along the screen such as orientation, surprise or stopping reactions.

Bodily Factors

[Michelis 2009, P.147f] observed a frequent ambition of users to position their body towards the center of a flat display that displayed their mirror image. [TenKoppel 2012, P.6f] analyze user positions, walking paths and f-formations in front of the three chained displays. In [Beyer 2013] and [Beyer 2014] we investigate how virtual frames influence user positions as opposed to physical frames.

Viewing Behavior

Focal awareness of displays in the context of user activities is discussed by [Brignull 2003, P.6]. In regard to the perception of large public display shapes (↺ Chapter 4.2.1), [TenKoppel 2012, P.4] describe the summative space where users can potentially look at in front of the used chained displays. [Müller 2013, P.6] investigate visual search of users walking along a wide wall display.

6.2.3 Study Design: Comparing Displays

Comparative Lab Study

For testing the posed hypotheses a comparative single user lab study was designed as described in [Beyer 2011, P.5f]. At that time we assumed that a highly controllable lab environment would be required for precise measurements of subtle human factors such as user positions, body orientations or the viewing behavior around a 360° display. As a lab setting excludes the situational variables of public space such as competing stimuli and social interaction with other people, the study would provide high internal validity at the cost of low ecological validity. In order to directly compare the reactions of the same individuals with both displays, we planned a within-subject design where each participant interacts with both displays in succession. This would abstract from real-world situations and limit the external validity, but also reduce individual differences.

Subject Prototypes

In the study we compared the Interactive Advertising Column with a flat and framed display of 16:9 landscape-ratio. Principally one could compare displays that provide a similar physical screen area, or that constitute interchangeable solutions e.g. by providing the same floor space. The objective of this study was instead to identify possible different behavioral effects of framed rectangular displays and round semi-framed displays which have no boundaries on the left and right. To isolate these display qualities we chose a flat display that provides a similar visible area as the column when perceived from an average position in front of it. Just as the column, this flat display was based on rear-projection.

Reframing Participants' Perspectives

One objective of the lab study was to create a controllable situation, but we also wanted to minimize the influence of the artificial setting and the comparative study design on participants' behavior and ensure that they behave at least in a semi-natural way. This was achieved by reframing participants' perspective on the situation: we designed a semi-authentic scenario in the lab similar to a museum tour where visitors are free to visit different rooms containing different exhibits. Therefor we prepared four rooms each of which contained an interactive or non-interactive prototype and sent participants on a round tour along these rooms to distract them as much as possible from the controlled study situation.

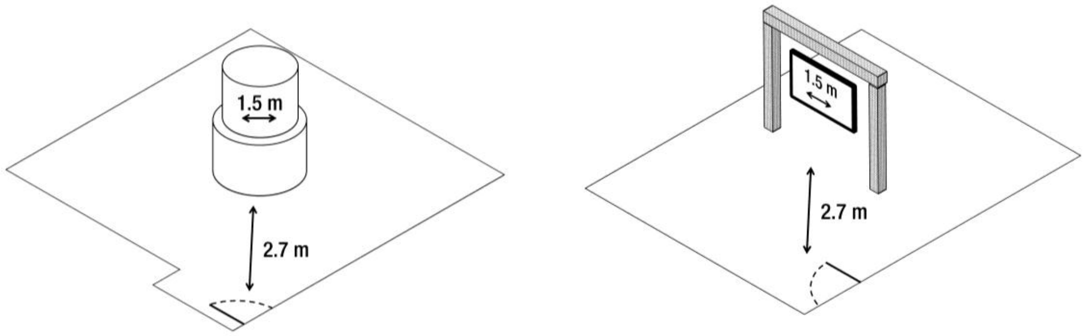


Figure 6.2: Layouts of the two rooms containing the column and the flat rectangular display.

Fake Prototypes

To reduce demand characteristics, i.e. situations where participants become aware of what is measured and what are the objectives of the study, two of the rooms just contained fake prototypes that had the only purpose to distract from the other two displays under investigation. One fake prototype was the adaptive advertising display described in [Beyer 2009] which reacted to the viewers' head movements and facial expressions and adapted the content accordingly. The other fake prototype was Fraunhofer's Digital Dome [Dingeldey 2010], a dome projection which was non-interactive during the study and just showed a movie.

Room Layout

To minimize lab-specific situational variables when comparing the flat and the cylindrical display, we designed the rooms containing the prototypes as similar as possible [Beyer 2011, P.6]. We deployed both displays which were under investigation at a distance of 2.7m and at an angle of 45° from the entrance door of each room, so that when entering the rooms they would visually appear at the same position, and potentially could be approached by participants using the same diagonal pathway (see Figure 6.2). Providing the same initial trajectory minimizes potential bias and maximizes the comparability of both displays in the artificial lab setting, but on the other hand also limits the generalizability for the flat display to some degree, as most flat out-of-home displays are approached frontally or parallel instead of diagonally (↺ Chapter 2.8). Both rear-projection displays further used the same screen material to prevent potential bias by prior experiences participants had with a specific display technology, for example that some screen materials afford touch and others do not (↺ Chapter 4.1.5).

Figure 6.3: Layouts of the two rooms containing the column and the flat rectangular display.

Interactive Content

The interactive content used in the study was originally designed to stimulate user movement around the advertising column by reacting to the movements of passers-by, but providing visual feedback only when they move [Beyer 2008, P.62]. When a passer-by approaches and enters the sensor space, visual feedback to the initial movements is given in form of flowers drawn onto the column. This effect can be used to initially communicate the interactivity of the column by an unaware initial interaction. Once the user is moving further along the display, more flowers appear at the current user position, and they also increase in size if the user is speeding up. This way a visual pattern of flowers can be drawn onto the column by any kind of body movement (see Figure 6.3). If the user stops moving, the individual pattern that has been painted slowly fades away until it cannot be seen any more. But it reappears when the user is moving on, thus encouraging him or her constantly to proceed moving.

Recruiting Participants

To ensure that the external validity is as high as possible in regard to the typical population that can be found in out-of-home environments, instead of inviting colleagues or students from the lab who have an expert background on topics such as human-computer interaction, participants were mainly recruited by bulletins informing about the paid-for study at public places such as shopping malls and train stations where people usually often encounter real out-of-home displays (↺ Chapter 2). Eventually, 15 people with a mean age of 32.7 years applied to participate in the study, of which 10 were males and 5 females. The professional background of the participants was diverse including students, office and blue-collar workers, artists and technicians [Beyer 2011, P.6].

Procedure

The within-subject design where all participants visit all four display exhibits can equalize individual differences in understanding media, but seeing the displays sequentially can also involve carry-over effects so that we counter-balanced the order of the visited prototypes among participants: for each second visitor we switched the position of the rooms containing the flat and the column display. After an initial briefing we sent participants onto the circuit which was signalized by arrows. To minimize reactivity, no study conductor was present or intervening when they were on their museum tour, yet they knew they were being observed by cameras. They were not informed which of the objects were the exhibits or that they were interactive, just asked to fill out questionaires after each room.

6.2.4 Data Collection

We acquired behavioral data of participants by following methods [Beyer 2011, P.6]:

Data Collection		
Video Recordings	AttrakDiff	Semi-Structured Interviews

Multi-Perspective Video Recordings

In each of the two rooms with the subject prototypes 4 cameras recorded all behavior, which allowed to track participants and their visual feedback around all sides of the column. Another camera with a resolution high enough to recognize the eyes recorded a close-up of participants to analyze their initial reactions to the feedback. For the video coding 4 video streams per display were combined to a synchronized and time-stamped 2x2 video file. To later accurately track and transcribe user positions and trajectories from the deformed video perspective, colored markers creating a grid of 60x60 cm^2 squares were attached to the floor.

User Experience Evaluation

As an interactive advertising column constituted a novel experience at that time, we used the standardized AttrakDiff questionnaire and evaluation system to aquire differences in the subjective experiences between the flat display and the column. Participants filled out the standard response-scales on hedonic and pragmatic dimensions directly after visiting each of the four display prototypes.

Semi-structured Interviews

The semi-structured interviews required the intervention of a study conductor and widely disclosed what we were interested in. Thus they were not conducted before participants had completely finished the museum tour. All interviews were audio-recorded and partially transcribed to also include individual, non-repetitive user statements to the analysis [Beyer 2011, P.7].

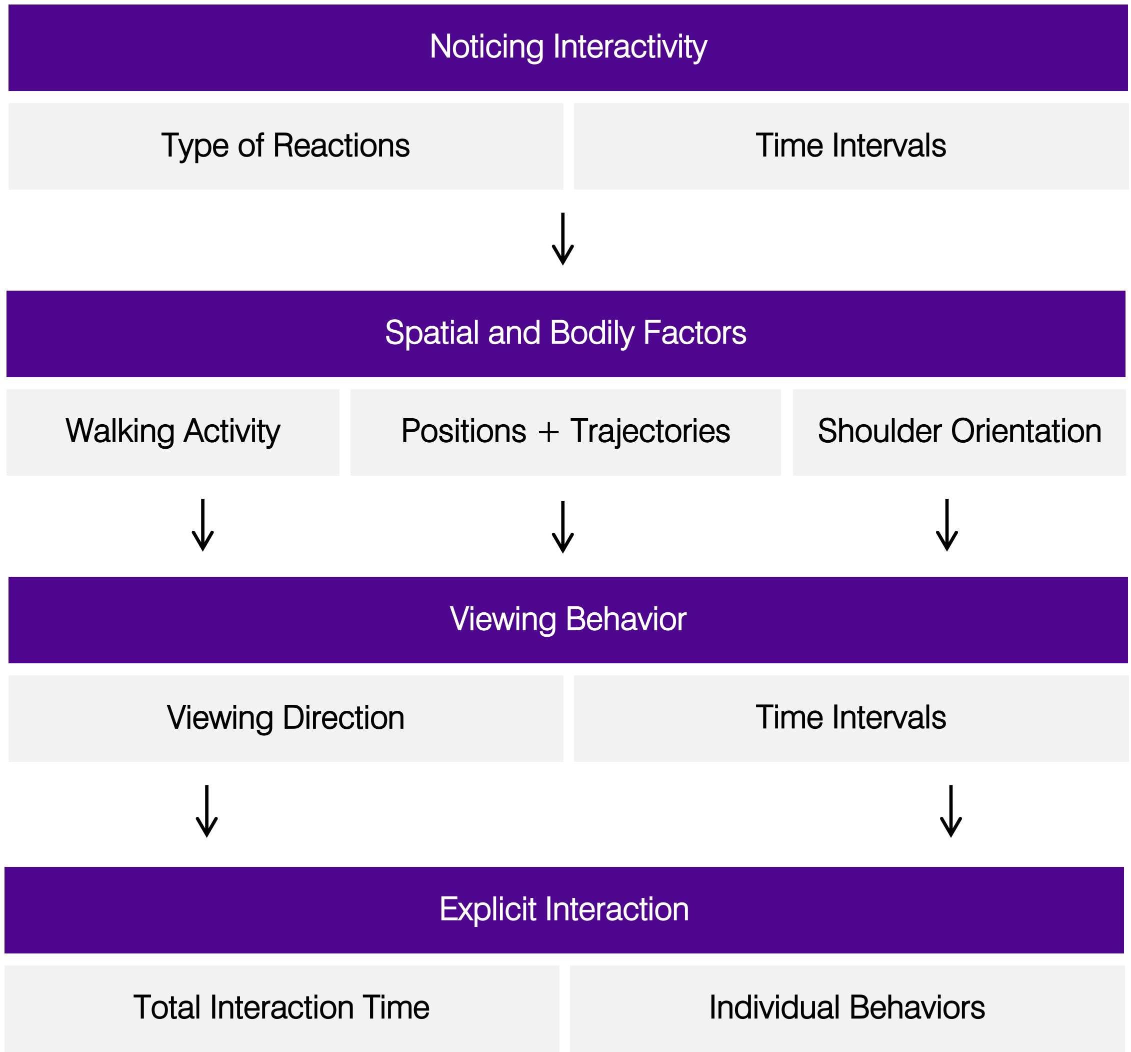
6.2.5 Video Analysis: Detailed User Reactions

Video Coding

Bodily factors, viewing behaviors and user reactions to interactivity were coded using the *Mangold INTERACT* and the *Noldus Observer* video coding softwares. The initial coding scheme included mutually exclusive behavior codes for *walking* (walking vs. standing with both feet on the ground), for the *shoulder orientation* (right vs. left vs. no shoulder towards the display), and for the *viewing direction* (gazing right vs. left vs. straight forward). To ensure inter-rater reliability among the two trained raters, Cohen's kappa coefficient was computed for all behavioral codes for a sample video [Beyer 2011, P.7]. Substantial agreement according to the scale of [Landis 1977] could be reached for the raters' subjective judgement on the walking and shoulder codes, but only a moderate agreement for the viewing direction, as the chosen exogenous camera angles made it difficult to analyze the viewing direction in relation to the viewers body. Using a head-mounted gaze tracking tool was no alternative as it would have revealed demand characteristics [Orne 1962] to participants and counteracted with the idea of reframing their perspective by a museum tour. Eventually we analyzed in which direction users are looking and where they focus their attention at when they move, which is more easy for observers to determine [Gibson 1966, P.318]. Further all relevant events in regard to noticing interactivity such as the time intervals until the first reactions to the visual feedback and all user interactions with the display were coded. Finally we interrelated all suitable behaviors with each other.

Trajectory Transcription

The grid formed by the colored markers in the two rooms was translated to a template and all participant positions and trajectories around the column and in front of the flat display were transcribed from the videos using *Visio*. From the counts of how often each grid cell was traversed heat maps were generated.


Noticing Interactivity
Type of Reactions
Time Intervals
Spatial and Bodily Factors
Walking Activity
Positions + Trajectories
Shoulder Orientation
Viewing Behavior
Viewing Direction
Time Intervals
Explicit Interaction
Total Interaction Time
Individual Behaviors

6.3 Findings

The study showed that
users moved within a circular interaction space and in an angular body orientation around the column, but stopped frontally in a central position in front of the flat display.

6.3.1 General Observations

Participant Behavior

In our lab experiment, study participants quickly focused their attention on the interactive displays after entering each room, even if it had not been disclosed to them which subjects were under investigation. Only two participants completely ignored the column, and instead investigated other hardware in the room. In the room with the column, participants walked around it right from the beginning, with the first extended stop occuring late. During the entire time of their stay they showed a strong walking activity, interrupted only by brief stops. In contrast, in the room with the flat display participants immediately stopped in front of the display within a central position after entering the room. During their entire stay they repeatedly turned back to similar centrical positions in order to stop for some seconds, and in all showed less movement as compared to the column.

User Types and Reactivity

While walking in front of the displays, female participants acted more carefully and often tended to fold their arms, thus performing most actions with their feet, while male participants often also used their arms when interacting. Participants with a technical background seemed more eager to examine the interactive capabilities of the displays. Apart from a few signs for study-induced situational involvement and curiosity, participants behaved quite autonomously within the rooms and showed no extraordinary shyness or compliance. Most ignored the cameras, while a few were even not shy to inspect or touch hardware.

6.3.2 Understanding Interactivity

Noticing Interactivity of the Column

Around the interactive column, the video analysis revealed the following recurring patterns in regard to the initial reactions of the 15 participants towards the visual feedback (↺ Chapter 3.3.4), which can be classified into two groups: First, 10 of the 15 participants (66%) showed *immediate reactions* which indicate an successful unaware initial interaction. When entering the room, they instantly approached the column and thereby looked at the visual feedback to their movements. Once they had fixated the visuals, they continued walking around the column without releasing their glance from them any more. Of these 10 early viewers, 6 stopped after 2.5s from the door to scan the visuals for ~2.6s before walking on, and the other 4 did not stop at all, but showed surprise reactions after discovering the feedback such as a smile or flinch (2 of them) or orientation reactions towards the visuals (the other 2). This happened after ~3s, as their initial attention was undirected and dominated by orientation fixations across the room. The second group of *late or no reactions* contains the remaining 5 participants (33%) who did not look at the column in the beginning. When walking in, they looked towards other directions within the room, or at the column only when they had already stopped. These participants showed no initial reaction towards or interest in the display. Three of them finally still noticed the feedback incidentally when walking alongside the column (only late after ~16s), and when becoming aware that the flowers followed them, shortly stopped just as the early viewers and from this moment on fully focused their attention on the feedback. The remaining two who showed *no reactions* also had not seen the feedback right when walking in, but ignored the column during their complete further stay in the room.

Noticing Interactivity of the Flat Display

When entering the room with the flat display, participants noticed the screen already from the door. Apart from a short overview scanning, 14 of the in all 15 entrants instantly oriented their attention towards and turned towards the display, thereby receiving visual feedback, and *initially stopped* within a central position in front of it (9 of them for on average 5s). Up to this moment they had shown no implicit reaction to the visuals such as surprise. Instead they started to interact explicitly while still standing (3 of them) or when moving on (another 6). Of the 14 initial stoppers, 5 stayed completely inactive within the central position until they left the room, just looked at the screen and showed no reaction to the visuals.

Figure 6.4: Participants interacting with the column (top) and the flat display (bottom).

Exploring Interactivity of the Column

Out of the 15 participants, 13 interacted with the column and 10 with the flat display. Most active users engaged with the displays the entire time instead of turning their attention towards competing stimuli in the rooms. The following actions indicate to which extent users explored and understood the interactive capabilities of the column display after the initial reactions: Around the column, most participants interacted with the visual content in its intended way as a content for short-time *passing-by interaction*. All 13 participants who engaged with the column circulated around it and repeatedly changed their directions while interacting with the visuals (see Figure 6.4 top and 6.5). Of them, 11 constantly fixated the visual feedback, while 2 sometimes looked at other parts of the screen. 5 participants *explored the interactivity* by moving their arms or waving their hands while walking around the column. 8 tested the reaction of the visuals by moving repeatedly to the left and right (tangentially back and forth) at one spot. Further behaviors include side-steps, speeding up, jumping, or kneeling down. Some users showed *subtle reactions* such as subtle head or upper body movements or sudden halts that can often clearly be attributed to testing interactivity. Some participants examined functions the column did not support: 5 users examined if distant positions affect the visuals and 3 touched the screen to test it for touch sensitivity. Further *expert tests* include hiding the arms behind one's back, or raising one's hands towards the supposed vision sensor. Beyond those 2 who ignored the column completely, another 2 interacted with it but did not constantly fixate the feedback. One of them often performed unsupported actions such as touching the screen and the other acted very passively.

Exploring Interactivity of the Flat Display

In front of the flat display, participants showed less activity than with the column. The even distribution of performed actions indicates that they were also more undecided what to do (see Figure 6.5). 9 of the 10 active users completely *passed the flat display sideways* from one side to another while looking at the visual feedback, thus showing that they understood the idea behind the interactive content (see Figure 6.4 bottom). Most of the time participants seemed to be occupied with *examining the interactive capabilities* of the flat display: 8 moved their arms to affect the visuals, 9 performed side-steps, and another 9 subtle upper body or head movements. About as many tested unsupported actions such as walking back and forth in front of the display, approaching the display closely, or assuming different positions within the room. Observed *expert tests* include stepping out of the anticipated sensor space in front of the display, performing hand gestures close to the screen (but usually without touching it), covering a supposed interaction sensor, or turning one's back towards the display. Beyond the 5 participants who remained completely inactive during their stay, the same user who had also tried unsupported actions with the column before spent most of the time with inspecting the screen and touching hardware. Of the in all 6 unsuccessful users, 3 were curious and looked behind the screen.

Column Display		Flat Display	
Circulating the column	13	Passing-by sideways	9
Changing directions	13	Side-steps	9
Left-Right movements	8	Walking back and forth	9
Waving hands	5	Waving hands	8
Subtle body movements	4	Subtle body movements	9
Position tests (distance)	5	Position tests (close/off)	8/7
Expert tests (touch/vision)	3/2	Expert tests (hand/vision)	4/4

Figure 6.5: Count of participants performing certain functions. Blue: unsupported functions.

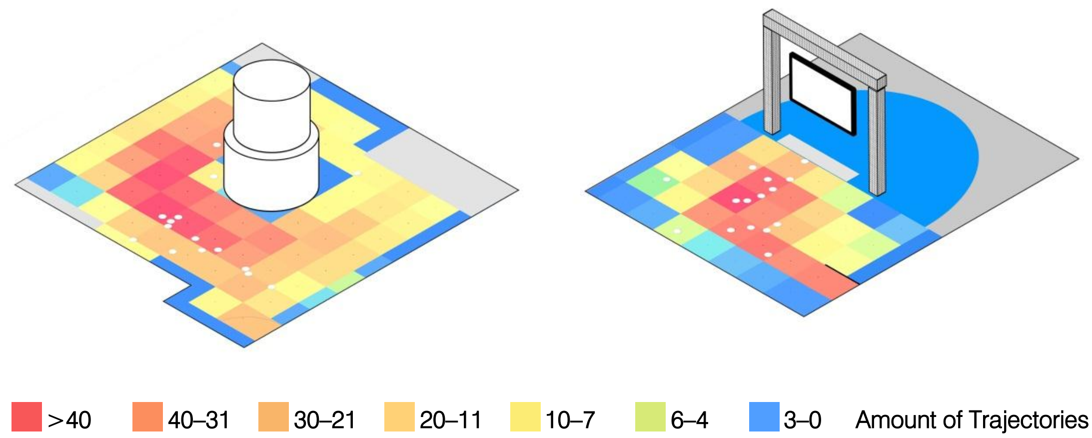


Figure 6.6: Heat maps visualizing how many times participants traversed each 60x60cm cell.

6.3.3 Spatial Behavior

Interaction Spaces

The data shows that users moved differently when interacting with both displays. Around the column, users moved to many locations and their walking trajectories nearly formed a *circular interaction space* (see Figure 6.6 left). Only one section behind the column was passed less often, as a table created a bottleneck. Users often turned around here to proceed walking around the column in the other direction. In front of the flat display, users also moved to various positions within the room. Thereby they did not only often cross the central region in front of the display, but they also often stopped there. In [Beyer 2011, P.8] we had initially named the region where users stop *sweet spot*. Yet when taking a closer look at all participants and differentiating between active users and those who did not notice interactivity, behaviors differ. In fact, the passive participants remained immobile during their stay within a clear-cut central area about 1.5 meters away from the display. Yet active users, instead of stopping at just one single spot, stopped within all distances on a *central strip* in front of the display.

Initial Standpoints

In the room with the column, users stopped for the first time at various positions, yet the majority not far from the door, for example when they noticed interactivity (see the white dots in Figure 6.6 which indicate the first stopping points after entering the room). After entering the room with the flat display, all but one of the participants moved themselves immediately to an initial standpoint which was located centrally in front of the display, but at different distances from it.

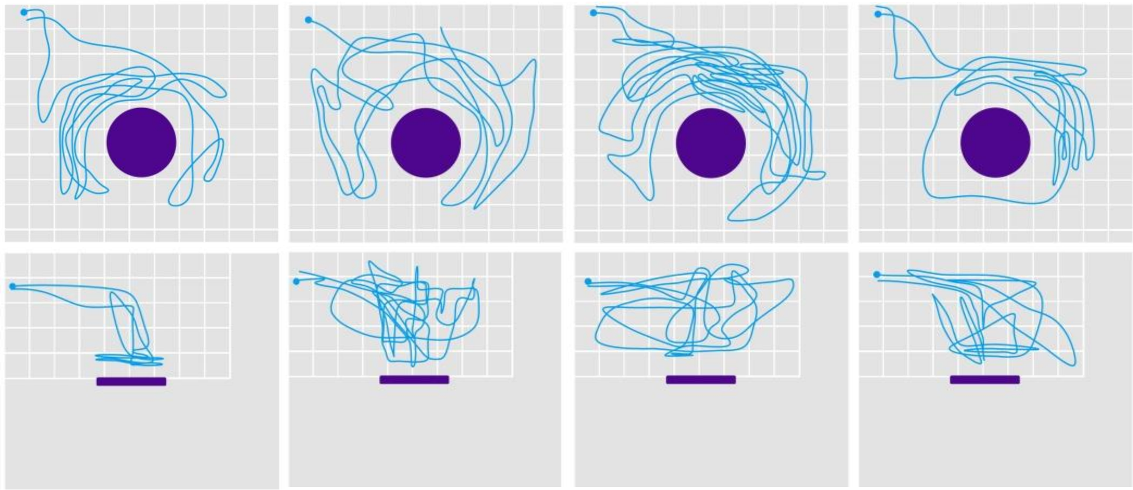


Figure 6.7: Sample trajectories of participants around the column and in front of the flat display.

Walking Trajectories

When users interacted within the circular interaction space around the column, they created distinct trajectories (see Figure 6.7). In front of the flat display the user trajectories showed centric and symmetric patterns that also often covered large parts of the room. Yet as individuals preferred many different sides around the column, their locations varied more: When comparing the *variance in locations*, users dispersed themselves to more than twice as many different rows (5.6 vs. 2.3) and three times as many columns (3.7 vs. 0.93) on the marker grid on the floor around the column compared to the flat display [Beyer 2011, P.7].

Standing Positions

Around the column users stopped at *arbitrary sides* and their standing positions distribute evenly within the circular interaction space. Sometimes they also stopped at more distant positions. In front of the flat display, the spatial behavior of participants reveals two patterns: The 10 active users visited various positions between the display and the distant corners of the room. But when they stopped they clustered within the mentioned *central strip* in front of the display (see the yellow dots in Figure 6.8). Users stopped nearly as often within this narrow central strip-like region of 60cm width as within all the rest of the room (95 vs. 112 stops). With on average 7.5s they also stopped nearly twice as long within this central region as within the off-center positions, where they remained for on average only 4.1s. The active users stopped at all distances on this strip in order to interact with or watch the screen and their standing positions distribute quite evenly from close to the screen to the back of the room. In contrast, the 5 passive participants stopped and remained immobile nearby a central *sweet spot* located about 1.5 meters away from the display (see blue dots in Figure 6.8).

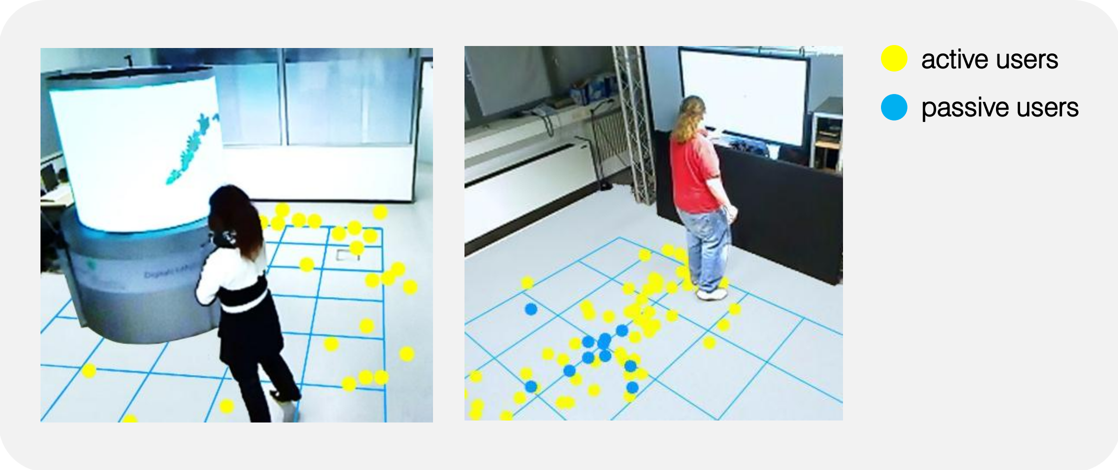


Figure 6.8: Standing positions of at least 4s duration for 12 column and 11 flat display users.

6.3.4 Movement Patterns

Covered Distance

With on average 47.3m participants walked significantly more around the column than in front of the flat display where they only covered 21.2m [Beyer 2011, P.7]. The difference is yet not as large when differentiating between active and passive participants. The 5 passive, immobile viewers in front of the flat display contributed with on average only 8.3m to the *walking distance*. With on average 34.5m the 10 active users walked more, but still less than around the column.

Walking vs. Standing

Similar is the situation in regard to the proportional *time* participants were walking or standing. Around the column they walked a lot and stood only 40% of their time, while in front of the flat display they spent 59% of their time standing. Again, the results are diverse in front of the flat display when differentiating between active and passive users: The 10 active users stood 54% of the time, while the 5 passive ones remained immobile 70% of the time and only moved in order to reposition themselves on the spot, or in one case in order to look behind the screen. While *stopping durations* vary strongly between individuals, users on average also stopped shorter around the column (see Figure 6.9). They continued walking after on average 3.7s compared to 7.6s in front of the flat display. Of the participants in front of the flat display the active users stopped for on average 5.7s and the immobile viewers for on average 22.1s. One outlier among the immobile participants even passively watched the screen for long 4.2 minutes.

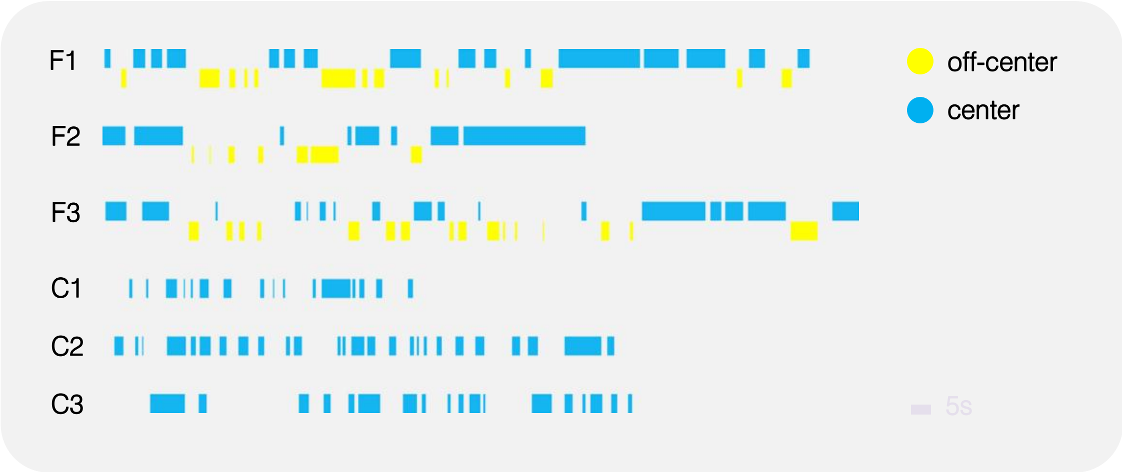


Figure 6.9: Exemplary standing intervals for 6 users of both displays.

The *maximum durations* participants spent on a single location were also diverse between both displays. Around the column, the average user stopped for no more than 14s, yet the values vary between users who nearly did not stopp at all during their stay (standing for maximal 1s) and a few users who stopped long to examine interactivity by arm or body movements (single stops up to 52s). In front of the flat display active users stopped for up to on average 24.2s, as well using the longest stops to carefully examine interactivity. The immobile viewers usually stopped only once or twice, with peak values between 34.5s and 4.2 minutes. The *stopping rates* were quite similar among both displays. While users stopped shorter around the column, with on average 8 stops per minute not more or less often than active users in front of the flat display who on average stopped 7.3 times. In other words, users stopped shorter around the column, but in return also walked longer. While in total all 15 participants stopped on average only 5.5 times per minute in front of the flat display, this lower value is yet substantially affected by the immobile viewers who stopped only 1.8 times per minute.

6.3.5 Body Orientation

Frontal vs. Lateral Orientation

Comparing the body orientations of participants independent from their current activity, users spent with 69.5% most of their time with *shoulders parallel* to the flat display, and significantly more than around the column which they faced frontally in only 41.5% of their time [Beyer 2011, P.7]. Yet, these figures still include the 5 passive viewers of the flat display who remained immobile.

Figure 6.10: Lateral body orientation when walking around the column (top) and frontal orientation when standing or walking in front of the flat display (bottom).

Correlation with Walking/Standing

When differentiating between time intervals when participants were walking or not, the data is divided and shows that the overall predominant lateral body orientation around the column can be clearly attributed to the walking situation. When *walking*, participants spent only 22% of their time with their shoulders parallel to the column, compared to 46% in front of the flat display. But when *standing*, users had their shoulders parallel to the flat display 81% of their time compared to a similar 69% around the column, which constitutes no significant difference [Beyer 2011, P.7]. These figures thus show a general trend to a frontal orientation when standing. In fact, the 5 passive viewers who remained 70% of their time immobile thereby faced the flat display frontally and thus contribute overproportionally to the 81%. Substracting them out, active users assumed a frontal orientation in about 70% of the standing time, regardless of the display. Except for an outlier no linear correlation between the user position and the body orientation could be observed in front of the flat display. While users faced the flat display frontally when standing in a central position (see Figure 6.10 bottom), they often also stopped with shoulders parallel to the display at off-center positions. Only at very excentric positions they frequently faced the display diagonally. When participants walked around the column, the angle between their shoulders and the screen tangent usually was not completely orthogonal, but slightly angular (less than 90°, see Figure 6.10 top). When users stopped or turned to change the direction, this angle decreased only in the very last moment.

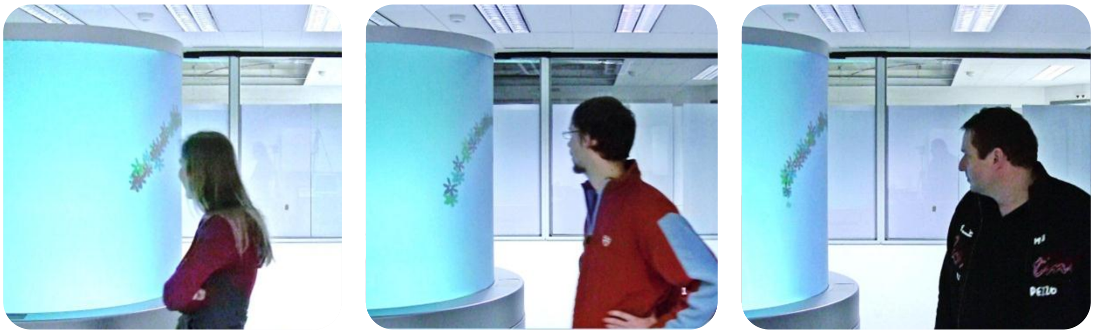


Figure 6.11: Active users constantly look at where the visual feedback is.

6.3.6 Viewing Behavior

Visual Focus on the Column

The video analysis showed that the answer to the question, where users are looking at, is trivial: when interacting with the displays, participants were gazing spellbound at the visual feedback, i.e. they were constantly fixating the spot where new flowers were emerging (see Figure 6.11). The content is programmed such that when used on the column, the point on the screen where the visual feedback appears corresponds with the user's radial position. In relation to the users body, this point is located on the middle of the display. When *walking* around the column in a lateral body orientation, users fixated the feedback by turning their head at an angle of about 45° away from the walking direction. This angle towards the display was further increased by keeping the shoulder angle at less than 90° (↺ Chapter 6.3.5). Thus, instead of looking at the column fraction in walking direction, the visual focus was always about on the middle of the display with the used content. When users were *standing*, as discussed usually in a frontal body position, they were looking straight towards the display. Many used this pause to get a better overview and inspect the whole visualization on the screen. For this, they were sometimes assuming more distant positions from the display for some seconds. Instead of looking at the column for short intervals only as we had hypothesized, users engaged constantly with the visual feedback when walking and seldomly released their gaze from it.

Visual Focus on the Flat Display

In front of the flat display users most of the time were assuming a frontal body orientation (↺ Chapter 6.3.5), thereby looking straight towards the display. They also showed this *frontal viewing* at off-center positions and even when performing side-steps. To maintain the visual focus on the flowers, they had to turn their head or body angular only when passing-by the display in a lateral orientation or when assuming very eccentric positions within the room (compare the observed interactions in Chapter 6.3.2). Yet users seldomly looked towards other directions.

6.3.7 Total Interaction Time

Users spent on average 2.49 minutes in front of the flat display and thus nearly twice as much time than around the column, where users who engaged with it only stayed for on average 1.32 minutes. When substracting out the 5 immobile viewers who spent long times on a single location, the average time in the room with the flat display even rises to 3.14 minutes. These 5 inactive participants did never start interaction and thus left the room earlier as the active ones. In fact, the longer engagement in the room with the flat display can be attributed to the active users who spent a lot of time with exploring the interactivity of the display.

Measure	Column	Flat (all – active/passive)	
Covered distance (m)	47.3 / 24	21.2 / 13.7	34.5 / 8.3
Time spent standing (%)	40	59	53.5 / 70.7
Duration of stops (s)	3.7	7.6	5.7 / 22.1
Max duration of stops (s)	14	34.5	24.2 / 45
Stops per minute (1/min)	8	5.5	7.3 / 1.8
Time shoulders parallel (%)*	41.5 / 21.3	69.5 / 17.2	
…while walking (%)*	22.1 / 10.6	46.3 / 16.1	
…while standing (%)	70.0 / 26.1	82.0 / 18.6	
Location variance (rows)*	5.6 / 1.4	2.3 / .96	
Location variance (columns)*	3.7 / 1.4	.93 / .57	

Figure 6.12: All statistical results (* p<.001, mean/std, yellow: higher value, grey: similar value).

6.3.8 Subjective Data

Participant Reactivity

The answers in the semi-structured interviews confirmed our observation that participants behaved quite autonomously during the trials and showed no substantial reactivity to the experimental situation. Especially they did not seem to feel intimidated by the installed cameras: "As soon as you start to play around with the media, you forget that you are observed" [Beyer 2011, P.8]. One participant who in the videos had ignored the column and also only had looked behind the flat display stated that she did not know, as we previously had not disclosed the objects of interest, on which of the many items in the rooms she had to focus on. She thus perceived the room with the column as a whole. This explains why she had been curiously investigating secondary items such as the required hardware instead of engaging with the displays.

