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VID GÖTEBORGS UNIVERSITET

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EXPLORING THE USE OF AMBIENT INFORMATION DISPLAYS

Designing and Evaluating Informative Art

Abstract

The use of and interaction with computers does not necessarily have to look like it does today. This thesis explores a field of alternative views on what computers can look like and how they can be used, especially information displays. It gives an overview of the field of ubiquitous computing, a future research vision where computers exist everywhere around us. It also introduces the notion of calm technology and ambient displays, that focus on finding a more human way of presenting information. The practical work presented here involves the design and evaluation of an ambient display: informative art. Informative art is an information display that looks like a traditional painting, but displays information. Similar, to other ambient displays there are several concerns that affect the suitability as an information display. Several issues that are important to consider when trying to design and evaluate such displays are presented in this thesis. The results include lessons learned from related work, practical experience from designing and evaluating informative art. The results also involve concerns about readability, rate of change and degradation, as well as considerations on how to conduct a suitable evaluation on such displays.

Author: Sara Ljungblad
Supervisor: Lars Erik Holmquist
Master thesis, 20 points

1 Preface

This thesis has been conducted within the Future Applications Lab, a research group at the Viktoria Institute. The objective of the institute is to do research in applied information technology, within different groups and areas such as mobile informatics, telematics, business technology. The Future Applications Lab conducts research mainly in the field of ubiquitous computing, that is based a future vision where computation power is everywhere. The design, development and evaluation of innovative media constitute a main objective in the conducted research, where several projects involve novel ways of presenting information. This thesis is one of the results from one such project; informative art. The result presented here, will be the conceptual elaborations that the practical design and evaluation of prototypes and the study of related work has given.

1.1 Acknowledgements

I am especially grateful to **Lars Erik Holmquist**, who is the leader of the Future Applications Lab and one of the driving forces behind the informative art project and this thesis. Without Lars Erik the project would not exist, and neither would this thesis without his patience and support. I also would like to thank **Tobias Skog**, who has been invaluable as a senior colleague in the project, and in designing the prototypes. Special thanks also to **all students and employees at the IT-university** who has participated in the study, and survived an almost everyday exposure of informative art. Thanks also to **Maria Håkansson, Johan Sanneblad and Lalya Gaye** for being there during stressful times. Finally, I also would like to thank **Thanos Magoulas** for the great amount of time and effort he put on a first version of this thesis.

2 Introduction

What comes in your mind when the word *computer* is mentioned? For most people, that will be something like “a screen with a keyboard and a mouse, i.e. a desktop computer, a laptop, or a handheld computer.

The view of what a computer is and can be used for, largely depends on the technical devices that already exist in our lives (Buxton (1996). Thus, we usually do not think beyond our own experience, when considering what a computer may look like. However, a computer does not have to look like any technical device that we already are familiar with. Also, rather than interacting by writing on keyboards and reading on screens, computers could allow a richer variation of output and input.

The computer devices that people associate with information displays, mostly have text or number based output today. For example, if you live in Göteborg you might have experienced displays at the tram stops, showing the minutes until the next tramp arrives. Working as a telephonist you might use a shared display to continuously get updated on the number of incoming calls. Being a car-manufacturer, you might adjust your work pace depending on a display showing the current production statistics in numbers. But is there not any alternative ways of showing information?

Consider Buxton’s statement about people’s views of computers. Imagine if you would consider putting a computer to display information in your bedroom, the living room or in your office at work. Even before considering what information it would show and what it would look like, it might not sound too appealing. This is either because you cannot directly think of any interesting information to display in such a space, or it might be the thought that such a device really would not fit in. Most people want to be surrounded by decorative objects and information displays used today are usually not considered decorative, rather the contrary. Especially when considering the previous examples.

Do however technical devices have to look in a certain way, just because that is what we expect them to? Why do you actually even have to see that it is a “technical device” at all? Why can it not look like something else, something that we enjoy having around us? Why not use traditional decorative objects that already surround us, as computer displays to present information?

This thesis will explore new ways of integrating information in the environment, introducing and evaluating the use of an information display that looks like a traditional piece of artwork; informative art.

2.2 Delimitation of Scope

The objective of this thesis is to introduce and describe a new concept on how to present information to the user, in a future where digital technology more or less can be accessed everywhere. Rather than focus on a mobile applications that the user carry with themselves, this thesis will focus applications that are meant to be part of the architecture that surrounds the user. Especially the output, the way that information can be presented for the users, will be a theme throughout this thesis.

The thesis will be based on visions within a research area called ubiquitous computing. To cover the entire field in this thesis would be impossible and even unsuitable. However, a brief overview will be given in the background section, a long with the related work that will serve as a theoretical background to the empirical and the conceptual work.

A concept called informative art, that combines information visualization and art will be explored throughout this thesis as empirical work. The long-term goal is that informative art will take a similar place in our daily environment as traditional artworks. But, in the same time as being a decorative object, it will also provide information that is relevant for the people in the place that it is situated in. The opportunities and the constraints of this information medium will be discussed in this paper in relation to other, similar research projects and paradigms such as *everyday computing (*where technology is integrated in our everyday lives), *calm technology* (designing for the periphery) and *ambient displays* (that communicates by e.g. sound or light).

This thesis will involve work that is currently going on in a research community, rather than something that already exist on today's market. Thus, business models or market implications is outside the scope of this thesis. Instead, the focus will involve design and evaluation issues in the design process of ambient displays, exploring an ongoing research field. The purpose with this thesis is to find out implications that can guide the designprocess of ambient displays. A theme throughout this thesis will thus be the following:

Informative art is a type of ambient display that can be used for visualising information. What are important design and evaluation requirements?

2.3 Academic background

This thesis is conducted at the departments of Informatics at Göteborg University. Informatics has its roots in information systems research, but is constantly changing to better fit the development and diverse use of information technology. In 1996 Bo Dahlbom proposed that the *new informatics* should involve information technology use, but also how to change and improve its use (Dahlbom, 1996). Dahlbom also suggests that the new informatics is a design-oriented discipline, which is central for the work presented in this thesis.

Dalbom also suggests that the discipline should focus on local design principles, rather than general laws, on heuristics and innovations rather than methods and proofs, and good and beautiful rather than true (Dahlbom, 1996). This thesis will thus involve my own reflections of the work as well as future implications, rather than acting as an attempt to find any general frameworks or models. Dalbom also stresses the importance of a "future oriented" approach that can contribute to development. This is also essential for this thesis, as the work that is

presented here is based on research prototypes, intended for a future use of information technology.

3 Background

This section will provide an overview of the field that motivated the empirical work. The background is primarily based on research papers within the field of ubiquitous computing. Thus, rather than focus on existing products and information-systems, I try to look beyond the current use of and interaction with technology, exploring a specific area of future information systems and interaction themes.

Information is already considered ubiquitous, so infiltrated in our everyday life that we do not even think about how we read, create and share it all the time. Currently much of this information is on paper but often it is also transmitted by some kind of technical device such as PCs, laptops, mobile phones and more. Even if many of these technical innovations might be around for a while, future information technology does not necessarily have to look anything like today's. Rather than being something that we put on our desktop or a device that we carry with us, it might become totally intertwined and considered a natural part of our surroundings. Technology is said to become ubiquitous.

3.1 Ubiquitous computing

Technical advancements including both hardware and software already allow many people to have constant access to networks and real-time information. Radio communication such as Bluetooth will soon allow technical devices to instantly hook up to each other to transmit information. Sensors are becoming small enough, to be integrated in our everyday environment, which will enable even a simple coffee cup to count how many sips you have taken (Gellersen et al, 1999). For visualising information, liquid crystal displays that are light and at low cost already exist and soon there will be electronic ink for displaying information on clothes and fabrics as well. Smart plastics, gel and more is rapidly moving technology beyond today's use, not only within different research areas, but also into our everyday lives.

Ubiquitous computing is a research area that proposes a future where computers are integrated everywhere, used by anyone, at any time, rather than being something we put on our desk. The area involves the creation of information technology that is ubiquitous, effortlessly used and perceived as being more "invisible" or "transparent" than traditional applications for the desktop computer. *Calm technology, tangible bits* and *ambient media* applications provide underlying ideas for a new interaction paradigm, involving a more humanized communication style for information technology which will be discussed throughout this thesis.

Weiser (1995) explain the history of computers as three waves, where each wave represents different use of computers. The first wave (see Figure 1) was the *mainframe*, where many people shared one computer (Weiser, 1995). This is the time when only specialists managed the computer that was situated in a specific computer room.

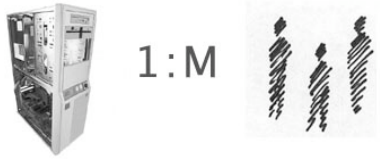


Figure 1, The first wave; mainframe

The second wave (see Figure 2) was *personal computing.* Here, one person uses one computer, having his or her own personal computer. This is when the PC was introduced and the Internet made it possible for people to potentially use millions of computers when surfing on the Internet. Even if the computers are used "virtually" each person interact physically with only *one* PC. First, many people and even companies only had dialup connections when using the Internet (Goldman, 1997). Today, the infrastructures allow more and more people to be "on line" all the time through fast broadband connections. Along with this possibility to constant access, other technical advancements like building smaller computers and other innovations inspire and influence new paradigms on how to interact with computers (Abowd & Mynatt, 2000).