User Experience

The results from the AttrakDiff questionaires revealed some tendencies in the perceived pragmatic and hedonic qualities of the two investigated displays. There were no significant differences between both displays, possibly because of the small sample size [Beyer 2011, P.8]. Yet the column tended slightly towards an emotionally binding experience (self-oriented character according to [Hassenzahl 2003]), while the flat display was rated as medium for all attractivity dimensions (see Figure 6.13): From a global perspective (ATT), participants rated the column display as very attractive, but the flat display only as medium attractive. They further ascribed both displays a neutral pragmatic quality (PQ), tending towards effective. In sum they rated the column to be of slightly higher pragmatic quality (to be more usable, predictable, practical) than the flat display, and were also more united on their neutral assessment of the flat display. Participants ascribed an outstanding and consistently higher hedonic quality (HQ) to the cylindrical column than to the flat display. In regard to the stimulative dimension (HQ-S) they found the column more novel, innovative, creative and facinating. They also identified more with the column (HQ-I) as they found it more stylish, presentable, involving and professional than the flat display.

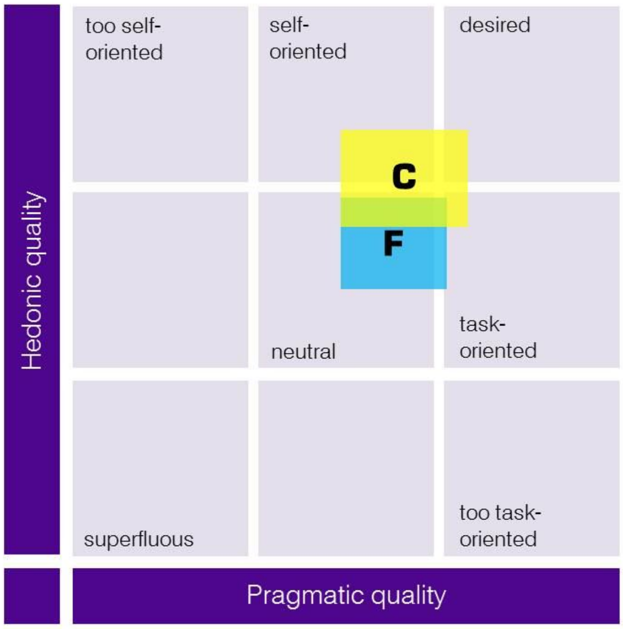


Figure 6.13: AttrakDiff portfolio for the column (C) and the flat display (F).

Understanding Interactivity

The answers of participants confirmed what could already be seen in the videos. The 5 participants who had remained inactive and immobile in front of the flat display (↺ Chapter 6.3.2) confirmed that they had not understood interactivity and considered the appearing flowers to be random. Some of them had expected to be offered television by the flat display (see Figure 6.14). Beyond the 3 participants who either had ignored the column or mainly tried unsupported actions, the one who had acted very passively also stated to not have understood interactivity. Others could exactly describe how they could affect the content, e.g. that one could draw a trace of flowers by left-and-right movements onto the column. Some understood interactivity in general, but the actual scope of control only unsufficiently. For example, one interviewee falsely assumed that the flowers could be controlled with back-and-forth movements in front of the flat display.

Participant Self-Perception

The interviews revealed interesting findings on how participants perceived the two displays and their own behavior in front of them (see Figure 6.14 and compare [Beyer 2011, P.8]): Outstanding was the fact that multiple interviewees compared the flat display to a television screen. Some described their experience in front of the flat display as static and their positioning as frontal, compared to a more active, dynamic and movement-stimulating experience around the column. One participant reported that the column felt closer than the flat display.

“For me, round is more comfortable than square. It was more organic. The flat was like a television feeling. The round was more dynamic. TV is more static.” (P3)

“You stand in front of it like in front of a TV. [...] It was more like a TV situation: you position yourself in front of it and think: what happens now. With the column you are engaged more actively [...] With the column you immediately had the feeling, you do more with it.” (P7)

“I come in, position myself in front of it, and initially I wait. With the column you walk around in this moment, you don’t do it here. Here you stand in front of it and say, ok, like television. What am I offered here?” (P4)

“The column was more spatial. It was more interactive because one moves more. [...] It is better if you can move around a fixed point than back and forth.” (P1)

Figure 6.14: User statements on their self-perception around the displays.

6.4 Interpretation

The observed different interactive, spatial and viewing behaviors
can be traced back to the distinct display qualities, to individual user expectations, and to the used interactive content.

6.4.1 Observed Different Behaviors

Unaware Initial Interaction

Around the column display, the moment when users became aware of the visual feedback was clearly recognizable in the observations. Participants who noticed it while walking, suddenly showed surprise or orientation reactions (↺ Chapter 3.3.8) towards the emerging visuals just after they had fixated them while scanning the room for salient stimuli. Another pattern is that 69% of the active users (9 of 13) suddenly stopped for some seconds after discovering the feedback. This did not only happen at the door when people first saw the column, but also when users were surprised by the visual feedback late when they were already walking within the room for some time. After they stopped they shortly inspected the visuals, possibly reflecting now that they just had caused the effect. When walking on they constantly fixated the point of motion, which indicates that from now on they were immersed in and identified with the visual feedback. With the flat display, the moment when users noticed interactivity was harder to perceive as they initially were not walking along the screen as with the column and thus no orientation or surprise reactions to the visual feedback could be observed. Instead, people immediately oriented their attention towards the flat display when entering the room, turned towards the screen and stopped in a central position in front of it.

> Around the column, the moment when people notice interactivity is easier to perceive due to sudden orientation and stopping reactions.

Role of the Content for Noticing Interactivity

The used interactive content and how it is related to the situation how people entered the rooms played a decisive role for noticing interactivity. Its functional principle is a causal one: the initial movements of passers-by along the display cause flower effects at their current position. When entering the room with the column, 66% of the 15 participants immediately looked at the visual feedback to their movements, became aware of and fullly focused their attention on it. The remaining 33% who either noticed interactivity late or never, did not look at the column instantly when walking in, only after they had already stopped to inspect the room. But at this time the flowers on the screen were not moving any more, just slowly fading away (↺ Chapter 6.2.4), such that viewers could not conceive any correlation between the visuals and themselves. In other words, the used content only conveys interactivity when people are in motion. The 20% who still noticed the interactivity of the column later, did so only when they were moving on again.

> ▶ In the case of movement-driven visual feedback, people will only notice interactivity if they look at the display while in motion.

Superimposing Factors

In the room with the flat display the bright display itself was the primary attractor, superimposing all information by the visual feedback. Those who had noticed the feedback in the beginning soon started to interact explicitly with the screen. But those who still had not noticed the feedback, instead of moving on as around the column and get a second chance to discover it, remained immobile. The interviews revealed that these passive viewers associated the framed display with television and expected to get offered respective content instead of having to become active themselves. They remained such static that they did not notice the feedback until they left the room. Four users incorrectly interpreted a video camera as interaction sensor. Around the column, two participants ignored it completely and instead inspected hardware in the rooms. They had expected to have to search the rooms for specific items (↺ Chapter 6.3.8), and it seems that the applied reframing procedure had affected them in an unfortunate way.

> ▶ Individual expectations on a display shape such as the association of a flat display with television can affect if people notice interactivity.

Carry-Over Effects

Due to the repeated measures design, participants may already have learned of interactivity when visiting the second display. All 3 users who had visited the flat display first and learned about its interactivity, belonged to the 10 who noticed the visual feedback on the column early, and all 4 users who had visited the column first and learned about its interactivity belonged to the 8 who noticed the interactivity of the flat display early. Yet as visitors of the second display showed the same initial reactions as first-time users, prior knowledge may also only have affected their behavior *after* they noticed interactivity. Participants further showed a constant individual performance in learning the interactivity of both displays.

> The repeated measures design of the lab study may have affected how participants learned about the interactivity of the displays.

Indicators for Understanding Interactivity

The scope to which users understood interactivity was revealed by the actions they could reproduce in the interviews, their visual focus and explicit interaction with the feedback and the persistence with which they examined functionality. Around the column, 85% of those who noticed the feedback (11 of 13) fixated the flowers continuously while moving along the display, which shows that they intuitively understood its reactivity and attributed the visual effect to themselves. While fixating the feedback, they also started to change directions, wave their hands or move the upper body. Many users told us that they noticed interactivity, but were unsure about the full scope of the functionality. Only 3 discovered that speeding up affected the size of the visuals. The flat display did not only convey interactivity less effectively than the column, but people also had difficulties to discover its functionality which was less self-explaining here. This resulted in strong explorative behavior and users spent much time examining unsupported functions. Still 60% understood the movement-reactive interaction principle and performed supported actions such as passing sideways or moving arms, but they did not continuously perform these actions as with the column, as moving sideways did not feel as natural as compared to moving around a fixed point.

> The strong explorative behavior in front of the flat display revealed that it conveyed the functionality less effectively than the column.

Circulating around the Column

The study revealed significantly different spatial and movement patterns between both displays. Around the column, users showed a strong walking activity, moved within a circular interaction space and to various sides as hypothesized. People walked 60% of their time and with 47.3m covered 40% more distance than active users of the flat display. Interviewees described this movement around a fixed point as more comfortable and engaging, and the UX evaluation confirmed this more stimulative experience around the column. Stimulation of movement was the design goal behind the content, but the qualities of the semi-framed column bring it to its best use: the lack of boundaries on the left and the right gives users more degrees of freedom and enables them to move freely around the cylinder and proceed where they would have to stop at the boundaries of a framed display. That also users who did not understand interactivity moved around the column indicates that also the cylindrical shape contributes to this stimulation.

> The semi-framed column encourages passers-by to move around it, especially in combination with a movement-stimulating content.

Sweet Spot of Passive Users

In front of the flat display many users also moved, but often stopped at central positions. Taking a closer look if participants interacted or not, behaviors differ between active and passive users: Those who did'nt notice interactivity remained immobile during their stay within an enclosed central area 1.5 meters away from the screen and just looked at it. Interviewees later reported that they felt like in a television situation and expected respective content. This pattern of passive viewers standing frontally within a defined sweet spot aligns well with Manovich's theory of imprisonment of the viewer's body in front of rectangular screens by the requirements of the image perspective [Manovich 2001, P.106]. When discovering the rectangle, these viewers anticipated television viewing, positioned themselves within the "prison" and expected the viewing regime to take over. At this position the entire frame was still in their visual field and they could see the screen from the best perspective. Yet the immobility prevented that they noticed interactivity.

> The display framedness caused the immobility of the passive viewers within a spot and thus prevented that they discovered interactivity.

Central Positioning of Active Users

Participants who had noticed the interactivity of the flat display moved within the entire room while interacting, but often positioned themselves within a central, strip-like region in front of the display. Those active users evenly covered all distances on this central axis from close by the screen to the back of the room and stopped there much more often and nearly twice as long than at offside positions. This cannot be simply explained by users seeking the best viewpoint. Instead, their spatial behavior seemed to be strongly related to their mental immersion in the visual feedback when interacting: To influence the felt feedback position, users moved some steps in any direction, but once they reached the screen boundary they avoided to leave the virtual space with their visual effect and instead strived back to the center of the screen where they had the most action possibilities and preferred to move back-and-forth and interact with the arms. Similarily, [Michelis 2009, P.147] observed that users positioned their mirror representation towards the center of the screen to avoid looking at a cut-off mirror image of themselves, which points to possible relations between self-attribution, gestalt laws and the ambition of users to sustain the virtual illusion.

> Active users often stopped within a central, strip-like region in front of the flat display where they could best sustain the virtual illusion.

Frontal vs. Lateral Orientation

The body orientations of users differed significantly between the column and the flat display in the walking situation. When walking, users almost 80% of their time moved laterally around the column and used the arm that was closer to the screen for interaction. Instead, in front of the flat display the frontality was such dominant that users maintained their shoulders parallel towards the display half of the time when walking, seemingly as this was more comfortable. When standing, not only the passive television viewers, but also 70% of the active users of both displays assumed a frontal body orientation. It seems that when standing, frontality is preferred regardless from the fact if a frame is present, and we mainly attribute this behavior to the ambition of users to get an overview of the screen.

> Standing users prefer a frontal orientation regardless of the display, and a lateral body orientation only when walking around the column.

Fixating the Feedback

Other than hypothesized, the viewing behavior was not determined by the walking direction, but by the mental immersion in the virtual effect. With the used interactive content that first attracts attention and then stimulates user movement by visual feedback, the question where users look at is trivial: almost the entire time they focused their attention on the visuals and fixated the point of motion. When walking around the column users concentrated so much on the virtual effect that they ignored the surrounding physical space and the display as a whole. Only when they stopped they showed an *overview behavior*, shifted their attention towards the whole visualization and often stepped back to more distant positions to get the entire display into their visual field. This concentration on the visual feedback could also be observed in front of the flat display. It remains open how this *virtual viewing regime* interplays with a conscious perception of the display frame when users stopped at the screen boundaries or repositioned themselves centrally and frontally in relation to the frame. The constant attention focus on the visual feedback demonstrates how the viewing direction is affected by the specific content, and that this might be quite different with other visuals.

> The viewing direction of users is more determined by the mental immersion in the visual feedback than by the walking direction.

Time Spent for Interaction

In contrast to our hypothesis, users did not engage longer with the novel, moving and spacious column, but spent about twice the time with the less-performing flat display. This shows that user engagement does not necessarily correlate positively with factors such as attractivity, understandability or movement activity. The longer dwell times in front of the flat display are explained by the strong explorative behavior of users. While the natural movement around the column quickly explained the interaction, the expectations and initial central positioning of users made it difficult to learn the functionality of the flat display. Thus users spent a lot of time with examining assumed further functions, and this exploration of the functionality became an emergent goal during their stay [Michelis 2009, P.161].

> If the display functionality is not immediately understood, this can lead to longer dwell times due to testing and explorative behavior.

6.4.2 Limitations

Artificial Lab Setting

The lab constitutes a low-ecological setting where behaviors can differ and thus cannot be generalized to the real out-of-home world. It excludes *formal factors* in public space such as the sight relations, contrasts and contours of the built environment. Instead, functional signs by the visible lab hardware can convey unwanted demand characteristics. The isolated lab environment also leaves out any *situational variables* such as competing stimuli, light conditions, weather, pedestrian traffic or social interactions with bystanders, and *subjective factors* in public space such as the expectations, the situational involvement and the habituation of real passers-by who encounter out-of-home displays incidentally and repeatedly. Instead, lab participants may arrive with raised expectations, and the study situation can induce situational involvement and reactivity.

Spatial Conditions

The limited space is a major limitation of the lab. While public displays are often deployed such that they are already visible from the distance, lab participants are suddenly standing in front of them when entering the rooms which affects how they become aware of them. Further, the room situation can cause specific behaviors, such as for example the observed behavior that participants first scanned the room from one wall to another to get an overview, and as a consequence initially ignored the investigated column display. The confinement by the room's walls may also affect user positions and movement patterns and define the interaction space. The available approaching trajectories in the lab do also only, at the very most, resemble quite specific situations in the real world.

Study Design

Some specific design decisions of the study also limit its generalizability. As only single-user behavior was investigated, no conclusions on the behaviors of pairs and groups or social interactions between users can be drawn. The repeated measures design allowed to compare the behaviors of the same individuals with both displays, but visiting four displays one after another possibly evoked carry-over effects and made participants learn about the presence of large displays and their interactivtiy over time. Finally, the small sample size and the self-selection of study participants limit the generalizability. For example, no kids or elderly people participated, but possibly some with special interest in the study.

Specific Display Designs

The findings of this study may not be generalizable to arbitrary columns and flat displays of any scale, ratio and framing. For example, the central positioning of users that we observed in front of our spatially limited flat display with its clearly delineated rectangular frame may not occur in front of very wide, semi-framed flat displays where no left and right boundary is visible for the user. Quite the contrary, when users are standing in front of large multi-display configurations, the frames that are created by the single sub-units may induce their own positioning effects and override those of the whole display. Further, the strong walking activity and circulation of users that we observed around our seamless column display may not occur with columns with other, smaller or larger diameters or such ones with surface roughness (↺ Chapter 4.1.3). For example, polygonal columns that consist of multiple framed sub-units may also produce similar central positioning effects as observed in front of our flat display.

Role of the Content

The results of this study are also content-dependent, as the interactive content used with both displays was specifically designed to actively stimulate user movement (↺ Chapter 6.2.4). This content works best when the user is moving to the left and to the right in front of the screen and thus gives advantage to semi-framed displays such as the column. It also ideally interacts with the natural movement around the cylindrical column. In contrast, the affordances of this specific content are harder to discover in front of a flat display where users initially approach frontally and stop within its center. Also the left and right frame boundaries, which demand users to turn repeatedly when moving sideways, limited the attractivity of the used content with the flat display. Yet other contents may be found which provide stimuli strong enough to make users to perform, despite the positioning stimulus of the frame, strong lateral movements in front of framed displays, or static behavior in front of columns, or which even evoke completely different movement patterns, user actions and viewing behaviors. For example, a mirror image of the user on the screen may not generate strong lateral movement around a round column, or an interactive ball game may make users to turn their head and look towards quite other screen regions.

6.4.3 Open Issues

Summarizing the findings and limitations of the lab study with the column and the flat display, the following issues are left open at this point of research:

Field Behavior
How do real passers-by behave around interactive cylindrical columns and flat displays in an ecological valid setting?

Multiple Users
How do multiple users interact around columns and flat displays, both with the screen and with each other?

Visual Frames
Is the central positioning indeed just caused by the regtangular frame, or do also other factors such as the screen area play a role?

Behavior Shaping
Can positioning effects such as the observed ones also be evoked by just displaying virtual frames?

Display Shapes
Can the behaviors observed around the column and the flat display be generalized to other semi-framed respectively framed displays?

Other Contents
How do other interactive contents than the used one affect user behavior around the two evaluated display shapes?

Evaluation
How can different display qualities such as the ones evaluated in this study be compared in a field setting?

6.5 Takeaways

Large cylindrical column displays and flat rectangular displays
influence user behavior around them differently which should be considered when designing interactions for them.

6.5.1 Recommendations for Columns

Strong Walking Activity

With the used interactive content, people walked around the cylindrical display from the beginning. This movement seemed to be natural and self-developing. As advertising columns are usually freestanding and deployed were people walk (↺ Chapter 2.2.2), the interactive content can take up this passing-by movement. Visual feedback to the initial movements of passers-by can be displayed to induce an unaware initial interaction, and if people stop when being surprised, the feedback can also actively stimulate them to move on around the column.

R 6.1 Design for Walking

People walk around columns from the beginning, which makes them ideally suited for transfering the intitial passing-by movement to lasting interaction.

Circular Interaction Space

In this study, users did not only walk a short distance alongside the column, but often rounded the semi-framed display to discover the whole circular interaction space. Interactive contents can make use of these circular trajectories around the column. For example, interactive tales can be told which encourage people to walk infinitely around the column, or multiple users can be dispersed within this very wide interaction space to interact with each other [Beyer 2008, P.53f].

R 6.2 Make Use of the Movement around Columns

People circulate around columns to discover the whole interaction space around them, and contents should make use of these trajectories.

Variable User Positions

Other than with flat displays, users could not use left or right frame boundaries to orient themselves when interacting around the semi-framed column. Thus, they stopped at arbitrary positions instead of at predefined ones. Individuals also preferred different sides of the column where they repeatedly moved back and forth. So instead of designing contents for a defined position, contents should work for variable locations and all sides of the column where people can move.

R 6.3 Design for Variable Positions

As users stop at arbitrary and unforeseeable locations around columns, contents should work for variable user positions and all sides of the screen.

Lateral Body Orientation

The study revealed that users assumed a lateral body orientation when walking around the column. In this situation, they usually only used the arm facing the display for interaction, while it was not comfortable to use the averted arm. For this reason, gestural interactions around the column should be limited to the arm facing the display. It should also be considered that the dominant hand faces the display only in one walking direction, and that in a lateral body orientation arm movements against the walking direction (towards the dorsal) are difficult.

R 6.4 Design for One-Hand Use

In the lateral body orientation that users assume when walking around the column, it is only comfortable to interact with the arm facing the display.

6.5.2 Recommendations for Flat Displays

Immobility of Passive Viewers

In this study we used a display with 16:9 aspect ratio similar to common screens of home television. Due to their prior knowledge of this format some participants anticipated television viewing and remained passive in front of the screen, which effectively prevented that they noticed interactivity. Such specific associations of users with certain displays have to be considered and measures have to be taken that novice users understand the purpose and interactivity of the display.

R 6.5 Consider Individual User Expectations

Due to their experience passers-by can associate certain flat displays with television viewing, which then can prevent the discovery of its interactivity.

Central Standing Positions

The flat and framed display encouraged users to head for central positions in the beginning and also frequently later, where they remained for some seconds. Yet users passed it sideways at most only shortly, as this movement did not feel as natural and comfortable as around the column. These central positions which are seeked by users themselves can be used as starting point for more complex contents. If the design goal is instead to make users move, the back and forth movement on the central axis that users preferred in our study can be used.

R 6.6 Design for Central Standing Positions

As users often position themselves centrally in front of framed displays, this position can be used as starting point for contents with higher complexity.

Frontal Body Orientation

In our study, users did not only face the flat display frontally when standing, yet often also when walking. In this frontal body orientation they used as well one or both arms for gestural interaction. Accordingly, interactive contents for framed displays can include both arms if needed, and as the arms are in equal distance from the screen, assume that they can perform the same symmetric movements.

R 6.7 Design for One-Hand or Both-Hand Use

As users often face flat displays frontally even when walking, contents can revert to both arms for gestural interaction with the screen if needed.

6.5.3 Designing Interactive Contents

Unaware Initial Interaction

The interactive content used in this study was designed to stimulate motion, and thus only provided visual feedback when people were in motion. This content quite effectively communicated interactivity when users were walking around the column, but in situations where the approaching users stopped before they looked at the screen the first time, no unaware initial interaction happened. Thus in situations where people can stop before they look at the screen, the visual feedback has to make the correlation clear also when the viewer is not in motion.

R 6.8 Design Effective Visual Feedback

In order to effectively communicate interactivity, visual feedback should be noticeable as such both when passers-by are moving and standing.

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Immersion in the Feedback

The visual feedback was effective in directing the users' focus of attention. When they were mentally immersed in and identified themselves with the virtual effects, they most of the time fixated the point of motion with their eyes and ignored their surroundings. With such interactive feedbacks that constantly attract the viewers gaze, no further assumptions on the viewing behavior have to be made. Yet this mechanism may cause change blindness in regard to the rest of the content.

R 6.9 Actively Direct the Viewing Behavior

Interactive visual feedback can be used to capture the user's visual focus in one point and thus control and actively guide the viewing direction.

Movement-Stimulating Content

The interactive content used in this study took advantage of the qualities of the round and semi-framed cylindrical display. For this reason it performed better with and thus favored the column. While we used the same content for both displays in this study to ensure comparability, in practice for each specific display shape the functionally most effective content should be used.

R 6.10 Use Format-Supporting Contents

On each display shape only such contents should be used that have been specifically designed considering its individual qualities.

6.5.4 Measuring Behavior

Reframing Procedure

Due to the reframing procedure we lost two participants who, instead of focusing their attention on the interactive display prototypes, assumed they had to search for items on the museum tour and thus were distracted by other parts of the lab such as the computer hardware. Such effects can be avoided by giving more precise instructions, by hiding the hardware, or by dimming the light to simulate night time conditions and thus direct the attention to the illuminated displays.

R 6.11 Reframe Carefully and Minimize Distractions

If the reframing is not done carefully, this can lead to excessive reactivity among participants and influence their behavior in an unintended way.

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Video Observation

With the exogenous perspectives of the multiple cameras that we had installed at the walls of the lab rooms, the analysis of user positions, trajectories and body orientations required enormous effort. It would have been easier to just use one camera filming the ground plane from the ceiling, or the fisheye sensor of the column which also would have facilitated the analysis of the viewing behavior.

R 6.12 Use Suited Camera Perspectives

The analysis of user positions or trajectories around large displays can be facilitated in the lab by a camera perspective from the ceiling to the floor.

Subjective Methods

In this study, we obtained subjective user opinions by semi-structed interviews and questionaires. While the user statements explained some of the observed behaviors, their validity is limited as users often did not consciously perceive the investigated human factors. A joint interviewer-participant video debriefing would have allowed to inquire participants' subjective experience of single events during the trials, and it would have helped to better understand why they reacted to the visual feedback in a specific situation or why they assumed certain positions.

R 6.13 Interrelate Findings by Video Debriefing

Interrelating the objective and subjective findings by video debriefing can help to better examine single behavioral events that occurred in the trials.

Lab Study

The lab setting involved many limitations for measuring user behavior around the two large displays, even beyond evident issues such as low ecological validity and participant reactivity (↺ Chapter 6.4.2). Especially, a genuine baseline behavior to which the measured user reactions could have been compared was missing. The repeated measures design allowed to compare the individual performance of users, but also affected their behavior. As observational field studies allow to analyze real audiences at the same level of detail, they should be preferred.

R 6.14 Consider Field Studies

In regard to the investigated human factors around large public displays, field studies allow to analyze real audiences at the same level of detail.

CHAPTER 7

SEAMLESS VS. FRAMED COLUMN

Audience Behavior around Seamless and Framed Interactive Advertising Columns

7.1 Background

When multiple passers-by encounter an Interactive Advertising Column
they can use the wide space around it, yet in contrast to really round columns framed ones might affect user positions.

7.1.1 Audience Behavior around Interactive Columns

The validity of the lab study with the Interactive Advertising Column presented in the previous chapter was limited by factors such as the artificial setting, the limited space in the lab and the fact that it involved only single users and voluntary participants who were aware of the research context (↺ Chapter 6.4.2). This study did not cover the complex situational factors and social interactions between multiple and arbitrary passers-by in the wild. Thus we wanted to explore unbiased audience behavior and all issues of attention, interactivity, spatial and social behavior within an ecologically valid setting in a follow-up field study.

7.1.2 Comparing a Seamless with a Framed Column

For cost reasons sometimes industry-standard flat displays are used for creating non-planar displays that approximate cylindrical or other seamless shaped displays. Yet such polygonal multi-display configurations are effectively squaring curved surfaces to several flat rectangular screens again and thus might affect user behavior differently than the truly round non-planar shapes that they approximate (↺ Chapter 4.2.2). For example, a round advertising column can be simulated by combining eight flat displays to an octagon (see Figure 7.1), yet the single frames might affect the user positions around it according to Manovich's theory on the influence of frames. If such a framedness and thus more display qualities than just the basic shape, the rough form factor can affect user behavior, is another issue that we wanted to examine in a second study with the column.

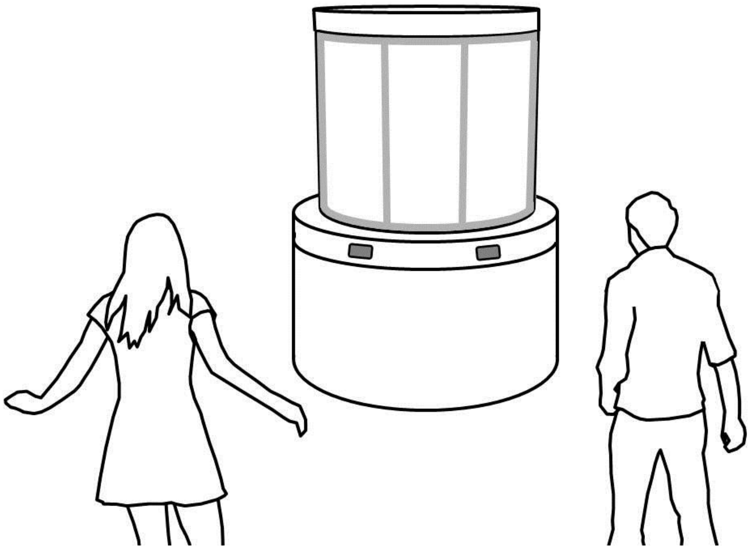

Figure 7.1: If an interactive advertising column is framed this might affect user positions.

7.1.3 Questions and Issues

In regard to the first issue of general audience behavior around interactive advertising columns in the wild we were interested in how passers-by become aware of them and thow they move and interact around them. In the first place we were interested in how the curved cylindrical screen which imposes major challenges to visibility (↺ Chapter 4.3.1) attracts attention and communicates interactivity and how passers-by notice the displayed visual feedback. Then we were interested in how people position themselves around columns, in how multiple users distribute themselves around them and which social constellations they assume within the large 360° interaction space. In regard to the issue of whether framedness can influence the positions of single and multiple users around columns as well as the social constellations between them, a particular challenge was to find a way to compare a seamless and a framed column in a comparative field study while maintaining the same external conditions such as the surrounding space, the approaching trajectories and the flow of passers-by. Finally, as we had observed in the lab study that users circulated continuously around an interactive column, another question was if this still holds true without the spatial limitations of the lab and when displaying other interactive contents. The main issues related to this field study can be summarized as follows:

RQ

Q 7.1 General Audience Behavior around Columns
Which behaviors and social constellations do multiple users show when interacting with interactive advertising columns in the wild?

Q 7.2 Noticing the Interactivity of Columns
How do passers-by notice the interactivity of column displays that provide visual feedback to their initial movements?

Q 7.3 Effects of Framedness on User Positioning
Do the multiple frames of polygonal columns affect user positions and user constellations compared to really round columns?

Q 7.4 Distribution around Columns
How do multiple users distribute around the circular interaction space of interactive advertising columns?

Q 7.5 Circulation around Columns
Do users also circulate around interactive columns with the spatial conditions in the field and different types of interactive contents?

Q 7.6 Evaluation of Columns
How can a seamless column be compared with a framed column in a field setting while maintaining the same external conditions?

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7.2 Field Study

We conducted a field study with the Interactive Advertising Column to explore audience behavior around it and to analyze if user positions can be affected by added visual frames.

7.2.1 Study Context

To explore how passers-by notice and behave around interactive columns and if they would position themselves differently around framed columns compared to round ones we conducted a field study with the Interactive Advertising Column. This work was done together with Florian Köttner, Manuel Schiewe, Ivo Haulsen and Andreas Butz. The study was conducted over a period of five weeks in June and July 2012 in Munich. Partial results of the study have been published at the CHI 2013 conference under the title *Squaring the Circle: How Framing Influences User Behavior around a Seamless Cylindrical Display* [Beyer 2013], and at a conjunct workshop under the title *Communicating the Interactivity of differently shaped Displays* [Beyer 2013B]. The Multi-Kinect framework used in this study was developed by Florian Köttner as part of his diploma thesis [Köttner 2012].

FACTS

Idea	Investigating Audience Behavior around an Interactive Column Display
Type	Observational Field Study
Directing	Gilbert Beyer, Florian Köttner
Hardware	Florian Köttner, Manuel Schiewe, Ivo Haulsen, Gilbert Beyer
Software	Multi-Kinect Framework [Köttner 2013], Rendering [Dingeldey 2010]
Date	25 June–22 July 2012
Location	Entrance hall of Schellingstr. 3, University of Munich
Prototype	Interactive Advertising Column
Publications	CHI 2013 Conference [Beyer 2013], CHI 2013 Workshop [Beyer 2013B]

7.2.2 Hypotheses and Assumptions

Noticing Interactivity around Columns

We anticipated two challenges for a successful unaware initial interaction with interactive advertising columns: First, due to the curved, convex screen and the various approaching trajectories it would be more difficult for passers-by to attribute the visual feedback to themselves when approaching from different angles (↺ Chapter 4.2.1). Second, for people passing the column tangentially the visual feedback would have to be eye-catching and moving, and to be displayed slightly ahead to be noticeable in the periphery of the visual field (↺ Chapter 3.1).

Effects of Framedness on User Positioning

While in the lab study we had only observed a central positioning of single users in front of a single display frame (↺ Chapter 6.3.3), we assumed that similar positioning effects may also be caused around a column divided by multiple frames. This hypothesis on the framedness quality (↺ Chapter 4.1.2) can be tested in a comparative study between a framed and an unframed column and by measuring for both conditions how often users position themselves within the central 50 percent of the frame sections in relation to the remaining space.

Effects of Framedness on Social Constellations

We further assumed that frame sections around columns would also affect multiple users and their social constellations and cooperation with each other. This may yet also depend on the current user activities and roles. In particular there might be differences between active users and passive spectators just observing other group members. This can be analyzed by recording the activities of each user at any point in time and then correlating them with the positions.

Distribution around Columns

We assumed that multiple users and especially members of larger groups would disperse themselves around the column and use the large circular interaction space instead of accumulating just at one spot.

Circulation around Columns

Finally, as we had already observed that single users circulated continuously around a column deployed in the lab (↺ Chapter 6), a similar behavior might also be observable in this field study. Yet the circulation in the lab might also have been caused by the movement-stimulating content or the spatial conditions.

RW ↗

Studies with Interactive Columns

In [Beyer 2011] we compared user behavior around the Interactive Advertising Column and in front of a single flat display in a lab study. [TenKoppel 2012] report on user behavior around polygonal display configurations, including one hexagonal display. Besides that interactive columns are investigated in the context of other domains than public displays, such as in [Kim 2012].

Noticing Interactivity

[TenKoppel 2012, P.6] report that many people noticed the interactivity of their hexagonal display too late and did not stop. In [Beyer 2014] we examine how passers-by notice the interactivity of a long display that is approached from the side and thus faces similar challenges of difficult viewing angles and untypical walking trajectories. [Michelis 2009] and [Müller 2012] conducted studies with standard flat displays installed behind shop windows in this regard.

User Positioning and Framedness

In [Beyer 2011] we analyzed how users positioned around a column and a flat display and attributed the observed central positioning of users in front of the flat one to the framing theories by Manovich and Pinhanez (↺ Chapter 6). [TenKoppel 2012] discuss user positions around polygonal displays in the context of the rough form factor, but not in regard to further display qualities such as framedness or seamlessness of shaped displays. [Fischer 2012] define different types of spaces in front of displays relevant to this work.

Distribution around Columns

[TenKoppel 2012, P.7] report that members of groups formed a passive audience around a single player in front of one of the displays of the hexagon, instead of dispersing to the remaining interaction space around it to interact themselves. They attribute this cohesion of the group to the maintenance of a shared attention area among its members.

Circulation around Columns

In [Beyer 2011] we found that users circulate constantly around the Interactive Advertising Column within the spatial conditions of a lab and when using a movement-stimulating content. [TenKoppel 2012, P.6] report that users follow a curved path around the hexagonal configuration in the beginning.

7.2.3 Study Design: Ensuring Seamlessness

To investigate the effects of framedness on user positioning, we used the same round column display to simulate both a framed and an unframed condition instead of comparing it to a separate polygonal display. This had the advantage that these two study conditions could be compared under the same external conditions and all other parameters that could influence user behavior such as display materials, illumination technology and installation site be maintained constant. As we wanted to measure how *framedness* influences user positions and not other attributes of the display shape, the sensors, interactive content or interaction style, we had to ensure *seamlessness* on different levels in this study:

Challenges of the Study	
Seamless Cylindrical Screen	Seamless Interaction Space
Seamless Interactive Content	Unbiased Interaction Style

First, the used *seamless cylindrical screen* (↺ Chapter 5.2.2) avoided any edges that could influence user behavior, and the framed condition was realized by just displaying virtual rectangular frames on this same column. This solution did not create the flat faces of a real polygonal display, but allowed us to isolate the framedness variable and investigate changes in user behavior by just activating this one switch. Second, a *seamless interaction space* around the column had to be ensured, as for investigating the influence of frames on user positions it was important that the sensor technology did not restrict interaction by invisible dead zones. This transition-free circular interaction space across eight Kinect sensors was realized by designing the Multi-Kinect version of the Interactive Advertising Column and in this context also the sensors were integrated as unobtrusively as possible to not affect user positions (↺ Chapter 5.2.3). Third, as also the content can influence user behavior in front of a public display and even to an extent that can override effects caused by certain display qualities, a *seamless interactive content* without any discontinuities around the column had to be used. Finally, an *unbiased interaction style* had to be ensured where the interaction principle did not require users to perform any specific poses or extraordinary gestures that could influence user positions, e.g. to stretch out their arms widely to perform an action which would prevent other players to assume nearby positions.

7.2.4 Interactive Content

Baseline Content: Interactive Ball Game

The baseline content in the study was an interactive ball game. When passers-by entered the sensor space around the column, Kinect skeletons were displayed. Once people recognized the abstract mirror representations of themselves, they were able to push falling balls in any direction or to other players. This content was continuous around the column and did not demand any specific gestures. We chose a space-saving skeleton representation as real mirror images would appear distorted on the curved 360° display (↺ Chapter 3.3.3), and as we also wanted to display all body parts including the legs. If people were passing the column tangentially and a skeleton could not be detected, a strongly moving particle cloud was displayed slightly ahead of them to attract their attention.

Study Conditions: Unframed vs. Framed Column

In the framed condition of the interactive ball game gray visual frames were displayed on the screen (see Figure 7.2). To isolate framedness as a single variable, the frames were just a visual overlay on the baseline content which represented the unframed condition. This way users and objects were displayed at any position behind the virtual frame bezels and could seamlessly transition between frames. The frames divided the column into eight rectangular sections so that it resembled an octagon. The 16:8 aspect ratio approximated a classical screen format and the bezel width of 2.4 cm was determined in a field overview. We refrained from randomizing the positions of the frames which would have allowed to eliminate possible effects of the sensors, but also would have made the experimental conditions and the analysis of user positions very complex.

Switching the Conditions

While switching the conditions constantly or several times a day may at first seem to minimize temporal effects and increase variation for recurring users, we found that the traffic and population at the deployment location alternated greatly between and within days, but distributed similarly for the same days of a week. For example, the peak times occured between lectures, and students of different disciplines and attendees of postgraduate education or public events preferred specific days and daytimes. Yet in particular as we wanted to avoid a change of conditions at times when users could observe it, which would possibly influence their judgment of the frames, we decided to switch the conditions weekly.

Figure 7.2: Interactive Advertising Column displaying visual frames in addition to the ball game.

7.2.5 Deployment and Setup

Deployment within an Entrance Hall

Following weeks of pretests, the Interactive Advertising Column was deployed for four weeks in a large entrance hall of a university building open to the public. The highly frequented building housed different disciplines such as linguistics, dramatics, physics or social sciences but also many non-academic courses, a cafeteria, cultural and other non-recurring events, thus providing a steady flow of novice users. According to the typical deployment locations of indoor columns in shopping malls and other public buildings (↺ Chapter 2.3.2), the column was positioned in a freestanding and central location within the hall, in the middle of an area where the main walking paths from all directions intersect (see Figure 7.3).

Hardware and Procedure

The Kinect sensors were integrated as unobtrusively as possible to avoid that users would recognize them and consciously or unconsciously align themselves to them (↺ Chapter 5.2.3). Also five computers for running the column and two for the video observation were hidden in the periphery such that they did not distract from the column or reveal the research character of the installation. The column was booted up daily at 9 am shortly before the arrival of the first students and shut down at 7 pm, the time when the frequency of passers-by usually dropped.

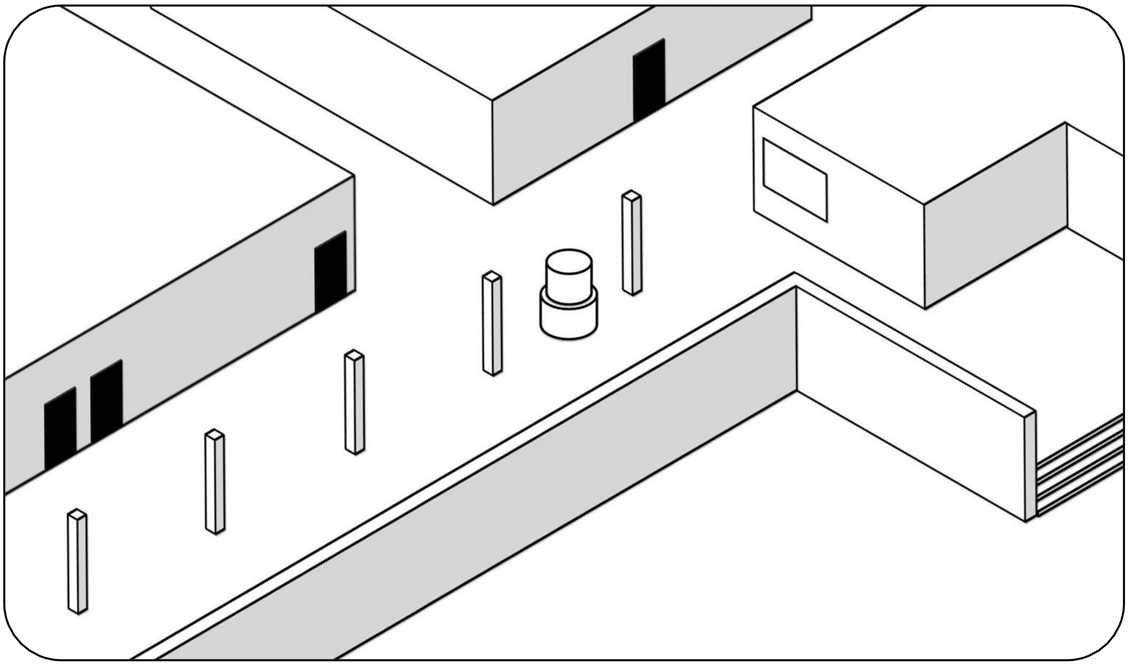


Figure 7.3: Deployment location of the Interactive Advertising Column within an entrance hall.

7.2.6 Data Collection

During the four weeks of the field study behavioral data around the column was aquired by several methods that complemented each other. Objective methods included field observation, multi-camera video recordings and sensor logging, and subjective data was aquired by semi-structured interviews [Beyer 2013, P.5]:

Data Collection			
Field Observation	Video Recordings	Sensor Logging	Semi-Structured Interviews

Field Observation

During the whole evaluation period, a field rater was hiding in a concealed chamber in the periphery where he could not be seen or anticipated to not affect the judgement and behavior of passers-by. From here he took qualitative notes on new and individual user behaviors and controlled the observation software. Additionally, the building's porter's lodge provided an unsuspicious place from which the building's desk officer could also monitor that everything was going well around the column without attracting attention.

Multi-Perspective Video Recordings

For a later qualitative review of single behaviors and a quantitive analysis of the events under investigation, videos were recorded from 4 camera perspectives and synchronized to a single video using the *Noldus Media Recorder* software. The multi-view camera system allowed us to observe the whole interaction space around the column as well as the approaching pathways. We refrained from using video data from the eight Kinect sensors integrated into the column as we wanted to observe how user actions correlate with screen effects. Further the exogenous camera perspectives seemed more suitable for analyzing behaviors than separate centric field of views of the Kinects as they provided absolute user positions around the column and views on users from different perspectives.

Sensor Logging

For each user interaction log data from the Kinect sensors such as date, time, duration, absolute and relative user positions, distance to the column and body orientation was collected. In a public and high-frequented environment such log data also inlude a large quantity of unaware and unintended interactions of non-involved bystanders and passers-by. As it was not possible to filter out just the intended interactions automatically, this log data was finally only used for manual verification of the video data in inconclusive situations.

Semi-Structured Interviews

Starting at the last day of the study, 79 semi-structured interviews of about ten minutes length were conducted outside the university building. The interviews were conducted only at the end of the study and involved only people that would not interact again with the column to not risk influenced behavior by recurring passers-by or hearsay. To avoid social desirability bias on sensitive topics such as interactivity, the interviewees were first asked open questions on each subject area before gradually inquiring further about details they did not mention by themselves. The standardized part of the interview was also carefully designed with regard to the order of questions and wordings to minimize context effects. The flexible part of the interview allowed us to inquire further in the case of equivocal or individual user statements. The interview included 24 questions on topics such as the approaching pathway, noticing the column, repeated encounters, attributes of the column, perceived visual elements, functionality, interactivity, assumed purpose of the installation and suggested improvements.

Figure 7.4: Two of the camera perspectives augmented with a grid mask for the video coding.

7.2.7 Video Analysis: User Positions around a Column

Analyzing a Sample of the Video Data

The four weeks of deployment resulted in several thousand interactions with the column, such that we draw a sample of 10 days from the video material which distributed evenly over the evaluation period and analyzed about 3 of the daily peak hours on each day. This resulted in 33 hours of detailed qualitative and quantitative analysis, while the remaining material was only analyzed randomly. The videos were analyzed in regard to the different research questions using the *Noldus Observer* video coding software. Multiple video raters were required, who they underwent an initial training until inter-rater reliability could be ensured.

Scoring Positions with a Virtual Grid Mask

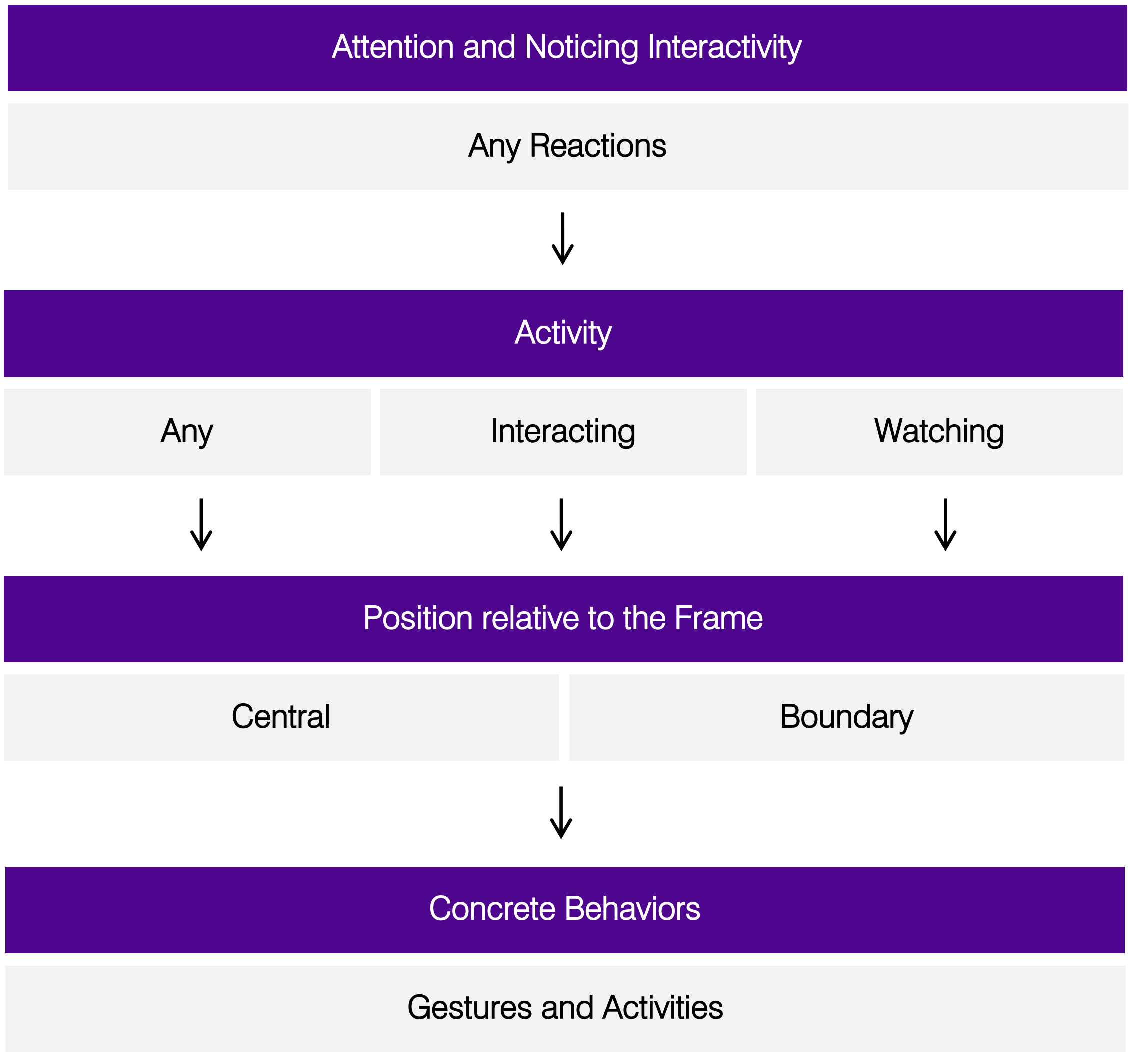
To quantitatively analyze the effects of framedness on user positioning, we had to exactly define where users positioned themselves relative to the frame when displaying the framed or the unframed condition of the interactive content. We distinguished between a user position within the central 50 percent of the angle covered by a frame, and a position in the remaining boundary area. To allow video raters a clear assignment of position codes, the videos were augmented with a radial grid mask visualizing the central and boundary areas (see Figure 7.4 and compare with the grid masks used in the lab study in Chapter 6.3.3). This grid mask was derived from visual markers on the floor which were the result of calibrations involving video recordings with test persons and Kinect log data to ensure that users would also perceive their screen representation in the respective central and boundary areas on the screen.

Coding Scheme: Correlating Activities and Positions

The defined central and boundary user positions created a simple categorical two-level outcome variable that, with the help of the virtual grid mask, could be easily scored for both the framed and unframed condition of the interactive content. As we were interested in the correlation between these position states and the actual activity of users, the coding scheme also contained the behavioral group interaction type for each passer-by around the column with state events *actor* (person interacting), *spectator* (person watching others interacting) and *attentive* (inactive person just watching the column). The user position intervals were scored simultaneously with the interaction type intervals so that they could be nested and correlated in later statistical calculations. Situations in which the user position was inconclusive while interacting (such as when a user moved constantly around the column) were not quantitatively scored but turned out to be rare. Non-involved persons around the column were not scored.

Annotation of Further Behaviors

In regard to attention and noticing interactivity, the typical orientation, surprise and stopping reactions (↺ Chapter 3) were recorded as well as any short glances towards the display when passing by. Further, the distribution and any social constellations of multiple users around the column were scored, as well as the movement behavior and any concrete gestures and activities users performed. The analysis process in the video coding for single users (i.e. disregarding any data on social constellations or user distribution) can be simplified as follows:


Attention and Noticing Interactivity
Any Reactions
Activity
Any
Interacting
Watching
Position relative to the Frame
Central
Boundary
Concrete Behaviors
Gestures and Activities

7.3 Findings

The study showed that
passers-by react quickly to interactivity and that active users position themselves centrally in front of added visual frames, which can affect the interaction with other users.

7.3.1 General Observations

Counted Passers-by

During the four weeks of deployment several thousand visitors of the building interacted with the column. Within the 10 days or 33 hours of analyzed video material, 762 interactions could be recorded as well as 205 people watching others. On average, users spent 40.9 seconds actively interacting with the content and 21.6 seconds watching others. The total time users engaged with the column ranged from several seconds to more than one hour [Beyer 2013, P.6].

Audience and Engagement

The audience passing the entrance hall included singles, pairs, smaller and larger groups and during peak times also large crowds. University students and staff made up the largest part of visitors, yet there were also many attendees of continuing education or cultural events. Parents with kids were also regularly present, while elderly people seldomly visited the building. The column attracted a lot of attention and people engaged intensely with it during the deployment.

Situation and Environment

Passers-by approached the column nearly equally often from the about five main trajectories. The entrance hall was primarily a transit zone, but many people also waited for lectures here or to meet fellows. Passer-by frequency and motivation for usage varied, e.g. shortly before lectures there was often a rush of people to much in a hurry to interact, while in relaxed situations they interacted longer.

Figure 7.5: Passers-by noticing interactivity when approaching frontally or tangentially.

7.3.2 Noticing the Interactivity of the Column

Group 1: Early Attention and Reactions from the Distance

Two basic types of becoming aware of the column and its interactivity could be identified. First, most passers-by who approached the column frontally noticed it already from the distance. They adapted their walking path slightly if required, walked purposefully towards the column and began to interact immediately – usually not later than 1–2 seconds after stopping in front of it. Many even began to interact already from the distance while still approaching the column.

Group 2: Late Surprise Reactions by Inattentive Passers-by

Groups or individuals that were busy with other activities maintained their walking path and noticed the interactivity not before they had approached the column. These inattentive passers-by showed sudden surprise and stopping reactions or a delay of their movement when they became aware of the interactivity. This happened either then when they were passing the column tangentially or already slightly before it – yet only seldomly after they had passed the column and not more than 1m behind it such that they didn't have to walk back. Reasons for the inattentiveness were conversations, the use of smartphones or being in a hurry.

Impact of the Walking Path: Approaching Frontally vs. Tangentially

For all walking trajectories that directly led to the column both the described early reactions and late surprise reactions by inattentive passers-by could be observed. A third behavior was identified for tangential walking paths in the distance that diverted from the column. People who passed the porter's lodge in 10 meters distance suddenly stopped at the height of the column after orienting their attention towards it. Then they adapted their walking path, turned their direction 90 degrees and approached the column. This behavior was caused by noticing the column or active users instead of one's own interactive feedback.

Reactions of Pairs and Groups

Pairs and groups likewise shifted their attention towards the column either already from the distance or when they were surprised late by visual feedback once they were passing by. While often one member of frontally approaching pairs and groups pointed towards the column to notify the partner or the rest of the group, all members noticed it more or less simultaneously and independently from each other. Sometimes one group member acted as a forerunner who started with the interaction first. Yet only if all group members were inattentive when approaching the column (e.g. when busy with conversations), one single member giving a hint to the column's interactivity played the decisive role.

Performance of the Visual Feedbacks

As most people approached the column halfway frontally and looked at it early, the skeleton representation played a major role for communicating interactivity compared to the particle feedback (↺ Chapter 7.2.4), which was only relevant for those who noticed interactivity late and when directly passing by tangentially.

Seeing Others Interact when Arriving

Only in a few cases passers-by stopped nearby the column because they were explicitly noticing users who were already interacting (↺ Chapter 3: honeypot effect and proxy interaction). Yet it cannot be ruled out that the attention of many passers-by had been raised earlier by seeing people interact from the distance.

7.3.3 User Positioning around the Unframed Column

Arbitrary Positions of Users

In the unframed condition, users assumed diverse positions around the column (compare [Beyer 2013, P.7] for all results on positioning). At first indeed, passers-by started to interact right on the side where they approached, and as most arrived on one of the five main trajectories there were sections around the column which initially were used more often than others. Yet after interacting for a while, users moved around the column to continue on another side. While interacting, they seemed to assume more or less arbitrary positions within the circular interaction space, at most depending on factors such as social interaction. Especially, they positioned both within sections that in the framed condition would be assigned to the central position as well as to the boundary position in relation to the frame.

Figure 7.6: Active and passive users assuming diverse positions around the unframed column.

7.3.4 User Positioning around the Framed Column

Repositioning towards the Center of the Visual Frames

In contrast, in the framed condition of the interactive column we observed a clear preference of users for certain positions, which already became very obvious during the live observation: users repositioned themselves towards the center of the visual frames (see Figure 7). While single users assumed a position exactly within the center of the frame, partners who interacted in front of the same frame had to share the space but also strived towards its center. Users seemed to be attracted by the frame centers like by a gravitational pull which kept them from leaving the rectangle. In cases where they needed to step aside to reach a ball with their screen representation, they returned to the center position immediately afterwards. Yet while engaging with the visual elements of the interactive ball game content, users did not seem to give any further attention to the virtual frames and also did not try to integrate them into their play.

Users Reposition when Starting to Interact

Passers-by did not unconditionally align themselves to the frames from the beginning. We observed that first, similar to the unframed condition, people were stopping where they approached the column. When starting to interact, however, users repositioned themselves such that they were standing centrally in front of one of the reactangular frames. Further we observed a difference between active users and passive spectators: passive bystanders just watching other users seemed not to be directly influenced by the frames, and also did not mind waiting within the boundary zones in between two frames (see Figure 7.7, image 3).

Distance towards the Column

In both study conditions, instead of approaching close users usually stopped early and interacted in surprisingly large distances of on average 1.5–2 meters towards the column display if they were interacting frontally with it.

Figure 7.7: Interacting users assuming central positions in front of visual frames.

7.3.5 Statistical Results on User Positioning

Unframed Column: Not Completely Even Distribution of Users

The numbers of the video analysis revealed that even around the unframed column there was not a completely even distribution of user positions (compare [Beyer 2013, P.7] for all statistical values): 57% of all users positioned themselves within the central and 43% within the boundary position. Nearly the same distribution (59% to 41%) could be observed when only looking at interacting users, while a contrast between actor and spectator roles in preferring certain positions became apparent by a reverse distribution for the passive spectators with only 41% preferring the central position but 59% the boundary position.

Framed Column: Higher Preference for the Central Position

However, in comparison and confirming our early subjective observations, in the framed condition a clearly greater share of 66% of all persons around the column preferred a central position in front of the rectangular frames, while just 34% positioned themselves at their boundaries. Statistical analysis shows that the association between the visual frames and whether or not users would assume a central position is indeed highly significant $\chi^2(1) = 9.497$, $p = 0.0002$.

Correlation of Activities with the Central Positioning

When correlating user's activities with their positions, in the framed condition passive spectators showed the same ratio between central and boundary positions as in the unframed one. Yet for interacting users the central positions increased significantly to 71% around the framed column compared to the 59% of the unframed column $\chi^2(1) = 14.328$, $p = 0.00015$. In other words, the central positioning in front of frames can be clearly attributed to the interacting behavior, while the preferred positions among spectators remain constant. Figure 7.8 shows the share and total numbers of central and boundary positions for all persons, actors and spectators for both the unframed and the framed condition.

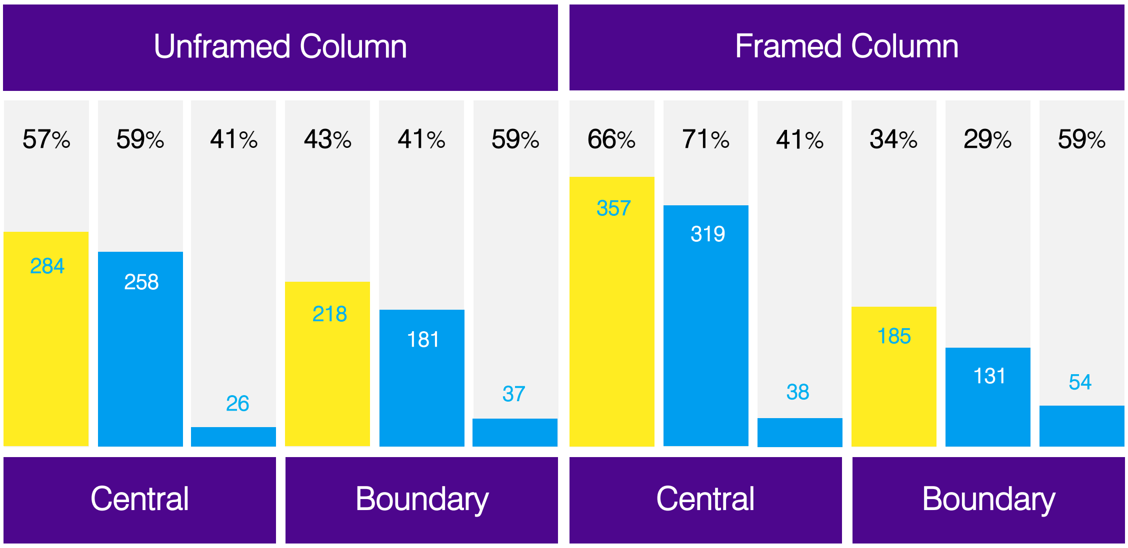


Figure 7.8: User positions for all users (yellow), actors (blue left) and spectators (blue right).

7.3.6 User Positioning: Pairs and Groups

Unframed Column: Comfortable Distances between Users

When pairs and groups dispersed around the unframed column, the distances between single members depended on factors such as the social relations between them and on user cooperation. For example, partners touching or boxing with each other were crowding closer together than when playing a ball game together or when exploring the column separately. Yet generally users seemed to assume comfortable distances between each other in all situations.

Framed Column: Clustering in front of Frames

In the framed condition, the pattern of central positioning in front of visual frames repeated itself for pairs and groups. Group members who joined the interaction took possession of the radially dispersed sections around the column that were centered in front of frames. By accumulating towards the frame centers the distance between active users in neighboring sections increased, leading to a pairing or clustering of people in front of the frames (see Figure 7.9, image 4). Yet if only one partner interacted and the other one just watched, the passive partner stood alongside the active one and thus where a boundary was. While watching the active player the bystanders ignored their own screen representation divided by the line of a frame. Also if all frames were already occupied, additional users waited within these in-between zones, watching the active players and ignoring their own, until it was their turn to enter the central position in front of the frame.

Figure 7.9: Conflicts within active pairs and groups interacting in front of the same frame.

Conflicts in front of the Same Frame

We observed two typical constellations around the framed column which were restricting the movement possibilities of pairs. In the first case, partners were standing close together or behind each other directly in the center of the same frame when cooperating with each other. As as result they were impeding each other or occluding the partner who interacted behind them (see Figure 7.9).

Conflicts between Neighboring Frames

A similar pattern could be observed for pairs cooperating or competing from adjacent frame positions: each partner occupied one of the slightly distant positions of two neighboring frame centers and tried to reach their partner with long arms when trying to touch or box the partner. It seems that unconsciously, none of the partners would step out of an invisible marking line denoting the area in front of the frame, even if the success of their interaction was limited this way.

7.3.7 Spatial Arrangements and Distribution

F-Formations between Users

The orientations between individual users depended on their activity and social relationship with each other. Most users positioned themselves on an imaginary circle around the column. While active partners stood on this circle side-by-side or also more distant to each other and facing the column frontally, pairs of one active and one passive, observing partner formed L-shaped [Kendon 1990, P.213f] or wide V-shaped [Paay 2013, P.11] arrangements. While temporary inactive groups formed closed, e.g. U-shaped or triangular formations when engaging passively in a conversation, semi-circular constellations re-emerged as soon as the group members were getting more active again. In this way these spatial arrangements were an indicator for the activity of the group. Very active groups also distributed evenly around the column forming star-shaped or Y-formations (see Figure 7.11).

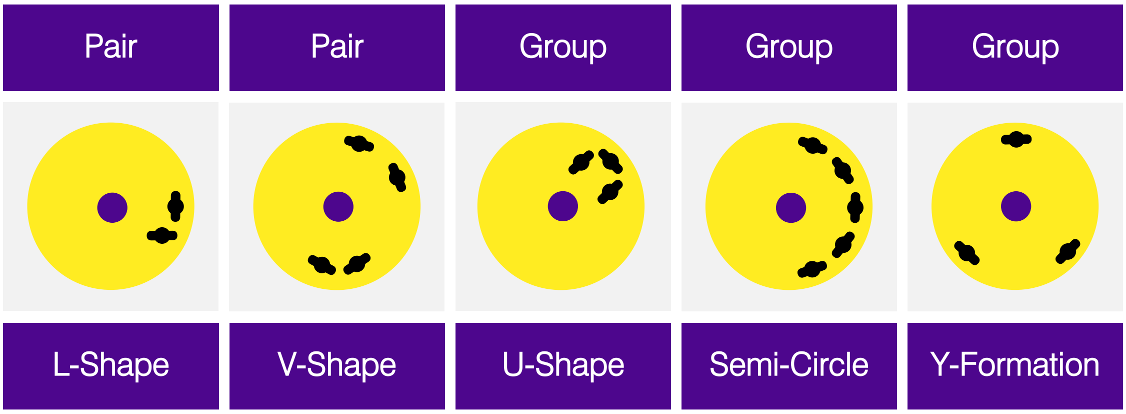


Figure 7.11: Examples for different spatial arrangements of users around the seamless column.

Distribution around the Column

The distribution of multiple users around the column increased together with their dwell time and activity: while groups still formed compact formations with many passive observers when arriving, more and more members became active the longer the group stayed – and when getting active they increased the distance between each other and dispersed around the column. Groups with many active members soon assumed semi-circular constellations around the column or even occupied the complete circular interaction space (see Figure 7.12). Again, the distribution also depended on the specific activity, on social interaction and on cooperation with each other. While users sought more distance to neighbors if interacting independently, partners came closer together when for example boxing with each other, when joining hands or in the case of intimate interaction.

7.3.8 Movement Patterns around the Column

Walking Behavior and Circulation

In front of the used interactive content with the skeleton representation and the ball game, users were most of the time standing instead of moving while interacting. They were walking only occasionally when they were repositioning themselves to another side of the column. Especially users did only seldomly circulate constantly around the column as they did in the lab study (↺ Chapter 6). In such cases where users really circulated constantly around the column, they usually were engaging with the particle cloud (↺ Chapter 7.2.4) after having discovered it when arriving tangentially at the column.

Figure 7.12: Examples for different user distributions within the circular interaction space.

7.3.9 Specific Behavioral Patterns

Independent Interaction: Exploration and Self-Expression

During the four weeks of the study we observed a variety of recurring behaviors and gestures around the column. Beyond actions that were clearly related to the interactive ball game such as kicking or passing a ball, individuals who interacted on their own performed many behaviors related to exploration and self-expression. Especially often people were dancing and performing all types of dance moves such as the egyptian, waving or the moonwalk (see Figure 7.13).

Social Interaction: Cooperation and Competition

Pairs often showed cooperative behaviors such as playing ball together, dancing together, joining hands or bodies, or perfectly synchronizing their movements (mirroring). The most popular competitive behavior among pairs was boxing each other. Users also showed intimate behaviors such as embracing each other, lifting or choking the partner. The primary aim of most actions seemed to be the exploration of the resulting screen representation just for the fun of it.

Performative Interaction

Members of pairs and groups sometimes showed signs of performative interaction [Dalsgaard 2008], but as users were usually interacting on the same level around the circular column and not in exposed positions, it was often not clearly recognizable if they were performing for others or just exploring. Recurring performative behaviors include special dance moves, pirouettes or handstands.

Passing-by Interaction: Greeting Gesture

The most frequently performed passing-by interaction was a behavior we call the *greeting gesture*: recurring users with prior knowledge of the functionality but not enough time to stay shortly waved hands with their skeleton while passing by.

Actions related to the Ball Game			
Pushing	Kicking	Grabbing	Passing
Balancing	Embracing	Jumping	Header Ball
Exploration and Self-Expression			
Dancing	Waving Hands	Egyptian	Moonwalk
Pirouette	Imitating	Lifting Arms	Miming
Collaboration, Competition, Performative Interaction			
Boxing	Joining	Hugging	Synchronizing
Playing Ball	Choking	Figuration	Handstand
Expert Tests, Digital Media, Passing-by Interactions			
Touching	Lifting Kids	Photo Taking	Greeting
Umbrella	Lifting Things	Skype Video	Circulation

Figure 7.13: Specific behavioral patterns around the column.

Photo Taking and Other Media

We observed many users taking photos or videos of their screen representation. In one case a user was filming the column with an open laptop obviously during a live Skype conference (see Figure 7.14).

Expert Tests

Only seldomly users performed expert tests around the column to investigate its technology. Expert tests included touching the screen, touching the audio speakers, lifting up a kid or things such as jackets or kick scooters. One user successfully tried to cheat the skeleton recognition and trigger the particle cloud by hiding behind an umbrella while running around the column (see Figure 7.14).

Figure 7.14: Specific behavioral patterns around the column.

Habits and Rituals

There were at least some recurring users coming to the building regularly such as university staff. Some of them developed habits and rituals when interacting with the column. For example, employees who brought their kids with them in the morning developed the ritual of letting their kids play with the column for several minutes before they continued to work. Some facility managers of the building also stopped and interacted shortly when they routinely passed by the column.

7.3.10 Subjective Data

User Experience

When we conducted the semi-structured interviews after the end of the study, passers-by were very cooperative when we asked them to participate (compare [Beyer 2013, P.8]): Of the 79 interviewees most were students (65) and university staff (12) from diverse disciplines. Their age ranged from 19 years to 66 years and the average age was 26. Almost no one of the interviewees had discovered the research character of the installation: when asked about the anticipated purpose of the column, the majority thought the purpose was entertainment of students, and some even suspected it was financed by tuition fees. When asking interviewees about attributes that would apply to the column using an open question, the majority described it between funny and entertaining, modern and technical (see Figure 7.15). Many interviewees even stated on their own initiative that interacting with the column and watching others was entertaining and they had enjoyed it, which also confirms our observations that people had fun with it.

Attributes of the Column			
16 Interesting	16 Modern	14 Funny	7 Colorful
6 Appealing	6 Large	5 Entertaining	5 Technical

Figure 7.15: Most frequent answers of users on attributes of the column (open question).

Noticing Interactivity

In regard to sensible subject areas such as noticing interactivity, we had put a lot of effort in avoiding context effects and desirability bias, e.g. by starting with open questions before gradually inquiring further (↺ Chapter 7.2.6). It turned out that 59 of the 79 interviewees (75%) had understood that the column was interactive and what they could do with it. Most of the remaining 20 interviewees who had recognized the column but not noticed its interactivity, had seen it only from a distant staircase or had been in a great hurry. Yet of the 59 interviewees who had understood interactivity most were able to describe the functionality of the column quite precisely. They had noticed the screen representation and the interactive elements such as the colored balls, were able to describe what they could do with them, and reported that it was funny to cooperate or compete with partners. Interviewees noticed that the skeleton representation was imitating their behavior. Most used the term stick-figure (63%) to describe it, and 8 surprisingly also used the term mirror, even if no mirror representation had been used.

Noticing the Frames

While interviewees could recall most of the interactive elements on the screen, surprisingly only one out of all 79 stated to have noticed the visual rectangles in the framed condition. Yet none of the others could remember them, even not the regularly recurring users and although it was the last condition that had been displayed right before the interview. To avoid context effects, we again had followed the method to first ask in an open question which elements had been displayed on the column, to then inquire again if there were further elements they may have forgotten to mention, before asking only in the last step directly whether they had noticed a gray rectangle or frame on the column. By explaining in detail what we meant by visual frames we made sure they were indeed not remembering them. However all but one could not recall their presence.

7.3.11 Add-on Study: The Graffiti Column

Research Question: Circulation around the Column

In contrast to the continuous circulation of users that we had observed around the column in the lab study using a movement-stimulating content (↺ Chapter 6), in this field study users surprisingly moved only little around the column while interacting with the interactive ball game. The differing movement behavior in both studies can either be explained by the different spatial conditions in the lab and in the field or by the role the interactive content plays in encouraging users to constantly move around columns or not. To test the latter, we added a one-day post study with another interactive content after the end of the main study.

Interactive Content: Drawing onto the Column Touchlessly

The new interactive content was an application where passers-by could – similar to the concept of graffiti spray paint – draw touchlessly colorful graffiti onto the column with the hand joints of their skeleton representation. The column showed a concrete wall as background and while people were spraying onto it the used spray colors changed every few seconds. The idea behind this content was that users might also move to other sides of the column while painting or once they had left one position fully painted. After some time of inactivity the graffiti slowly faded away to make room for new paintings. Also the skeletons of people who interacted unintentionally while passing by left spray paint on the column.

Video Analysis: Scoring Movement around the Column

In the video coding we recorded the circulation distance around the column in quarter steps from no to full circulation for each active user. For each of these events we further discriminated between two circulation types: we either scored if users were constantly moving while interacting or if they were just repositioning themselves to start anew on another side of the column. We further annotated the social constellation, i.e. if users were interacting alone, in pairs or groups.

<table>
<tr><th colspan="5">Circulation</th></tr>
<tr><td rowspan="2">None</td><td>Quarter</td><td>Half</td><td>Three-Quarter</td><td>Full</td></tr>
<tr><td colspan="2">Constant Movement</td><td colspan="2">Repositioning</td></tr>
</table>

Figure 7.16: Interacting users drawing onto the graffiti column using their hand joints.

Results: Circulation and Repositioning

During the one-day study 66 passers-by interacted with the column. Similar to the previous study users noticed interactivity quickly with the graffiti content and began immediately to use their screen representation to draw onto the column. Some users approached the column directly, while others again noticed the graffiti feedback only right when passing by, showing the typical surprise and orientation reactions. Before circulating the column, users usually interacted for a while. The video data revealed that a majority of 56% walked around the column, and 59% of them (33% of all users) moved constantly while interacting, while the remaining 41% only repositioned themselves to restart interaction on another side. This is in contrast to our observations in the preceding field study were no users circulated while interacting with balls. Yet users also did not continuously circulate around the graffiti column as in the lab study (↺ Chapter 6). Most moved little more than a quarter (26%) or a half orbit (21%) around the column, and only 6% circulated it completely (see Figure 7.17). No user circulated it multiple times. The longer three-quarter and full circulations always involved constant movement while interacting. If passers-by just repositioned to take several static positions, this was often connected with their natural walking path around the column.

Behaviors of Singles, Pairs and Groups

Longer circulations around half of the column or more were mostly performed by individuals and pairs. While active groups often dispersed around the column and thereby occupied large parts of the circular interaction space, only single members circulated the column constantly, not the group as a unit. Differently, with pairs often the second partner followed the forerunning one, taking either the same or the opposed direction such that partners met again on the other side. When drawing onto the column users often performed the *butterfly gesture*: they moved both arms symmetrically up and down to draw a butterfly onto the screen. Users also showed many behaviors that we already had seen in the previous field study such as waving hands, dancing, jumping, boxing or miming.

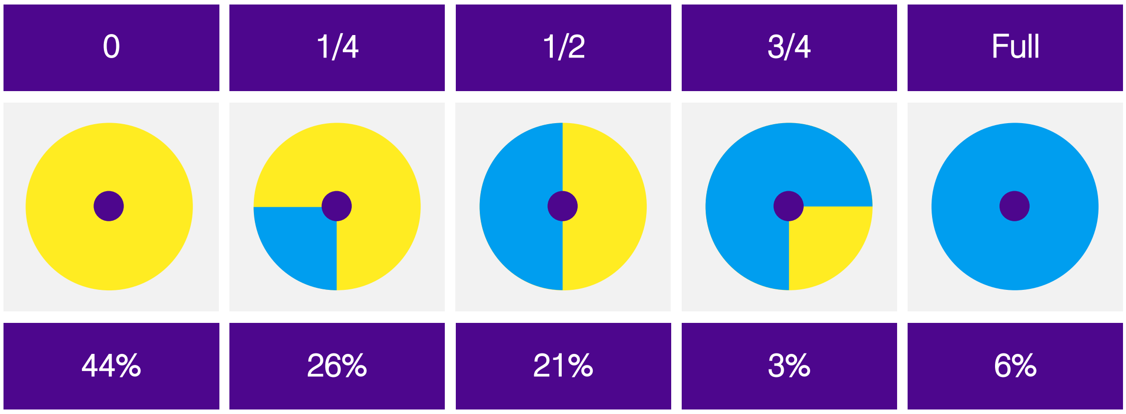


Figure 7.17: Share of the different circulation distances among all interacting users.

7.4 Interpretation

The eye-catching Interactive Column attracted the attention of passers-by early, and with increasing activity users dispersed around it, but did not question the added visual frames as positioning stimulus.

7.4.1 Observed Behaviors around the Column

Unaware Initial Interaction around a 360° Column Display

The Interactive Advertising Column was deployed freestanding and at a highly visible central location, as is typical for advertising columns. Due to its Prägnanz (↺ Chapter 3.1.2) and its position at the junction of the main walking trajectories within an entrance hall it attracted the attention of many passers-by early when they approached from the distance. Yet a deciding factor for how people noticed interactivity was to which of two characteristic groups they belonged: attentive or inattentive passers-by. As one approached nearly frontally from most directions, attentive passers-by could perceive the column for several seconds before standing in front of it. When they entered the interaction space, they immediately understood that the skeleton representation was mirroring their behavior and what they can do with it, as the observations and interviews revealed. When approaching frontally this way, difficult viewing angles were a minor issue even around the curved column screen. In contrast, inattentive passers-by reacted differently: they noticed the visual feedback only shortly before or right at the column when they where passing it tangentially. Torn out of their current activity and becoming aware of the correlation of the feedback with themselves, they showed surprise and orientation reactions or suddenly stopped at that moment.

▶ Highly visible columns can communicate interactivity effectively, but attentive and inattentive passers-by react quite differently.

Influence of Frames on User Positioning

In this field experiment we controlled framedness on a cylindrical display, while seamlessness remained constant. The statistical results from the video analysis confirm our field observations that there is a significant association between framedness and whether users assumed a central position: just adding visual frames to the seamless column attracted users to the center areas in front of the displayed frames. These findings comply with our prior findings in the lab study (↺ Chapter 6) that a single frame can influence where users position themselves. This field study adds to these insights by showing that also the visual structure of shapes that are more complex than a single rectangle such as polygonal displays can lead to the effect that users assume certain positions. In our case, users positioned themselves centrally in front of the eight rectangles around a simulated octagon when we switched on framedness. These results show, that in addition to the form factor also the framing of a display influences how people adjust in front of it, and that each factor should be taken into account separately.