Figure 2, The second wave; personal computing

The third wave(see Figure 3)*; ubiquitous computing* indicates that one person has many computers as well as many people using many computers (Weiser, 1995).

The area of ubiquitous computing involves researchers that explore on how to integrate computers *in our physical surroundings* by designing technology for homes, clothes and much more. This also involves and depends on new advancements concerning networks and computing systems, environments, operating systems, software platforms, applications and more with the capability of serving the needs of a broad range of new services involving both mobile and embedded systems.

Figure 3, The third wave; ubiquitous computing

Abowd and Mynatt (2000) argue that there have been several interaction themes in the past decade within research ubiquitous computing; *natural interfaces, context- awareness* well as an area of emerging technologies; *everyday computing*. Everyday computing and natural interfaces are closely related to what will be presented in this paper. It is important to note that the themes sometimes overlap, where several of them can occur in one application.

Ubiquitous computing inspires application development that is "off the desktop". This means that it is less like the current desktop/mouse/display paradigm and more like the way humans interact with their physical surroundings. *Natural interfaces* is an area of ubiquitous computing that has involved for example speech related interfaces, pen-based or free-form interaction as well as tangible user interfaces. Tangible interfaces and other "off the desktop" applications will be exemplified and further explored in the coming sections.

Another area of ubiquitous computing is *context awaress*, where devices adapt their behaviour based on information that is sensed from the physical and computational environment (Abowd and Mynatt, 2000). There are many challenges to face in creating reusable representations of context having context derived from sensor fusion and activity recognition that comes beyond location and identity. Some of the interaction devices that are discussed here will involve less complex forms of context awareness.

Everyday computing is a part of ubiquitous computing that was presented by Abowd and Mynatt (2000) as promoting informal and instructional activities, that are typical like much of our everyday lives. Continuous in time and as a constant ebb and flow of actions without a clear starting or ending point, these activities could consist of communication with family and friends or managing information (Abowd and Mynatt, 2000). Instead of traditionally where the user deliberately activates the system, a ubiquitous application might be executed or constantly running without having the user to care or know about when or where. This will be further described in coming sections, where everyday artefacts become information displays.

Ubiquitous computing pushes the interaction away from the traditional desktop interaction, and changes the relationship between humans and computers. Instead of being a being a localized tool the computer moves to being a constant presence (Redström, 2001). This will be further described in the coming sections, where tangible media is a form of "natural interface" that supports communication and background awareness. Everyday computing offers many challenges to the HCI research community, where the design for a continuously present computer interface is one (Abowd and Mynatt, 2000). Closely related is to present information at different levels of the periphery of human attention, as well as connecting events in the physical and virtual world. Abowd and Mynatt stress that there is much to do to integrate these two disconnected spaces, where the virtual space of e.g. email and documents should be combined with the physical world with "face to face" and "face to things" interactions. The related work presented in this thesis will exemplify some of these thoughts.

3.2 Calm technology

Ubiquitous computing involves moving towards "invisible in use" and to embed computation within life (Tolmie et al, 2002). Weiser (1995) speaks of calm technology, which is also closely related to the idea of embedding computation in our everyday life. Instead of being a technology that is attention demanding, calm technology strives to stay in our background.

Weiser stresses that calm technology engages both the *center* and the *periphery* of our attention, and moves back and forth between the two. The word "periphery" is used to name something that we are attuned to without attending to explicitly. For example, when people drive their attention is centered on the road, the radio and passengers, but not the noise of the engine. But if an unusual noise occurs, this is noticed immediately. Weiser argues that this exemplifies how we may be "attuned" to a noise in the periphery, and thus can come quickly to attend to it. In this way technology that resides in the periphery of our attention, may still provide information whenever we need it.

According to Abowd and Mynatt (2000) everyday computing applications might be executed or constantly running without having the user to care or know about when or where. When technology is integrated in our surroundings and constantly running, it suggests that the technology itself should not attract the users attention. I believe that calm technology must

stay in the periphery, until the user him or her self wishes to pay attention. Otherwise the technology can not be considered as a calm technology.

Schmidth, Gellersen and Beigl (1999) suggest that calm technology involves peripheral and subconscious awareness and involving new ways of consuming information. I however suggest that Weiser (1995) never intended calm technology to involve subconscious awareness. It is known that our ability of paying attention is highly restricted (Preece, 1999). If several technological devices demand awareness in the same time it would be very stressful and perhaps impossible to perceive all the information. Even if the devices somehow would promote subconscious awareness, we still have a limited capacity to perceive information, thus this would prevent us from perceiving all information in the same time.

However, I believe that it is possible to make people aware or get an overview of more or less information, depending on how you present it. Several devices that use alternative “calm” ways of presenting information could represent a more humane approach to present information, especially when a person herself can choose when to attend to the information.

We believe that Weiser meant that our attention should move *between* being attended or not attended rather than involving subconscious awareness. This way, calm technology is not about subliminal attention. Instead it is about designing so that the user could move his or her attention easily back and forth, depending on his or her intention. The notion of calm technology is highly relevant for the focus of this thesis, since I believe that this approach can allow the user to easily move his or her attention depending on his or her intentions. To exemplify an approach to design for calm technology one of the first application ideas will be described - the AmbientROOM.

3.2.1 The ambient room

The AmbientROOM exemplifies some of the first approaches towards calm technology and new interaction styles, such as making digital information graspable (Ishii et al 1998). The work that was conducted here can be said to have initiated the related work of ambient displays, that will be described in the next section.

The AmbientROOM consisted of:

(1) *Interactive Surfaces*: where e.g., walls, desktops, ceilings, doors, windows where turned into an active interface between the physical and digital world.

(2) *The coupling of Bits and Atoms* where everyday graspable objects like cards, books, models was connected to or coupled with the digital information.

(3) *Ambient Media* using sound, light, airflow, and water movement for background interfaces at the periphery of human perception.

In this way the room had several devices that where integrated and allowed users to attend to and interact to several displays in the same time (Ishii et al 1998). The AmbientROOM implies that digital information may be presented tangible or communicated with ambient media. The work of Ishii have lead us in to the area of ambient displays, but before going into related work, I will describe a more specific background to the empirical work conducted for this thesis.

3.3 Informative art

One approach to integrating information in the surrounding and to explore calm technology is *informative art*. The concept of informative art was developed by Redström, Skog and Hallnäs (2000). Informative art are information displays that imitate the look of an artwork. Instead of providing a static picture, informative art is continuously updated to reflect dynamically changing information.

The previously described Ambient Room had tried to integrate information displays within an architectural space, in more or less tangible presentations. Informative art can be said to take inspiration from everyday computing, keeping the notion of a traditional art object, and turning them into abstract information displays (Redström, 2001). The idea is that it should be constantly running in the background, showing information but without being distractive or attention grabbing which is closely related to calm technology.

The long-term goal with informative art is that it will take a similar place in our daily environment as traditional artworks. Besides acting as a decorative object, it will also provide information that is relevant for the place that it is situated in.

Figure 4, Prototypes of informative art in a leisure space at the research lab.

Various painters have inspired the first prototypes of informative art. Painters, whose styles has been used as inspiration include Andy Warhol (Figure 5), Bridget Riley (Figure 6) and Piet Mondrian (Figure 7) (Holmquist et al 2003). Their compositions have proven useful to map data to graphical objects.

Figure 5 Andy Warhol's painting 100 Campbells Dosen

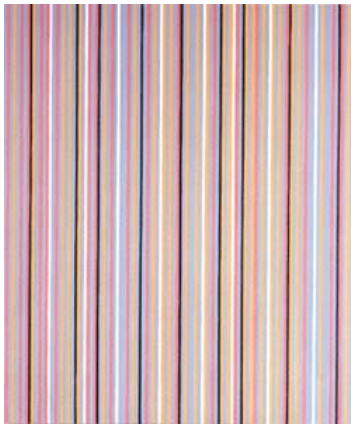


Figure 6 Bridget Riley's painting

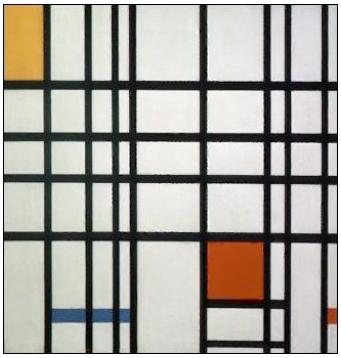


Figure 7 Piet Mondrian's painting "Composition with Red, Yellow, and Blue"

Data that has been visualized includes a Warhol clock (Figure 8), the activity level in a room in the style of Riley (Figure 9) and Mondrian inspired e-mailtraffic (Figure 10) and weather (Figure 11) (Holmquist et al 2003). The *Warhol* soup-clock works like an egg-clock, where the asparagus soup cans are replaced with tomato soups as time passes by. When approaching the set time, more and more cans become asparagus, until the painting is totally filled and the time is up. In the *Riley* inspired activity level prototype, the activity is represented by colored lines. Each line represents a time interval, indicating more or less activity during that time depending on its color. For example, a bright red line might indicate more activity whereas a dark blue line indicates less. The style of *Piet Mondrian* have been used to visualise email traffic and weather in six cities around the world. In the first example, each person's inbox was represented by a colored field which size indicate how many emails that person has. Every field had the same position, so that it would be possible to differentiate between different people in the office, but nor the colors or the lines carried any information.