> Frames influence user positioning, even around more complex display shapes with multiple frames such as polygonal displays.

Correlation with Interacting Users

The study further revealed that the central positioning correlates with an active user role: users repositioned themselves to the central areas as soon as they started to interact, while passive bystanders were not directly influenced by the frames. Yet the numbers also reveal a small reverse distribution for spectators, which according to our observations can be attributed to the fact that bystanders were often standing alongside their active, centrally standing partners and thus where in the framed condition a boundary was. Obviously, while watching the screen representation of their partner, they did not mind that their own skeleton was divided by this boundary. In contrast, the central positioning of interacting users may be explained by that users try to avoid that their screen representation is divided by visual frames in violation of the law of good gestalt, and instead show the ambition to keep their skeleton free by centering it (↺ Chapter 6.4.1).

> Central positioning correlates with the user role: interacting users try to avoid that their screen representation is divided by visual frames.

Uneven Positions around the Seamless Column

The statistical results showed that even around the column in the unframed condition users did not prefer all positions in equal manner and that there was a slight preference of the frame sections even if no frames were displayed. On the one hand, this may be explained by the fact that some walking paths within the entrance hall where the column was deployed overlapped by chance with the regions that were assigned to the central user positions respectively the frame centers. Another reason may be that the sensor coves, despite their unobtrusive design, were still salient enough to attract users towards frame positions. While this does not invalidate ours results, as we there was still a significant difference in user positions between the two tested framedness conditions, it shows that even with a completely seamless display there are further factors that influence user positioning and that in their entirety cannot be perfectly eliminated.

> In addition to frames also further factors such as walking paths and visible sensors might affect user positions around shaped displays.

Influence of Frames on User Cooperation

The pattern of central positioning in front of the frames repeated itself for single users, pairs and members of groups. Passers-by started to occupy the frame sections around our convexly curved column and accumulated towards their centers; this way the distance between users in neighboring sections increased. Using the terminology of [Fischer 2012, P.6], gap spaces between the users were created by the frames and thus by the system design itself. But framedness did not only invite users to step into the restricted areas aligned to the frame centers, the frames also kept users from leaving them. In contrast to the comfortable distances between users in the unframed condition, this caused conflicts when pairs were interacting in front of the same frame or cooperating with each other from neighboring frame centers: two partners in front of the same frame were interfering with each other, while the interaction between partners from the positions of two adjacent frames was restricted when they tried to interact with each other but also refused to step out of the invisible area in front of their frame.

> Frames can affect user cooperation and lead to conflicts by restricting the space or creating distance between users.

Blindness for the Frames

Most interesting is the result that interviewees did not recall the presence of the visual frames. This is consistent with our field observations that users ignored the rectangular frames when interacting and did not integrate them into their play, although they influenced their positioning behavior. One possible explanation is that users were unconsciously influenced by the gray rectangles (↺ Chapter 3.4). Due to prior experience users might have been thus used to the specific design that is typical for display frames, that they just might have recognized this scheme preattentively and independently from their selective attention which focused on the interactive stimuli. Still the visual frames provoked a conditioned reaction. Yet as we cannot assess people's subconscious at that moment, we cannot conclusively determine if the self-alignment to the rectangles happened unconsciously, or if users considered this as obvious and quickly forgot about it.

> Frame blindness where users did not recall the frames that affected their position may indicate an unconscious reaction to the frames.

User Distribution around the Column

The study showed that multiple users often dispersed around the column, depending on their activity and social interaction with each other. We observed the pattern that members of groups distributed around it with increasing activity: after watching initial users of the group for a while, they moved to free spaces around the column to also assume an active role. Finally users often covered the half or even the whole circular interaction space. This differs from observations of [TenKoppel 2012, P.7] with a hexagonal display that passers-by belonging to a group would not disperse to other screens for long but quickly return to the first actor. But in this case flat and angled and thus at least implicitly framed displays were used, and the different results might be explained by distance or gap spaces the sections of the polygonal display created between the players. While different deployment sites, walking paths and used contents of both displays are further possible explanations, also framedness and surface roughness (↺ Chapter 4) might account for the different results how people adjust around the displays.

> The distribution of users increases with their dwell-time and activity: users dispersed around the column to assume an active role.

Movement around the Column: Repositioning and Circulation

In each of the three studies with the Interactive Advertising Column we observed a partly different movement behavior of users. Two basic movement patterns can be distinguished: walking around the column with just the purpose to reposition oneself and continue interaction on another side of the screen, and constant circulation around the column while interacting with it. While the repositioning behavior could be observed within all studies, there were substantial differences in regard to the constant movement around the cylindrical screen: in the lab study users circulated continuously around the column (↺ Chapter 6), while in the first field study where the interactive ball game was displayed users moved only seldomly constantly around it, and in the second field study where the graffiti content was displayed users again circulated a little more around the column, but still less than in the lab study. While the differences between the lab and the field could also be explained by different spatial conditions, the two field studies with their different contents produced different movement behavior under the same external conditions. This indicates that cylindrical column shapes do not per se encourage constant movement around them while interacting, but that instead the key factor is a movement-stimulating content. The flower content used in the lab and the graffiti content that motivates users to discover the still unpainted sides of the column were more movement-stimulating than the interactive ball game, which works best when users interact in a frontal body position to the screen in which it is less comfortable to move around the column.

> The column shape potentially allows to circulate around the display, but if people really move around it depends on the specific content.

7.4.2 Limitations

Generalizability to other Display Shapes

In this field study we focused on isolating the framedness variable on the same seamless display, and thus the generalization of the results is limited in regard to other shapes of large displays. For example, while around our convexly curved column framedness created distance between users such that the cooperation between them from adjacent positions was restricted, this may be quite different in front of concavely curved or flat displays that are divided by multiple frames.

Generalizability to Polygonal Displays

In our study we simulated an octagon by just displaying eight visual frames on a seamless column and thus could not fully simulate a real polygonal display. Yet as we found that only displaying gray rectangles on the screen can already alter user behavior, polygonal displays with their angled flat faces and straight edges which create a visible rectangle and indicate a clear direction might even have a stronger effect on user positions than the visual frames in our experiment.

Possible Novelty Effects

At the time of the study, a large digital and interactive cylindrical column display that reacts to the movements of passers-by was still a quite uncommon thing. For this reason the novelty factor might have played a certain role in attracting the attention early and in enticing large numbers of users.

Role of the Interactive Content

As the different movement patterns across the studies with the column show, user behavior in front of the screen strongly depends on the interactive content. In the study which investigated framedness we used a skeleton representation and an interactive ball game which prefer a static and frontal positioning of users. A more movement-stimulating content like in the lab study might have counteracted the gravitational pull of the rectangular frames stronger.

Situative Limitations

During the field deployment the pattern that users noticed the column early and understood interactivity immediately prevailed. Yet it cannot be ruled out that some people had been enticed to visit the column by rumors and hearsay outside the building and thus already knew of its interactivity.

7.4.3 Open Issues

Summarizing the findings and limitations of the field studies with the Interactive Advertising Column, the following issues are left open at this point of research:

Other Curvatures
How do frames affect user behavior around other curved displays, e.g. concavely curved displays with overlapping frame regions?

Frame Blindness
Is the central positioning in front of frames really an unconscious reaction and can a detailed analysis of the viewing behavior reveal more here?

Frame Design
While the used design of the visual frames oriented itself by a classical screen format, can other sizes and ratios provoke similar effects?

Interactive Frames
If virtual frames performed well to draw users to a position, can frames also be employed dynamically and interactively to shape the audience?

Other Contents
Can other, for example strongly movement-stimulating interactive contents override the observed positioning effects and movement patterns?

7.5 Takeaways

Interactive Advertising Columns
are eye-catching displays that attract our attention early and provide space for many users, but added frames can affect user positioning and cooperation.

7.5.1 Recommendations for Columns

Column Displays and Attention

In this study the interactive column attracted attention early and communicated interactivity very effectively, also in comparison to the other studies in this work. Approaching passers-by often already reacted from the distance to the visual feedback, but even inattentive ones still noticed the column when walking by. The advantage of the cylindrical 360° display was that it covered all directions and that the concise shape was highly visible when located centrally and at the intersection of multiple walking paths. Thus if strong attention shall be generated in similar environments, columns should be used and be deployed centrally.

R 7.1 Use Columns and deploy them centrally to effectively attract Passer-by Attention

Most passers-by will notice the column display already from the distance.

Columns and Multi-User Interaction

The large circular interaction space around columns allows multiple users to interact with the screen simultaneously and from all sides. In the conducted study members of groups distributed around the column the more they got active themselves. Thus columns are ideal for multi-user interaction, yet certain display qualities like framedness can restrict cooperation between users.

R 7.2 Use Cylindrical Columns if Multiple Passers-by are supposed to Interact in Parallel with a Display

Users will disperse to the large interaction space with increasing activity.

Circulation around Columns

The different studies with the Interactive Advertising Column showed that users do not move constantly around cylindrical displays per se. While the column shape principally has the quality that one can walk around it, this indeed seems only to be the case if also the content encourages movement. If movement is wanted, thus a movement-stimulating interactive content should be used.

R 7.3 Use Contents that Stimulate Movement to Make Users Circulate Around The Column

Passers-by will not circulate around cylindrical displays with any content.

7.5.2 Seamless vs. Framed Displays

Effects of Framedness on User Positioning

The field study revealed that not only single display frames can influence user positioning, but also multiple frames around more complex display shapes such as cylindrical columns. It further showed that user positions between real round and seamless displays and polygonal ones can be significantly different. Thus the rough common form factor should not be considered in isolation, but also further display qualities such as framedness should be taken into account when designing for new display shapes and interpreting user behavior around them.

R 7.4 Do not only consider the Basic Shape in Isolation but also other Influencing Factors such as Framedness

Even around a cylindrical display frames can influence user positions.

When to Use or Avoid Frames

For positioning single or multiple users at certain positions in front of the display, for example to assign specific sections of a large display to individual users, frames are ideally suited. In our study already just the visual framing of a round column significantly influenced how users positioned around it, which shows that even virtual frames are effective to draw users to certain positions.

> **R 7.5 Positioning Users: Use Frames**
>
> For attracting users to certain positions in front of the display frames are ideally suited, even virtual ones.

If the content requires close-by cooperation between two users avoid frames. The study showed that partners were interfering with each other when a pair interacted in front of the same frame. But also the interaction between partners who tried to interact from the adjacent positions of two neighboring frames was restricted as they both refused to leave the area in front of the frames. Seamless displays which allow users to position themselves freely are more suitable here.

> **R 7.6 Close-By Interaction: Avoid Frames**
>
> For close-by interaction avoid frames as users will impede each other when interacting in front of the same frame or from two neighboring frames.

If a certain distance between users shall be achieved, for example to establish a specific user distance that the interactive content requires or to prevent that multiple users do impede each other, frames can both be useful or not. This depends among others on the curvature of the display, as convex framed displays will create gap spaces between users, while concave shapes will not.

> **R 7.7 Regulating Distance: Use or Avoid Frames**
>
> For regulating distance between users frames can be useful or not: this depends on how much distance is wanted and the form factor.

If the number of users around a display shall be maximized, avoid frames as they limit the available user positions. For example, the 8 frames around our simulated octagon in the study provide only 8 optimal positions for interaction.

R 7.8 Maximizing Users: Avoid Frames

For maximizing users, avoid frames as they limit the optimal positions for interaction around the display: n frames means n optimal positions.

Seamless vs. Polygonal Displays

When having the choice between a real seamless display and a framed display with the same basic form factor, consider that seamless displays are more flexible as they are leaving the option open to also use frames. In our study the used virtual frames were already very effective to draw users to certain positions.

R 7.9 Seamless Displays provide More Options

Seamless display are more flexible than configurations of multiple flat displays as they leave the option open to also use virtual frames.

7.5.3 Measuring Behavior

Exogenous Camera Perspectives

It is helpful to figure out the optimal camera perspectives for each study in advance. While centric perspectives can be useful if user trajectories or body orientations around a column have to be transcribed (↺ Chapter 6.5.4) we used exogenous camera perspectives to record the user behavior in this field study. The reason was that we wanted to observe how user positions and user actions correlate with the visual frames and the interactive feedback on the screen. Further we wanted to analyze individual user actions from different perspectives.

R 7.10 Use Exogenous Camera Perspectives to Analyze how User Actions correlate with Screen Effects

This way user positions can be correlated with visuals on the screen.

Video Coding with Virtual Grid Masks

Simplify the video coding by using a suitable grid mask for each task. Differently from the lab study with the column where we had used a square grid to analyze user trajectories, this time we used a radial grid mask to score the central and boundary user positions around the same column. This proved to be an effective method and made the work for the video raters much easier.

R 7.11 Use Virtual Grid Masks to facilitate the Scoring of User Positions within the Interaction Space

For scoring positions around a column, a radial grid mask can be used.

Sensor Logging

Automatize the filtering and analysis of sensor log data in advance to the study. In highly-frequented field environments huge amounts of data can accumulate that will only be evaluable if uninteresting values can be filtered out. For example, the log data we collected from the Kinect sensors in this study (↺ Chapter 7.2.6) included thousands of unaware or unintended interactions by non-involved passers-by, and it was difficult to impossible to correlate the interaction data with individuals and systematically filter out only the intended interactions afterwards.

R 7.12 Automatize the Filtering of Sensor Data

In field environments log data from interaction sensors will only be usable if the loads of unaware and unintended interactions can be filtered out.

CHAPTER 8

APPROACHING FRONTALLY

Attracting Attention and Communicating Interactivity when frontally approaching Flat Life-size Displays

8.1 Background

When passers-by are approaching frontally the narrow displays that are typically used have to communicate that they relate to the appearance or the nearing movement of passers-by on a very limited space.

8.1.1 Attracting Users when Approaching Frontally

Out-of-home displays are preferably installed such by display providers that they are oriented towards the viewing directions of passers-by. In walking situations the primary viewing directions correspond with the walking trajectories, so that flat displays on the pedestrian level are optimally installed along or at the end of these trajectories and in orthogonal orientation towards them (↺ Chapter 2). This has the advantage that when passers-by are approaching them frontally, notice chances and viewing durations are maximized compared to displays in parallel orientation. Yet not all visual feedbacks will communicate interactivity effectively in this frontal situation, and indeed they have to be specifically designed for it.

8.1.2 Unaware Initial Interaction with a Flat Life-size Display

In order to not block the way of passers-by who are approaching frontally, in freestanding locations mostly narrow portrait-ratio displays are used. This brings some challenges for communicating interactivity by an unaware initial interaction and designing visual feedback to the movements of passers-by: the changing distance cannot be translated as directly to the screen as the lateral position when passing sideways, and the limited horizontal space of narrow screens also restricts the use of eye-catching lateral animations. On the other hand the direct view towards the display makes feedback based on self-perception (↺ Chapter 3.3) very promising. We wanted to explore the effectiveness of such different visual feedbacks when people approach flat life-size displays frontally (see Figure 8.1).

Figure 8.1: If a display is approached frontally this requires suited visual feedback.

8.1.3 Questions and Issues

In regard to the performance of different visual feedbacks when passers-by are approaching frontally we were interested in how effectively they would attract attention, as well as how effectively they would communicate their interactivity. Not all visual contents may accomplish both defined goals equally well or at the same moment. While visual feedbacks based on self-perception such as mirror images and silhouettes seem promising in the frontal scenario, they constitute a quite specific solution leaving not much room for other content (↺ Chapter 3.3.2). For this reason we also wanted to find further feedback mechanisms which are equally effective in this frontal situation. While lateral movement will only be marginal when passers-by are approaching frontally, orthogonally deployed flat displays can use the constantly decreasing distance on a comparatively long approaching trajectory as input for the feedback. The question is now how such distance-controlled feedbacks can make the correlation to passer-by movement clear by suited visual effects. To compare the performance of different visual feedbacks, we first of all had to identify the initial phases of becoming aware of the display and noticing its interactivity as well as the respective user reactions. The main issues related to this research can be summarized as follows:

RQ

Q 8.1 Attracting Attention Frontally
How can narrow flat displays such as life-size displays attract the attention of passers-by when they are approaching frontally?

Q 8.2 Communicating Interactivity Frontally
How can narrow flat displays at the same time communicate interactivity effectively when passers-by are approaching frontally?

Q 8.3 Effectiveness of Self-Perception
How effectively do visual feedbacks based on self-perception such as mirror images communicate interactivity in the frontal situation?

Q 8.4 Distance-Controlled Visual Feedbacks
How effectively do visual feedbacks that use the decreasing distance of approaching passers-by as input communicate interactivity?

Q 8.5 Passer-by Awareness and Reactions
Which phases of becoming aware of the display and its interactivity can be distinguished and which reactions do passers-by show?

8.2 Field Studies

We conducted two field studies with two Interactive Life-size Displays
to explore the effectiveness of different visual feedback strategies when passers-by are approaching displays frontally.

8.2.1 Study Context

To explore how narrow interactive out-of-home displays can attract attention and communicate interactivity when passers-by are approaching frontally and to compare the effectiveness of different visual feedback strategies, two field studies were conducted with life-size displays which are typically used in this situation. Jens Fakesch carried out this research as part of his bachelor's thesis [Fakesch 2013]. He conducted the two field studies in December 2012 at the University of Munich: first an outdoor field study with an interactive door display, then a follow-up field study of one week length within a large entrance hall with the Interactive Life-size Display presented in Chapter 5.

FACTS

Idea	Attracting Users when Approaching a Display Frontally
Type	Observational Field Study
Directing	Jens Fakesch
Advising	Gilbert Beyer
Software	Open Lab Day and Christmas Contents [Fakesch 2013]
Date	3th December and 18th – 21st December 2012
Location	Amalienstr. 17 and Theresienstrasse 37, University of Munich
Prototypes	Interactive Life-size Display, Interactive Door Display
Publications	Bachelor's Thesis Jens Fakesch [Fakesch 2013]

8.2.2 Hypotheses and Assumptions

Noticing Interactivity when Approaching Frontally

This work assumed that narrow flat displays which are approached frontally can attract attention and communicate their interactivity best if the visual feedback makes use of the clear direction they indicate. Two visual feedback strategies are promising to be effective in this situation, feedback based on images of humans and distance-controlled feedback (compare [Fakesch 2013, P.5f]):

Self-Perception: Images of Oneself or of Others

The first category of suitable visual feedbacks when approaching frontally includes mirror images that rely on self-perception as soon as passers-by enter the sensor space (↺ Chapter 3.3). Another option is to shoot and display a photo every 5 seconds as long as a person is detected [Fakesch 2013, P.13]. Compared to realtime mirror images such 'freezed mirrors' have the advantage that a person can be seen on the screen at any time. The identified frontal feedback strategies that rely on self-perception or images of others can be summed-up as follows:

Images of Oneself or of Others		
Realtime Mirror	Augmented Mirror	Photo Mirror

Movement: Distance-Controlled Feedback

Distance-controlled feedback uses the movement towards the display when passers-by are nearing frontally to impact the color intensity, vertical position or size of visual stimuli [Fakesch 2013, P.7f]. Such visual feedbacks rely on attention cues such as physical intensity or looming (↺ Chapter 3.2). Passers-by can also be given the impression to walk through a 3D scene in first-person perspective when they are approaching [Fakesch 2013, P.12], thus amplifying the perception of optical flow. The distance-controlled feedbacks can be categorized as follows:

Distance-Controlled Visual Feedback			
Intensity	Position	Looming	Optical Flow

RW ↗

Studies with Portrait-shaped Displays

Most similar to the life-size displays which we used in this study are the four screen units of the Magical Mirrors display row which were installed behind the street windows of the SAP headquartes in Berlin [Michelis 2007]. Most other works on interactive public displays used smaller, standard-size portrait-ratio displays such as [Reitberger 2009] and [Müller 2012]. In order to display user representations of passers-by on preferably large displays, [Grace 2013] further used a landscape-shaped display and [Akpan 2013] a wide wall display.

Approaching Displays Frontally

The field studies presented in this chapter examine the common situation in public space when passers-by approach interactive displays frontally. In contrast, the life-size displays of the Magical Mirrors were installed along a typical sidewalk trajectory where passers-by passed sideways [Michelis 2009]. The displays of [Müller 2012] were located at a corner shop where they were not approached frontally. The displays by [Peltonen 2008] and [Grace 2013] were installed behind a shop window respectively within an indoor corridor and were also not located directly at the end of a frontal trajectory. In our field study [Beyer 2013], the centrally deployed Interactive Advertising Column was approached frontally and directly in the majority of cases (↺ Chapter 7.3.2).

Noticing Interactivity

In regard to attracting attention and understanding interactivity, [Michelis 2009] compares different conditions including mirror images and abstract visual effects, [Müller 2012] different mirror images and call-to-action, [Beyer 2013] and [Grace 2013] stick-figures, and [Beyer 2014] mirror images and different interactive illustrations. In this chapter we examine the effectivity of interactive mirror images, illustrated and abstract feedbacks when they are seen frontally.

Analyzing Passer-by Reactions

In regard to analyzing passer-by reactions, most studies simply count the number of interactions with the screen. [Grace 2013, P.4] recorded who faced the display for at least one second, and [Michelis 2009, P.137f] even kept count of single interaction phases such as subtle, direct and repeated interaction. In this work, we further break down the analysis to detailed initial phases such as attention, initial reactions to the feedback and explicit interaction.

8.3 Study 1: Door Display

The first study with a Door Display revealed several situational challenges that can occur if passers-by approach an interactive outdoor display frontally but need to directly pass through it.

8.3.1 Using a Front Door as Interactive Display

Outdoor Deployment and Hardware

In this first study exploring the reactions of passers-by to visual feedback when approaching frontally, we used a front door of a university building as interactive display (see Figure 8.2). The front door had the same size as the screen of the designed Interactive Life-size Display (↺ Chapter 5.3), but allowed us to conduct a field study within an outdoor environment during the harsh weather conditions in December. One specialty of this Interactive Door Display was that passers-by did not only approach it frontally, but also directly until they finally passed right through it. The walking trajectory towards the display was 30 meters long such that passers-by discovered it early. The display was realized with rear-projection from inside the building using the same opaque material as the life-size display, and the Kinect sensor was also integrated unobtrusively from inside the building.

Study Procedure

The field study was conducted in the evening hours during a public event, the institute's open lab day. Visitors of the event had to use the walking path towards the interactive door display which constituted the only access to the building, thus perceiving the interactive contents when approaching. When they opened the door to come inside, the rear-projection was automatically interrupted until it closed again to not dazzle them by the beamer light (↺ [Fakesch 2015, P.15f]).

8.3.2 Interactive Content

Visual Theme: Event Advertisement

To instantiate single study conditions for the defined variables and to ensure comparability, Jens Fakesch designed a constant visual theme such that all visual feedbacks used the same colors and graphical styles. According to the event taking place, all conditions represented interactive adverts for the open lab day and thus used visual elements relating to this topic. They further were equal in that they all ended with the animated text 'Welcome to the Open Lab Day'.

Single Visual Feedback Conditions

On the basis of this visual theme Jens designed 10 visual feedback conditions (see Figure 8.2). According to the identified attention cues for distance-controlled feedbacks (↺ Chapter 8.2.2), in the first condition the movement of approaching passers-by was translated such to the screen that the color intensity of the visual elements increased (intensity), in the second the same visuals increased in size (looming), and in the third they formed a circle and moved apart radially, thus giving the impression of walking through a tunnel (optical flow). In the fourth condition a status bar was moving upwards when people were coming closer (position), the fifth realized the optical flow by letting passers-by walk through a 3D scene in first-person perspective when approaching, and in the sixth the intensity (amount, size and speed) of particles increased. The visual feedbacks based on self-perception included a greenscreen image, a greenscreen image augmented with particles, and a static photo image of the area in front of the screen which was updated every 5 seconds as long as a person was detected. The non-interactive baseline just showed a classical static poster advertisement.

8.3.3 Data Collection

In this study the objective methods included field observation, video recordings and sensor logging, as well as semi-structured interviews for the subjective data. The videos were recorded from three different camera perspectives, two being targeted towards the direction from where passers-by were approaching and the third filming from the opposed direction to also capture the visual feedback on the screen. 24 interviews were conducted, but only inside the building after users had entered the door, to avoid that the interviewer himself would be an attractor.

Figure 8.2: Visual feedbacks when approaching the interactive door display frontally.

8.3.4 Preliminary Findings

Within the 3 hours and 20 minutes of analyzed video material 112 encounters of passers-by with the door display were counted, which included 62 (55%) singles, 36 (32%) pairs and 14 (13%) groups. Even slightly more people left the building during that period. Merely 13 feedback reactions such as people suddenly stopping, smiling or pointing to the display could be observed, and also only 16 entities (6 singles, 7 pairs and 3 groups) interacted actively with it by moving their arms or walking back and forth. We could trace this low engagement back to the harsh weather conditions on that winter evening (it was sleeting), but also discovered a design fault of the door display: people leaving the building did not only interfere with the visual projection when coming from inside, but many of them – now privy to the display's interactivity because of the interviewer on the stairwell – started to interact only now. In total 19 entities (7 singles, 8 pairs, and 4 groups) interacted after they had left the building, and as a result 10 singles, 5 pairs and 4 groups who were arriving became aware of the display by the honeypot effect and of its interactivity by proxy interaction (↺ Chapter 3.3.4), and not by themselves. We also observed that 6 people were distracted by looking down onto their smartphones when arriving, and that 3 took photos of the display. The interviews revealed that of the 24 interviewees 13 (54%) had noticed the screen when entering the building, 9 (37.5%) had understood that it somehow reacted to them, but only 3 had tried to interact explicitly and 2 recognized the distance control. We further observed that switching the single conditions all 60 seconds was too fast, such that many people had no chance to recognize the feedback.

8.4 Study 2: Entrance Hall

The second study with the Interactive Life-size Display was conducted within an indoor environment similar to a shopping mall, where passers-by approach the display frontally but can pass it at the side.

8.4.1 Study with an Interactive Life-size Display

Deployment within an Mall-like Environment

In the second study on exploring how passers-by notice visual feedback when approaching frontally, we used the Interactive Life-size Display (↺ Chapter 5.3). We deployed it within a main university building with a high passer-by frequency and a floor plan similar to a shopping mall with straight arcades and intersections. According to the typical deployment locations of flat portrait-ratio displays in shopping malls (↺ Chapter 2.3.3), we installed the life-size display in the middle of the hallway where passers-by approached the display frontally but could walk by on the left and right main trajectories if they did not stop to interact (see Figure 8.3). This way we could avoid many of the interferences experienced in the first study. The display was installed nearby an intersection and most passers-by did not discover it before coming around the corner so that the chance of noticing interactivity by seeing others interact from afar (proxy interaction) was minimized.

Study Procedure

The field study was conducted over four days in the week before christmas.The reactions of all visitors of the building that approached the display frontally from the three main trajectories during that time were analyzed, while people who approached in the reverse direction from behind the display were ignored. According to the finding of the first study that switching the contents every 60 seconds was too fast, the interval was extended to 5 minutes. Also in this study, Kinect and camera sensors were integrated unobtrusively to the environment.

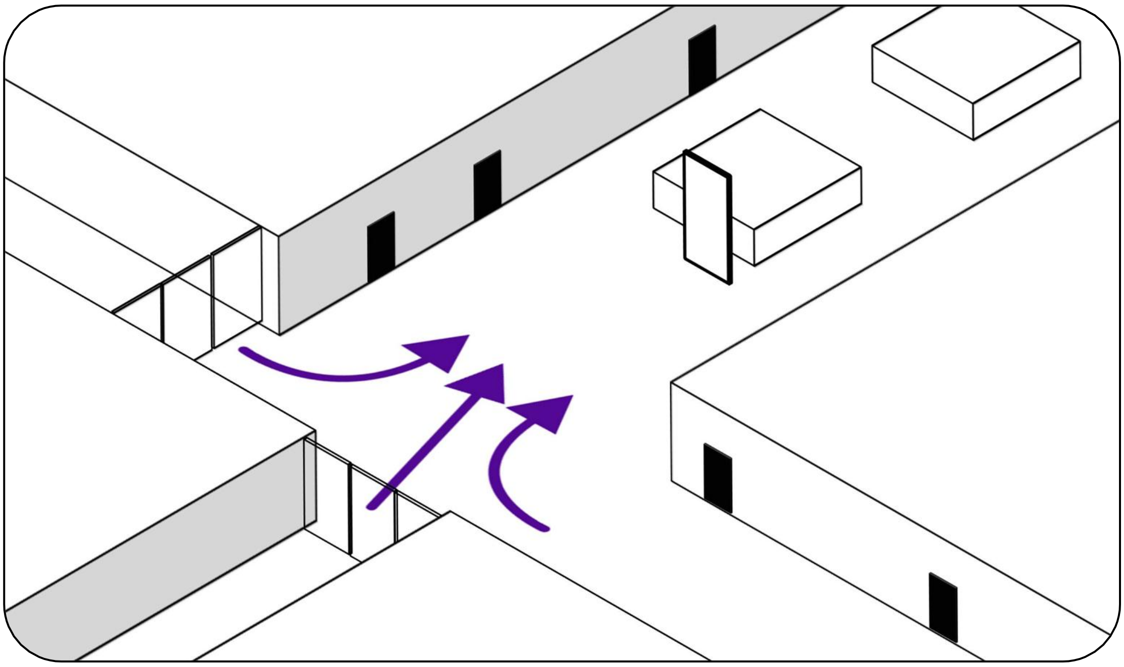


Figure 8.3: Deployment of the Interactive Life-size Display within a mall-like location.

8.4.2 Interactive Content

Visual Theme: Christmas Theme

The open lab day theme used in the first study was not relevant anymore, and as situation-related contents attract more attention and the second study was conducted in the week before Christmas, Jens Fakesch designed a Christmas theme with visual elements such as baubles, snowflakes and decorated trees to instantiate the same conditions as in the first study. The ending animation of all feedback conditions now displayed the same text 'Merry Christmas'.

Visual Feedbacks based on Self-Perception

On the basis of this new visual theme another 10 visual feedback conditions were designed which followed the same interaction principles as the contents of the first study (see Figure 8.4). The visual feedbacks based on self-perception again included realtime and static mirror images in live size, which were not controlled by distance but allow any action by the users: the greenscreen image (GS), the greenscreen image that was augmented with particles emerging at the user's hands (AS), and the photo image (PH) that freezed an image of the scene in front of the screen for the next 5 seconds as long as someone was detected within the sensor space. The non-interactive baseline (B) just showed a Christmas tree.

Figure 8.4: Visual feedback conditions: mirror feedbacks and distance-controlled feedbacks.

Distance-Controlled Visual Feedbacks

In the distance-controlled conditions the passer-by vertical movement was again translated to color intensity (IN), the looming stimuli size (SZ) and growing circle (CI), with the only difference that now visuals such as Christmas baubles were used. In the condition were the movement was translated to the vertical position (VE), instead of a status bar a Santa Claus was shown climbing a chimney. In the three-dimensional optical flow condition (FL) approaching passers-by could now trudge through the snow of a winter scenery in first-person perspective. The last visual feedback were the particles (PA) increasing in amount, size and speed.

8.4.3 Data Collection

Similar to the first study, data on passer-by reactions was again obtained by field observation, video recordings, sensor logging and semi-structured interviews:

Data Collection			
Field Observation	Video Recordings	Sensor Logging	Semi-Structured Interviews

One camera recorded passers-by reactions frontally from top of the display, and a second one from diagonally behind to capture the correlation of user actions and visual feedback. To avoid that the interviewer attracts attention, all interviews were conducted at a remote location with people who had already interacted.

8.4.4 Video Analysis: Attentional Reactions

Coding Scheme: Defining Subjects and Conditions

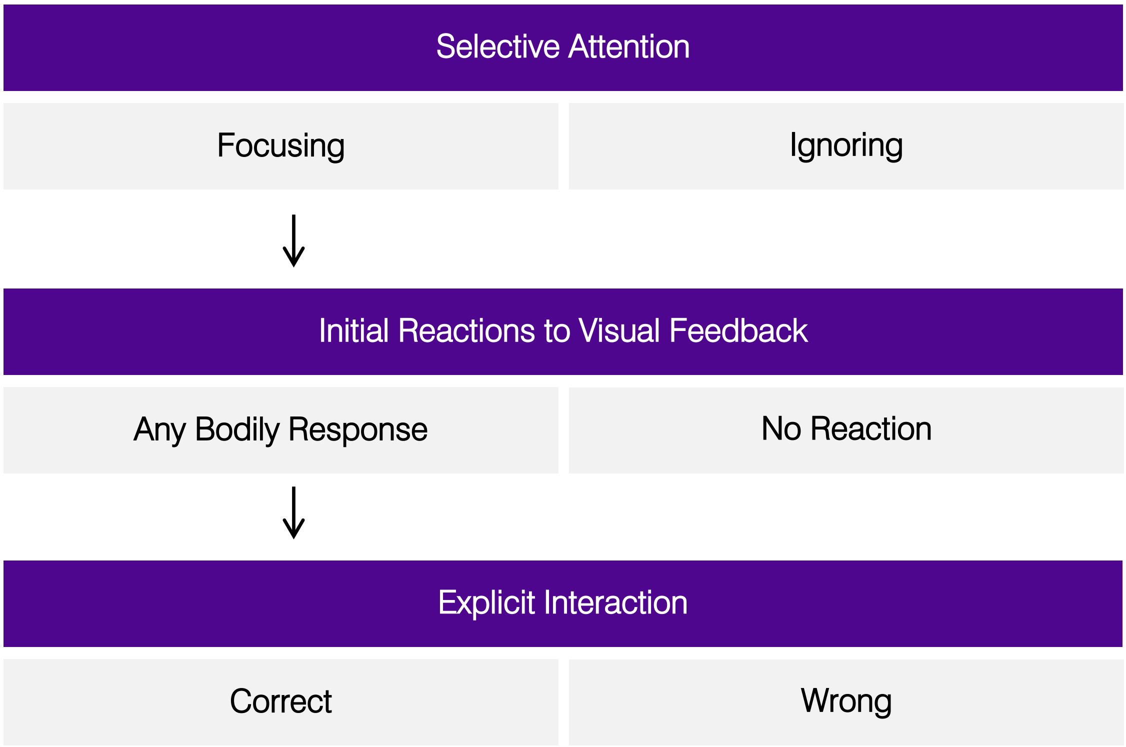
Of the four days of the field study, a sample of 17 hours of the video material was analyzed using *Noldus Observer*. In the coding scheme, not each passer-by was coded as a single person, as members of groups can also learn about interactivity from the reactions of the first active user instead of from the feedback. As this special case was not of interest, subjects were defined as singles, pairs and groups. To correlate passer-by reactions with the currently shown visual feedback, the changing conditions were also scored continuously.

Coding Scheme: Analyzing the Initial Reactions in Detail

To distinguish how effective the tested visual feedback conditions were in regard to different levels of attracting attention and communicating interactivity, a main objective was to identify the single stages of the initial reactions of passers-by such that they could be analyzed in detail. The distinguished stages of noticing the visual feedback (↺ Chapter 3.3.2) were attention, intentionality of controlling the feedback, and understanding of the interactive capabilities:

Attention	Awareness	Control	Understanding
Focusing	Aware	Intentional	Correct
Ignoring	Unaware	Unintentional	Wrong

Only conclusions on viewer awareness of interactivity could hardly be drawn from the video data, and required subjective measures such as interviews. Instead, selective attention could be easily identified by analysing passers'-by viewing behavior and bodily responses such as orientation and surprise reactions. Intentionality could be interpreted by looking at both passive reactions and explicit actions, and the understanding of the interaction by evaluating the success of all explicit actions, i.e. by looking at if mainly supported (correct) or unsupported (wrong) actions were performed. This resulted in combined behavioral states such as for example *focusing and unintentional* or *focusing and intentional and wrong*. To further compare the performance of the feedbacks, the durations of such single states and the time that had passed since entering the sensor space was kept. The analysis process can be simplified as follows:


Selective Attention
Focusing
Ignoring
Initial Reactions to Visual Feedback
Any Bodily Response
No Reaction
Explicit Interaction
Correct
Wrong

8.5 Study 2: Findings

The study showed that
mirror images, photos and visual feedbacks that correlate with passer-by movement are effective, but differently in attracting attention and communicating interactivity.

8.5.1 General Observations

Counted Passers-by

During the four days of deployment the entrance hall was highly frequented with passers-by and in this week before Christmas many people seemed to be in a rush. Within our sample of 17 hours of analyzed video material 434 encounters of passers-by with the Life-size Display were counted, which included 317 (73%) singles, 85 (20%) pairs and 32 (7%) groups of different sizes.

Initial Reactions to Visual Feedback

Passer-by reactions to the visual feedback usually could be clearly determined and included orientation and surprise reactions (indicated by sudden stopping or smiling) as well as adaptation of walking trajectories. Passers-by almost instantly looked at the screen and reacted within seconds to the visual feedback. We also observed a small number of recurring passers-by, who could be clearly identified as they were starting explicit interaction immediately. If passers-by ignored the display they were often in a rush, in deep conversation or thought.

Explicit and Correct Interaction

If passers-by had noticed interactivity they often engaged for several minutes and their progress on understanding the contents could be clearly determined. For example, if passers-by posed in front of the freezed photo image and waited for the next photo to be taken, or if they walked back and forth in front of the distance-controlled feedbacks, they had understood the respective principles.

Figure 8.5: The static photo, optical flow and the looming stimuli attracted the most attention.

8.5.2 Feedback Performance in Attracting Attention

Noticing the Screen

Out of the 434 passer-by entities who entered the interaction space, 235 (54%) focused their attention on the screen. The most effective feedbacks in attracting attention were the freezed photo image (PH) with 72% of passers-by looking at it and the optical flow (FL) where 71% noticed themselves walking in first-person view. The looming stimuli size (SZ) and circle (CI) were also more effective than average with 62% and 57%. All other feedbacks performed below-average. Even the real-time mirror conditions greenscreen (GS) and augmented greenscreen (AS) did not attract more attention than the non-interactive baseline (B).