Figure 8 Andy Warhol inspired Informative art as an egg clock, where time gradually replaces asparagus cans by tomato soup cans.

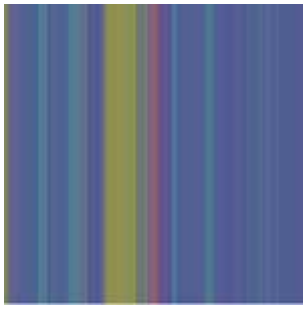


Figure 9 Bridget Riley inspired informative art, showing the activity in a room.

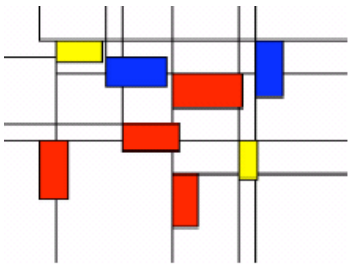


Figure 10 Piet Mondrian inspired informative art showing email traffic, where each square represent one persons mailbox

A second example of a Mondiran inspired prototype is the weather information for six cities around the world. The data was collected from a weather site in real time. Each city was represented by a colored square, whose size was mapped to the current temperature in the city. The higher the temperature gets, the larger the square would get. The color of the square is mapped to weather conditions, where yellow color means sunny or clear, blue means downfall i.e. rain or snow and red means overcast.

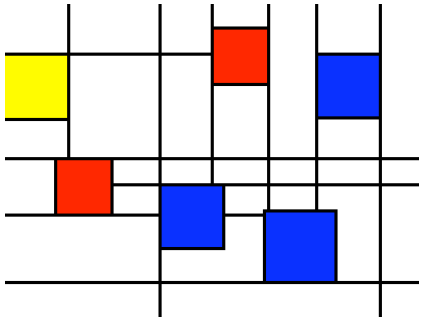


Figure 11. Piet Mondrian inspired prototype showing the weather in six cities around the world.

These prototypes has not been properly user-tested, but presented at venues such as Siggraph 2001, Emerging technologies (Skog et al 2001).

Redström (2001) stress that there are at least two good reasons to complement the desktop PC display with other information techniques. First, most screens are already crowded with more information than the user can overview. Second, information is dependent of where and when people are doing something. Redström also argues that much of the design strategies that are used for the ordinary PC will not hold for ubiquitous computing. One reason for this is that the PC is designed to be one of the most important “things” to its user, being in focus and continuously attended to when in use. This may work as long as we only have one device, but if there will be several around us, it will become intolerable. Thus, to achieve the benefits of ubiquitous computing, we have to develop information technology that can reside in the periphery and be part of our everyday environment. Traditional art can be looked at to get a moment of reflection and mental rest, perhaps informative art can do the same, but provide information as well? This and other issues that relates to the design of informative art will be further discussed throughout this thesis, where informative art from now on will involve the practical, rather than the theoretical material in this thesis.

4 Method

This section will describe the strategy used to find answers to the questions that initiated this thesis. It aims to understand an area involving a new way of thinking about computers. To get a better understanding of the field, I have conducted a thorough examination of the existing literature on similar projects and prototypes of ambient displays. To further explore the concept and to gain some practical experience, the work has also involved designing prototypes and conducting evaluations of those. However, the informative art project is an ongoing project that involves several people, including myself. Thus, there will be material in this thesis that is based on collaborative effort, which also several references will suggest. This thesis (and my role in the project) mainly concerns how to conduct evaluations and in this way contribute with new implications for design in an iterative process. However, it would be pointless to write a thesis about evaluation only, as the design and the conceptual work behind the prototypes affect the evaluation. Thus, the method presented below involves both literature reviews and the design process that includes more than only evaluation.

4.1 Literature review

The literature that provides the background and the related work in this thesis has been chosen to represent the ongoing research within the field. The information that has been used when reasoning about informative art and ambient displays is approved at journals and conferences, and has been found in databases or in conference proceedings. Studying the reference list in such papers, have also shown to be a useful method to find additional publications. Various books on human-computer-interaction have also been used.

4.2 The design process

A design project could involve a replacement or an update of an established system. It can also involve developing a totally innovative product without any obvious precedent (Preece, 2002). Thus, there may be an initial set of requirements or not. Here, the concept of informative art has requirements that are vague and it has no precedent that can help to guide the process. Whatever the initial situation and aim is, the requirements, aspirations and expectations have to be discussed, clarified and most likely re-scoped (Preece, 2002). Thus, the requirements for informative art firstly need to be explored, before they can be defined and re-defined in the design process.

When finding out about the requirements, there is a need to understand the user's tasks, goals and how they will use the product, among other things. Given the iterative nature of interaction design, the identification of the user's needs may be hard as some design may occur while the requirements are established, and the design will evolve through a series of evaluation-redesign cycles (Preece, 2002). This is the case for this project as well, as it will perform iterative steps to clarify possibilities and requirements to explore the potentials of the concept.

4.2.1 Prototyping and Evaluation

Prototyping can be used for a variety of purposes. It could be used to test out the technical feasibility of an idea, clarify vague requirements, do some user testing and evaluation or check that a certain design direction is compatible with the rest of the system development (Preece, 2002). Prototyping is good for refining and communicating ideas, but it could also be

used as means of stimulating and generating further ideas (Martin et al, 2000). This thesis will present how prototypes of informative art are designed and evaluated in order to find specific design requirements, but especially to contribute to an understanding of the overall requirements and possibilities for the concept. This thesis will thus involve prototyping as a method to explore, design and evaluate informative art. By studying related work and comparing it to the one conducted here, experience that can improve both design and evaluation can be reached.

Evaluations can be conducted in several ways and a few approaches that concern ambient displays will be discussed in this thesis. As an introduction, before describing the related and the empirical work of evaluations, some general aspects of data gathering will be discussed.

Two broad categorisations of techniques to collect data are interviews and observations that both can be conducted in a natural setting or in a controlled environment such as a lab. Questionnaires and interviews both represent an approach that is based on verbal or written answers form a subject, with more or less structured questions. Another approach is to use observation, observing rather than asking questions. The methods have different suitability depending on the purpose of the evaluation (Patel et al, 1994). *Observation* makes it possible to study how people act as well as other things that in a natural context. The problem with observations is that there in many cases are things that are not possible to observe, and what is being observed is not necessarily representative. Another aspect is that observations are time-consuming and thus quite expensive. *Interview*s are a method that can be used instead of or in combination with observation. They are often personal and conducted face to face, either with one subject or with several. Both interviews and questionnaires are dependent on the willingness of the subject to answer questions (Patel et al, 1994). It is also possible that subjects make up answers to please the interviewer trying to find out the motivation of the questions. It is thus important to try to avoid leading questions. An interview and a questionnaire can be more or less structured. A less structured interview allows the questions to be asked in a different order and to be changed to fit the reviewer and each subject. This way, interviews allow questions to be complemented if needed during an interview. The section about designing and evaluating informative art will present how less structured interviews can be used in a natural setting, to achieve a less formal user evaluation of a prototype.

My role in the design process will involve finding a suitable evaluation method, and to conduct interviews or use questionnaires as an empirical method to collect data. Some alternative methods of gathering data will be discussed throughout this thesis, mainly in the section about related work and evaluation of prototypes.

5 Related Work

The related work section describes prototypes of displays that build upon the ideas presented in the background section. It will also describe common properties among the exemplified displays, as well the methods used to evaluate them.

5.1 Ambient displays

Several researchers within the area of ubiquitous computing and *natural interfaces* are working on finding new ways of presenting information in a more natural and humanized manner using nonverbal information like sound, light and movement. *Ambient displays* are an approach to this, initially explored by Ishii et al (1998) and further explored by Wisneski (1999) and others. Ambient displays are described as physical devices that transmit information, often in the background of a person's attention (Wisneski, 1999). Schmidt, Gellersen and Beigl (1999, s.1) use similar description about ambient media, describing it as; "means to present information in our surrounding space in subtle and unmonopolizing ways, promoting peripheral awareness." Greenberg (1999) defines ambient display media to be appearing as physical things that have ambient properties, surrounding us like light, sound and airflow. All these explanations may sound a bit abstract, taking into consideration that an ambient display can be a lamp, a string, water, pinwheels, bottles and more, where water ripples in the ceiling, the intensity of a traffic sound or the feeling of heat and cold (in a handheld object) might represent the information. Thus these devices communicate to more of our senses where both sight, hearing, smell and touch might be involved. To explain this concept further related work will be exemplified below.