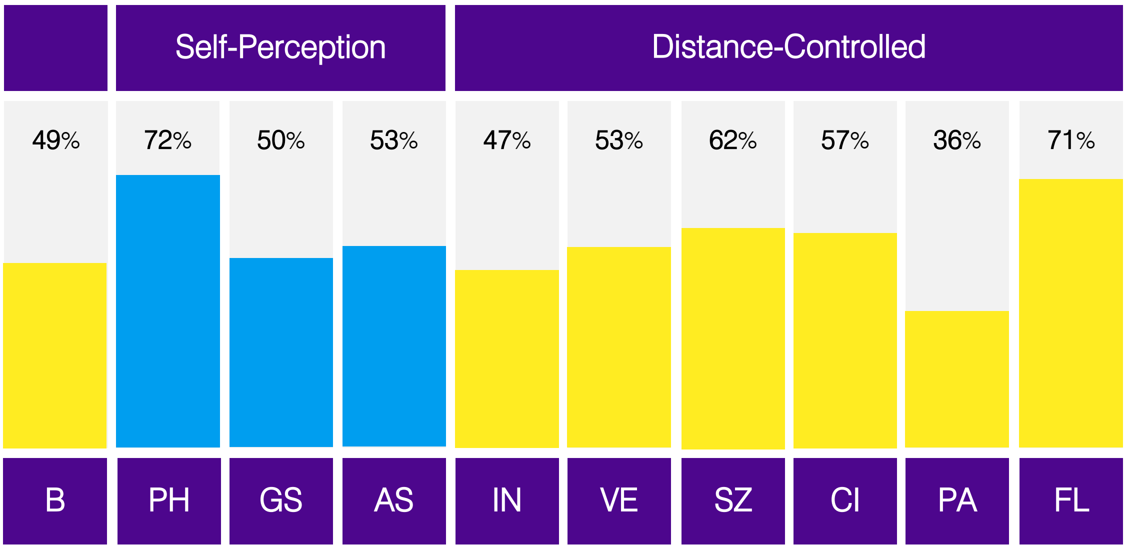


Figure 8.6: Attention performance of the different visual feedbacks when approaching frontally.

Durations until Attention

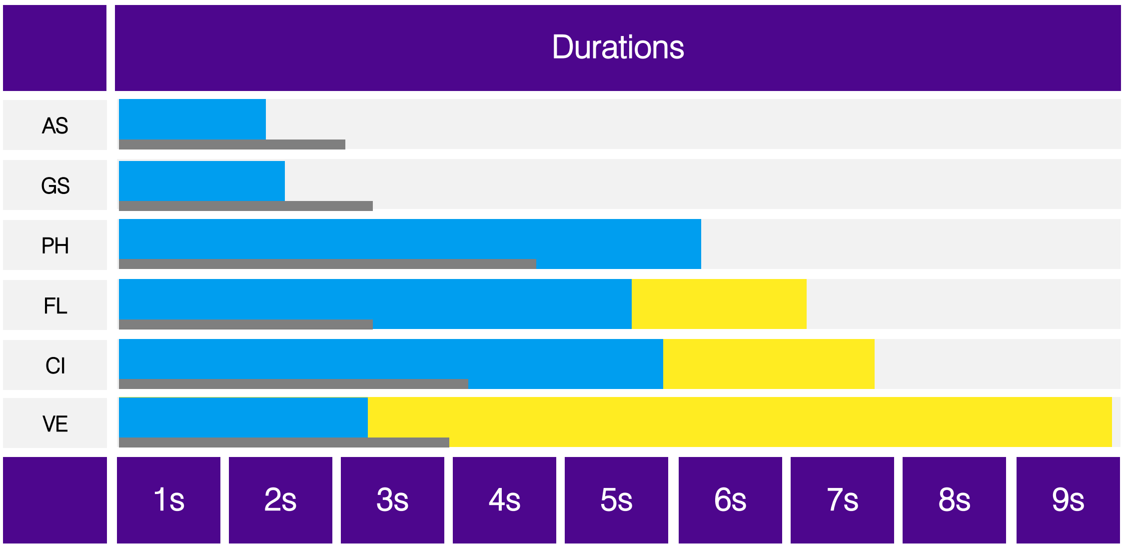
Passers-by looked quickly towards the screen: after entering the sensor space they interacted unintentionally with the display for on average only 1.3 seconds. This initial phase was nearly equally short for all feedback conditions (σ: 0.1s).

Figure 8.7: The realtime mirror images and the optical flow communicated interactivity best.

8.5.3 Feedback Performance in Communicating Interactivity

Durations of the Initial Interaction Phases

If passers-by had focused their attention on the visual feedback it lasted on average another 2.5 seconds before they showed any reaction, and this phase of unintentional interaction was also comparably short for all conditions (σ: 0.6s). In contrast to these initial reactions, the time it took viewers until they began to interact explicitly after entering the sensor space varied strongly between the single conditions, and the durations until they interacted correctly with the contents varied even more. The principle of the augmented mirror images was understood fastest. Figure 8.8 shows for the six most effective conditions the mean durations that viewers interacted unintentionally with the visual feedbacks after noticing the screen, as well as the time that elapsed after entering the sensor space until any explicit interaction and until any correct interaction.



8.8: Durations of unintentional (grey), time until any (blue) and any correct interaction (yellow).

Explicit Interaction with the Feedbacks

The best performance in communicating interactivity in general (i.e. that some kind of interactivity is available) was attained by the real-time mirror images and by the three-dimensional optical flow. Of all passers-by who initially noticed the screen, 43% interacted actively with the greenscreen, 44% with the augmented one, and 40% with the optical flow (see Figure 8.9, top values). Also a notable number of the initial viewers tried to interact with the vertical stimulus (29%), the color intensity (20%), the circle size and the photo (each 19%). The looming size of the stimulus and the particles enticed the fewest people to interact.

Correct Interaction with the Feedbacks

The feedback conditions that effectively signaled presence of interactivity at all often also performed well in communicating their actual interactive capabilities. This is of course trivial for real-time mirror images, as there is per se no wrong gesture and people can only interact in a correct way with them. Beyond the two greenscreen conditions, the best performance in communicating the correct way of interacting was attained by the three-dimensional optical flow. Of all people who had initially noticed the screen, finally 32% understood the principle of walking back and forth very well (see Figure 8.9, solid bars). The static photo and the vertical stimulus attained 19% and the growing circle 15%, while the rest performed low in communicating their actual interactive capabilities.

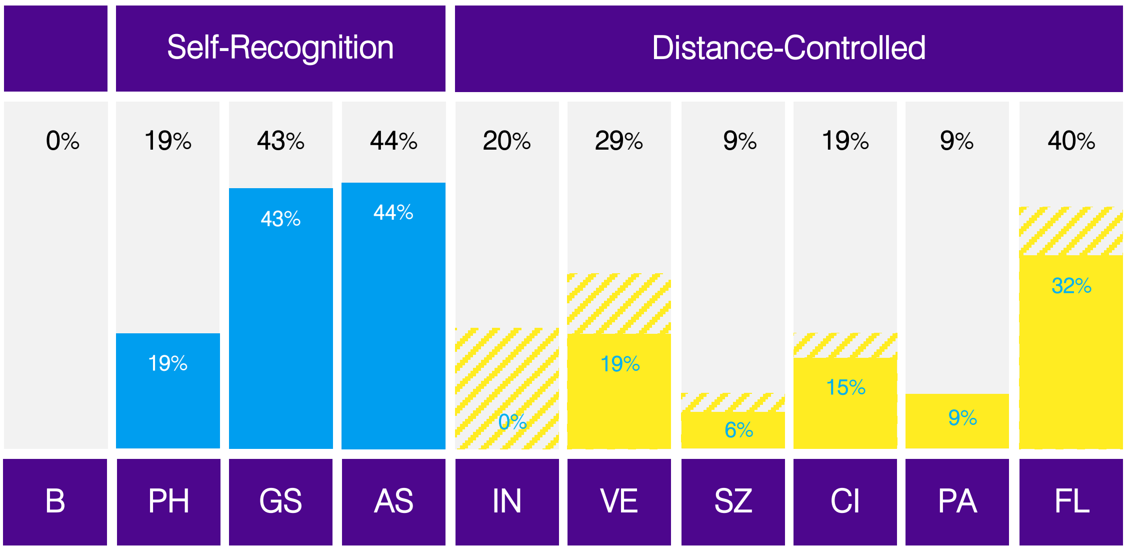


Figure 8.9: Share of viewers who interacted explicitly (top values) and correctly (solid bars).

Figure 8.10: Users interacting with the visual feedbacks after they noticed the interactivity.

8.5.4 Reactions of Singles, Pairs and Groups

Attention Performance

Of the 199 entities who ignored the display, 78% were singles 19% pairs and only 4% groups. Of the 235 who noticed it 69% were singles, 20% pairs and 11% groups. This shows that especially groups are more likely to notice the screen.

Noticing Interactivity

The size of an approaching group of passers-by seems also to influence how intensively users engage with the content and how well they understand its interactive capabilities. While singles represented the majority of passers-by who noticed the display, only 10% of them finally also interacted correctly with the content. Instead, despite their low overall share, 35% of pairs interacted correctly with the feedbacks, and of all groups who noticed the screen even 40% would end up with at least one member figuring out the interaction principle.

8.5.5 User Position in Front of the Life-size Display

When interacting with the interactive feedbacks, users mostly positioned themselves or moved within the limited central region defined by the horizontal width of the Life-size Display, similar to the observations made in Chapter 6.3.3. Both with the distance-controlled feedbacks and the mirror conditions users walked back and forth within this central corridor when interacting with the contents (see Figure 8.10). Multiple users either shared this narrow strip in front of the screen, or alternatively passive users waited at the side. When passers-by initially approached the display, they were at first often in a slightly diagonal body orientation as they headed for one of the trajectories going past the display at the side. As soon as they noticed interactivity, they adapted their walking path and walked up to the display now assuming a completely frontal body oriention.

8.5.6 Subjective Data: Noticing Interactivity

Moment of Noticing the Display

Out of 15 people that were interviewed, 8 (53%) came around the corner of the nearby intersection and began to approach the display frontally, 3 (20%) turned into the frontal trajectory after entering from the side entrance of that intersection, and another 3 approached the display directly from the opposing entrance. Except for two interviewees who had already noticed the display the day before, most stated that they had become aware of it when coming around the corner.

Moment of Noticing Interactivity

The interviews confirmed the findings from the video analysis that passers-by usually noticed the display's interactivity within seconds (↺ Chapter 8.5.3). As only passers-by were interviewed who had previously interacted with the display, all of them had noticed or learned about interactivity in some way. Out of the 15 interviewees, 7 (47%) stated that they had noticed the visual feedback right in the moment when they were approaching the display frontally, 3 (20%) when coming around the corner, and another 3 (20%) when they were passing the display.

Reasons for Noticing Interactivity

Discovering the images of persons or visual feedback to one's own movements were the two main reasons for noticing interactivity. When asked why they had become aware of interactivity, 7 (47%) of the interviewees stated that they had recognized a mirror image or photo of themselves or other people, and 5 (33%) stated that they had become aware of interactivity by the reactions the display gave to their body movements. Only one interviewee had learned about interactivity by hearsay, and another had seen people interacting the previous day (proxy interaction). Also only one interviewee had discovered and could identify the disguised Kinect sensor installed on top of the display.

User Experience

The interviews confirmed the observation that the display with its festive, situation-related contents was received positively by the audience and that passers-by had fun interacting with the contents. When asked for the assumed purpose of the display, 6 believed that it had been set up to provide fun and entertainment, and 3 that the property just wanted to wish the visitors a Merry Christmas. Further assumed purposes were advertising or visitor information.

8.6 Interpretation

Early visible and salient visuals
such as photos with key stimuli better attract attention, while mirror images and feedbacks that are based on mental models do better communicate interactivity.

8.6.1 Strong Attention Performance of Some Feedbacks

Good Perfomance of the Photo Condition: Images of Humans

Surprisingly, the static photo condition with 72% reactions performed best in attraction attention in the frontal situation, and in particular was considerably more effective than the two interactive feedbacks based on self-recognition, the greenscreen and the augmented greenscreen, with 50% and 53% of passers-by reacting (↺ Chapter 8.5.2). The reason for this may be that human perception does not only provide capable mechanisms for recognizing onself, but also for quickly recognizing other humans. While the photo images are neither physical intense nor dynamic, they show previous passers-by engaging playfully with the screen. Such images of humans and the involved faces, gestures and social interactions are key affective stimuli, triggering automatic reaction patterns (↺ Chapter 3.2.2). The shown social scene may also match with an internal schema image that is processed holistically and without mental effort before any details are decoded. The photo condition thus relies on basic mechanisms of the classic toolset of advertising to attract attention. In addition, the better performance in comparison to the mirror images may result from the fact that the static photo images can already be seen from the distance, while interactive mirror feedback cannot be perceived until passer-by have entered the sensor space in front of the display.

> Images of humans performed best as they are rapidly recognized affective stimuli and are also visible outside the sensor space.

Good Performance of Some Distance-Controlled Feedbacks

Of the distance-controlled feedbacks, the optical flow with 71% reactions performed just as well as the photo image and better than the mirror images in attracting attention. The looming stimuli size and circle size with 62% and 57% were also very effective, while color intensity and vertical motion performed low. When approaching frontally, there are two possible reasons for initially becoming aware of the screen: people are either attracted in the classical way by physical and emotional attributes of the visual contents, or surprised by an unaware initial interaction (↺ Chapter 3.3.2). We observed that frontally approaching passers-by mostly recognized the distance-controlled feedbacks, similar to the photo image, already before entering the sensor space. If they afterwards noticed interactivity by an unaware initial interaction, this led to further attention to the screen, but the initial attention was raised by the salience of the initial state and not interactivity. Thus the physically intense optical flow which used the common schema winter scenery was most effective, while contents which were too subtle were not.

> ▶ When approaching a display frontally, classical attraction cues can raise the initial attention before interactive feedback is triggered.

Overproportional Attention of Pairs and Groups

Similar to the prior field studies, fewer pairs and groups encountered the public display than single persons, but they disproportionately often noticed the display and with 35% and 40% correct interactions also understood its interactivity best. This is explained by the fact that in this scenario where passers-by approach the screen frontally successive groups and group members can see how other people walking in front of them interact, respectively how they unintentionally and possibly unawarely trigger the interactive feedback while striding through the sensor space (proxy interaction, ↺ Chapter 3.3.4). This means that while many contents of this study attracted attention early by classical attraction cues which are already visible before entering the sensor space, in the case of multiple approaching passers-by also the surprise over the observed unaware interaction respectively visual feedback of preceding people can be the triggering stimulus.

> ▶ When succeeding groups approach frontally, people become aware of the display and its interactivity by seeing others trigger feedback.

8.6.2 Feedbacks that Effectively Communicate Interactivity

Good Performance of Self-Recognition

While the static photo outperformed the interactive mirror feedbacks in attracting attention, the opposite was true when it comes to conveying interactivity: the greenscreen image and augmented greenscreen with 43% and 44% correct interactions were understood much better than the static photo with 19%, and with durations of 1.5 and 1.3 seconds until the first interaction also much faster than the 5.1 seconds it took to discover the photo funtionality. The reason for the fast comprehension of the realtime mirror images may be that when passers-by are approaching frontally such as in this study, both mechanisms for recognizing onself in a mirror, visual appearance matching and kinaesthetic-visual matching, can come fully into effect (↺ Chapter 3.3.5). This would be different if the display is approached from other angles. Even if the static photo depicted the surrounding space, it was not understood before it refreshed with a flash each 5 seconds.

> ▶ While mirror feedback atttracts attention less effectively than photos of humans, it conveys interactivity effectively when it is seen frontally.

Good Performance of the Optical Flow

The distance-controlled optical flow condition, which gave passers-by the illusion of striding through a three-dimensional scene in first-person view, did not only perform outstandingly in attracting attention, but also in conveying interactivity. With an average duration of 4.5 seconds until the first explicit and further 1.5 seconds until the first correct interaction, it was understood fastest among all distance-controlled feedbacks, and with 40% of attentive passers-by interacting (32% correctly) understood just as well as the mirror feedbacks (↺ Chapter 8.5.3). This condition may have been comprehended so well because it simulated the real optical flow which we perceive during locomotion in space and which is an integral part of visual kinesthesia [Gibson 1979]. Humans also have a mental model of striding through a corridor. If they notice that their own movement correlates with the reverse motion of a virtual corridor, they are caught by surprise.

> ▶ The optical flow builds upon basic mechanisms of spatial motion perception that can be easily recognized and be related to oneself.

Other Distance-Controlled Feedbacks

The other distance-controlled feedbacks performed low in conveying interactivity. Only few passers-by interacted correctly with the looming stimuli size and circle and it also took them long to discover the function principle of these feedbacks. The reason for this may be that the mode of action of looming stimuli is to startle viewers out of the corner of their eye [Schönhammer 2013, P.167]. But while this could not take effect in our case where frontally approaching passers-by often noticed the contents before they could trigger any feedback (↺ Chapter 8.6.1), such stimuli also do not correspond to any common mental model or functioning principle. The same applies to the feedbacks translating user movement to color intensity or particles, as such specific correlations have no analogy in real life and thus are hard to discover. At least the interactivity of the vertically moving stimulus was noticed by 29% and after 2.2 seconds, but also only 19% discovered the correlation to the user distance and did not interact correctly before 8.8 seconds.

> Distance-controlled feedbacks that did not rely on a common mental model usually performed low in communicating interactivity.

8.6.3 Summarizing the Conclusions

Both the visual feedbacks based on self-recognition and the distance-controlled feedbacks showed individual strengths and weaknesses in regard to attracting attention and conveying interactivity. In the tested situation where passers-by approach the display frontally and thus can already see it before they enter the sensor space and trigger feedback, the contents already attract attention by their visual salience. The static photo and the looming feedbacks performed well in attracting attention but low in conveying interactivity, while mirror images vice versa grabbed less than average attention but instead were understood effectively. This shows that feedback strategies can perform well in one task and at the same time low in another. The distance-controlled optical flow performed well in both tasks und thus is a potential alternative to classical mirror feedback.

> Feedback strategies have their assets and drawbacks and can be differently effective in attracting attention and conveying interactivity.

8.6.4 Open Issues

Summarizing the findings of the field studies with the Interactive Life-size Display and the Door Display, the following issues are left open at this point of research:

Other Installation Sites
How can portrait-ratio displays effectively attract attention and convey interactivity if they are approached from other angles or seen from afar?

Frontal Display Rows
How can effective visual feedback be designed for frontal display rows where the single screen units are deployed one after another?

Distance-Controlled Feedback
How can long-range distance-controlled feedback be provided to multiple passers-by walking at different distances at the same time?

Mental Models
Which other mental models can be used as visual feedback that effectively conveys interactivity when approaching displays frontally?

Combining the Advantages
How can visual feedbacks that better attract attention be effectively combined with such ones that better communicate interactivity?

8.7 Takeaways

Interactive Life-size Displays
are suited for visual feedbacks that work when approaching frontally, but most do not perform equally well in attracting attention and conveying interactivity.

8.7.1 Recommendations for Life-size Displays

Approaching Displays Frontally and Directly

In the first study with the frontally approached door display, people coming from behind the display interrupted the interaction process on the front side when passing through the door. Even if a frontally oriented display is not passed through directly such as in the second study, people coming from the opposite direction still cause more interferences with the front side as compared to lateral displays where people interact at the side. Further, the narrow interaction space of frontal displays encourages crowding, honeypot effects and proxy interaction.

R 8.1 Consider Interferences if People can Approach the Display frontally and also from both Sides.

People coming from the other side can interfere with the interation process.

Initial Interaction and Sensor Space

When a display is approached frontally, it often can already be seen from afar. This can affect the process of the unaware initial interaction with the display, if passers-by notice salient contents long before they enter the limited range (in our case 4 meters) of the sensor space and thus before visual feedback can be triggered. This is another difference compared to lateral displays, where people discover the screen and the visual feedback late when passing by sideways.

R 8.2 Consider the Limited Range of the Sensor Space in front of Frontally Approached Displays

Passers-by can notice the content before visual feedback is triggered.

Content Loop

In the first study, the single conditions switched every 60 seconds which was too fast: some approaching passers-by had no chance to discover that the content reacts to them when the condition suddenly changed. This also compounded the analysis as no clear statement could be made for what reason a person reacted. This finding is also relevant for other types of displays, but especially for frontally approached ones as they are observed longest by arriving passers-by.

R 8.3 In Case of a Content Loop Avoid Switching the Single Conditions Too Fast

Otherwise many passers-by will not recognize the visual feedback.

8.7.2 Designing for Attention vs. Understanding Interactivity

Strengths and Weaknesses of Interactive Feedbacks

The second field study revealed that most of the tested feedbacks have their strong and weak points and are differently effective in attracting attention and conveying interactivity, such as the photo condition or the looming feedbacks which performed stronger in attracting attention or the mirror images which performed stronger in conveying interactivity. For this reason, visual feedbacks should be tested for their individual strengths and weaknesses first and then be chosen according to the current situation, display site and content requirements.

R 8.4 Test Interactive Feedbacks for how they Perform in Attracting Attention and Conveying Interactivity

Most contents may not perform equally well in both domains.

8.7.3 Designing Initial Feedback when Approaching Frontally

Static Photos as Strong Attractor

We found out that in the frontal situation, the photo condition did attract much more attention than the mirror feedbacks and most of the distance-controlled feedbacks, as images of humans are strong affective stimuli and can already be seen from afar. This is why smooth photographs of humans are one of the most commonly used image motifs in classical advertising. Yet as the interactive photo was not very effective in conveying interactivity, it may be combined with further feedbacks which are more effective once people enter the sensor space.

R 8.5 Use Static or Moving Images of Humans if a Strong Attractor is Needed

They can be seen even before people are entering the sensor space.

Mental Models as Effective Alternatives to Mirror Images

As the distance-controlled optical flow condition performed almost as well as the mirror feedbacks in conveying interactivity and even outperformed them when it comes to attracting attention, it constitutes an effective alternative in the frontal situation. The good performance of the optical flow can be explained by the fact that it, in contrast to other distance-controlled feedbacks, relies on widespread and deeply ingrained mental models and perceptual mechanisms.

R 8.6 Use Feedbacks that follow a Clear Mental Model

Otherwise particularly distance-controlled visual feedbacks might not be able to convey interactivity effectively.

Intensity of Feedback

Some feebacks were not physically intense and distinguishable enough, such as the condition which translated the movement of approaching passers-by to color intensity. As it did not only lack a mental model but also was too subtle due to the absence of movement, no passer-by found out the correct way to interact.

R 8.7 Avoid Too Subtle Feedback

If the visual changes are not discernible enough, people will not be able to link the reaction on the screen to their own movement.

8.7.4 Measuring Behavior

Camera Setup

In this scenario where users are approaching frontally, basically only two camera perspectives are required: one camera that is directed right towards the approaching passers-by from the top position of the display in order to record the viewing behavior as well as all bodily responses such as orientation and surprise reactions, and a second one in front of the display that captures the screen and users diagonally from behind and thus keeps track of the correlation of user actions and visual feedback, as well as the user distance to the screen. Further, as described above, contents should not be switched too fast, such that usable conclusions on user reactions can be made in the video analysis.

R 8.8 Use Suited Camera Perspectives

In the frontal situation, it needs one camera for passers'-by reactions, and another for correlating user actions and the visual feedback on the screen.

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CHAPTER 9

PASSING BY SIDEWAYS

Attracting Attention and Communicating Interactivity when passing by long Interactive Banner Displays

9.1 Background

When passers-by are passing by sideways the challenge for attracting attention and conveying interactivity is that the display and its content are at first only perceived in the periphery.

9.1.1 Attracting Users when Passing By Sideways

The most common way people encounter advertising displays on city sidewalks is sideways: the screens are installed behind shop windows or building façades in parallel orientation towards the walking trajectory (↺ Chapter 2.3). When walking along streets, passers-by largely look towards the movement direction, but they also scan the environment for salient stimuli and their viewing direction can be determined by social interaction or mobile screens (↺ Chapter 3.1). Thus, a major challenge is how their attention can be attracted and interactivity be conveyed at such typical sidewalk trajectories where the display appears at an angle of 90°.

9.1.2 Unaware Initial Interaction along a Long Banner Display

When people are passing by sideways this way, visual feedbacks that work well when approaching frontally may not be effective when perceived in the periphery and thus cannot be simply transferred to such sidewalk situations. Instead, to make people turn their heads away from their movement direction to become aware of the screen at 90° and surprise them by an unaware initial interaction, an effective combination of both a suited display and visual feedback is required. We had developed the Interactive Banner Display with a long continuous surface to expose passers-by as long as possible to visual feedback and to avoid the disruptions of display rows that make it difficult to understand the correlation with one's movement (↺ Chapter 5.4). Now we wanted to explore which visual feedbacks are effective with such long displays in sideways orientation (see Figure 9.1).

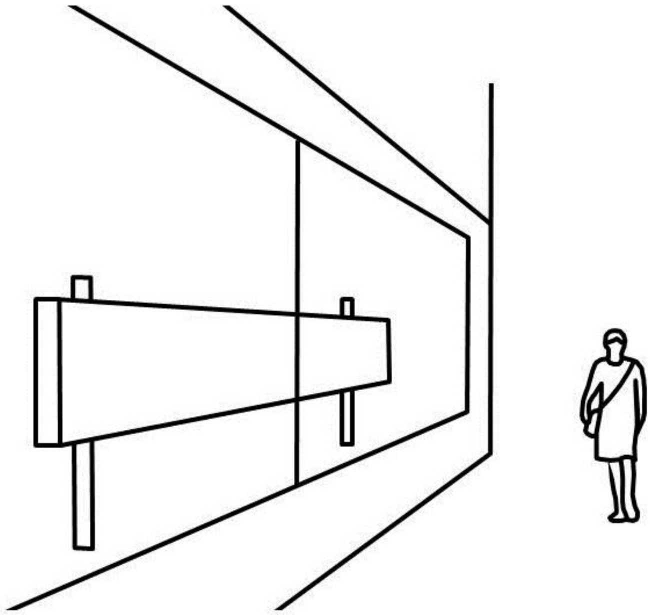


Figure 9.1: If a public display is passed sideways it has to attract passers-by at an angle of 90°.

9.1.3 Questions and Issues

Consequently, the most generic question of this research was how do visual feedbacks have to be designed to attract attention and convey interactivity on such long displays which are parallel to sidewalk trajectories, and how can interactive strategies for displaying them achieve that passers-by who are passing by sideways notice them in the periphery and turn their glance towards them for a more detailed inspection (↺ Chapter 3.1). In detail, we wanted to know which positions and movement strategies for displaying the visual stimuli would facilitate the recognition and understanding of the interactive feedback. For example, stimuli which are displayed parallel to passers-by at an angle of 90° may be hard to perceive, while positions ahead of them are closer to the line of sight and thus may be more noticeable. Further, the movement of visual stimuli in relation to passers-by may play a role in how effectively they understand the correlation with their own movement when walking by. In addition, different visual representations such as mirror images or more abstract, stylized or illustrated stimuli may be differently effective when perceived in the periphery or from a slanted angle. Finally, a basic question at the very beginning was where, in practice, passers-by would generally look at in typical sidewalk situations.

RQ

Q 9.1 Attracting Attention Sideways
How can long displays attract the attention of passers-by when they are passing by sideways and the display appears at an angle of 90°?

Q 9.2 Communicating Interactivity Sideways
How can long displays convey their interactivity when people are passing by sideways, and which reactions do people show when they notice it?

Q 9.3 Positions and Movement of Visual Feedback
Where on a long sideways display should visual feedback be displayed and how should it move such that people notice and understand it?

Q 9.4 Effective Visual Feedback Representations
Which visual feedbacks such as mirror images or more abstract stimuli are effective when being perceived in the periphery?

Q 9.5 Passer-by Visual Attention
Where do passers-by generally look at when walking along sidewalks and how does this affect how people notice interactive displays at the side?

9.2 Field Study

We conducted a field study with the Interactive Banner Display
to explore the effectiveness of different strategies for displaying visual feedback when passers-by are passing by sideways.

9.2.1 Study Context

To explore how long continuous interactive out-of-home displays can attract attention and communicate their interactivity when passers-by are passing by sideways and to compare the effectiveness of different visual feedback strategies, a field study was carried out. Nina Jäger carried out this research as part of her bachelor's thesis [Jäger 2013]. The research work began in autumn 2012, and Nina conducted the outdoor field study of six weeks length discussed below in early 2013 with the Interactive Banner Display presented in Chapter 5. Partial results of this field study have been published at the DIS 2014 conference under the title *The Puppeteer Display: Attracting and Actively Shaping the Audience with an Interactive Public Banner Display* [Beyer 2014].

FACTS

Idea	Attracting Users with a Long Banner Display when Passing by Sideways
Type	Observational Field Study
Directing	Nina Jäger
Advising	Gilbert Beyer
Software	Underwater World [Jäger 2013]
Date	March 2013–April 2013
Location	Street Window, Amalienstr. 17, University of Munich
Prototype	Interactive Banner Display
Publications	Bachelor's Thesis Nina Jäger [Jäger 2013], DIS 2014 Conference [Beyer 2014]

9.2.2 Hypotheses and Assumptions

Noticing Interactivity when Passing by Long Displays

Implicitly assuming that the Interactive Banner Display would be long enough to make people react and stop before they had passed it completely (↺ Chapter 5.4), in regard to potential screen contents we hypothesized first of all that providing interactivity or reactivity in the form of visual feedback to passers'-by movements when they are passing by sideways would attract more of their attention than just displaying non-interactive visual stimuli without any relation to passers-by.

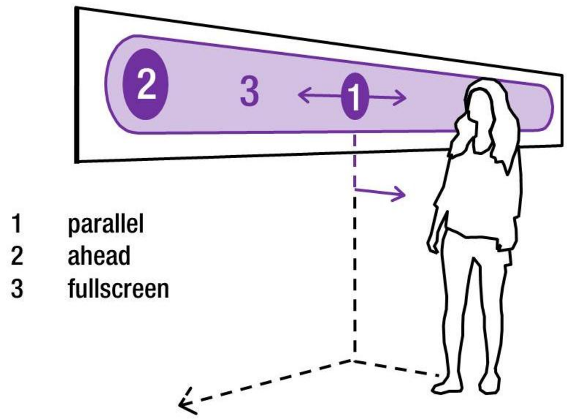


Figure 9.2: Positions and directions of visual feedback when people are passing by sideways.

Position and Direction of Visual Feedback

We further assumed that the position and direction of displayed visual feedback would affect the performance of the unaware intial interaction (see Figure 9.2): First, in regard to the horizontal position on the screen we hypothesized that visual feedback which is displayed running ahead in front of passers-by or fullscreen at any horizontal position might be more effective than feedback that is displayed parallel to passers-by at an angle of 90°, as this region is at best only perceived in the far peripheral field when looking in walking direction. Second, the direction of movement of visual feedback may be a relevant factor in signaling passers-by the correlation with their own movement. Here the visual stimuli may either continuously follow passers-by at their walking speed, or vice versa move at the same speed in the reversed direction, thus doubling the perceived speed of the optical flow. A third option would be that the visual feedback emerges orthogonally to passers-by as looming stimuli, thus provoking startle or defense reactions to a perceived possible threat (↺ Chapter 3.2.2).

Interactivity	
Non-interactive	Reactive

Position		
Parallel	Ahead	Fullscreen

Direction		
Aligned	Reversed	Looming

Representation	
Mirror Image	Foreign Being

Effective Visual Feedback Representations

Finally, the used visual representation or effect may also influence how effectively visual feedback is noticed in the periphery and understood as such. In practice the used visual stimuli will be strongly content-dependent and there are infinite possibilities for visual feedback designs which can attract passer-by attention by multiple factors such as their salient size, shape, color, animation or emotional or surprising image schema (↺ Chapter 3.2.2), which cannot be explored in a single study. In this study we focused on differences between mirror and silhouette representations and, from a perspective of content and screen design, more flexibly applicable graphical illustrations of foreign beings that react to passer-by movement. This comparison is especially interesting as with mirror images which show people from the side when they are passing by sideways the mechanism of self-recognition (↺ Chapter 3.3.2) may not be effective in the beginning, different from frontally deployed mirrors where one recognizes oneself easily. Moreover, mirror images which are displayed parallel to passers-by are also only perceived in the periphery. Thus we also hypothesized that the salience of the stimuli may be a more important factor for initially noticing visual feedback in the periphery.

RW ↗

Studies with Long Sidewalk Displays

The Magical Mirrors [Michelis 2009], a row of four displays deployed along a sidewalk trajectory, cover a large distance when people are passing by, but also involve disruptions between the single units (↺ Chapter 3.3.7). This is why we developed the long continuous display used in this study (↺ Chapter 5.4). Similar wide or long screens are the City Wall [Peltonen 2008], the Climate Wall [Dalsgaard 2010], the display by [Grace 2013] and the wall display by [Schmidt 2013], of which only the Climate Wall was deployed at a comparable street sidewalk.

Noticing Interactivity

In regard to surprising passers-by by interactive feedback in the sense of an unaware initial interaction when passings by sideways, [Michelis 2009, P.161] describes that people stopped in surprise when they noticed the reaction of the interactive effects to their own movement and the representation of their mirror image, but ignored the first display when passing by and stopped only at the second or third screen to start interaction. This observation is confirmed by [Müller 2012, P.8] with two consecutive displays at a sidewalk. In our study with the column [Beyer 2013] many people approached frontally and noticed interactivity before they arrived, but inattentive ones also reacted late, shortly before the column or when passing it tangentially (↺ Chapter 7.3.2).

Analyzing Passer-by Reactions

In regard to the quantitative analysis of passers-by reactions to the display, most studies count the number of interactions with the screen. [Grace 2013, P.5] additionally recorded who faced the display for at least one second, and [Michelis 2009, P.137f] even kept count of single interaction phases such as subtle, direct and repeated interaction of passers-by with the screen.

Attention towards the Periphery

When passing by shop window displays sideways, peripheral attention is a more important issue than with frontal or diagonal approaching trajectories towards public displays. Peripheral awareness is discussed in the context of a waiting zone environment in [Brignull 2009] and in regard to interaction phases in [Vogel 2004]. In a field study, [Schmidt 2013] explore how a public display which is oriented sideways can enable more comfortable reading, if the content is rotated, translated or zoomed when people are walking by.

9.2.3 Interactive Content

Visual Theme: Underwater World

To instantiate different study conditions for all defined variables and to allow comparisons, Nina Jäger designed an Underwater World theme (see Figure 9.3). All visual stimuli were part of this visual theme which involved various types of fish, and used constant colors and graphical styles to ensure comparability. Graphically they where designed in a concise and recognizable way suitable for an outdoor advertisement. As not all kinds of contents are suitable for a long banner display, choosing the Underwater World as basic theme had several advantages in regard to the design requirements and the validity of the study:

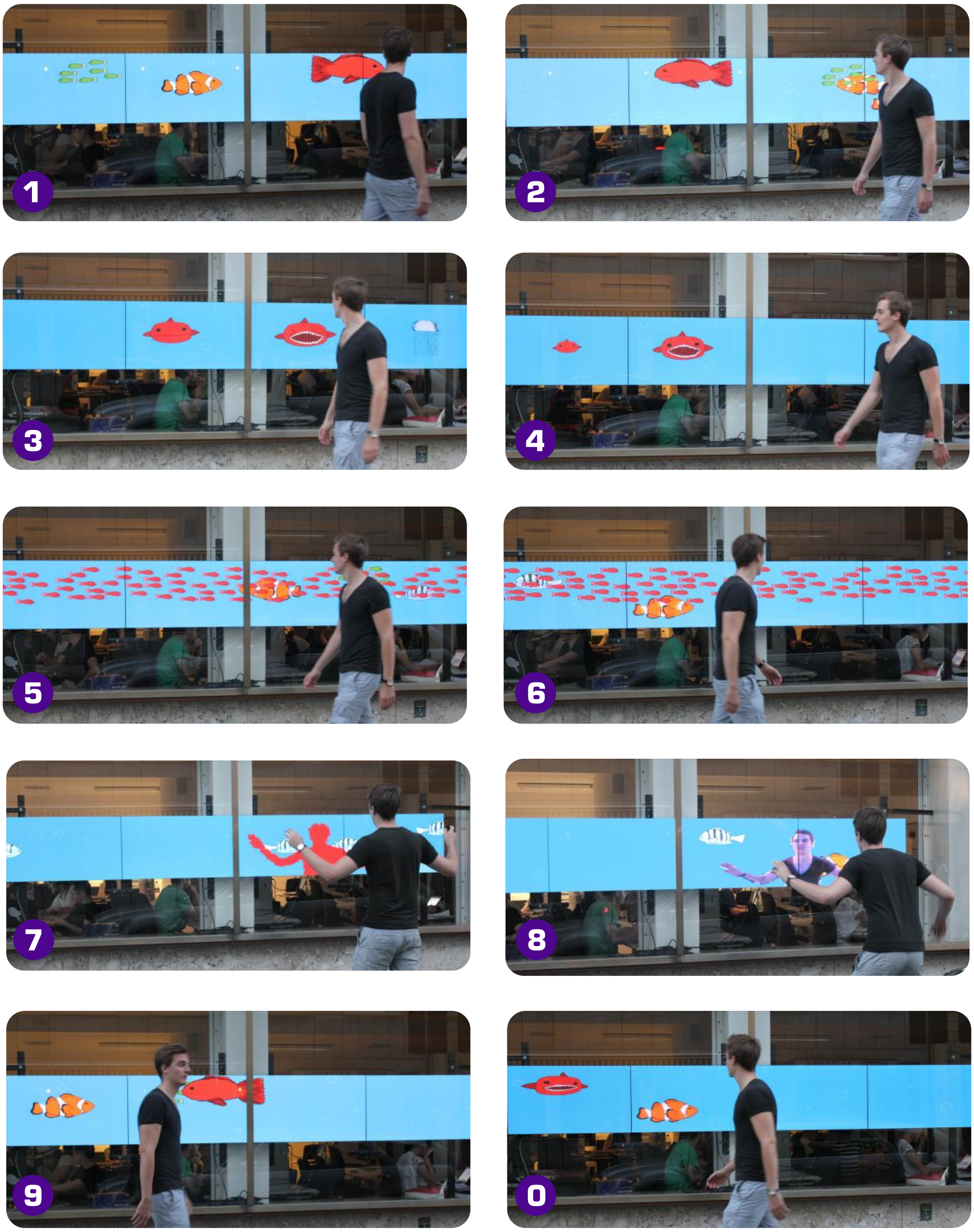
Requirements for the Visual Theme			
Comparability	Flexibility	Generalizability	Extensibility
Understandability	Compatibility	Reasonableness	Identifiability

From a study design perspective, the used fish stimuli provide a constant basis for comparisons (comparability), swimming fish can be designed in numerous variations and allow to implement the variables interactivity, position and direction (flexibility), and this theme is generalizable and extensible to other contents such as other animals or products (generalizability and extensibility). From a user design perspective, fish constitute a non-abstract visual metaphor which viewers can easily understand (understandability), they can be displayed and animated on the used long screen format (compatibility), and other than for example mirror images fish representations also make sense for viewers when they perceive them ahead of their own position, from the side or even fullscreen as a school of fish (reasonableness). Further, viewers can distinguish and later identify differently designed fish which allows to ask them about interactivity and their perception of individual design elements in post-hoc qualitative interviews (identifiability). Besides, the fish had also a building-related semantic meaning, which was of course not evident to the arbitrary public audience: before we had installed the banner display, the people working behind the large street window were often compared to fish in a fish tank by passers-by (↺ [Jäger 2013, P.13]).

Figure 9.3: The Underwater World theme with interactive fish as visual feedback to passers-by.

Single Visual Feedback Conditions

On the basis of this visual theme the single visual feedback conditions were designed (see Figure 9.4). In regard to the position variable, in the *Parallel Stimulus* condition a red fish was displayed parallel to passers-by at an angle of 90° such that it would be perceived in the far peripheral field when looking in walking direction. In the *Advanced Stimulus* condition the same fish was displayed at a position 1 meter ahead of the user, since people passed the display at about this distance such that the running-ahead stimulus would be perceived at an angle of 45° or in the mid-peripheral field when looking straight forward. If people changed direction, this stimulus also turned and smoothly catched up to their position. The *Fullscreen* condition was a school of red fish which also followed passers-by at walking speed but was displayed at any position on the screen. To test the influence of the stimulus direction, in another condition this school of fish moved in reverse direction, and in a *Looming* condition biting fish attacked people from the side. While the fish represented foreign beings, we also tested mirror images and silhouettes to investigate the performance of self-recognition in this sideways situation. We refrained from testing unpractical combinations of variables such as different positions or directions of mirror images. We also tested a *Rotated Stimulus* where a fish gazed at passers-by. The baseline for the interactivity variable was the Underwater World just displaying animated stimuli.



1	Parallel Stimulus (PS)	2	Running-Ahead Stimulus (AS)
3	Parallel Looming Stimulus (PL)	4	Running-Ahead Looming Simulus (AL)
5	Fullscreen Stimulus (FS)	6	Reversed Fullscreen (FR)
7	Silhouette (SI)	8	Greenscreen Image (GS)
9	Baseline (B)	0	Rotated Stimulus (RS)

Figure 9.4: The single visual feedback conditions for position, direction and representation.

9.2.4 Deployment and Procedure: Sidewalk Study

Deployment at a City Sidewalk

The Interactive Banner Display was installed at a Munich street sidewalk behind a shop window, and the surrounding shopping and nightlife district ensured a steady flow of novice users and a broad demographic (↺ Chapter 5.4). Most passers-by approached on the sidewalk such that the screen appeared at the side at an angle of 90° from the walking direction. Only a few noticed the display from the other side of the street and then crossed over to approach it frontally.

Study Procedure

The study was conducted over a period of 6 weeks in the afternoon and evening hours to provide optimal lighting conditions for tracking users by the sensors. Multiple conditions were shown each day, each for 45 minutes before switching to the next such that the data would grow evenly amongst them, and only when certain external conditions were met such as sufficient lighting and weather (no direct sunlight or rain) and no obstacles in front of the displays (parked bikes).

9.2.5 Data Collection

In this study, the methods for aquiring behavioral data included field observation, multi-perspective video recordings, sensor logging and interviews [Beyer 2014, P.4]:

Data Collection			
Field Observation	Video Recordings	Sensor Logging	Semi-Structured Interviews

Objective Data

The field rater was supervising the sidewalk from an unobtrusive location behind the shop window. Videos were recorded from four camera angles, including top-down views onto the sidewalk and views towards the approaching trajectories. The four video streams were synchronized to a single video using *Noldus Media Recorder*. In order to analyse the stopping positions in front of the long display, we drew unsuspicious chalk annotations looking like children's drawings onto the sidewalk. Also, Kinect data was logged to obtain precise user position data.

Subjective Data

20 retrospective interviews were conducted, but only with passers-by who had already been attracted by the visual feedback and engaged with it. Again the interviewer initially had to remain concealed in order to not be an attractor herself and to ensure that the attention of approaching passers-by is only attracted by the visual feedback, and this was a particular challenge in this sidewalk situation.

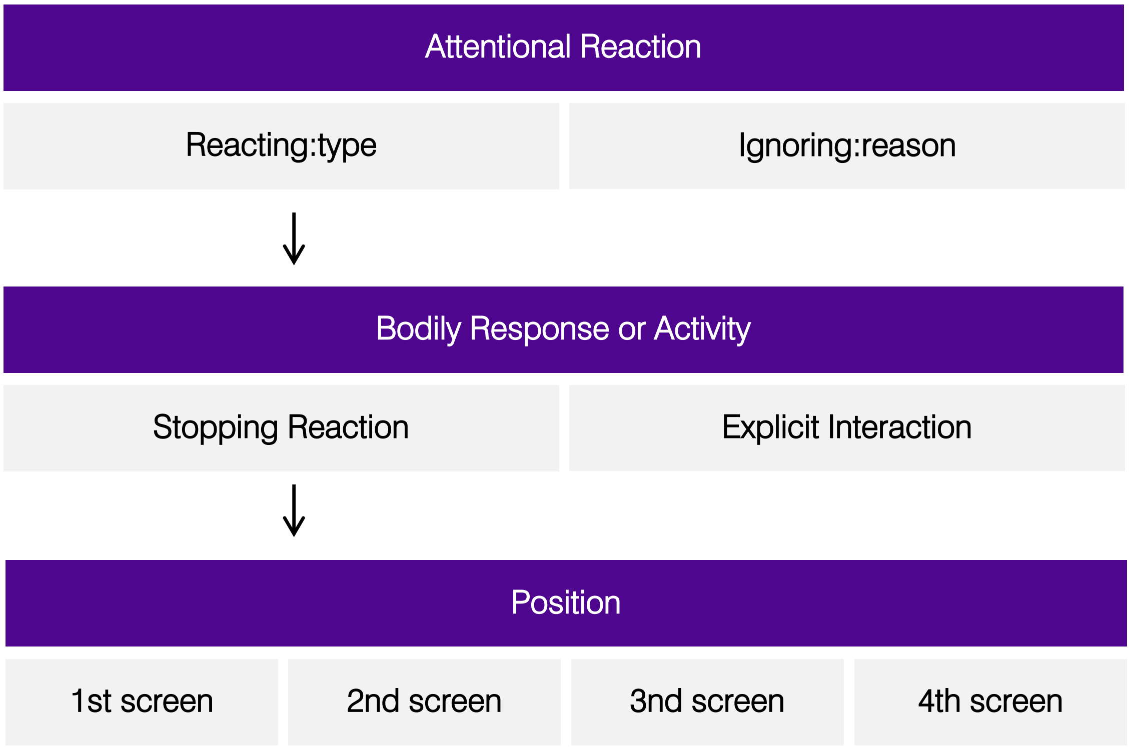
9.2.6 Video Analysis: Attentional Reactions

Coding Scheme: Defining Attentional Reactions

Of the video material from the 6 weeks of the field study, a sample of 26 hours was analyzed using *Noldus Observer*. In the developed coding scheme, subjects were defined as singles, pairs and groups analogous to Chapter 8.4.4. To assess the different performance of the visual feedback conditions in regard to attracting attention and conveying interactivity, for each passer-by first the initial attentional reactions were scored with the states *reacting* or *ignoring*, and then specified in greater detail using modifiers describing the reaction type (such as *orientation reaction*, *glancing continuously* or *surprise reaction*) or the identified reason for ignoring the screen (such as *looking across the street* or *being engaged in a conversation*). If attentive passers-by further showed a strong bodily response or activity, the states *stopping* or *explicit interaction* were scored. For all those events also the time that had passed since they had entered the sensor space was kept. Finally, the reaction and stopping positions in front of the long display were scored. For the statistical analysis we grouped the numerous conditions to compare content differing in only the independent variable of current interest.

Identifying Attention along the Banner Display

While most attentional reactions could be quickly identified when reviewing the multi-perspective video recordings, there were some ambiguous cases which required a more detailed analysis. For example, in a few situations passers-by suddenly glanced towards the building façade before they entered the sensor space, and we found out that this reaction was related to a competing stimulus. Difficult to resolve were also some situations with pairs in conversation, where we had to conclude if attentional reactions or gestures were related to the partner or the display, and also such where passers-by reacted while being occupied with another task such as phoning. The analysis process can be simplified as follows:



Attentional Reaction
Reacting:type
Ignoring:reason
Bodily Response or Activity
Stopping Reaction
Explicit Interaction
Position
1st screen
2nd screen
3nd screen
4th screen

9.3 Findings

The study showed that
visual feedback in the periphery attracts more attention than non-interactive visuals, but that different interactive stimuli were nearly equally effective in this situation.

9.3.1 General Observations

Counted Passers-by

During the six weeks of the field study several thousand passers-by walked by the long banner display and reacted to the visual feedback. Within our sample of 26 hours of analyzed video material 1866 encounters passed the display, including 1469 single persons, 343 pairs and 54 groups. At least one person reacted to the interactive feedback shown on the display in 52% of the groups, 35% of the pairs and 27% of the single persons [Beyer 2014, P.4].

Passer-by Viewing Behaviors

Passers-by showed the following general viewing behaviors when walking along the street sidewalk: most performed *natural scanning movements* across the environment, whereby their glances alternated between fixation points on the left and on the right side of the street (↺ Chapter 3.1). Situationally, they often looked towards the other side of the street at exactly the same spots, which indicates that salient stimuli exist within the street that competed with the display. Their viewing directions also correlated with their distance towards the building facade: people either walked in the middle of the sidewalk or close to the wall, and the latter were more likely to look towards the other side of the street than the centrally walking ones. The viewing behavior further depended on the individual activities such as conversations or smartphone use. Along with the challenging deployment of the display at the very side, the chance for passers-by to notice it strongly depended on the viewing direction at the very moment when passing by.

9.3.2 Passer-by Reactions

Attentional Reactions

Unlike in the study with the advertising column (↺ Chapter 7.3.2) passers-by showed no sudden direction changes while walking by the long interactive display, as they were all equally approaching it sideways on the same sidewalk. Of those who became aware of its interactivity, 54% who had scanned the street environment for arbitrary stimuli now began to continuously glance at the screen while walking alongside it, while 24% only punctually fixated the screen and 22% performed sudden orientation reactions towards the display. 6% of them showed surprise reactions indicated by suddenly slowing down or stopping in front of the display. 6,4% interacted explicitly with the visual feedback, showing actions such as walking back and forth or making gestures with their hands (see Figure 9.5).

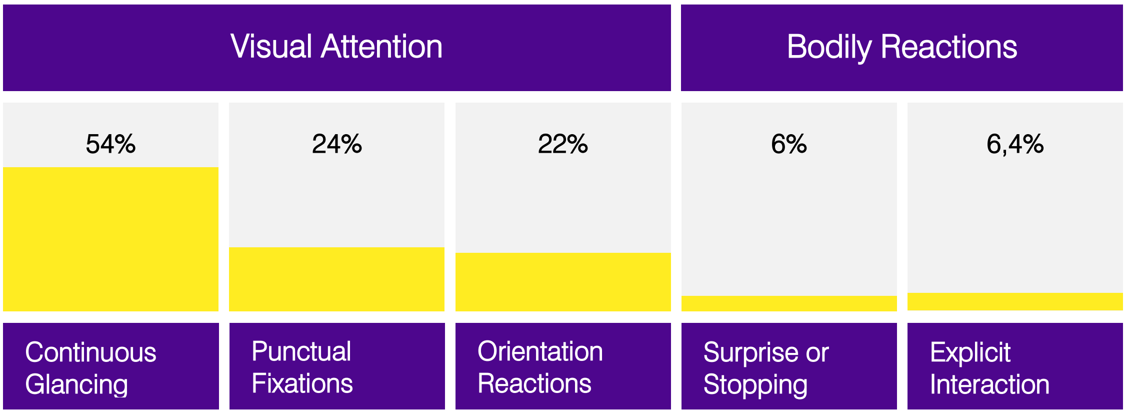


Figure 9.5: Observed attentional reactions of people passing by the banner display sideways.

Reactions of Pairs and Groups

Pairs and groups noticed the visual feedback significantly more often than single passers-by ($\chi^2(2) = 23.514$, $p < 0.00001$), and their higher attention rates of 35% and 52% had other reasons than a higher probability: In case of pairs the outer partner on the sidewalk often noticed the feedback first due to his or her inbound head orientation within the conversational arrangement, and then looked behind the partner's back to scan the screen. If pairs stopped, they often showed pair-specific interactions such as taking a photo of the mirror images. Groups were even more attentive as they were not as often in conversation as pairs. Within arriving groups, the visual feedback was noticed equally often by foregoing members, outer going ones and members going behind, but less often by people in the middle that were close to the screen. The other group members subsequently became aware of it by the first person's reaction or hint at it.

Reasons for Ignoring the Display

In 73% of cases where the display was ignored, reasons for the inattentiveness could be identified. 19% did not pay attention because they turned their gaze, often at the same position, towards competing attractors on the other side of the street, 6% were looking into the distance, 19% passing the display too close, 15% were looking down at the ground and 8% down at a smartphone screen, 7% were making a phone call, 4% pulling trolleys or carrying heavy things, 13% were occupied with other activities such as searching their pockets, eating or drinking or lighting a cigarette while walking by. Situative influences such as bad weather also made people hurry or take protective pose, thus leading to limited attention. The most frequent reason were yet conversations between partners, indicated by speech or gesticulation between two people, accounting for 20% of all inattentive passers-by and even 78% of the inattentiveness of all pairs (see Figure 9.6).

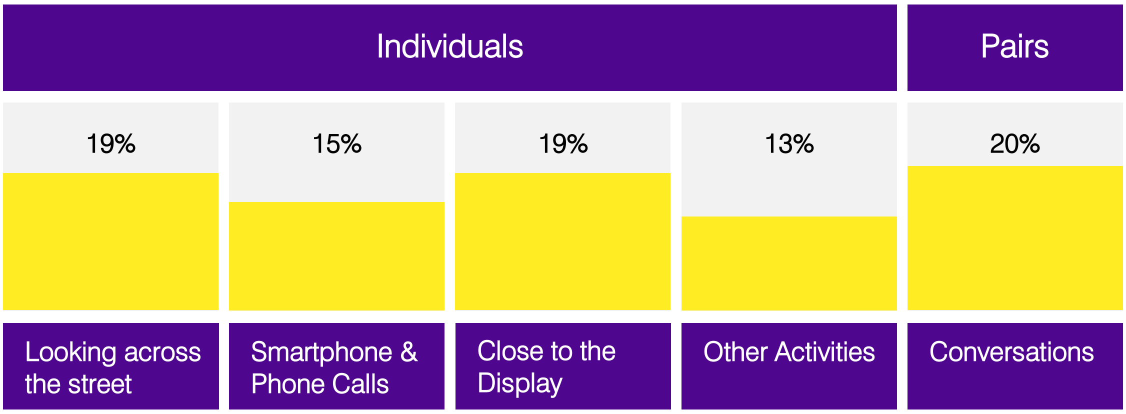


Figure 9.6: Observable reasons for people ignoring the banner display when passing by.

Orientation Reactions and Stopping Positions

Sudden orientation reactions of passers-by towards the display mostly occurred in front of the displays 1 to 3 (37%, 30% and 28%) of the four seamless display modules the Interactive Banner Display was consisting of, but only seldomly at the last screen (5%). In contrast, the stopping reactions increased steadily with the covered display length, from 10% stopping in front of the first, 25% and 30% at the two middle and 35% at the last screen. Almost no one missed the display. This proves that the 3.75 meter long display was long enough to fulfill its planned purpose: to sufficiently resolve the problem observed by [Michelis 2009, P.161] that with single narrow displays passers-by often miss the opportunity to stop in time in front of the screen when they are passing by sideways (↺ Chapter 3.3.7 and 5.4.1). Consequently passers-by also did not have to walk back from their stopping positions towards the screen as described by [Müller 2012, P.7f].

Figure 9.7: Passers-by showing different attentional reactions towards the interactive display.

9.3.3 Attraction Performance: Interactivity vs. Baseline

Correlation of Interactivity and Attention

Comparing all interactive conditions with the non-interactive baseline revealed that interactivity respectively reactivity of the display through the visual feedback was correlated with attention to the display [Beyer 2014, P.5]: On average 30% of passers-by reacted to the interactive conditions by looking at them, while only about 12% turned their heads towards the baseline content (see Figure 9.8). This difference in attraction efficiency is highly significant ($\chi^2(1) = 10.482$, $p < 0.005$). In contrast, interrelating the interactive conditions individually revealed only slight differences between the single visual feedback solutions. Qualitatively, in case of the merely dynamic basline content which just showed the animated fish, those who became attentive were often glancing continously at the visual content while passing by, but neither showing any surprise or stopping reaction nor any further interest in the underwater world. Also, not a single passer-by wrongly assumed interactivity when the baseline was displayed. Instead, the entire spectrum of attentional reactions and any form of engagement with the screen only emerged when displaying the interactive conditions. Yet, also with the interactive conditions we discovered some demographic differences: while the younger population stopped disproportionally often to actively engage with the interactive contents (see Figure 9.7), elderly people who had stopped when noticing the visual feedback usually prefered to only passively watch the screen for a while.

9.3.4 Performance of the Single Feedback Conditions

Performance of Different Stimulus Positions

Comparing the single interactive conditions in detail, all visual feedbacks that varied in the horizontal position (↺ Chapter 9.2.3) revealed slight but no statistically significant differences. The running-ahead stimulus (AS), which shiftet the visual feedback towards viewers' mid-peripheral field, with 31.3% reactions was almost equally effective to the parallel stimulus (PS) with 28.7%. The same was true for the looming stimuli, where the stimulus that appeared at a forward position (AL) with 27.7% was only slightly better than the stimulus that appeared alongside passers-by (PL) with 23.7%. The best results were obtained with the fullscreen stimulus (FS) which attracted the attention of 34.2% of passers-by (see Figure 9.8).

Performance of Different Stimulus Directions

Statistical analysis also revealed moderate but again no statistically significant differences in the effectiveness between different movement strategies for the visual feedbacks (↺ Chapter 9.2.2). When comparing the direction of movement between the aligned fullscreen stimulus FS and its reversed counterpart RS, the school of fish was slightly more effective when moving along with the user than when moving in reversed direction (34.2% to 29.7%). Stimuli continuously moving along with the passer-by (PS and AS combined) with 30% were likewise only slightly more effective than the looming stimuli uncontinuously approaching from the side (PL and AL combined) with 25.7%, which is yet interesting as the animated looming stimuli were visually more salient (see Figure 9.8).

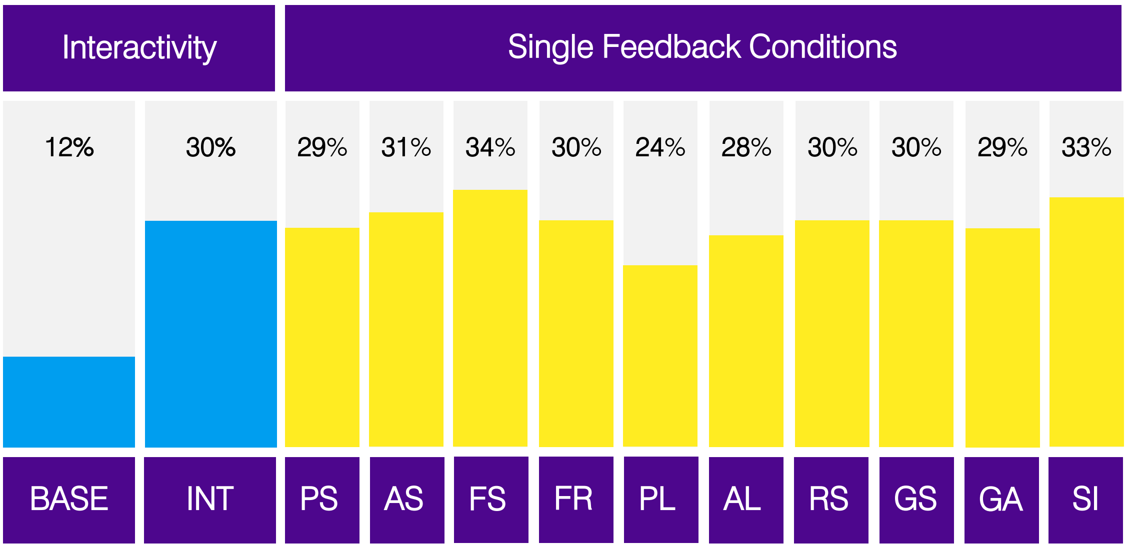


Figure 9.8: Attraction efficiency of the different visual feedbacks when passing by sideways.

Performance of Different Visual Representations

In our situation with the long sidewalk display where all feedback stimuli are often only noticed in the periphery, the numbers also revealed no significant disparity between the different visual representations used (↺ Chapter 9.2.3): The illustrated fish, representing foreign beings that were used to realize different positions and directions of visual feedback, with around 30% reactions were not attracting substantially less attention than the mirror representations. Comparing the parallel fish stimulus (PS) with 28.7% reactions with the greenscreen stimuli (GS) with 30% and the slightly more effective silhouette (SI) with 33% revealed no significant difference in attraction efficiency. Also the rotated stimulus (RS) with 30% and the mirror images which were augmented with additional virtual effects (GA) with 29% provided no exceptional outlier (see again Figure 9.8).

Explicit Interaction with the Interactive Stimuli

About 7.5% of the people who noticed and looked at the display stopped and engaged with it, and 6.4% interacted with the feedback by walking back and forth, using their hands or taking photos. The plain and augmented greenscreen images (GS and GA) with 14% and 11.6% and the running-ahead stimulus (AS) with 8.6% generated a high ratio of interactions, yet not the looming stimuli positioned ahead (AL). Far more people interacted with the fullscreen feedback if it moved in reverse direction (7.5%) than along with the user (1.8%, see Figure 9.9). Further, different passer-by constellations showed a varying willingness to start interaction: with 32.1% significantly more attentive groups interacted than pairs (11.3%) and singles (3.1%, $\chi 2(2) = 42.6778$, $p < 5.403e\text{-}10$) [Jäger 2013, P.65f].

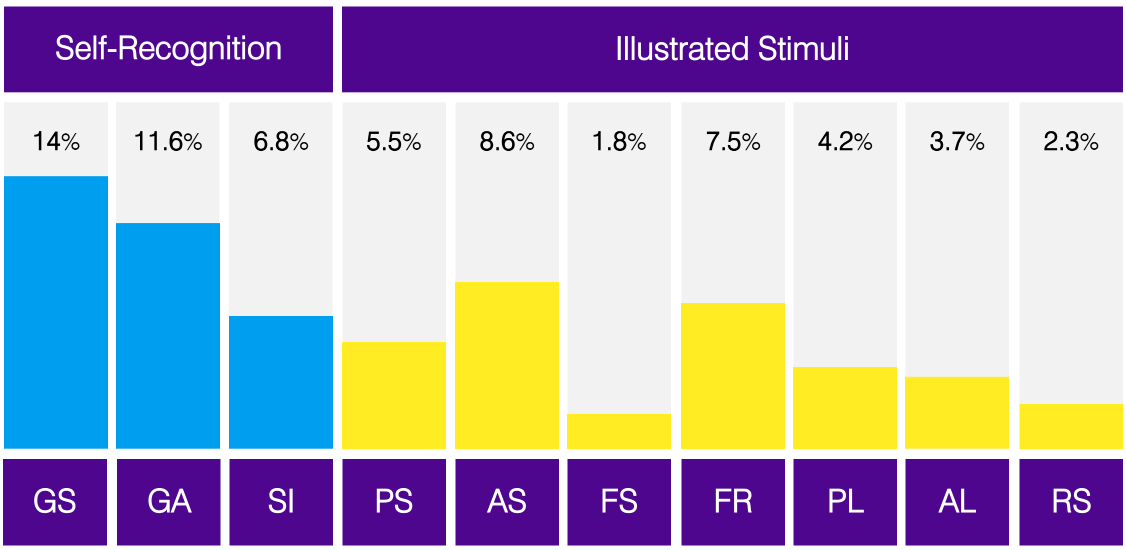


Figure 9.9: Share of passers-by who interacted explicitly with the visual feedbacks.

9.3.5 Subjective Data: Noticing Interactivity

Moment of Noticing the Display

Out of the 20 interviewed passers-by who had previously been attracted by the visual feedback and had engaged with the display, most stated to have noticed it immediately, only four mentioned a slight delay. 80% of them had not noticed the display before. When asked about the assumed purpose of the display, 30% believed that it was a student's project, 25% advertising, each 15% that it was decoration or relaxation and 10% entertainment of passers-by [Jäger 2013, P.69f].

Moment of and Reasons for Noticing Interactivity

All 20 interviewees stated that they had discovered the interactivity of the display at the moment when they were passing by, and that they had become aware of the fact that the display reacted to them by the visual element moving along with them. Yet most of them also stated that the first thing which they had noticed was the underwater scenario as a whole, and in fact they were able to precisely reproduce the different animated characters on the screen. Only two passers-by had discovered the Kinect sensor and were familiar with it [Jäger 2013, P.72].

Self-reported Interactions

People could remember well how they engaged with the visual feedback. Of the 20 interviewees, 18 stated that right after they had noticed interactivity they tried to control the interactive contents [Jäger 2013, P.72]: in the case of the illustrated, direction-related visual feedbacks by walking back and forth (64%) or also by stopping (36%), and in the case of the mirror feedbacks by waving hands (33%), other subtle body movements (50%) and facial expressions (17%, see Figure 9.10).

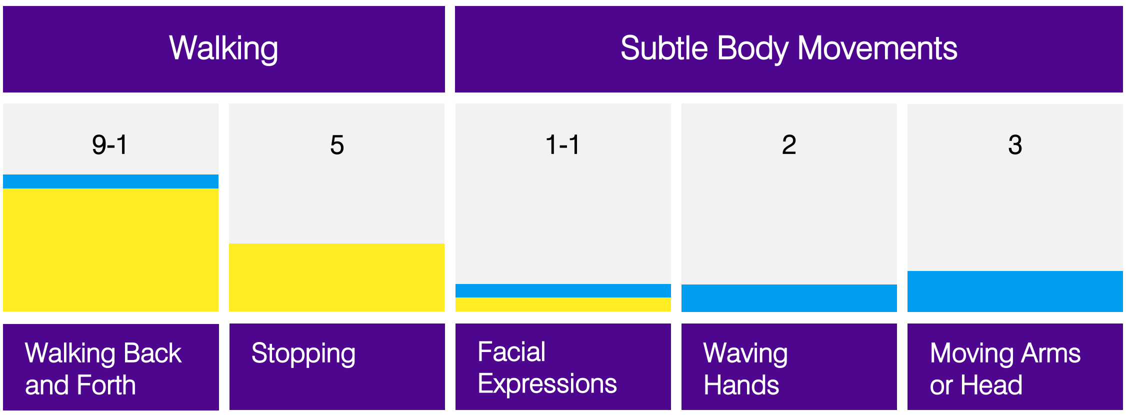


Figure 9.10: Self-reported interactions with the illustrated (yellow) and mirror feedbacks (blue).

9.4 Interpretation

Interactivity increases our attention towards the periphery
if we notice an eye-catching and unexpected local movement and conceive that it clearly correlates with our own movement.

9.4.1 Performance of the Feedback Strategies

Passer-by Visual Attention on Street Sidewalks

In this study we wanted to investigate how the attention of passers-by can be attracted and interactivity be conveyed at sidewalk trajectories where the display appears in the periphery at an angle of 90° from the walking direction, and at first it is important to understand the typical viewing behaviors in this situation. In the video analysis we observed characteristic and challenging behavioral patterns when passers-by approach on a sidewalk that add to the already difficult visibility of laterally-oriented displays (↺ Chapter 9.3.1): First, many passers-by perform a constant visual scanning of the environment whereby their glances alternate periodically between one side of the street and the other, and thus the chance to notice the sidewalk display depends on the random viewing direction when they are arriving. Whether people look in walking direction or towards the other side of the street also depends on their either centered or near-wall trajectory on the sidewalk. Further, visual attention in streets is situation-dependent and people often look towards a competing stimulus such as a neon sign on the other side of the street at exactly the same position. Finally, the viewing behavior and attention of passers-by strongly depends on their current activity and many ignore the display as they are using smartphones or are in conversation.

▶ When walking along sidewalks, passers-by show viewing behaviors which strongly affect the chance to notice a display in the periphery.

Better Performance of Interactive Stimuli

To handle the difficult conditions around sidewalk displays such as limited visibility and low visual attention, we used a very long display and compared the attraction efficiency of interactive feedback to that of non-interactive visual stimuli. The results showed that the interactive feedback achieved that roughly one third of all passers-by showed an attentional reaction and glanced at them, and thus was significantly more effective than the just animated visuals which were only noticed by 12%. Also, 7.5% stopped and 6.4% interacted explicitly with the visual feedback conditions, while nobody showed a distinct bodily reaction to the baseline. In other words, when passing-by sideways, interactive feedback attracts attention better to the screen as it is a more unexpected, surprising stimulus than the just animated stimuli (↺ Chapter 3.3.2). As all feedbacks were connected to the user speed the surprise may result from becoming aware of the correlation to the own movement and the involved causality (↺ Chapter 3.3.5).

> ▶ Also when passing by a long display sideways, interactive feedback surprises and attracts people more than classical attraction cues.

Similar Performance of different Stimulus Positions

To our surprise, moving the visual feedback to a position ahead of passers-by in order to shift it closer to their line of sight brought no essential advantage for attracting attention. Both the continuously displayed feedback stimuli and the looming stimuli each performed only about 10–15% better when they were shiftet towards viewers' assumed mid-peripheral field. One reason for this may be that, while in the periphery the perception of details and color falls of (↺ Chapter 3.1.1), peripheral vision is yet good at detecting motion due to the rod cells [Bartram 2002] such that passers-by who are looking towards the walking direction still become aware of a local anomaly in the corner of their eye, i.e. in the far peripheral field. Further, as many people perform a visual scanning of the environment and move their head towards both sides, the stimulus position within the visual field is not static anyway. Only the fullscreen feedback was more effective because it used the whole screen and thus the chances to notice it were correspondingly higher.

> ▶ Moving visual feedback is still noticed well in the far peripheral field, as peripheral vision is good at detecting motion due to the rod cells.

Better Performance of Stimuli in the Same Direction

The study revealed that visual feedback is more effective when moving in the same direction as the passer-by. The reason for this may be that stimuli moving in the same direction can be correlated easier with one's own movement. When walking along sidewalks, we sense motion also by visual kinesthesia [Gibson 1985], and any moving stimulus in the field of view regardless of its direction of motion represents a salient local movement relative to the perceived global optical flow [Goldstein 2015, P.180]. Based on our familarity with the sensory overload in urban settings we usually ignore most stimuli in the corner of our eye – unless they are moving with us at our own speed, which is a rather unexpected, surprising event. This is an example for humans strong sense for causality and attentiveness to events in the environment that correlate with the own behavior (↺ Chapter 3.3.5). After all, if we unwittingly have an effect on any object within our environment, for example get stuck and drag something along, this can pose a risk to us.

> Visual feedback moving in the same direction is easier to correlate with one's own movement and is also the more unexpected event.

Lower Performance of the Looming Stimuli

The looming stimuli used in this study were slightly less effective than the visual feedbacks moving along with passers-by continuously. This further supports the assumption that the realization of the correlation between the feedback and one's own movement (the process of becoming aware of interactivity or unaware intial interaction) is a much more effective mechanism for attracting attention than the visual salience of stimuli. Looming stimuli capture more attention than other dynamic events [Franconeri 2003], as humans interprete a rapid expansion of a visual object in the periphery as an approaching threat and react with a defensive or startle reaction to prevent an impending collision (↺ Chapter 3.2.2). Still with the threefold repeated visual impulse of our looming content the continuous horizontal movement required to understand the correlation with the own motion gets lost [Jäger 2013, P.74], and thus the more unexpected and surprising effect of discovering the fact of one's own causality, of having an effect on the screen.

> Looming stimuli lack a continuous horizontal movement and thus are harder to correlate with one's own motion when passing by sideways.

Similar Performance of Mirror, Silhouette and Illustrated Representations

The study revealed no significant disparity in the attraction efficiency between the visual feedbacks when passing by sideways: mirror images, silhouettes and illustrations of foreign beings were about equally effective. The reason may be that when we perceive mirror feedback in the shadowy, low-acuity periphery or from a slanted angle, the mechanism of self-recognition (↺ Chapter 3.3.2) can yet not be effective in this initial phase of visual attention. Instead, as peripheral vision is highly sensitive to motion, the correlation with the own movement may be the first thing people are becoming aware of. In psychological terms, visual appearance matching may be less effective than kinesthetic-visual matching in the sideways situation. Just the red silhouette was slightly more effective than the other stimuli, possibly due to its physical intensity (↺ Chapter 3.2.2). While peripheral vision is color blind [Ware 2013 P.175], its salient color may have been noticed when the head was turned during the observed scanning movements.

> ▶ When passing a display sideways and perceiving it in the periphery, kinesthetic matching is more relevant than appearance matching.

Overproportional Attention and Engagement of Pairs and Groups

We observed that pairs and groups noticed interactivity significantly more often than singles. Beyond the higher probability by the larger number of individuals, one reason was the conversational arrangement of pairs where the outer partner often noticed the feedback first. Within groups foregoing members, outer ones and those ones lagging behind noticed the feedback equally often, but more often as members in the center of the group who where more likely to be in a deep conversation. In other words, individuals in the peripheral positions within the group were often more attentive or sometimes had a better view onto the screen. The first attentive members often attracted the attention of the rest of the group to the screen by their reaction or hint to the feedback. Pairs showed more engagement due to pair-specific motivations such as taking a souvenir photo of the mirror images. In contrast, single passers-by often moved along after they had quickly explored the easily understood interactive effects by a few glances.

> ▶ Pairs and groups are more attentive and active due to single attentive members, group constellations, and specific motivations to interact.

9.4.2 Open Issues

Summarizing the findings of this field study with the Interactive Banner Display, the following issues are left open at this point of research:

Other Installation Sites
How can long displays attract attention and convey interactivity at other sites such as curved streets, pedestrian subways or town squares?

Peripheral Attraction Cues
Which other peripheral stimuli constitute effective visual feedback to convey interactivity when passing displays sideways?

Movement-Controlled Feedback
Which other animations of visual feedback triggered by the passing-by movement are recognizable and effective?

Customized Feedback
Can feedback be more effective that is customized to different passer-by constellations, numbers and types such as singles, pairs, groups or kids?

Mass Interaction
How can visual feedbacks on wide displays effectively convey interactivity in busy situations, when large numbers of people are passing by?

9.5 Takeaways

Interactive Banner Displays
are deployed in challenging situations, and to attract passer-by attention to the periphery by interactive feedback the full screen and all visual means should be used.

9.5.1 Recommendations for Sidewalk Displays

Display Format along Sidewalk Trajectories

For this study we designed a 3.5 meters long Interactive Banner Display in order to overcome the problem that passers-by do not stop in time in front of narrow displays or single units of display rows when they approach from the side on city sidewalks and pass them sideways. As most people stopped in front of the third or fourth quarter of the banner screen, it fulfilled its planned purpose. Generally, in each individual case the walking speed, situational factors and architectural preconditions have to be considered when determining the exact display length.

R 9.1 Use Long Banner Displays as they are able to attract Passers-by before they have passed the Display

Passers-by often stopped in front of the third or fourth quarter of the banner such that they did not have to walk back once they conceived interactivity.

Interaction Space and Initial Interaction

When a display is approached from the side, passers-by often cannot see it until they are passing by sideways right in in front of it. In other words, the interaction space in front of sidewalk displays is limited by the display width. We observed that the viewing directions of passer-by on sidewalks are hard to predict. In order to increase the attraction efficiency, sidewalk displays thus should provide visual feedback for the initial interaction evenly across the full extents of the display.

R 9.2 Consider the Limited Interaction Space and the Challenging Viewing Behaviors on Sidewalks

As passers-by notice lateral displays late and their viewing directions are hard to predict, use the full extents of the display to provide visual feedback.

9.5.2 Designing Initial Feedback when Passing By Sideways

Attraction Cues for the Periphery

In this study we found out that also in the situation where people are passing by sideways, visual feedback attracts significantly more attention than classical, non-interactive visual attraction cues, even if they are perceived in the shadowy periphery when walking along the sidewalk. Best suited are interactive feedbacks which convey that they clearly correlate with the passer-by movement, while different feedback stimuli and positions are nearly equally effective.

R 9.3 Use Interactive Feedback also when Passers-by are passing by Sideways

Interactive visual feedback attracts significantly more passer-by attention also in the difficult situation when the display appears in the periphery.

Movement Direction of Feedback

The study revealed that visual feedback moving in the same direction as the passer-by and at their speed is more effective in conveying interactivity and attracting attention than if moving in reversed direction, as it can be correlated easier with one's own movement. For the same reason, visual feedback moving along with passers-by continuously without interruption is more effective than visual feedback which is presented uncontinously such as the looming stimuli.

R 9.4 Use Feedback that aligns with the Passer-by Movement Direction instead of Reversed Feedback

The correlation of aligned visual feedback with one's own movement is much easier to understand for passers-by.

Feedback Position

On urban sidewalks passers-by show challenging viewing behaviors such as the constant visual scanning of the environment, or they are distracted by competing stimuli in the street or activities such as smart-phone use or conversations. While putting the visual stimulus to a forward position brought only few improvements compared to the parallel stimulus, the fullscreen feedback was significantly more effective as it maximized the chance for passers-by to notice the visual feedback.