Before the term ambient media was introduced, a device called the Dangling String (Figure 4) was developed by the artist Natalie Jeremijenko (Weiser, 1995). This system consists of a plastic string hanging from the ceiling in an office. The string is connected to a motor, which is connected to an Ethernet so that each network package that passes gives the string a twitch. The strings sound and motion increases with the network traffic. The thought behind the Dangling String was to display information about the current network traffic in a subtle and non-intrusive way, using a tangible object to show information. The Dangling String was one of the very first applications that were considered to follow the notion of the previously mentioned calm technology.

Figure 12. Live wire; The Dangling String (Weiser, 1995)

Another example of an ambient display is the Waterlamp (see Figure 13) created by Ishii et al 1998). The Waterlamp is standing on the floor and creates water ripples in the ceiling that reflects information. Instead of having physical raindrops, “bits” or digital information that “falls from cyberspace” creates physical water ripples. A light shines upwards through a pan of water, and is actuated by changing information (Ishii et al, 1998). The basic idea is to present some kind of real-time digital information in a tangible way, and to move beyond the current model of Graphical User Interfaces (GUI) where flat rectangular displays is bound to a mouse and a keyboard.

The waterlamp causes ripples on the cieling, with different intencity to reflect information. A lamp is situated below a glass plate that is filled with oil. The light shines through the plate to create ”ripples” on the cieling. This lamp was presented as a part of the AMBIENT ROOM.

Figure 13. The Water Lamp (Ishii et al, 1998)

As showed above, ambient displays become part of our physical environment, when different spaces of a room, like a wall, the ceiling or the floor can be used to present information. Both the waterlamp and the dangling string are examples of displays that can be shared by several people. However, ambient displays can also be designed as personal displays.

Wisneski (1999) created a group of small wireless devices that display information by getting warm or cold and dynamically shaking and shifting (see Figure 14). Despite the above mentioned shared displays. These displays are small, physical devices that is worn to display information to a person in a subtle, persistent, and private manner.

Figure 14. Personal ambient displays designed by Wisneski (1995)

Today some people prefer that their pager or mobile phone to vibrate rather than beep when someone calls. Wisneski's goal was to create an object that could shake or vibrate at variable strengths or frequencies. This way it would be possible to catch a persons attention if, for example an important message would arrive. Likewise, a message that is not extremely vital only a slight movement would occur. Wisneski (1995) suggested that these devices for example could be linked to a student's calendar thus be used as a schedule reminder.

Holmquist et al (1998) explored ambient displays, promoting awareness of nearby friends or colleagues with devices called "hummingbirds". These devices started to "hum" when another "hummingbird" was detected within a certain distance. In this subtle way, the hummingbirds would simplify meetings of colleagues that occasionally were nearby. This device proved to be very useful in crowded areas or other places where one would like to run into a friend.

The ambient displays explained so far, all typically denote a simple and natural way of interacting with technology. By using sound, airflow, water movement and light, Ishii et al (1998) stress that they make background interfaces, at the periphery of human perception. Ambient displays can be seen as a possible approach to avoid information overload, when integrating technology in our everyday surroundings.

5.1.1 Computationally augmented objects as ambient displays

The ambient systems mentioned so far all have involved designing a new device. Considering the aim of everyday technology to embed computation within life (Tolmie et al, 2002), why not have the approach of letting already existing objects display information?

Mynatt (2002) means that when ubiquitous computing aims to pervade our everyday environment, being visible or invisible, it is intertwined with a daily experience. She is concerned about the importance of understanding the use of common everyday objects and their use and then to design new capabilities that enhance and renew these practices.

Chang et al (2001) designed "The Lumitouch system" that consists of a pair of interactive picture frames (see Figure 9). This system communicates by using both sight and tactile information. Two persons each have a picture frame and when one of the users touches her picture frame, the other picture frame lights up. Thus the touch is translated to light over an

Internet connection. This is an example of an ambient display that is based on an everyday object, giving people a sense of being connected to others. In this case, rather than having several levels of complexity, the frames only have an on- or off- function. The data source is also different from the previous examples as it react on some ones touch, and thus displays more emotional than fact based information.

Figure 15 Connected picture frames; The Lumitouch system (frameshttp://tangible.media.mit.edu/projects/LumiTouch/lumitouch.htm)

Picture frames have also been used to present more complex information. Mynatt, et al (2001) designed a digital family portrait (see figure 16), providing a qualitative sense of a person's daily activity and well-being. The information was available from sensor information and the picture frame is designed to work as a traditional portrait, blending with other household decorations. In contrast to traditional static frames, the look digital of the frame changes daily, reflecting a portion of the person's life. Icons on the frame reveal the wellbeing of the person that is shown in the frame. The current day is white and time proceeds clockwise around the frame. Four activity levels can be differentially depicted which is revealed by the size of the butterflies. For this portrait, the woman's activity is measured based on movements between rooms in her home, detected by sensors. By touching a butterfly for a particular day, the viewer may see more details about that day and that individual.

Figure 16. A Digital Family Portrait where butterflies reveal the wellbeing of the person on the portrait

InfoCanvas (see Figure 17) are specialized computer displays that provide awareness of some source of information using images that creates a form of virtual paintings (Miller and Stasko, 2002). An abstract pictorial representation of awareness information is presented as a painting hung on a wall, or a picture frame set on a desk. This project is similar to informative art in a sense, since it is supposed to blend in the environment and provide awareness information while acting as a decoration. One important difference is that InfoCanvas is supposed to allow user themselves to create the graphical scenes, and place objects that will represent information. Thus, designing an eye-pleasing display is up to the user. The InfoCanvas is designed to desire minimal user interaction, be calm and undemanding and personalized. It is also designed to obscure personal data, an effect achieved by the abstract images.

Figure 17 a.) InfoCanvas diplaying several kinds of information. b.) The personalized peripherial awareness display is intended to be similar to a painting hung on a wall, or a picture frame set on a desk.

These last three examples have shown that there are ways to integrate information in our environment, using already existing objects. Thus, innovative design, especially within ubiquitous computing does not have to involve designing totally new devices. Instead, common used objects may serve as inspiration to explore ambient displays.

5.1.2 Defining common properties of ambient displays

This section will try to find and discuss properties among the exemplified displays. Some of these findings will explain possible properties only, whereas others will provide a basis for future design and evaluation of ambient displays. The most prominent findings will be presented with italic letters under each discussion.

5.1.2.1 Complexity of displays

The theoretical background presents several ambient displays that have different levels of complexity. Trying to categorize these, complexity can actually be related to how information is presented. The least complex display has only one kind of information without different parameters. An example of this would be the Lumitouch system that displays one kind of information, indicating if someone is touching the other display. The system does not show any intensity or has any parameters tied to the information. Another example of a not very complex display, even if it is more complex than the previous, is the water lamp (that visualizes email-traffic) where the intensity is shown by the amount of ripples in the ceiling.

A more complex display preferably has one kind of information but with several parameters or has several kinds of information that each has one parameter. An example of this would be

the informative art prototypes that visualize the email traffic and the “Weather in six cities” (see Figure 16 and17). The email visualisation has several kinds of information (different persons email inboxes) that each has one parameter (amount of email). The “Weather in six cities” prototype shows several kinds of information (weather in different cities), where each kind also has several parameters (temperature and weather condition). I thus define complexity with how many kinds of information that is shown in a display as well as how many parameters each kind has. However, it is important to note that the complexity of the display does not necessarily say anything about its utility or suitability. It might even be the case that a less complex display is the best option in some cases, depending on the situation.

How complex the display is, depends on how many kinds of information it shows and how many parameters each kind has.

5.1.2.2 Limited interaction

Calm technology is one of the main reasons to explore ambient displays. Displaying peripheral information with limited interaction possibilities can be seen as an approach to this which also has been mentioned e.g. in the design of InfoCanvas (Miller et al, 2002). The fact that you give the display a glance, should make it more peripheral than if one would interact directly by touch, sight and etc. Another interaction issue that is prominent in the above stated examples is that they all denote output, more than user input. This might be due to the fact that calm technology suggests that interaction should be peripheral rather than direct. It might be harder to design for peripheral input, rather than output. An example of this is the Lumitouch system. The input is direct (touching the frame) whereas the output might be considered to more easily move between the periphery and the foreground (either glowing or not). Still, keeping the input as simple as possible (a touch) should preferably make it more calm, than a more demanding input.

An ambient display should provide peripheral information, which can be supported by offering limited interaction possibilities.

5.1.2.3 Information Tempus

Considering the theoretical background, three different event categorisations of information has been identified; *past, current* and *future* in ambient devices.

For example the Dangling String (Weiser, 1995), showed *current* networktraffic, as well as the ambient displays created by Ishii et al (1998) and Wisnesky (1999) that corresponded and synchronised to one real time occurring event. Their utility is to provide awareness about some current phenomena, using ambient communication. Digital family portraits show both *present* and *past* information (Mynatt, Rowan, Jacobs and Craighill, 2001). Compared to the previously described work by for example Ishii, the digital family portrait focus on portraying trends over a period of time. Miller et al (2003) exemplifies how *current* and *future* information in the InfoCancas i.e the trafficreport and tomorrows weather in the same display.