R 9.5 Use Fullscreen Feedback on a Long Display

On sidewalks the current viewing direction of passers-by is hard to predict, and fullscreen feedback maximizes the chance that they will notice it.

Feedback Representations

In this situation where a display is passed by sideways, we found out that mirror images of passers-by and graphical illustrations of foreign beings were about equally effective in attracting attention, as the peripheral detection of motion and kinesthetic-visual matching are the primary mechanisms for becoming aware of the visual feedback here. But salient stimuli such as the red silhouette were more effective than the others, as people are also turning their head when passing by.

R 9.6 Use Salient Feedback

When passing by sideways feedback is mainly noticed due to its motion, but salient feedback even better as people are also turning their head.

Strengths and Weaknesses of Interactive Feedbacks

This study proved that interactive feedbacks can have individual strong and weak points beyond their effectiveness in attracting passers-by. We observed that feedbacks which convey interactivity effectively may not necessarily perform well in motivating users to interact explicitly, and vice versa. The interactivity of the fullscreen feedback that moved in the same direction as passers-by was easier to notice than that of the reversed feedback, but much more passers-by interacted with the obviously more playful latter one once they had unterstood it.

R 9.7 Consider that Interactive Feedbacks may not be equally effective in Attracting and Motivating Users

Visual feedbacks which attract attention and convey interactivity effectively might still not achieve to motivate users to interact explicitly, and vice versa.

9.5.3 Measuring Behavior

Camera Setup

In this scenario where users are passing by sideways, four camera perspectives were required: two cameras were directed towards the two main approaching trajectories of passers-by on the sidewalk to the left and to the right of the display site, and two further overlapping camera perspectives recorded the long banner display and the whole sidewalk in front of it from above.

R 9.8 Use Suited Camera Perspectives

In the sidewalk situation, it needs two camera angles for the approaching trajectories plus as many needed to cover the whole interaction space.

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Visual Annotations

In this study where passers-by walked along straight ahead on the sidewalk trajectory from one side of the banner display to another, we drew unsuspicious chalk annotations disguised as children's drawings onto the sidewalk in order to facilitate the scoring of passer-by positions in the case of any reaction to the feedback in the video coding. In this situation these annotations proved to be a similarly effective tool as the virtual grid masks described in Chapter 6 and Chapter 7.

R 9.9 Use Visual Annotations to facilitate the Scoring of Passer-by Positions in front of Outdoor Displays

In the case of the sidewalk scenario these annotations proved to be useful enough in order to score passer-by positions in the video coding.

CHAPTER 10

SUBTLY DIRECTING USERS

Actively Influencing User Positions and Shaping Audience Constellations in front of Wide Displays

10.1 Background

If passers-by can be subtly directed to arbitrary positions by dynamic and interactive visual cues on the screen, this can be used to distribute users and to dissolve crowds in front of wide displays.

10.1.1 Subtly Directing Users in front of Wide Displays

Wide out-of-home displays principally allow multiple users to interact in parallel, but the optimal conditions for convenient simultaneous interaction often do not emerge spontaneously. Instead of distributing themselves along the screen such that each user has sufficient space to interact, members of arriving groups may crowd together in front of one region of the display. Certain contents such as interactive games may also require specific user positions unknown to arbitrary passers-by. To resolve such problems we proposed to actively and subtly direct users in front of wide displays by dynamic and interactive visual cues on the screen, and to guide them to empty spots or preferable positions (↺ Chapter 3.4).

10.1.2 Dissolving Crowds in front of the Banner Display

In front of the wide Interactive Banner Display we indeed observed that members of arriving pairs and groups, after turning towards the display, crowded together instead of using the available free space. This usually could be attributed to group affiliation and passive bystanders watching an initial user from close positions behind or next to him or her. But bystanders often did not even detach from the crowd if they joined the interaction, which led to active group members impeding each other. Possibly the crowded space also prevented many passive members from taking an active part. This situation in front of the banner display provided an ideal case study to explore if one can actively direct users by visual cues and dissolve such crowds and by-standing behaviors (see Figure 10.1).

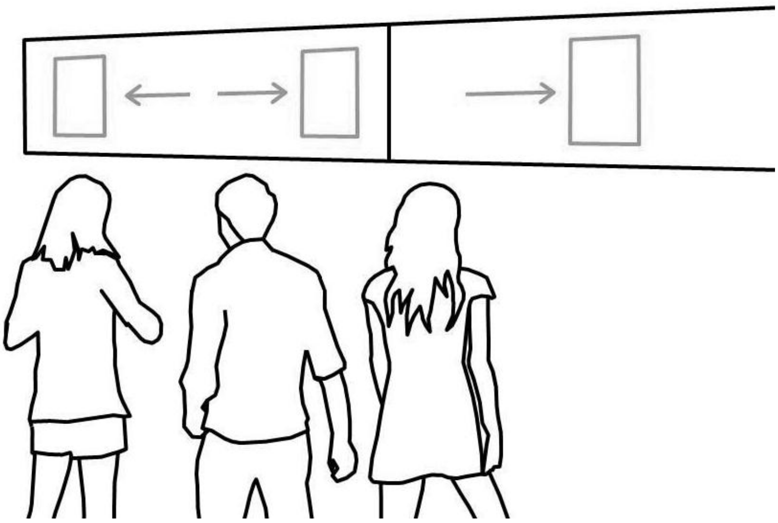


Figure 10.1: If users crowd together they could be actively guided to empty spots by visual cues.

10.1.3 Questions and Issues

In order to establish preferable conditions in front of public displays by actively directing users, first of all it has to be found out if visual stimuli or positioning cues on the screen can be used to subtly manipulate user positions at all. We called the idea of actively influencing user positions and regulating audience constellations in front of public displays by visual stimuli and dynamic strategies for displaying them visual audience moderation (↺ Chapter 3.4.3). As stated this process of active behavior management poses the basic problems of user positioning, user repositioning and distribution of the audience. According to this concept we wanted to find out for different visual cues if they can be effectively used to draw arriving users to arbitrary positions in front of wide displays, to reposition users who are already interacting with the display in order to free space for new arrivers, and to guide multiple users to empty spots and distribute them more equally. To achieve these goals we also had to explore which visual representations are effective positioning cues that can attract users, as well as which strategies to dynamically position, move or display them interactively are effective in influencing user positions. Finally, we also had to better understand the actual social constellations of passers-by in front of our wide display and the observed unfavorable situations such as crowding and bystanding effects. The main issues related to this research can be summarized as follows:

RQ

Q 10.1 Actively Influencing User Positions
Can the positions of users in front of a display be subtly manipulated and users be actively directed by visual positioning cues at all?

Q 10.2 User Positioning
Can visual cues on the screen be used to effectively draw arriving users to arbitrary positions in front of wide displays?

Q 10.3 User Repositioning
Can visual cues on the screen be used to reposition users who are already interacting in order to free space for new arrivers?

Q 10.4 Distribution of Multiple Users
Can visual cues on the screen be used to distribute multiple users and dissolve crowds by actively guiding single users to empty spots?

Q 10.5 Effective Positioning Stimuli
Which dynamically positioned, moving and interactive visual stimuli are effective to attract and subtly direct users in front of displays?

Q 10.6 Crowding and Bystanding Effects
Which social constellations and unfavorable situations such as crowding and close bystanding can be observed in front of wide displays?

10.2 Field Study

We conducted another field study with the Interactive Banner Display
to explore if passers-by can be subtly directed and distributed by visual cues such as interactive frames and ellipses.

10.2.1 Study Context

To explore if users in front of wide out-of-home displays can be subtly directed and distributed by dynamic and interactive visual cues on the screen, a field study was conducted. Vincent Binder carried out this research as part of his bachelor's thesis [Binder 2013]. He conducted an outdoor field study of five weeks length in summer 2013 with the Interactive Banner Display presented in Chapter 5. Partial results of the study have been published at the DIS 2014 conference under the title *The Puppeteer Display: Attracting and Actively Shaping the Audience with an Interactive Public Banner Display* [Beyer 2014] and at a conjunct workshop under the title *Visual Audience Moderation: Actively Shaping User Constellations to Improve Touchless Interaction with Public Displays* [Beyer 2014B].

FACTS

Idea	Actively Directing Users in Front of Displays by Interactive Visual Cues
Type	Observational Field Study
Directing	Vincent Binder
Advising	Gilbert Beyer
Software	Interactive Frames [Binder 2013]
Date	10 June–28 July 2013
Location	Street Window, Amalienstr. 17, University of Munich
Prototype	Interactive Banner Display
Publications	Bachelor's Thesis Vincent Binder [Binder 2013], DIS 2014 Conference [Beyer 2014], DIS 2014 Workshop [Beyer 2014B]

10.2.2 Hypotheses and Assumptions

Subtly Directing Users

The main hypothesis of this research was that passers-by can be subtly directed by visual cues along wide public displays at all. Further we assumed that according to the presented concept of visual audience moderation it would be possible to draw users to arbitrary positions by visual cues (user positioning), to make active users step aside to free space for others (user repositioning), and to effectively dissolve crowds and distribute multiple users (audience distribution):

Visual Audience Moderation		
User Positioning	User Repositioning	Audience Distribution

Variables: Movement, Interactivity and Representation

For actively directing users and distributing them along the display we identified three variables for displaying visual positioning cues [Beyer 2014, P.5]: movement, interactivity and representation. First, such visual cues can be displayed dynamically at various static positions, or move continuously along the screen. They may either be non-interactive, react to the current user position, or be really interactive and act in relation to previous states and user constellations. Finally, the used visual representations have to be an effective positioning stimulus that is wittingly or unwittingly understood and immediately accepted by users:

Movement	
Static	Moving

Interactivity	
Non-interactive	Interactive

Representation
Any behavior-effective Stimulus

RW ↗

Studies with Long and Wide Displays

In regard to wide interactive public displays, [Peltonen 2008] studied the social behavior of passers-by, [Schmidt 2013] how they perform in reading text when walking by, and [Grace 2013] how an information display and [Beyer 2014] how a long sidewalk display can convey its interactivity by visual feedback to the movements of people who are passing by sideways. In contrast, in this study we used a wide public display to influence user positions in front of it.

Adaptive Displays and Proxemics

Related to our work are adaptive displays which adjust content in regard to implicit and explicit user behaviors, positions or orientations [Vogel 2004], mediate between proxemic needs of multiple users [Ballendat 2010], or visually assign adaptive personal territories to them [Klinkhammer 2010]. In this study we wanted to explore if the classic notion of displays adapting the content to users can also be reversed by displays which in the opposite way adapt and actively shape the audience which is interacting in front of them.

Effective Positioning Stimuli

In view of behavior-effective positioning stimuli, we could build upon our study with the column [Beyer 2013] where we found that large visual frames simulating display bezels influenced user positions (↺ Chapter 7). In contrast we now wanted to test if visual frames could also be employed dynamically to direct users. In regard to systems that actively guide users in front of displays by visual cues on the screen, follow-up research to our Puppeteer Display presented here [Beyer 2014], the GravitySpot [Alt 2015], applies effects such as brightness, pixelation or jitter to the whole screen in order to inform a single user about the remaining distance to a defined position.

Problematic Social Constellations

Similar to our observations of crowding and bystanding effects in front of the wide banner display, when using narrow displays [Michelis 2007] found that people initially stand by the first user and [Müller 2012] that users often start interacting right behind existing groups, this way blocking the way of other passers-by. [Peltonen 2008] also reported crowds and even conflicts between close users in front of another wide display. This confirms that such problems can even occur if enough space for many users is available.

Figure 10.2: After being attracted, users need to be optimally distributed along the display.

10.2.3 Study Design: Ensuring Unbiased Positions

Using again the Interactive Banner Display which was installed behind a shop window at a street sidewalk (↺ Chapter 5), public interaction with this long screen occurred in two stages: First, arbitrary passers-by initially had to be attracted by an unaware initial interaction when they were approaching and passing the display sideways (see Figure 10.2, top). To achieve this we used visual feedback techniques similar to those described in Chapter 9. Second, after attention had been caught and users were turning towards the display, we wanted to subtly direct and distribute them along the screen by visual cues (see Figure 10.2, bottom). To avoid that user positions were influenced by other external factors, beyond using a long seamless display we also had to ensure a continuous interaction space without any disruptions in front of the display, as well as a seamless and unbiased content just as in the study with the interactive column (↺ Chapter 7.2.3).

10.2.4 Interactive Content

Baseline Content

Vincent Binder designed five different strategies to position, reposition and distribute users by dynamic and interactive visual cues on the screen. They all involved a ball game as background content similar to the one of Chapter 7.2.4, in which users can bounce balls falling from above with a visual representation of their tracked skeleton (see Figure 10.2). To ensure unbiased user positions, this simple game was continuous along the whole screen and did not prefer any special position or body orientation in front of the display. For initially attracting users sideways and communicate display interactivity to users, eye-catching particles were displayed as running-ahead visual feedback (↺ Chapter 9).

Designing Behavior-effective Stimuli

The positioning stimuli were now displayed on top of this background content. To integrate these visual cues with the content, they ideally should be designed content-related, but even more important is that graphical representations are used which are effective positioning stimuli that are wittingly or unwittingly understood and immediately accepted by users (↺ Chapter 3.4.4). Similar to the visual frames used in Chapter 7 they have to subtly draw users to their position, but this time also when displayed dynamically on the screen. For this study two basic visual representations were designed: *frames* and *ellipses*. We chose frames as we had already found unwitting positioning effects in front of the large visual frames which were simulating display bezels around the Interactive Advertising Column, and ellipses as an alternative to investigate if any further visual cues inducing such positioning effects would exist at all.

Refining the Positioning Cues

The color, size and aspect ratio of the frames and ellipses were partially predetermined by the other content and the screen dimensions. For example, the frames had to provide enough space for the visual user representations, but still fit on the physical screen. The exact size, aspect ratio and bezel thickness were determined in iterative pretests. In these tests we found out that a suitable shape of the visual cues was crucial, as frames too small or too large could be misunderstood or disregarded. As the frames, the ellipses were white and also provided sufficient space for one user representation. The ellipses appeared in the lower part of the screen to convey the impression of spotlights on a floor or platforms where users could place their screen representation (see Figure 10.3).

Figure 10.3: Ellipses were one of the cues which we used as positioning stimuli.

Movement Strategies for the Visual Cues

On the basis of these designed frame and ellipse cues, different strategies to position, reposition and distribute users were designed (see Figure 10.4). The first three strategies tested the movement and representation variables. In the most basic concept *Static Frames (SF)* two seemingly static visual frames were displayed in addition to the game. This condition was designed to find out whether users would position themselves in front of frame stimuli which are displayed dynamically at several positions on the screen. The wide distance between the frames was chosen to distribute users and thus reduce any mutual interference between active players. In fact, the static frames were not completely static but imperceptibly moving such that they crossed the whole screen in 7 minutes. The idea behind this slow movement was to randomize the frame positions in order to minimize the influence of any external variables on user positioning, such as the perceived relation of one's current position to the shop window bezels or the display. The second condition *Static Ellipses (SE)* tested if the same concept of two visual cues displayed wide apart would also work with the ellipse representation and if it would induce similar positioning effects as observed with the frames. Just like the static frames, the ellipses moved only at the same low speed to randomize positions. In contrast to these invisibly moving stimuli, in the *Moving Frames (MF)* condition a single frame was moved in horizontal direction along the screen surface at a perceptible speed. Moving at 0.15 km/h, it took the frame 90 seconds to traverse the complete screen once. At this speed users could easily adapt their position to the frame by occasionally stepping aside. This condition was designed to check whether users would be willing to follow the frame and adapt their position repeatedly.

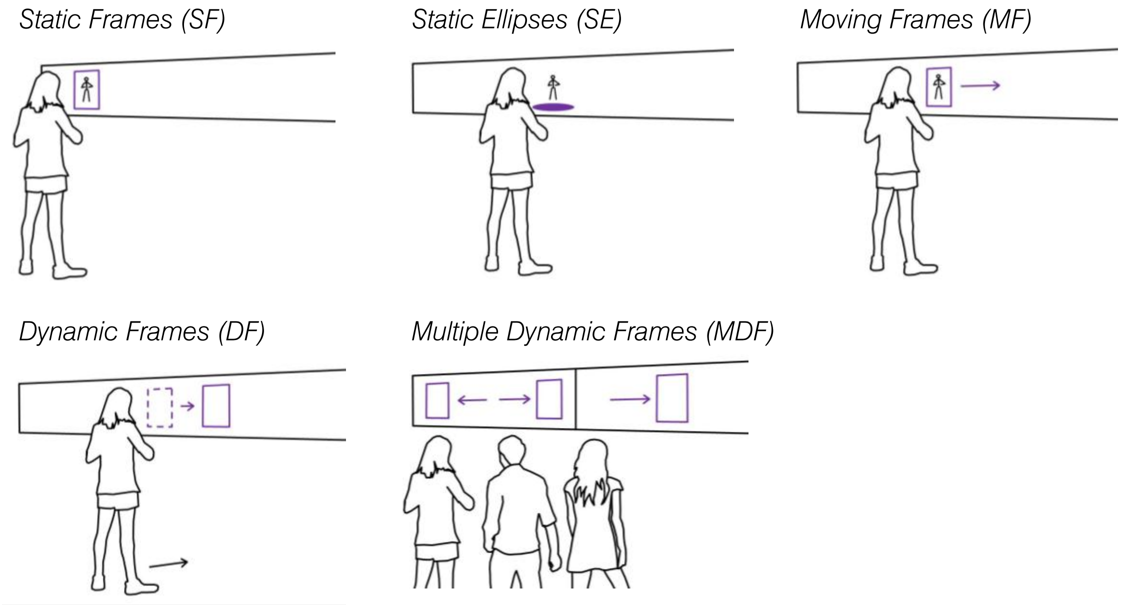


Figure 10.4: The single strategies for dynamic and interactive visual cues on the screen.

Interactive Strategies for the Visual Cues

In contrast to the previous concepts, *Dynamic Frames (DF)* were only created upon user interaction and reacted to the user's position: When a user started to interact with the screen, he received an individual frame, which after half a second moved sideways by one frame width. This combines the positioning stimuli of the static and moving frames: It was designed to test if users would recognize a frame that was individually created for them when they had approached, and consequently perform a side step towards the displaced frame. Finally, the *Multiple Dynamic Frames (MDF)* were an extension of the dynamic frames concept, in which frames for up to three simultaneous users were coordinated with each other. The first approaching passer-by received a frame where he or she stopped. If a second user approached and stopped near the first user, the frame split into two frames moving apart until their positions provided enough space for both to comfortably interact in parallel. Hence the first user received a stimulus to reposition himself and make room for the second user, which might not have happened automatically. At the same time the second user received a stimulus to move to the resulting free space and occupy it. If a third person approached, a third frame appeared in a distant space. This condition was used to verify, if dynamic frames can be used to direct multiple users simultaneously and optimally distribute them across the screen surface.

10.2.5 Situation and Procedure

We used again the Interactive Banner Display (↺ Chapter 5), so that this field study involved a city environment with arbitrary passers-by approaching sideways, and the same hardware configuration with two Kinect sensors installed below the plasma displays. In regard to user positions in front of the screen, the street sidewalk potentially allowed users to move left and right and freely disperse along the display without any restrictions. Only the vertical distance towards the display was limited by the sidewalk width, respectively by the traffic lane on the back. The field study was conducted over a period of five weeks and similar to the study in Chapter 9 only in the afternoon and evening hours to provide optimal lighting conditions for tracking users by the Kinect sensors, and the single conditions were also switched all 45 minutes such that data would grow evenly.

10.2.6 Data Collection

In this field study behavioral data was again obtained by field observation, video recordings, sensor logging and semi-structured interviews [Beyer 2014, P.4]:

Data Collection			
Field Observation	Video Recordings	Sensor Logging	Semi-Structured Interviews

Similar to the study presented in Chapter 9, the field rater was supervising the display unobtrusively from within the building. Videos of all passer-by behavior in front of the wide banner were recorded from five different camera perspectives, including one camera directed from the street towards the display in order to be able to correlate user positions with the positions of the visual cues on the screen during the video analysis. The log data was primarily used to locate user events and for occasional verification of user positions. For obtaining subjective data 20 semi-structured interviews were conducted, and on the sidewalk it again posed a challenge that the interviewer initially had to remain concealed in order to not influence user positions and behaviors. The passers-by were contacted by the interviewer once they had finished interaction in front of the visual cues.

10.2.7 Video Analysis: Positioning Behavior

Coding Scheme: Defining the Positioning Behavior

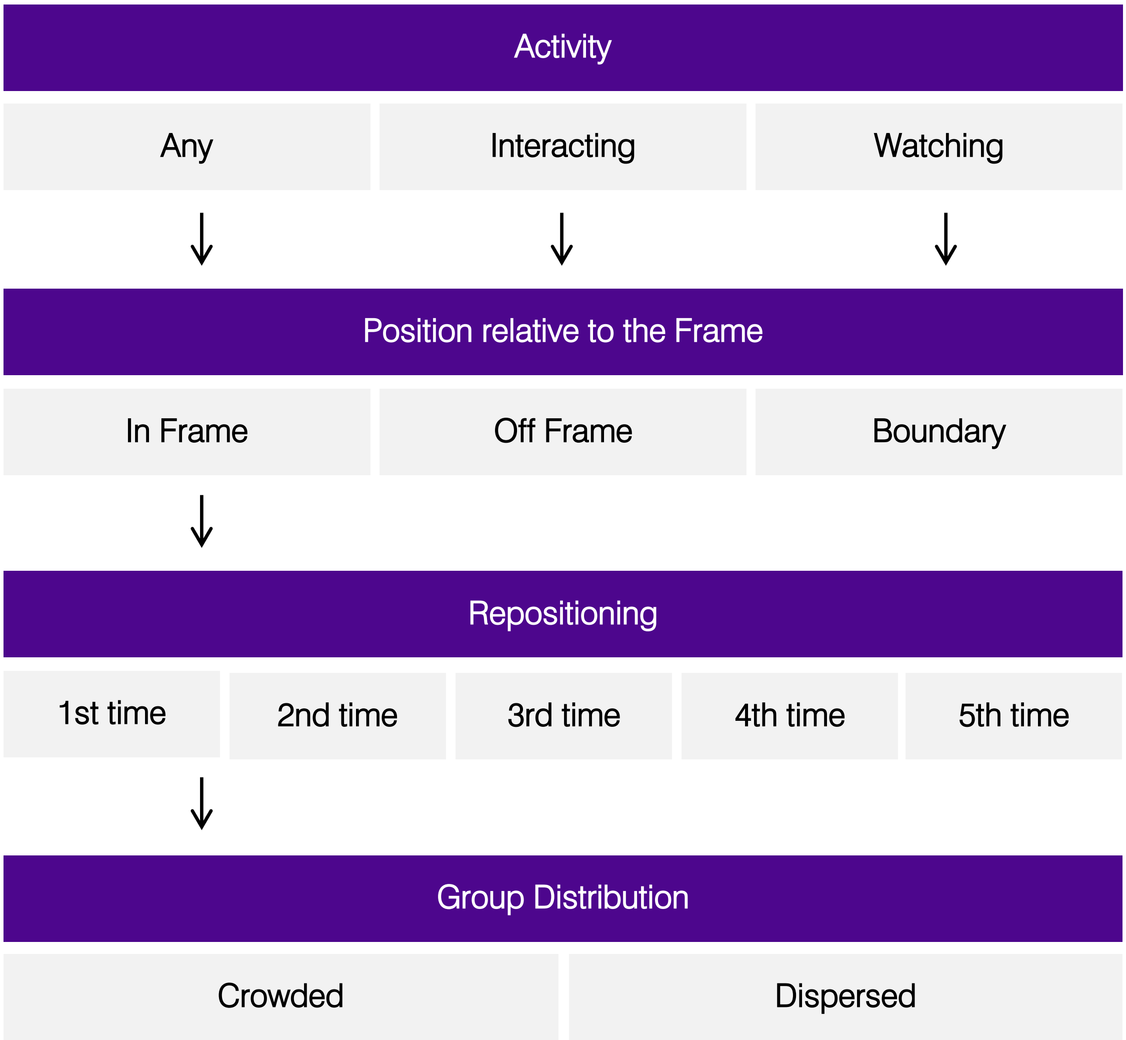
Of the video material from the five weeks of the field study, a sample of 28 hours was analyzed using *Noldus Observer*. In the developed coding scheme, each single stopping passer-by was recorded as a numbered subject, and according to the three identified basic tasks of visual audience moderation (↺ Chapter 3.4.3) then was further described by his or her positioning and repositioning behavior, the currently performed user activity, and in case of multiple users by their distribution in front of the wide display (compare [Beyer 2014, P.7]):

Scored Behaviors			
Positioning	Repositioning	Distribution	Activity

When scoring the *positioning behavior* for each active or passive user, the state framed was set if he or she positioned fully within the boundaries of a visual stimulus such as a frame or ellipse, boundary if he or she was not fully within but still tangent to it, and off frame if he or she stood apart from any visual cue or was in range of one by pure chance. As users can position themselves multiple times in front of a visual stimulus, for example when they leave its position to temporarily observe another player before returning to resume interaction in front it, the *repositioning behavior* which was scored as modifier along with each framed state kept count of how many times a user repositioned himself in front of the same visual cue. In the case of multiple users in front of the display, the *distribution behavior* was scored to quantify crowding effects and their resolution. Thereby the state crowded was set if pairs or groups crowded together and interfered with each other, and otherwise dispersed was set if all users owned at least one arm's length personal distance to the neighbor.

Coding Scheme: Correlating Activities and Positions

For each user also his or her *user activities* such as interacting or observing were scored to correlate active or passive engagement of users with their positioning behavior, and to reveal social constellations, i.e. the combined behaviors of two or more persons in front of the display describing for example the positioning of a group if all members are interacting or if only one member is performing and the rest is watching passively. The analysis process can be simplified as follows:


Activity
Any
Interacting
Watching
Position relative to the Frame
In Frame
Off Frame
Boundary
Repositioning
1st time
2nd time
3rd time
4th time
5th time
Group Distribution
Crowded
Dispersed

10.3 Findings

The study showed that
static, dynamic and interactive frames and ellipses can subtly direct and distribute users along the display, but static or slow moving ones are more effective than fast ones.

10.3.1 General Observations

Counted Passers-by

During the five weeks of the field study hundreds of passers-by, arriving either as singles, pairs or in groups, interacted with the ball game displayed on the wide banner display. Within our sample of 28 hours of analyzed video material the behavior of 304 passers-by who stopped and engaged with the display was scored. Of these, 267 interacted with the screen, while 37 were mere observers only watching the other active players (compare [Beyer 2014, P.7f]).

Unaware Intitial Interaction

The initial visual feedback to the movements of passers-by walking by the screen sideways worked effectively. Once people noticed the particle cloud moving along with them in the periphery, they stopped and turned towards the display, then recognized the skeleton representation and started to interact soon, many moving their skeleton towards one of the visual positioning cues quickly.

User Positioning

Most active users seemed to instinctively accept the prescribed stimuli and positioned themselves in front of the positioning cues instead of chosing a position themselves. Childs and young adults positioned themselves more frequently in front of one of the frames or ellipses, while the willingness to position oneself and to interact in general decreased with increasing age.

Figure 10.5: Bystanding and crowding behaviors in front of the wide interactive banner display.

10.3.2 Behavior in Front of the Baseline

Crowding and Bystanding Behaviors

The video analysis confirmed our early observations that groups and pairs often crowded together when interacting with the wide banner display, even though there was enough free space available in front of it. This crowding usually could be attributed to group affiliation and passive bystanders watching an initial user from close positions behind or next to him or her, partly in orthogonal orientation to the display (see Figure 10.5). This way the partners were forming L-shaped or side-by-side formations in front of the display, in a few cases were also standing behind others. If a passive member later joined the interaction, then often without detaching from the crowd or partner and ignoring the other users, which resulted in users interfering with and occluding each other. Such initial close by-standing turning into interaction without adapting one's own position was more often the reason for close distances than collaborative interaction between users.

Distribution and Repositioning

Overall 61 passers-by engaged with the baseline of which all were interacting except one person who was only watching others. In 54% of the cases in which multiple users interacted in front of the wide display, they crowded together instead of using the available free space. To quantitatively compare the baseline with the other conditions beyond this mere distribution value, we had to find further suitable measures. As user positions relative to visual cues on the screen such as *framed*, *off-frame* or *boundary* cannot be determined for the baseline which does not contain such positioning cues, we correlated the baseline to the other conditions also in regard to the count of repositionings of single users, which can indicate that users try to obtain more space [Binder 2013, P.24]. Only one third of the active users (20 out of 60) repositioned themselves, for example to gain more space while interacting, while the rest remained quite static.

Figure 10.6: Users being subtly directed along the display by imperceptlbly moving visual cues.

10.3.3 Positioning Effects

General Observations: The Puppeteer Display

When displaying the conditions with the dynamic or interactive visual positioning cues, in all cases we observed strong positioning effects in front of the cues. Passers-by immediately and willingly aligned themselves to the center of the frames and ellipses just in the moment when they were starting to interact. Also, users did not only align themselves only once, but actually became attached to the visual cues that were slowly moving across the screen (see Figure 10.6). As the wide banner display directing its users from one side to another and back, or guiding passive users to empty spots in front of the display, from the other side of the street looked like a puppeteer to us who manipulates the positions of puppets by strings, we named this work *The Puppeteer Display* in [Beyer 2014].

Positioning in front of the Visual Positioning Cues

Of the entire audience, 243 passers-by engaged with the visual strategies, out of which 207 interacted and 36 only observed others. Of those who interacted, about 70% at least once deliberately moved to and aligned themselves to the center of the offered positioning cues (see Figure 10.7 for each strategy).

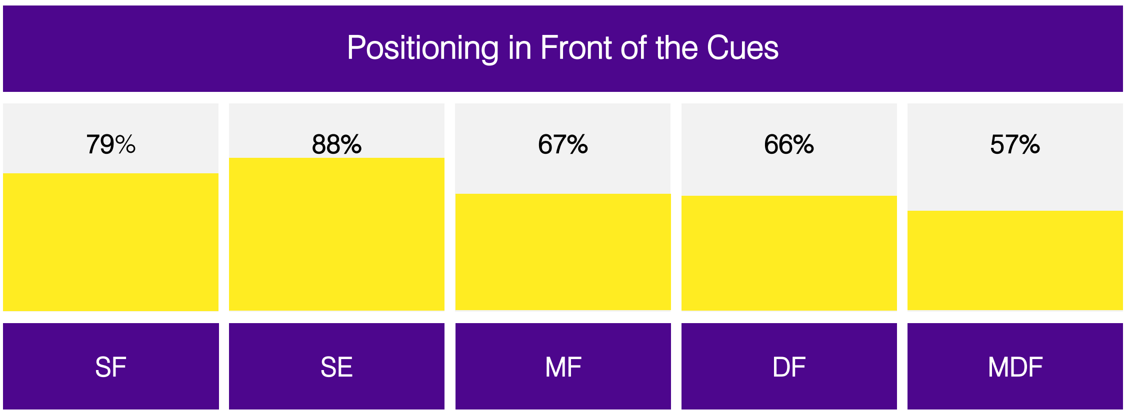


Figure 10.7: Share of active users who aligned to each of the five visual positioning strategies.

Need for Side-to-Side Movement

Qualitatively, users showed no signs of consciously paying attention to the visual cues in the front of which they were positioning themselves or trying to integrate them to their play. Yet users often showed a side-to-side movement when interacting in front of the frames and ellipses. Many obviously moved their upper body or made small steps to the sides to reach for balls, returning to the center of the positioning cues immediately afterwards. But we also observed that some users showed a steady side-to-side movement in front of the ellipses, which seemed to have no specific goal except for satisfying a need of moving the visual skeleton on the screen from one edge of the platform to the other.

Correlation with Activities

When correlating user positions and activities the numbers revealed that the strongest position stimulus during interaction is generated by the imperceptly moving *Static Ellipses*. Users spent 83% of their interaction time in front of them, such that they are significantly more effective than the second best *Static Frames* with 58% of time spent in the central position (see Figure 10.8 left). Yet, the time users spent in front of the cues also reveals a varying effectiveness of the strategies to hold users, as in contrast to the slowly moving cues most of the interaction time was spent off-frame for the *Moving Frames* and *Dynamic Frames*. Active users also aligned to the *Multiple Dynamic Frames* for about half of the time, a good result considering that the visual cues make up only for a small fraction of the screen real estate. In all cases passive observers usually preferred off-frame positions, and the boundary position was only passed shortly.

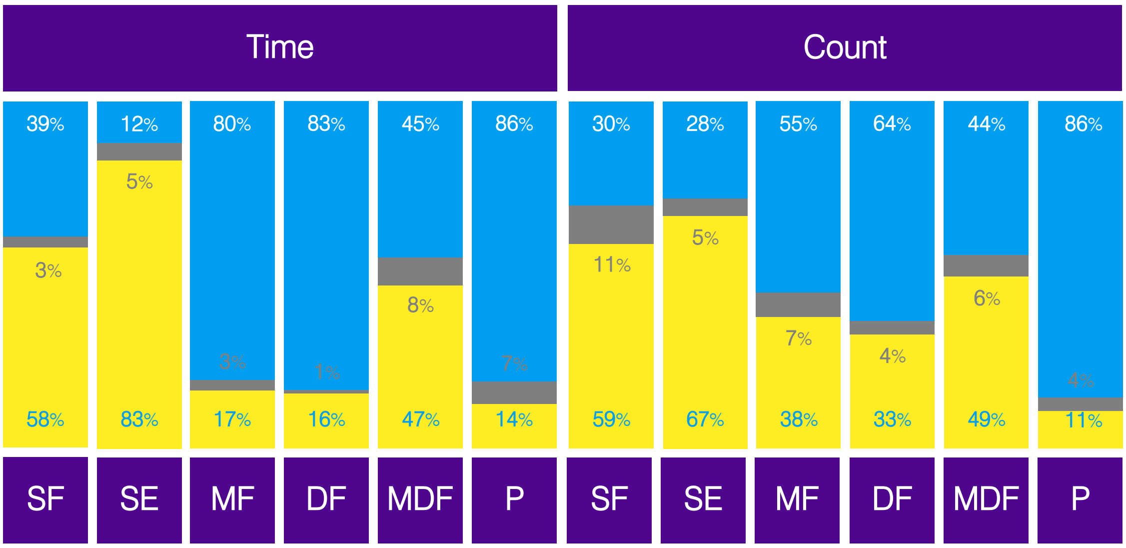


Figure 10.8: Positioning time and count when interacting with (P: passively observing) visual cues.

Figure 10.9: The ellipses were an even more effective visual positioning cue than the frames.

Repositioning in front of the Visual Cues

In contrast to the marginal dynamic in front of the baseline (↺ Chapter 10.3.2) passers-by were rarely static in their behavior while interacting with the visual positioning cues. Often they repositioned themselves more than once within the same continuous interaction, after they had temporarily left their position to either observe another player or pass balls to or cooperate otherwise with a partner before being attracted back to the cue. Here, too, the *Static Ellipses* generated the most repositioning, with 36 out of 41 interacting users or 88% repositioning at least once and 13 or 32% repositioning a second time. One person was even coming back a fifth time to the ellipse cue (see Figure 10.10). Chi-squared tests showed that with all visual strategies significantly more users repositioned a first time than with the baseline (all $p<0.005$, MDF: $p<0.05$). Interestingly, when looking at the mean durations after the first and second repositioning, interaction times decreased for the *Static Frames* and *Static Ellipses*, but increased for the *Moving Frames* and *Dynamic Frames* (see Figure 10.10 right). It seems that once users finally accepted the lower performing moving stimuli as reference for their positioning, they stayed longer in front of these cues the second time.

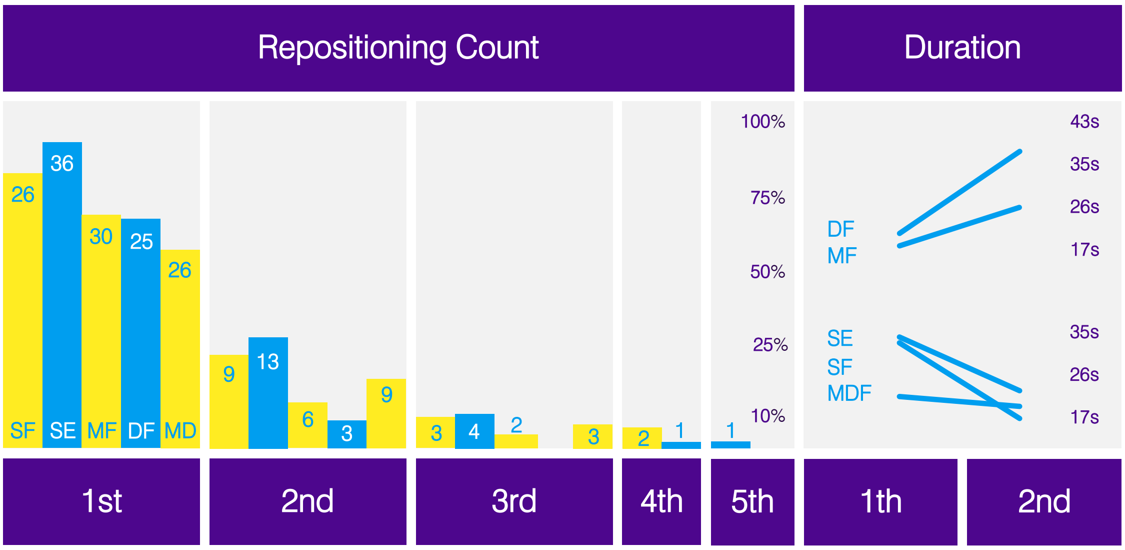


Figure 10.10: Repositioning count of interacting users and mean interaction durations (right).

Figure 10.11: An arriving group distributing themselves in front of the multiple dynamic frames.

Distribution in front of the Visual Cues

For all conditions that included visual cues, a distribution of interacting pairs and groups across the display was observed more often than crowding situations. While group members often also showed an initial bystanding behavior, they soon moved to the still free visual positioning cues after having watched the first active member interacting in front of such a cue for a while. Once a second user had left the crowd towards a free visual cue to also become active, further members were likely to follow regardless of whether cues were still available. This worked quite effectively as pairs and small groups of up to four people were the most frequent group constellation on the city sidewalk. Yet often passers-by were also following the cues and spreading across the wide screen immediately. Chi-squared tests showed that the distribution of passers-by was significantly higher for all visual strategies when compared to the baseline, except for the *Dynamic Frames* (all $p<0.005$, DF: $p>0.05$). The best results were achieved with the strongly dynamic *Multiple Dynamic Frames* with a distribution in 96% of cases. Also the steadily moving *Moving Frames* and the effective *Static Ellipses* performed well with 88% and 86% of passers-by distributed (see Figure 10.12).

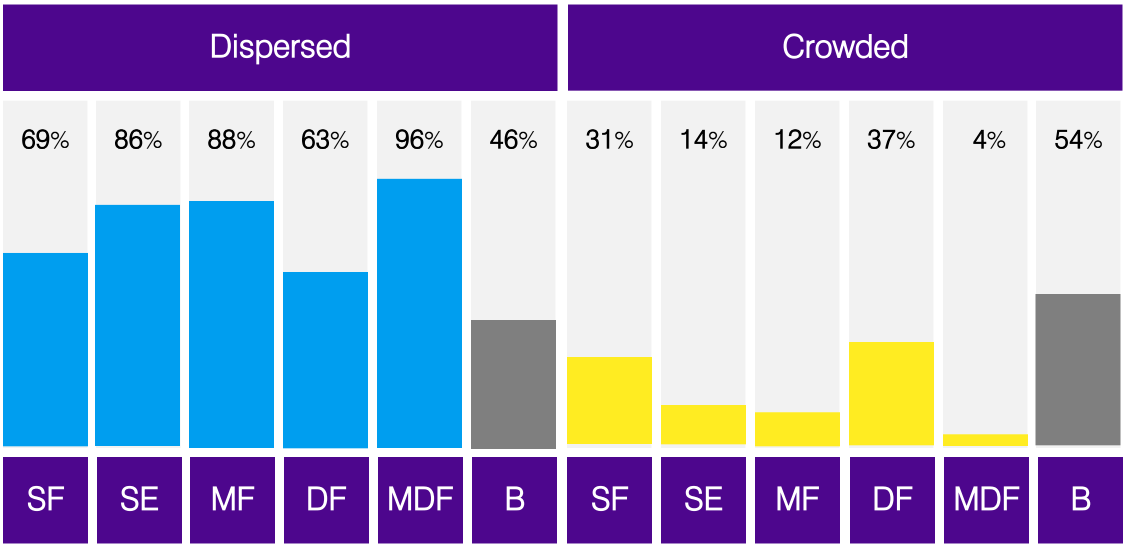


Figure 10.12: Distribution of two or more users for all visual strategies and the baseline (grey).

Social Interaction: Performing in front of the Cues

In contrast to the baseline where active users initially being watched by their partners and group members sometimes followed by close users interfering with each other was the most frequent behavior (↺ Chapter 10.3.2), such situations were much rare when users were interacting with the dynamically and interactively displayed visual cues. While close bystanders could also be observed in front of the visual cues, active users were detaching from the initial actor to position themselves in front of the frames and ellipses. They were only leaving their position and temporarily coming back to observe the partner if he or she had to show something, or sometimes if they wanted to cooperate. Initial or temporary bystanding behaviors could still be observed in situations with large numbers of people in front of the display when not enough visual cues were available. When interacting persons were observed by others, they tended to position themselves even more eagerly in front of the visual cues, as if they would want to demonstrate to the bystanders how to position accordingly (see Figure 10.14).

Social Constellations

When we analyzed the concurrent behavior of multiple users in front of the display for each visual strategy and correlated the activities and positions of each single user, we found that in the majority of social constellations at least one or two members were interacting in front of the visual cues at the same time. Figure 10.13 exemplarily illustrates the activites and positions just of pairs across all visual strategies, where in 122 of 184 or 66% of the observed user constellations one or both of the two partners are interacting in front of a visual cue.

Pair Constellation		Count	Duration	Mean Time
P1 interacts off-frame	P2 watches	7	01:22	00:12
interacts boundary	watches	7	02:03	00:18
interacts framed	watches	38	07:33	00:12
interacts off-frame	interacts off-frame	47	20:25	00:26
interacts boundary	interacts boundary	1	00:15	00:15
interacts framed	interacts framed	35	11:51	00:20
interacts framed	interacts off-frame	49	14:39	00:18

10.13: Concurrent activities and positions (blue: framed) of two partners in front of the display.

Figure 10.14: Active users being observed by others while performing in front of the visual cues.

10.3.4 Subjective Data: Awareness of the Visual Cues

Recall of the Visual Stimuli

Out of 20 passers-by that were interviewed after they had interacted with the sidewalk display, 15 were students, 5 in employment, 14 men and 6 women. Their age ranged from 22 years to 48 years and the average age was 25. When asked about the anticipated purpose of the display, the most frequent answers were entertainment, fun, attracting attention, and motivating passers-by to play. 10 of them had interacted with the *Static Frames*, 3 with the *Static Ellipses* and 7 with the *Multiple Dynamic Frames*. All could recall the basic elements displayed on the screen such as the colored balls and the skeleton representation they had controlled, and all but one could describe what one can do with the ball game. Interestingly, all of them had recognized the frame or ellipse stimuli, and of the 16 who had positioned themselves in front of these visual cues 15 answered they did so because of the cue. This differs from the results of the study with the advertising column (↺ Chapter 7.3.10), where interviewees stated to not recall the large static frames in front of which they had positioned themselves.

10.4 Interpretation

Visual positioning cues on the screen can be effective in directing users if they are perceived as having functionality or if they are key stimuli for instinctive behavior, but users will only comply up to a certain treshold.

10.4.1 Performance of the Visual Strategies

Subtly Influencing User Positions by Visual Cues

In this study we wanted to subtly influence user positions by visual cues instead of using explicit textual instructions, but when analyzing user behavior we had again the problem that we cannot assess people's subconscious (↺ Chapter 7.4). In the video analysis we could observe that while passers-by quickly positioned themselves in front of the frames and ellipses, they seemed to ignore them and not integrate them to their play. On the other hand, participants of the interviews could recall the visual cues and confirmed to have positioned themselves as a consequence of them. The process of positioning thus may proceed as follows: When users approach in the beginning, a perceptual grouping and segregation of all visual elements on the screen takes place preattentively, but as no threatening or strongly emotional stimuli are involved a direct motor response to the positioning cues is unlikely in this early phase (↺ Chapter 3.4.4). Instead, users interpret the visual cues according to their prior experience, and here the depth of processing probably is the lower the more familiar the perceived schemes are. In our case users quickly focused their selective attention on the ball game, but also interacted at length in front of the visual cues and thus processed them at least such intensively that they could recall them later from short-term memory.

> Users ignored the visual cues apart from positioning themselves in front of them, but processed them enough to recall them later.

Effect of the Visual Frames

The visual frames effectively influenced the positions of single and multiple users. Similar to the large static frames around the column (↺ Chapter 7), passers-by interpreted the virtual rectangles correctly as positioning cues and instinctively accepted the prescribed stimuli instead of choosing the position themselves. Yet this time the frames were even then effective when displayed dynamically and interactively on the screen. In contrast to the column study, interviewees also recalled to have positioned themselves in front of the frames. This may be explained by the fact that the frames on the column were processed differently as they simulated real physical display bezels which viewers knew from prior experience. This scheme was already recognized preattentively and then only processed low before it triggered a conditioned reaction. Instead, the dynamic frames were smaller and did not coincide with the real frame, and thus had to be interpreted first as a component of the virtual content having some functionality.

> ▶ The frames in this study were effective as they were interpreted as a component of the virtual content having some functionality.

Effect of the Ellipses

The ellipses even outperformed the frames in influencing passer-by positions. One explanation is that ellipses are also perceived as a functional element within the screen content. Yet while ellipses may be associated with solid platforms of computer games where a user representation can stand upon, they are not as common as rectangular frames in contemporary digital content. Further our understanding of spatial perspective may play a role. According to [Gibson 1966] the most important plane of reference in 2D and 3D space is the ground plane which has relevance for human orientation, and the instinctive need for standing on a solid floor may have contributed to the preferred positioning of one’s screen representation on a platform within virtual space. This perception of a solid floor may also be related to the need for a left-right movement on top of the ellipses. Finally, also individual content-related associations may have caused the positioning, such as interpreting the ellipses as illuminated positions on a stage.

> ▶ The ellipses were interpreted as a functional element, or they even are an instinctive stimulus based on the role of the floor for humans.

Static vs. Moving Stimulus

With the *Static Frames* and *Static Ellipses* conditions, where the positioning cues were moving slowly at an imperceptible speed, users interacted longer in front of the positioning cues than apart from them. They did not only align themselves once to these stimuli, but also became attached to them, which appeared to us like puppets being attached to strings. This strong bonding to the cues could not be observed for the *Moving Frames* and *Dynamic Frames* where the stimuli were moving away quickly from the user. Yet there was no such significant difference between static and moving concepts in regard to the number of first positionings in front of the cues. This means that users generally did not position themselves less often in front of the strongly moving cues, but they were simply not willing to follow them and to reposition themselves repeatedly at this fast speed. When such a fast moving stimulus pulled away, they also may have recognized that interaction was also possible outside of it and that it had no actual functionality.

> Users positioned themselves in front of slowly and fast moving cues, but refused to follow them if the speed exceeded a certain threshold.

Distribution of Passers-by

While in front of the baseline members of a pair or group were often standing such close together that they did not have enough space to interact without impeding each other, the investigated strategies for displaying positioning cues can resolve such crowding effects: Except for the *Dynamic Frames*, which were not very effective in distributing users as they were regionally limited, all visual strategies generated a significantly better distribution of users during interaction than the baseline, and also for all significantly increased repositioning numbers were obtained. This means that visual positioning cues can not only be used to control the positions of single users, but also to equalize and dissolve groups, and consequently also to actively provide for more free space, dynamic and interaction in front of the display. The *Multiple Dynamic Frames* performed best in distributing users, possibly as they were strongly dynamic and by dispersing multiple frames on the screen clearly communicated the desired purpose.

> Dynamic visual positioning cues can be effective to distribute users if people attach to them or can decode the meaning behind them.

Figure 10.15: The ellipses were the most effective and possibly instinctive positioning stimulus.

Social and Performative Interaction

The dynamically and interactively displayed visual positioning cues proved to be effective to dissolve crowds and bystanding effects and to distribute users more evenly along the display. Yet sometimes a play of forces between the influence of the visual cues and social interaction between two or more users could be observed, when members of pairs or groups repeatedly left the position right in front of the cue in order to cooperate with or observe another player. Then or when large numbers of people were in front of the display, close constellations with passive observers watching active users could still occur. Yet after a short timespan these observers returned to their own cue to resume interaction. Interacting users who felt that they were observed by others tended to position themselves even more eagerly in front of the cues, a behavior that can be attributed to a so-called performative interaction [Dalsgaard 2008]. This means that the interacting user takes a presenting role and thus underlies social pressure to entertain the watching audience, but also to show that he or she understands how to interact properly and controls the system in an exemplary manner.

> A play of forces between the cues and social interaction can occur, but performative interaction often increases the positioning stimulus.

10.4.2 Limitations

Generalizability to other Display Shapes

The presented visual strategies for influencing user positions and directing users have been designed for and tested with a wide, flat interactive banner display. Other large display shapes such as interactive advertising columns also allow that multiple users interact with them simultaneously, and we had found that large visual frames can influence user positions around them (↺ Chapter 7). Yet, the dynamic and interactive strategies for displaying visual cues investigated here may not be equally effective around columns due to their curvature.

Generalizability to other Environments

The wide interactive banner display used in this study represents a solution for common sidewalk situations in cities. Yet other large displays which provide enough space for multiple users may underlie specific situative limitations. For example, other than a sidewalk display they may be approached frontally, allow for more user distance or provide less free space at the sides, factors which may affect how users crowd together and how positioning cues have to be designed.

Role of the Interactive Content

In this field study we used a seamless display and an interactive ball game as continuous background content which did not prefer any special position of the players (↺ Chapter 10.2.4). This way we tried to avoid that other factors than the visual positioning cues influence the user positions in front of the display. Yet in practice many different interactive contents may be displayed on a long banner display, and if these contents are not seamless it should be tested how they interact with or possibly weaken the effect of the positioning cues.

10.4.3 Open Issues

Summarizing the findings and limitations of this study on subtly directing users, the following issues are left open at this point of research:

Other Visual Cues
Which further visual cues do exist that are effective positioning stimuli with which one can subtly direct users in front of displays?

Improving the Positioning Stimulus
How can positioning cues be made more effective such that users also keep attached to them if they are moving fast along the screen?

User Constellations
Can such positioning cues be employed to create even more specific user constellations, such as required starting positions of multiplayer games?

Display Shapes
How can the positions of multiple users be actively influenced in front of other displays with large interaction spaces such as columns?

Awareness of the Cues
How can behavioral research find out more about how users perceive and are aware of such visual cues by objective and subjective measures?

10.5 Takeaways

Visual Audience Moderation
is a strong tool to direct users and distribute them along the display, yet visual cues have to be tested for their effectiveness first and also should not move too quickly.

10.5.1 Designing Interactive Positioning Cues

Behavior Effectiveness of Visual Positioning Cues
In our study the used frames and ellipses performed well as positioning stimuli. With other applications designers may want to use other visual cues that are designed content-related. For example, on a field of flowers, sunbeams may be more meaningful in the context of the content than frames [Binder 2013, P.75]. But designers should be aware that arbitrary visual cues are not necessarily effective positioning stimuli. In our case the idea to test visual frames was inspired by our prior observations of strong positioning effects in front of rectangular frames in other studies, and also the effectiveness of the ellipses had to be proved first.

R 10.1 Ensure that Visual Cues are Behavior-effective

Do not only select visual cues according to their content-relatedness, but also make sure to find behavior-effective positioning stimuli.

Pretesting the Effectiveness of Visual Stimuli
Further not all variations of a certain visual representation may be equally effective. In our study we had to iteratively refine the visual frames and test different sizes, aspect ratios and bezel thicknesses until we had found a design which seemed to constitute a strong positioning stimulus. Such determinants can be te evaluated in pretests in advance to the real deployment.

R 10.2 Iteratively Refine the Visual Cues in Pretests

Not all variations of a cue are equally effective, such that its effectiveness as positioning stimulus should be refined iteratively before use.

Movement Strategies for Visual Positioning Cues

Our study with the frames and ellipses showed that static positions and slow movement of visual positioning cues should be preferred to fast moving ones. We found that strong motion significantly reduces the willingness of users to stay in front of the visual cues as they have to reposition themselves quickly and as they notice that the cues have no real functionality once they leave the position in front of them. Static positions means in this regard that motionless visual cues are displayed dynamically at different static positions, or that they slowly move at imperceptible speed, but they should not move too quickly along the screen.

R 10.3 Visual Cues Should not Move Too Quickly

Passers-by position themselves in front of dynamically positioned or slowly moving cues, but they are not willing to follow constant quick movement.

Interactive Strategies for Visual Positioning Cues

The interactive strategies for visual positioning cues used in this study showed that a strong dynamic can be useful in some ways or not. In the case of the *Dynamic Frames* where the visual cue pulled away from the user position, people showed reluctance to reposition themselves repeatedly. In contrast, the meaning of the dispersing and strongly dynamic *Multiple Dynamic Frames* was clearly understood by users as an invitation to distribute themselves along the display.

R 10.4 Interactive Positioning Cues Can be Strongly Dynamic, if this Conveys a Certain Meaning to Users

If users decode the meaning, they will even follow strongly moving cues.

10.5.2 Measuring Behavior

Correlation of Visual Cues and User Positions

Similar to Chapter 7, in this field study we wanted to observe how user positions correlate with the dynamically displayed visual positioning cues on the screen. For this we had to install a camera that could record the sidewalk display and user behavior at the same time. Thus the camera was directed towards the display from a slightly angular position from the street. Other cameras that recorded the whole sidewalk in front of the long banner display from above were instead helpful to analyze the distribution of multiple users in front of the display. As in prior studies, this shows that for each analyzed behavior a specific camera perspective can be required and should be carefully planned before the study.

R 10.5 Use Suited Camera Perspectives

For correlating user positions and visual cues on the screen the camera can be directed from the street, and for user distribution from above.

Comparing the Baseline

The baseline was compared with the other conditions in regard to the distribution of users, but not in regard to positions of single users as it did not display any positioning cues. To further quantify and compare the behavior in front of the baseline the repositioning behavior was used, which also described the level of attachment of users to the visual positioning cues. To compare the baseline with study conditions, the introduction of such auxiliary behaviors can be very helpful.

R 10.6 Introduce Auxiliary Behaviors if Needed

The repositioning behavior did not only describe the performance of the visual cues, but also helped to quantify and compare the baseline.

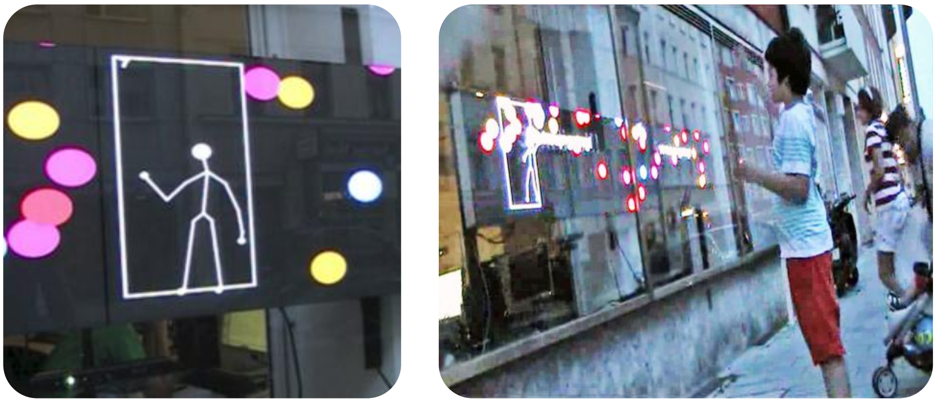


Figure 10.16: Improving the positioning stimulus by additional functionality: a game counter.

10.5.3 Outlook: Enhancing Visual Positioning Cues

Adding Additional Functionality

To improve the performance of the less effective visual cues such as the quickly moving frames and encourage users to follow them constantly, they could be augmented by additional functionality such as a game counter. We conducted first field tests with game counters integrated to the top left corner of the visual frames which keep count of how many balls a user hit (see Figure 10.16). The idea is that if users perceive such an obvious advantage of standing in front of the visual cue, this may increase the positioning stimulus and lead to them accepting more control over their positions and movement [Binder 2013, P.71].

Spotlight Cueing

The effectiveness of the tested positioning stimuli could also be improved by additional visual cues such as the exogenous and endogenous cues for shifting the attention of users to spatial spotlights such as proposed by [Posner 1980]. Comparably, if current users in front of the screen have to be repositioned, instead of moving the frames quickly and risk that users do not follow them, these positioning cues could be instantly displayed at their target position, and to first direct the attention to them arrows pointing to the frames (exogenous cue) or flashing frames (endogenous cue) could be used (see Figure 10.17).

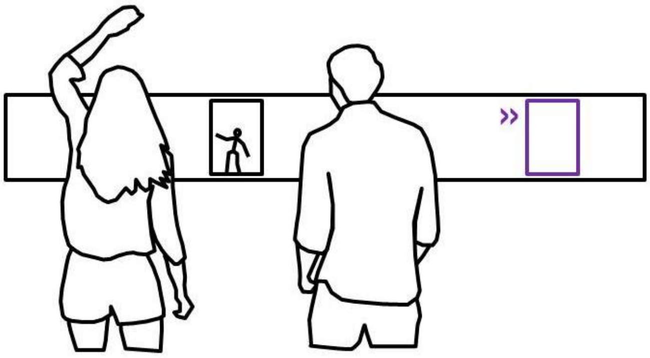


Figure 10.17: Arrows pointing to the visual cues or flashing can first direct the attention to them.

Future Applications and Uses

Future research could further investigate if actively created public audience constellations can trigger engagement and improve the performance of more complex collaborative applications such as interactive multiplayer games. For example, incidentally arriving passers-by first could be actively and subtly guided by the display to the starting positions of a game, and then it could be observed if, without contacting them in any way or giving them any further information, they recognize the interaction possibilities by themselves and start the game.

CHAPTER 11

CONCLUSION

Progress Made,
Contributions,
Future Work

11 Conclusion

This work made progress towards
novel interactive advertising displays, contributed theories, content solutions and display designs, and proved the future potential of these displays.

11.1 Progress towards Interactive Advertising Displays

Potential of the Novel Display Shapes

This work presented novel interactive advertising displays such as an interactive advertising column, large interactive life-size screens and a long interactive banner display, which are based on historical display shapes of the out-of-home domain, but are equipped with digital screens and vision and depth sensors that enable passers-by to naturally and touchlessly interact with them. It further presented interactive content solutions with which these displays can convey their interactivity to passers-by and thus better attract their attention, and others with which they can subtly and actively guide users along the screen to better distribute them and avoid close bystanding and crowding in front of the display. While at the beginning we did not know if passers-by would accept, understand and interact with these novel displays, the five field studies and the lab study which we conducted proved that the proposed display designs and interactive contents were very effective, by communicating their interactivity attracted more attention than classical public displays and in the case of the column and the banner encouraged dedicated multi-user interaction. Thus they have a high potential for out-of-home advertising. We also observed that the thousands of passers-by who engaged with the displays had a very playful experience and often interacted for a long time, some even for hours. In the interviews people also confirmed that they had fun playing with the displays and some even expressed their wish that the displays should remain in place after the study.

Conveying Interactivity

In this work we showed how public interactive advertising displays can convey their interactivity by giving visual feedback to the initial movements of passers-by when they are walking by, a mechanism which we call *unaware initial interaction*. We did not only show this for one display, but for different common out-of-home display shapes and considering the typical approaching trajectories and visual-spatial conditions around them. While all investigated display types effectively conveyed their interactivity and thus attracted more attention than when just showing dynamic, non-interactive content, we found that each display has its own requirements for effective visual feedback. The field study with the life-size display described in Chapter 8 showed that mirror images and distance-controlled visual feedbacks that rely on familiar mental models can be almost equally effective in conveying interactivity when passers-by are approaching frontally. The field study of Chapter 9 with the long banner display revealed that when people are passing by sideways, different visual feedback stimuli and positions are nearly equally effective if passer-by can clearly conceive that the local movement on the screen correlates with their own movement. This study also proved that the banner display is an effective alternative to display rows on city sidewalks. The studies of Chapter 6 and Chapter 7 revealed that the advertising column, which combines multiple frontal and tangential approaching trajectories, is very effective in signaling interactivity due to its central location and high visibility. Another finding is that visual feedbacks can perform differently well in attracting attention and conveying interactivity. For example, the photo condition of Chapter 8 was less interactive than the similar mirror images, but attracted more attention.

Actively Shaping the Audience

We further showed that a wide public display can subtly and actively guide single and multiple users in front of it by displaying dynamic and interactive visual cues on the screen according to our vision that displays in public space become more active themselves and shape their audience. At the beginning of this work we had no clue that this would be possible at all. This mechanism which we call *visual audience moderation* represents a solution to dissolve crowds in front of the display and direct individual users to empty spaces or interesting spots in front of it. The study presented in Chapter 10 revealed that different visual positioning cues such as frames or ellipses and strategies for displaying them are differently effective. We found out that the used stimuli have to be behavior-effective and not move too fast in order to be accepted by users.

The Influence of Display Qualities

Another main hypothesis of this research work was that different display qualities such as the form factor, the framedness or the surface structure of a large public display can influence passer-by, audience and user behavior in front of it. The lab study described in Chapter 6 revealed that cylindrical, semi-framed advertising columns can, with the help of suited interactive contents, stimulate users to circulate around them while interacting and thus make them walk long distances. In contrast, the frames of flat rectangular displays can influence the movement and positioning of active users in such a way that they frequently position themselves within a central, strip-like region in front of the display. The shape and the framing of the displays also affected the body orientation of users when interacting with the different displays, but not their viewing behavior which was dominated by the displayed visual feedback. The field study of Chapter 7 revealed that such positioning effects can also occur in front of single framed sub-units of display configurations such as a polygonal column display, and thus what can happen if multipe behavior-influencing display qualities interact with each other. The frames around the polygonal column did not only stimulate single interacting users to position themselves frontally and centrally, but also influence the distance and cooperation between multiple interacting users. That in fact just visual frames which were displayed on the seamless column caused this behavior, shows that digital screens can simulate display qualities such as framedness virtually, and this way adapt their behavioral effects situationally.

Details Matter

This example of the polygonal, framed column display, where the active users positioned themselves centrally in front of the single frames instead of interacting at arbitrary positions such as around the seamless column, demonstrates that display qualities should never be considered in isolation, but in regard to their possible interplay with each other. Seemingly small details of the design can change completely how people behave around a display. Also the interactive content can influence user and audience behavior. For example, the movement-stimulating content of Chapter 6 made users move continuously around the column, while with the graffiti content used in Chapter 7.3.11 people walked less around it, and with the interactive ball game they usually did not circulate around it at all when interacting. How small details can matter is also shown in Chapter 10 by the findings that visual positioning cues such as frames only then effectively influence user positions if they have a specific design and do not move too fast.

The Role of Passer-by Expectations

The principle of communicating interactivity to unsuspecting passers-by by an unaware initial interaction is, as outlined in Chapter 3, another example of attracting attention by a surprising stimulus. In all studies of this work we observed that almost all passers-by did not expect interactivity of the displays when they were approaching, which is why surprising them by visual feedback proved to be a very effective mechanism once their gaze crossed the screen. The field studies with the advertising column and the banner display described in Chapter 7 and Chapter 9 revealed that the later passers-by noticed the feedback and the more they were startled out of their thoughts or other activities they were occupied with, the more they reacted with strong surprise. Passer-by expectations and prior knowledge also played an important, but quite different role in the study of Chapter 6, where one third of all participants remained completely immobile and inactive within a central position in front of the flat rectangular display. Due to their prior experiences these passive viewers associated the framed screen with television viewing, and this way the framing even effectively prevented that they ever noticed interactivity. Similarily, in the field study of Chapter 7 passers-by associated the displayed virtual rectangles on the column with real display frames and adapted their behavior accordingly. In the study on subtly directing users in front of a wide display of Chapter 10 the familiar looking visual frames and platform-like ellipses had a useful effect when interacting users immediately interpreted them correctly as positioning cues. All these examples show how important it is to consider and examine passer-by expectations and possible associations when designing public displays and interactive contents for them.

Situational Factors

Another lesson learned from the field studies is that situational circumstances often have a huge impact on the success or failure of the initial interaction. In all studies passers-by were less likely to notice the interactivity of the displays if they were in a hurry, distracted by smartphones or in deep conversations with a partner. In Chapter 7 we were able to clearly classify passers-by into attentive ones who noticed the column and its interactivity early, and others who were initially inattentive and thus reacted with surprise only once they had arrived at the screen. In the study of Chapter 9 with the banner the chance that passers-by who approached on the sidewalk noticed the display often depended on the question whether they were looking towards the building facade or towards a competing stimulus on the other side of the street at this very moment when they arrived.

11.2 Research Contributions

In summary, this work contributes to the field of interactive out-of-home displays by presenting the following novel theoretical and practical solutions:

Interaction Concepts

Novel conceptions on how to interact with different public displays, such as unaware initial interaction, a solution to convey display interactivity to passers-by by visual feeback on the screen, and visual audience moderation, the idea to actively and subtly direct users in front of the display by visual cues on the screen. These conceptions can be further developed by follow-up research and be practically implemented with public displays by out-of-home practitioners.

Interactive Display Designs

Concrete proposals for novel interactive counterparts of historical out-of-home display shapes, such as interactive advertising columns, banner displays and life-size displays, and the proof of their practical applicability and successful operation in public space. The presented display designs can be further developed and used in the field of interactive out-of-home advertising.

Interactive Content Solutions

Concrete interactive visual contents, feedbacks and cues for the different display shapes based on the developed concepts to attract users, convey interactivity or actively guide and distribute users in front of the screen. These solutions can be adapted by designers who create effective applications for public displays.

Empirical Findings

Qualitative and quantitative empirical findings from large amounts of behavioral data around interactive public displays which have been gathered in long-term field studies, and a set of interpretations for these findings, which contribute to a better understanding of the interaction with novel display shapes, the behavioral effects of different display qualities, and interactive public displays in general.

Evaluation Methods

Practical recommendations on how to conduct and evaluate field studies with interactive displays in public space and analyze complex behavioral patterns of multiple users around them. The presented set of methods can be of practical use for further display-related research in comparably complex settings.

11.3 Future Work

Further Display Shapes

One promising direction for future work is to investigate the distinct qualities and possible behavioral effects of further popular display shapes of the out-of-home domain as well as the typical passer-by, user- and audience behavior around them. The results of the field studies presented in this work prove that the most classical and prevalent advertising display formats such as round columns, flat portrait-shaped displays and long banner displays are ideally suited for public interaction with passers-by. As outlined in Chapter 2, one common advantage of these ground-level displays is that they are deployed where people walk and enable an unambiguous one-to-one interaction between display and user. Further inspiring display shapes can be found in urban spaces worldwide, but a good starting point are also the overviews on formats and standards provided by the national outdoor advertising associations and by the [Technical Literature] which lists the available out-of-home display formats on the market. For each novel interactive display design the inherent display qualities have to be identified, and analogous to our initial prototype design as described in Chapter 5 it should be found out how these displays can provide seamless interaction around them.

Further Visual Feedbacks

Future work can extend the presented content solutions for initially conveying the interactivity of the display. Further effective visualizations for visual feedback other than the used mirror images and graphical illustrations can be examined as well as further movement strategies for them. While our designed interactive feedback solutions were optimized for the most common situations in which passers-by approach out-of-home displays frontally, pass them sideways on the sidewalk or encounter them at highly visible central locations such as with the column, future work can investigate the possibilities and specific requirements of further environments and situations and other display types and configurations such as display rows for visual feedback. It would also be interesting to find out how the effectivity of the tested visual feedbacks can be increased by combining them with classical attraction cues and advertising techniques such as outlined in Chapter 3.2, for example with principles of visual-textual rhetoric or the technique of reframing. Finally, as these interactivity cues just represent an initial entry point to the interaction with the display, it can be investigated how suitable transitions to the subsequent, more in-depth interaction stages can look like.

Further Contents that Actively Shape the Audience

In regard to the notion of public displays that actively influence the positions of users and subtly direct them along the display, this work can be refined and extended by investigating further visual positioning cues and finding out if they can be made more effective, possibly trigger further user actions, and be used to support more complex applications. As discussed in Chapter 10, such positioning cues first of all have to be based on behavior-effective visual stimuli that succeed in subtly influencing user positions in front of the display. While we used frames and ellipses, further content-specific visuals may be found that integrate well with other interactive background contents. As we tested the effectiveness of the dynamic and interactive visual cues only in front a wide flat display, it could be examined if the proposed interactive functionality is equally effective around displays with a different curvature, such as with convexly curved columns where users may loose sight of visual cues which disappear to the invisible sides of the screen. The effectivity of the principle could also be tested in other common environments than our narrow street sidewalk. It should also be investigated how positioning cues can be made such effective that they accomplish that users keep attached to them even when they are moving fast along the screen. First tests that we conducted indicate that one promising strategy is to increase the positioning stimulus by additional functionality to the visual frames and ellipses such as a game counter. Further, it can be investigated if such positioning cues can be employed to create even more specific user constellations. As discussed in Chapter 4, the visual cues could subtly guide users to the initial starting positions of multiplayer games, even such games that are unknown to them, or they could assign different user roles to passers-by. Finally, as discussed in Chapter 10, it can be explored if the positioning cues can be supported by further visual cues that first shift the visual attention of users to them according to the concept of spotlight cueing, and if the whole system can be made more effective this way.

Enhanced Evaluation Techniques

Our method to assess audience behavior around the interactive displays shapes in public space, which relied on existing video coding software, multi-camera observation systems and additional tools such as virtual grid masks or markers for scoring passer-by positions and trajectories, proved to be effective, but often required significant effort. Future sofware solutions for analyzing public audience behavior should further facilitate and automatize the scoring of factors such as the positions, body orientations, reactions or the viewing behavior of passers-by.

11.4 Final Remarks

We observed that the designed novel interactive display shapes, in combination with our interactive content solutions, were very effective in attracting the attention of passers-by, in conveying their interactivity to them and in actively influencing user positions. The results from the field studies proved that our vision of interactive public displays that become more active themselves in order to increase the engagement of passers-by with them and improve the user experience in front of the screen is viable and beneficial for display providers. The different display shapes and playful contents were accepted very positively by passers-by and effectively entertained them, and thus in our view have a high potential for future interactive out-of-home advertising. We expect that the proposed interactive display designs and applications will establish themselves as soon as shaped displays are available at more affordable costs. They might be further pushed forward once bendable and flexible digital screen materials enter the market that can be attached to shaped displays just as easily as the foil- and paper-based posters of classical out-of-home advertising as discussed in Chapter 2. The developed interactive content solutions for round advertising columns, long banner displays and flat rectangular displays could also be advanced by combining them to an all-in-one framework that can be used flexibly with various differently shaped displays or even larger networks of advertsing displays, and that allows to exchange specific advertising contents or brand visuals in an easy way. In the field of advertising research, it can further investigate how such popular playful interactive public applications can also increase the recall of and the positive attitude towards the displayed brands or advertising messages. Finally, it would interesting to see if such techniques where unaware passers-by are brought to perform specific actions by subtly stimulating them can also be used in other fields of public applications.

APPENDIX

References, Common Work, List of Figures

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A.2 Common Work

My contributions to pre-released research cited in this work were:

Chapter 6

This chapter includes results of the CHI 2011 conference paper *Audience Behavior around Large Interactive Cylindrical Screens* [Beyer 2011] and contains additional and previously unpublished research, data analysis and interpretation. My contribution to that paper was: Core idea and concept, which is partly based on my diploma thesis at UdK Berlin [Beyer 2008], what also applies to the hardware (360° interaction sensor) and the software (computer vision and interactive contents). Further co-designing, conducting and analyzing the lab study and lead author. The cylindrical display (VROD or Digitale Litfaßsäule) has been designed by Fraunhofer FIRST. The lab study from 3th–4th December 2009 has been conducted together with Florian Alt and Jörg Müller and been technically supported by Ivo Haulsen, Karsten Isakovich, Manuel Schiewe and Stefan Klose at Fraunhofer FIRST in Berlin. My contribution to the research work published as the CHI 2011 workshop paper *On the Impact of Non-flat Screens on the Interaction with Public Displays* [Beyer 2011B] was: Core idea and concept, lead author.

Chapter 7

This chapter includes results of the CHI 2013 conference paper *Squaring the Circle: How Framing Influences User Behavior around a Seamless Cylindrical Display* [Beyer 2013] and contains additional and previously unpublished research, data analysis and interpretation. My contribution to that paper was: Core idea and concept, hardware (integration of the Kinect sensors together with Florian Köttner), designing, conducting and analyzing the field study, field observation and lead author. The used Multi-Kinect software framework and the interactive contents have been developed by Florian Köttner [Köttner 2012]. The digital column display (Digitale Litfaßsäule) as well as the software for the image correction and blending (Player) has been provided by Fraunhofer FIRST. All software and hardware work has been done in close cooperation with Ivo Haulsen and Manuel Schiewe and the VISCOM team at Fraunhofer FIRST (since 2012 FOKUS). This paper received an Honorable Mention Award at CHI 2013. My contribution to the research work published as the CHI 2013 workshop paper *Communicating the Interactivity of differently shaped Displays* [Beyer 2013B] was: Core idea and concept, lead author.

Chapter 8

This chapter includes results of the work by Jens Fakesch on the Interactive Door Display and the Life-size Display. He conceptualized and designed the interactive contents, conducted the related field studies and the data analysis and contributed to the presented theories and interpretations in the form of his bachelor's thesis [Fakesch 2013]. Chapter 8 contains additional and previously unpublished research, data analysis and interpretation.

Chapter 9–10

This chapter includes results of the DIS 2014 conference paper *The Puppeteer Display: Attracting and Actively Shaping the Audience with an Interactive Public Banner Display* [Beyer 2014] and contains additional and previously unpublished research, data analysis and interpretation. My contribution to that paper was: Core idea and concept, hardware (design of the interactive banner display and sensors), lead author. Nina Jäger [Jäger 2013] and Vincent Binder [Binder 2013] conceptualized and designed the interactive contents, conducted the related field studies and data analysis and contributed to the presented theories and interpretations in the form of their bachelor's theses. My contribution to the research work published as the DIS 2014 workshop paper *Visual Audience Moderation: Actively Shaping User Constellations to Improve Touchless Interaction with Public Displays* [Beyer 2014B] was: Core idea and concept, lead author.

Other Chapters

My contribution to the work published as the Pervasive 2010 workshop paper *Design Space for Large Cylindrical Screens* [Beyer 2010] was: Core idea and concept, lead author. This work is based on my diploma thesis at UdK Berlin [Beyer 2008]. The works published as the Mensch & Computer 2009 workshop paper *Die Digitale Litfaßsäule als interaktives Werbemedium* [Beyer 2009B], the Pervasive 2009 workshop paper *Person Aware Advertising Displays: Emotional, Cognitive, Physical Adaptation Capabilities for Contact Exploitation* [Beyer 2009], the ITS 2012 workshop paper *Towards a Design Space for Non-Flat Interactive Displays* [Rümelin 2012] and the SASO 2008 workshop paper *Simulating Adaptive Control in Multimedia Applications* [Serbedzija 2008] have been developed in cooperation with the respective authors.

A.3 List of Figures

Eidesstattliche Versicherung

(Siehe Promotionsordnung vom 12. Juli 2011, § 8, Abs. 2 Pkt. 5.)

Hiermit erkläre ich an Eides statt, dass die Dissertation von mir selbstständig und ohne unerlaubte Beihilfe angefertigt wurde.

München, den 30. April 2018

Gilbert Beyer