An ambient display can be used to show real-time information, past trends and/or prospective information.

5.1.2.4 Public and Private Displays

A natural categorisation is to divide the displays into personal and public (shared) displays. As a point of reference they have also been related to already existing information technology devices.

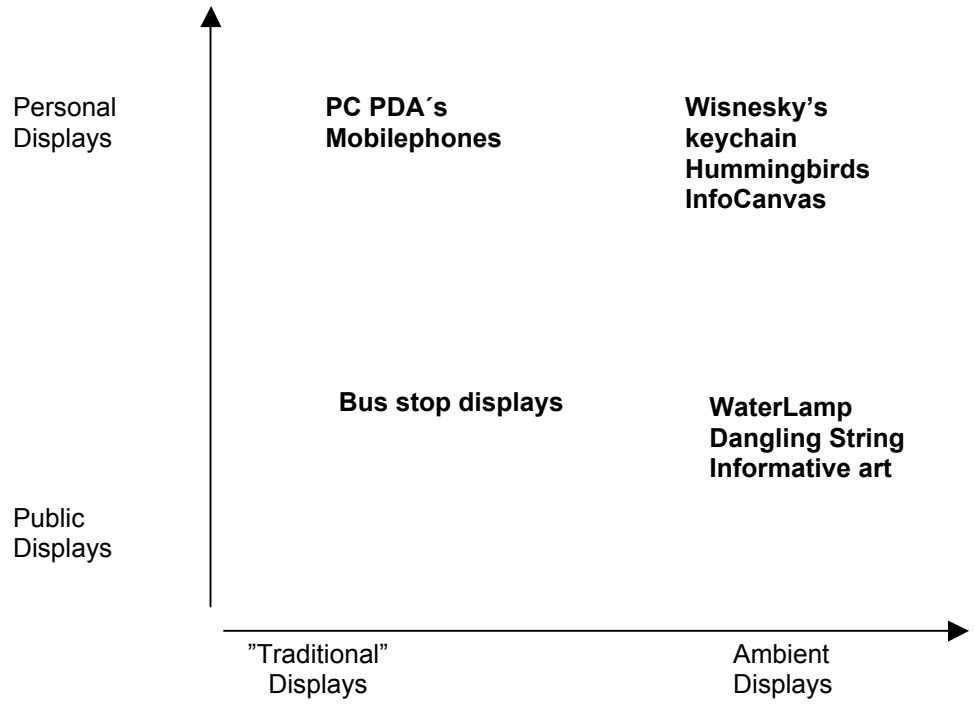


Figure 18. Comparing public and personal displays.

A difference can be found in output between the personal ambient displays and the public (shared) ones. The personal displays created by Wisnesky have a subtle and intimate signal, as well as the hummingbirds (that both were buzzing). Their small size also makes them suitable for personal, rather than shared use, intended to be carried by one person. The InfoCanvas is intended for personal use rather than public. I believe that this specific case has more to do with the chosen information, rather than the output. The InfoCanvas visualizes several kinds of information that has been chosen specifically to fit one person, rather than many. This makes it less suitable for shared use, unless a group decides on what information to show. The public displays i.e. the Dangling String, informative art and Digital Family Portrait are sometimes similar to art installations, placed in a space where several people can view them. If it is positioned in someone's office the display preferably is intended for a private use rather than public. The placement of the display can thus suggest if it is intended to be private or not. The aesthetics may also be affected if the display is intended to be private or public. The aesthetics for a private display can be more individually chosen, than in the case of a public display, where several people share it. This is also affected by people's previous experiences, as someone might consider a display to be intuitive, whereas someone else does not, which is problematic when there are several users of a display.

The intended use of the display, where it is situated, if it is a private or a public ambient display affect its design.

5.1.2.5 Suitable information

It is clear that ambient displays are not suitable for all types of information. Schmidt, Gellersen and Beigl (1999, p.200) argue that it could be assumed that ambient media is highly suited for peripheral information awareness, but that the question remains of which information to select and what kind of ambient medium to use for the presentation. Wisneski et al (1998) also pointed out this issue without having any good answers. The ambient displays that have been exemplified so far have involved information like; email, weather, traffic as well as emotional content. I believe that the current information often is chosen to show the high-level functionality and interaction aspects. Thus, rather than trying to categorize the exemplified information sources, I find that it is more important to find out what information that can be reflected, and why that is. I hope that some answer to this can be provided when designing and evaluating informative art, as the literature cannot provide an answer at this point.

What information that is suitable to show with an ambient display is not clear in the existing literature.

5.1.2.6 Informing users

One question that is related to the information that is shown, is how the users will find out about that the display shows information, what it shows, and how it is read. This is not so much an issue for the private displays, but more important for the public ones. In the case of InfoCanvas, the users will chose the information themselves and thus be aware of it. However, in the case of public displays such as the dangling string, the waterlamp and informative art, this question is not yet solved. This will be discussed further in the evaluation section as well as the coming sections about informative art.

How users are informed about what information that is shown in a display is not covered in the literature.

5.2 Evaluating ambient displays

The previously described prototypes of ambient displays, all represent prototypes of something that does not exist today, but rather is something that might come into use one day. How can we find out if ambient displays are a suitable way of presenting information? What are the important questions to be answered? A way of finding out is to let the prototypes go through some kind of evaluation.

In ”traditional” information systems, a model that is general and commonly accepted as a product quality specification is the *software quality ISO model*. The ISO model (http://www.iso.ch/iso/en/ISOOnline.frontpage) involves the following criteria’s:

- **Functionality**
  (Suitability, Accuracy, Interoperability, Compliance, Security, Traceability)

- **Reliability**

(Maturity, Fault tolerance, Recoverability, Avaialbility, Degradability)

- **Efficiency**
  (Time behaviour, Resource behaviour)

- **Usability**
  (Understandability, Learnability, Operability, Explicitness, Luxury, Clarity, Helpfulness, User-friendliness)

- **Maintainability**
  Analysability, Changeability, Stability, Testability, Manageability, Reusability)

- **Portability**
  (Adaptablity, Installability, Conformance, Replaceability)

This model as well as the majority of today's evaluation techniques for any kind of information systems are task-centred. When the user's tasks are known, the evaluation is performed to determine the fitness of the system and its interface for completing that task. However, with ubiquitous computing and "peripheral" systems such as ambient displays, it is not clear how to apply this "task centred techniques" to the informal everyday computing situations that many ubiquitous computing systems and ambient displays constitute (Abowd and Mynatt, 2000). Abowd and Mynatt (2000) argue that traditional HCI methods need to be modified to support the design for informal, peripheral, and opportunistic behaviour. They also suggest that evaluation requires a realistic deployment into the environment of expected use.

Few evaluations have been performed and documented of ambient displays. An early evaluation was conducted by Wisnesky (1999) who performed pilot user studies of the Waterlamp (see Figure. This test will be described below, acting as a point of reference for the upcoming discussion about evaluating ambient displays.

The purpose with Wisneskys studies was to gain a primary insight to identify design issues and problems when creating ambient displays. His study involved six undergraduate male subjects that were tested in multiple trials each test. Totally four tests with the Waterlamp were conducted in a classroom with minimal distractions, regarding the interference of other people as well as other devices.

Wisneski made a total of four experiments. Experiment 1 and 2 investigated how many perceivable states there are depending on background and foreground, without involving time or order. The waterlamp was designed to drive the lamp at six different levels of intensity, thus the goal of the first and the second study was to find out how many different states that could be perceptually attained depending on if the lamp was in the foreground or in the background of the users attention. For the foreground test the subjects were asked to watch and listen to (actively perceive) the Lamp and indicate whenever they noticed any change in its state, when the intensity changed. In the background experiment the same kind of experiment was done, with the difference that the subjects were concentrated playing Pac-Man on a desktop computer while listening to the lamp. Experiment 3 involved time, where the subjects were exposed to a randomly pattern of transitions between different intensities. Experiment 4 investigated locations, where the Lamp was moved 90 degrees off-center. The

results showed that subjects sometimes had problems with perceiving different levels of intensity thus less levels than ten should be considered.

Wisneski discovered that sound had a huge impact on its perception; people used sound as the primary tool of attending the display. To prove this, another experiment was conducted to test the display's visual effectiveness. The sound was removed by giving the subjects earphones; performing experiment 3 again while subjects was completing a foreground task (Pac-Man).

The results of the study showed that it was much harder to notice changes in the display without auditory cues, where only major changes in state where noticed. Even when observing the display in the foreground, the sound proved to be the best indicator of the display's state.

The digital family portrait (Mynatt, et al 2001) has been evaluated though, through field trials with a grandma and her grandkids. Mynatt stressed that it would have to be tested *in the field* with real families, as it was to be a surrogate social support system. The prototype was designed after a field trial and then daily telephone interviews were performed with daily updates of the system. This way, a better understanding of the daily use of the display could be reached.

Miller et al (2003) have not yet conducted, but initiated a field-study to evaluate prototypes of InfoCanvas. The plan is to evaluate during six to eight week, where a short interview will be held with each participant, each week. Miller argues that this period would be enough to eliminate novelty effects. Novelty effects occur when a system is first experienced, and can thus affect the result of the evaluation. The interviews are planned to focus on if the participants actually used the display, and if they have any difficulties to interpret it.

Mankoff et al (2003) have presented a technique to evaluate the effectiveness and usability of ambient displays. Instead of evaluating "out in the field", the evaluation is conducted with an *inspection method*, a heuristic evaluation that is adapted to fit ambient displays. The original heuristic evaluation was introduced by Nielsen et al (1990) to find usability problems on task-based systems e.g. webpages. When evaluating, the problems are found in a general review or usage simulation, where the heuristics act as a high-level guide. The heuristics are presented below with a cross over the heuristics that has been modified or removed in the evaluation presented by Mankoff et al (2003).

- **Visibility of system status**
  The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

- **Match between system and the real world**
  The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

- **User control and freedom**
  Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

- **Consistency and standards**
  Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

- **Error prevention**
  Even better than good error messages is a careful design which prevents a problem from occurring in the first place.

- **Recognition rather than recall**
  Make objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

- **Flexibility and efficiency of use**
  Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

- **Aesthetic and minimalist design**
  Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

- **Help users recognize, diagnose, and recover from errors**
  Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

- **Help and documentation**
  Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Besides the above kept heuristics, the following were added in order to further modify the method in order to make it more suitable for ambient displays:

- ***Sufficient information design***
  The display should be designed to convey ”just enough” information. To much information cramps the display, and to little will make the display not as useful as it could be.

- ***Consistent and intuitive mapping***
  Ambient displays should add minimal cognitive load. Cognitive load may be higher when users must remember what states or changes in the display mean. The display should be intuitive.

- ***Visibility of state***
  An ambient display should make the states of the system noticeable. The transition from one state to another should be easily perceptible.

- ***Aesthetic and pleasing design***
  The display should be pleasing when it is placed in the intended setting.

- ***Useful and relevant information***
  The information should be useful and relevant to the users in the intended setting.

- ***Easy transition to more in-depth information***
  If the display offers multi-leveled information, the display should make it easy and quick for the users to find out more detailed information.

- ***"Peripheriality" of display***
  The display should be unobtrusive and remain so unless it requires the users, attention. User should be able to easy monitor the display.

5.2.1 Considering Evaluation Methods

The above describes three different approaches to conduct a user test of ambient displays; experiment, field-studies and inspection method. These will be discussed below, to find out what aspects that are important to consider when conducting an evaluation of ambient displays.

5.2.1.1 Experiment

The pilot studies that Wisneski (1999) conducted on ambient displays are similar to experimental methods traditionally used by psychologists. Such methods were originally used to study cognitive processes in basic research, attempting to single out and measure cognitive processes. There is a clear difference evaluating psychological domains like sensation, perception, attention, memory and decision-making versus evaluating HCI systems like ambient displays. While the psychologists wants to measure cognitive processes, the HCI practitioners and researchers want to get answers on how to design things to work in a for the user in a satisfying way. Thus analysing cognitive capacities are quite different from analyzing happenings in the real world of human interactions. Dumais and Czerwinski (2001) stress that there is an unnecessary large gap between psychology theory and HCI design. Traditional experimental designs and tasks in HCI which use factorial designs and many subjects are usually not feasible in a design process where a real world design of a study consist of to many variables, hence a study of all possible combinations is not possible nor appropriate in most cases. Unanticipated use is another problematic issue of a system hence difficult to predict and test in a lab.

In the real world, external variables like people talking, music or sounds from other devices or the light in a room may affect the perception of an ambient display. The study of both displays showed that the participants read the display by its sound. Thus, a totally different perception could occur in a real world situation where background noises exist. When conducting a test without considering the intended setting, it is possible to miss complex aspects that would only occur during real use. Another related issue is that depending of the setting, the sound might be perceived as annoying over time, which a lab study would not show and Wisneski (1999) actually does not discuss at all.

Another issue that Wisnesky study does not test is if the display can be used for its intended purpose. Even if people can tell the different intensities, it might be possible that they cannot

relate to and understand the meaning the current intensity, without directly comparing it to a previous intensity. Thus, in a real world situation it might be hard to interpret the current intensity when changes do not vary in the same time intervals as done in the lab. For example the changes might be much slower in reality than in the test lab. This could also be related to what information that is shown, and how fast it changes. This will be furter discussed in the section about informative art.

In addition to experimental methods, practitioners use a wide range of observational techniques and heuristics in the HCI area. Field studies, contextual inquiry, heuristic evaluation, rapid prototyping, questionnaires and focus groups, can be conducted to better understand system usage and to inform design (Dumais et al, 2001). Techniques like this are often borrowed from anthropology or sociology where qualitative descriptions of how the system is used in the real world is more benefiting than a quantitative lab study of some system components.

5.2.1.2 Field study

Mynatt (2001) conducted a field study to test her design. Unfortunately, there is not much detail given about how it was conducted. Still, Mynatt argued that the field test was the only suitable method to be used. One motivation was that the display was considered a social system. A system that was lived with, rather than used only, as it would be part of the everyday life of the people. Rather than acting as a desktop computer that one turn off after use, the display would be *part of the setting*, acting as a dynamical piece of the furniture. Miller et al (2003) also prefer to test the displays in field, even though their evaluation is not yet performed.

Field studies make it possible to discover unanticipated use of a system and to understand how real users employ the technology in a specific setting. When the technology is used over time, the risk of novelty effects is reduced (Miller et al, 2001). Another aspect is that the actual use or especially the lack of use can bring up design implications, which might not have been found in a lab study or with an inspection method.

5.2.1.3 Heuristic Evaluation

Heuristic evaluations are traditionally known to be low in cost and effort. A heuristic evaluation is a predictive evaluation, which means that problems are predicted by a reviewer rather than found by a user. The traditional heuristic evaluation was conducted on web design and other window based systems, and has been considered a low cost and fast method to establish user problems (Nielsen, 1990). I find that several issues are not solved, when using a heuristic evaluation on ambient displays. The main reason it that it imitates a method that initially was meant for webdesign and applications. Thus, the overall method does not involve the actual use of ambient displays, where physical places and specific contexts matters. In fact using a heuristic evaluation neglects the importance of the setting, and suggests that ambient displays should be evaluated in a lab setting. This will be illustrated by the following example.

Mankoff et al (2003) conducted a heuristic evaluation of an ambient display designed as a lamp, where the intensity of light would convey information. Light itself is ambient and dependent on the space that it is situated in. As the surrounding light changes, the light intensities from the display will be perceived differently depending on the setting. Thus, the evaluation that took part in the lab, might have guided a design that would not work at all the

intended setting. Neglecting the role of architecture might be problematic when designing ambient displays. To get some further insight in what the heuristics suggest, a few of them will be discussed below.

What is found *aesthetic and pleasing design* in the intended setting is personal, and context dependent, especially considering objects that are to be considered furniture or decorations in a space. I believe that aesthetics in someone's living room is quite different from aesthetics in web design. Thus, without taking the intended setting into consideration, how could one know that it is perceived pleasing in that specific context? *Consistent and intuitive mapping* suggests that both the viewers and the users would have the same previous experiences. What people suggest as being "intuitive" is usually very culturally dependent and based on previous experiences. This makes it hard to know beforehand what is intuitive without involving the users. The work with informative art discussed in chapter six, will also involve a discussion about intuitiveness and its consequences for design.

The heuristic *Recognise, diagnose recover from errors* is not applicable according to Mankoff (2003). But, how will users *know* if they misunderstand a display? Is there anything important to know about how users learn and remember a display? In this case, would it be possible to include this in an evaluation?

I find that the heuristic evaluation brings up several important issues, even if I find that some important aspects are missing. But for example, issues like *visibility of state*, *useful and relevant information* and *visibility of system status* seem intuitively important and are already covered in the heuristic evaluation. I believe that heuristic evaluation answers several questions about what to focus on when evaluating. However, those answers are more related to *what*, than *how* to solve the problems. Thus, I hope that a practical evaluation will provide some answers or a least exemplify "how".

5.2.2 What questions need to be answered?

Rather than stating a few questions, I will highlight some aspects that I consider to be important. An issue that needs to be discussed is the overall reason for evaluating an ambient display. Currently, these displays are still research prototypes, rather than used by the consumer market. The reason that motivated Nielsen to perform heuristic evaluations on information systems, might thus not be the same reason that motivates researchers to evaluate ambient displays. I suggest that the role that the displays can play in our everyday lives are just as interesting to investigate, as e.g. the readability of a display. For example, in the case of ambient displays there might be information that is not suitable to show with ambient displays. This could involve the setting, the intended use or other aspects, that is not possible to see without the intended setting. A closely related issue to this is how complex information the information should be to be readable and to be useful in a specific situation and placement.

We believe that the guidelines such as heuristics provide help for the designer, especially if and when ambient displays enter the consumer market, similar to how the method works in web design. However, there are still many issues that come beyond these guidelines, which might be even more important to consider at this point. For example, the reason for conducting an evaluation might also involve questions on how it affects people that the everyday surroundings changes from being static and physical to dynamical constantly

displaying digital information. The introduction of such technology might change people's habits and everyday routines. What aspects are then important to design for?

One aspect that none of the previously mentioned evaluations discuss is how is the knowledge of what the display shows is gained and maintained. Can it be remembered or do people tend to forget what it is displaying? Is there a way of performing an evaluation that involves this or is there other similar aspects that can guide an evaluation? This will be further discussed in lessons learned as well as in the discussion and future work section.

6 Designing and evaluating informative art

Previous sections have involved a theoretical background and related work within the field of ubiquitous computing and ambient displays. To get an empirical insight in the field, informative art, which is as a kind of ambient display, has been designed and evaluated. This section will describe the practical experience of the design process.

6.1 Preliminary evaluation: Weather Forecast

A preliminary evaluation informative art has been presented at the Siggraph conference (Skog et al, 2002, Ljungblad et al, 2003). It was performed to test the informative art as a concept, rather than trying to formulate design and evaluation issues for informative art and ambient displays.

To get general perceptions and opinions form as many as possible, the IT-university was chosen as a setting. Approximately 150 students are present at the University every day. Before the evaluation, a pre-study was conducted to ensure that the piece would display information that was found interesting for the students. One of the most common suggestions was to display weather forecasts and therefore, a weather display was designed and the previously mentioned Dutch painter Mondrian, was used as a source of inspiration. The reason for this was that we were already familiar with his composition and had found it suitable for previous prototypes (see fig.10, 11). This prototype revealed information in the following way:

Each colored square in the display represents the weather of one day. The current temperature is reflected by the size of the square, so that the higher the temperature, the larger the square. The weather condition is shown by the color; yellow represents a sunny day, blue indicates rain and red, clouds. The display is read from left to right, top to bottom, so that the top left square represents today's weather and the top left represents the weather tomorrow and so on.

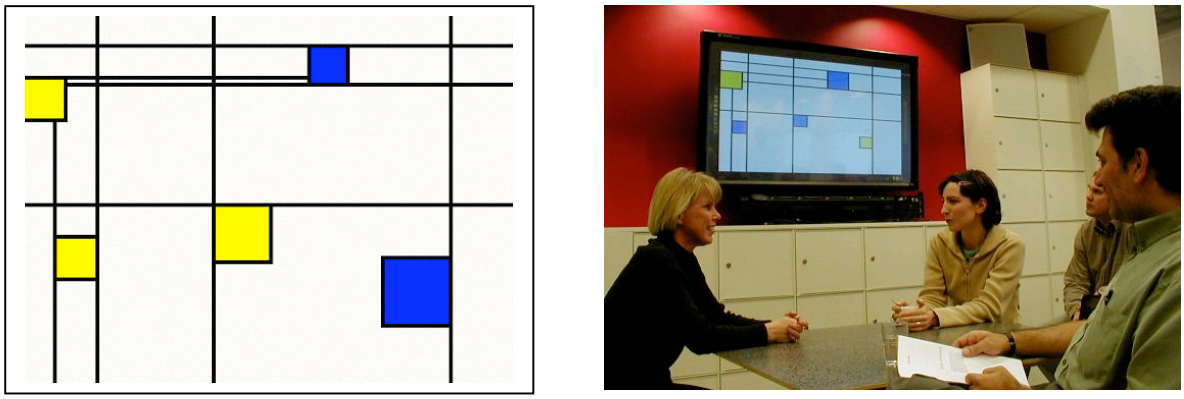


Figure 19 a.) A five day local weather forecast, superficially looking like a Mondrian painting. b.) The Mondian weather display set up at the IT-university, during the evaluation.

The piece was displayed for a week, and questionnaires were handed out twice during this period. The first day a group of 30 students were introduced to the piece, what it represented, and how they would read it. There were 40 questionnaires returned in total out of which 15 came from students who attended the briefing.

6.1.1 Results and Design Implications

This preliminary study focused on the comprehension of the display rather than the extended use. It is possible that this study involves some novelty effect, as the last interviews were held only a week after the visualisation had been set up. This has previously been found to be an issue e.g. by Miller et al (2002), that should be avoided in the design of ambient displays.

6.1.1.2 Comprehension

4 out of 15 that had been to the briefing had definitely understood the display. 7 gave answers that suggested that they may or may not have been able to fully understand it, and 4 could clearly not read it. Some misreading occurred among the participants. For instance, some people had different ideas about what the colors should represent. One person suggested that she wanted blue to indicate blue sky rather than rain. Another person thought that it was hard to know the order of the days and a third thought that it was a five-day forecast, while it in fact was the current day plus a four-day forecast.

6.1.1.3 Art vs. Information

The students that had not been to the briefing could not tell that it was information that was visualized. Some perceived it as art and some perceived it as a static image. It also seemed like it was hard for them to perceive any changes in the piece. This might be affected by the fact they did not know that changes would occur.

6.1.1.4 Peripheral Awareness

No one claimed that they found the display disturbing or attention grabbing. Someone even claimed that they did not want it to be taken down. Thus, it seems like the display was perceived as a natural part of the surroundings. One person wanted the display to be more interactive. He stressed that the current display had an interface that suggested interactivity, but that the visualisation did not.

6.1.1.5 Questionnaires as a Method

During this first evaluation it was discovered that questionnaires can be hard use when trying to understand how people could read and understand the visualisation. The reason for this was that some people wrote answers that were too short to determine whether they actually could read the visualisation, or if they were only claiming that they could. This might have been avoided with a different design of the questions, but still, if people do not bother answer all questions, how would it be possible to find out what they really know?

6.2 New Evaluation: Bus Departure Times

During the design of the weather visualization, another of the most frequently requested datasets was public transportation information. At the time it did not exist any source data, thus it was not possible to visualize that kind of data, unless showing a regular timetable. However, such information would be static and not reliable, since the busses often are delayed.

In the early 2003, the local transit authority started providing a new web-based service keeping track of buses and trams in the public transportation network. The service uses the

transit authority sensor system, keeping track of buses and trams in the city, This information is often provided at larger bus stops, in the form of large text based LED-displays, indicating how many minutes that remain until the next bus or tram arrives (see figure).

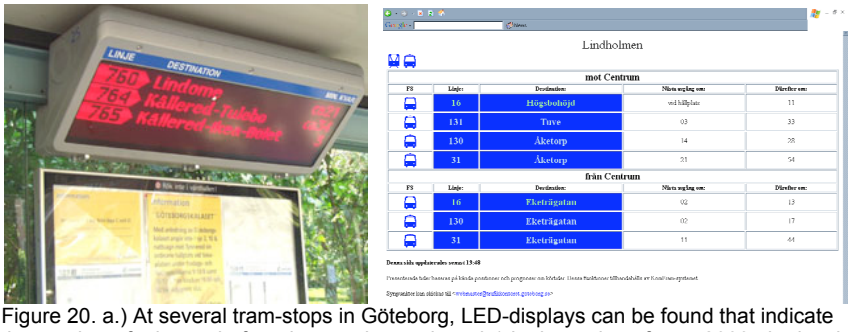


Figure 20. a.) At several tram-stops in Göteborg, LED-displays can be found that indicate the number of minutes before the next bus arrives, b.) In the spring of year 2003, the local transit authority started to offer a web-based service, where the user can get the sensor-based information from each bus

As soon as the information was available on the webpage (figure 20 b.) it was possible to create a new visualization for the students at the university. The most frequently used bus was a bus that was connecting the university and the central parts of the city. This was considered a suitable way to show in one of the common areas in the university where now over 300 students and teachers were regularly spending time in these areas.

6.2.1 Preliminary visualization

The first design showed the departure times of the buses on line 16. Mondrian was chosen again as inspiration and the information was mapped the following way:

Each bus is represented by a colored square. The size of the square shows how much time is left before the bus leaves the University. The less time that remains, the smaller the square is. Its color shows intervals of time that it would take to catch the bus. The timing for the intervals was based on the actual experience of walking from the university to the bus stop. As in previous Mondrian's visualizations information was mapped to the three primary colors.

- *Blue means that you have plenty of time before the bus leaves.*
- *Yellow means that it is time to pack your stuff and start walking.*
- *Red means that you are in a hurry.*

We used the positions of each square to indicate where the bus is headed. The two squares on the *right* side would represent buses going towards the town whereas the squares on the *left* hand would represent buses travelling from the city centre.

6.2.2 User Feedback

Three groups of students were interviewed in order to get feedback on the preliminary visualization. They were aware about the webpage containing the same information, but rarely used it. The visualization was presented with real, online data on a laptop, as the students were interviewed about it. Three groups were interviewed about what they thought of the display. The interviews were unstructured, and adapted after each group. Mainly, how to read the display was explained and then we asked for their comments. Our first impression

was that they seemed enthusiastic about having this kind of visualization available and they were helpful in clarifying important aspects of the proposed visualization.

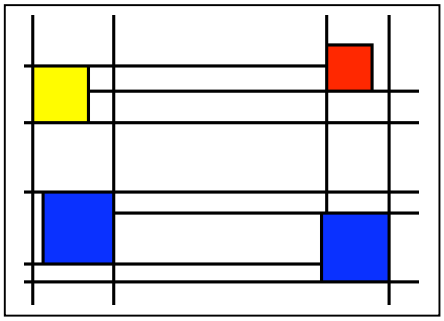


Figure Y. a) Students gave feedback on the first preliminary visualisation. b) The first prototype.

They found the use of size and colors to indicate departure intuitive and easy to understand quickly. They also helped to identify a few problems:

Direction The students found it hard to identify what buses were travelling in what direction. The use of positioning was not intuitive enough.

Reference to the real world During the interviews, the students seemed to use the visualization as an abstract map of the bus stop, to make sense of what bus was heading in what direction. Some of them asked about which wall that the display would be situated, using the physical surroundings as a point of reference.

End stop During rush hour traffic there is an extra bus, which offloads the regular bus service. Those buses only go to the central station. Some of the students indicated that they wanted to travel past the central station, and would prefer not risk to end up on the wrong bus.

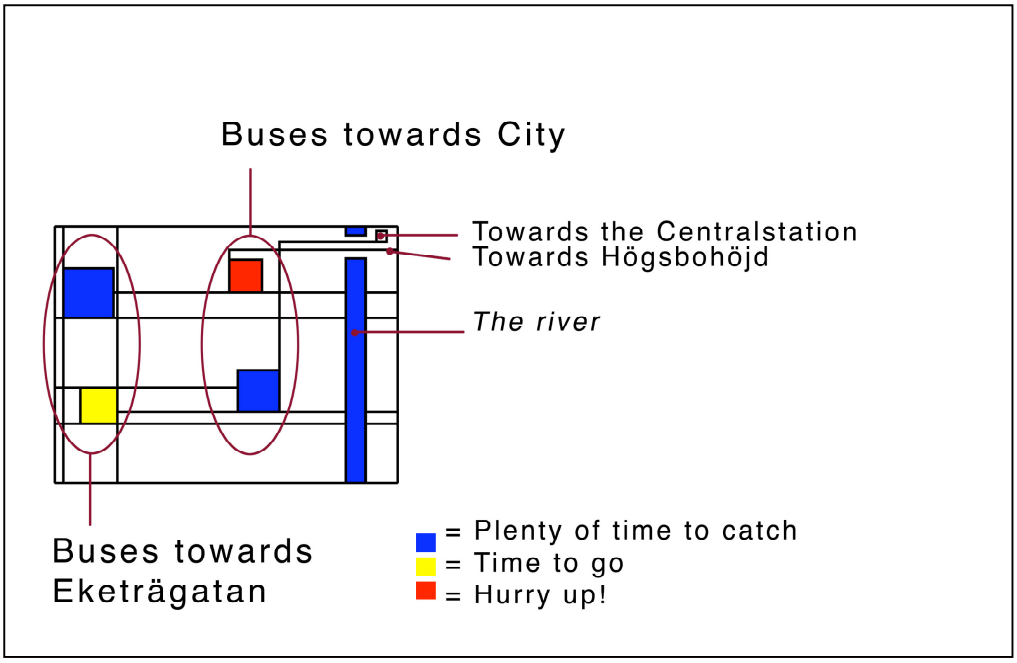
Relevance Two of the students pointed out that there was no need to show buses that were to late to catch.

6.2.3 Redesign

Based on the feedback from the students, the visualisation was improved. The resulting visualisation can be seen in figure 20.

To make it easier to see which *direction* the buses were going, the suggested *reference to the physical world* that was given by the students was used. In the redesigned version, a blue rectangle was added on the right hand side that represented the river running through Gothenburg. The area left of the blue rectangle acted as an abstract map of the bus stop. The buses in the visualisation would now follow right-hand traffic so that the two squares to the left now represent the buses travelling from the city. Naturally, those to the right would represent buses going to the city. In contrast to the first version, the squares were also arranged vertically according to the direction of the bus. For the squares at the left, the square at the bottom represents the closest bus whereas the reverse is true for the right-hand side. This way, the resulting visualisation was intended to give a more intuitive impression of buses that drive in opposite directions, running in both directions along the river.

To satisfy the students that were concerned about the *end stop*, the rush hour extra buses were differentiated from the regular ones. This was done by adding information to two black lines that would indicate the final destination of the buses, travelling towards the city centre. The squares are connected with lines that suggest if they are going to the central station or further. A line that leads to a small white square in the top right corner, represents a destination to the



central station. The other line ends up at the edge of the screen, and represents that the destination is beyond the central station (see figure 20).

Figure 20. The redesigned prototype was set up with an instruction note on the side, looking like this (here freely translated to English).

Some students had suggested that there was no need to show buses that are to late to catch. To improve the visualisation, such buses were represented with white squares. This would mean that the squares would still exist, but they would be less visible that the squares of other colors. A reason for not removing the squares totally, was that it was found too disruptive to the visualisation as a whole.

The final modification was done after the prototype had started running at the university. The database server running the application at the transit authority turned out to have a lot of down time. Thus, it was clear that some kind of mechanism that would indicate breakdowns, had to be added. This was done by changing all the squares colors to black, whenever the server broke down. The black squares would then indicate that there was no reliable data available for the application.

6.2.4 Evaluation

This time the plan is to let the visualization run for an extended period of time, to get *long term usage* data. When this study was conducted it had been installed for 15 days, but effectively running for about 10 days. This was due to server breakdowns at the public transportation network and other technical problems. When conducting the evaluation, open-ended ways for people to use the visualisation were provided, so that the usage would be natural rather than forced.

Figure 21. The bus vizualisation running in a common area at the It University in Göteborg.

When the visualisation firstly was set up, a caption with instructions for how to interpret the information was placed next to the screen (see figure 20). Instead of arranging any public presentations that was the case for the preliminary evaluation (see chapter 6.1), about 30 handouts were placed next to the display. The IT University also added news on their homepage about informative art, which included instructions on how to read the display. This way no one was directly instructed or asked to use the display, even if information on how to use it was available for those who were interested.

At this point, the first set of interviews have been held. The plan with the long-term study is to keep on doing interviews, with regularly intervals, to see if and how the use of the display evolves over time. The first interviews were conducted during the afternoon on an ordinary weekday. Seven people were asked for an interview, when passing by or staying in the area of

the display. Four were men and three were women, where one woman actually was not interviewed, as she only made sporadic visits to the University. This way, only those who were constantly spending time in the area were involved in the study.

6.2.5 Results

The results presented below are the first that has been collected from the initiated long-term study. A difference from the previous results is that this evaluation focuses more on the actual use of the display rather than the comprehension. The results will be presented with a broad framework of a three-step scale, where each step is a pre-requisite for the next.

- *That* something is visualised –does the person know that the display is an information visualisation and not simply decoration.
- *What* is visualised- does the person know what is visualized, but cannot read it.
- *How* the data is visualised – can the person read and interpret the visualisation correctly?

The reason for this framework is to clarify that it is only when a person is reaching the third step she has enough understanding for actually using the display. However, each step is helpful when it reveals facts about the reason for why a person has not reached the next steps, in order to be able to use the display. Below are the results:

That

From the six persons that were interviewed, one person did not know that some data was visualised on the display. This person did not travel with the visualised bus.

What

The reminding five people all knew *what* was visualised i.e. departure times for bus line 16. All these travelled with the bus with some regularity.

Out of these two people knew *what* was visualised but did not know how to read it. Both of them could explain that the colors on the buses represented something like ”hurry”, ”leave now” and ”there is time left”. One of the two pointed out one square, suggesting that it probably went to the town, which was correct. Even if they did not have sufficient understanding for practical use of the visualisation, they had still picked up some of the essentials. None of them believed that they would use the display in the future. They did not use timetables , unless they were staying late at the university, which they had not been doing lately. One of them said that he preferred more exact, number-based information, suggesting that people might need different amount of time to catch the bus that according to him was not supported by the current visualisation.

How

Two of the three people that knew how to read the visualisation, had also been using it to catch the bus. One person had used it three times, and was planning to use it even more. This person commented that it was great to get information at a glance, and that it was particularly good in this place. One person had used it once. After that it had broke down, and she had not been using it since.

Another person claimed that she could not read the visualisation, but it turned out she could. She had been on her way to use it once. She claimed that, she at the time did not have “the energy” to get herself into it. She already had her outdoor clothes on and simply left for the bus instead. This person claimed that she would like to use the display, mainly if she was going home. If she was planning to continue the trip she would rather use the website provided by the public transportation authority, where more detailed information could be found.

7 Lessons learned

This section will describe lessons learned both from the theoretical and the practical work, involving design as well evaluation implications for informative art. The ambient displays presented in this thesis are very different from each other, thus it would not be meaningful to try to make a more general framework. Instead, theory and practical experience have give rise to design and evaluation implications for informative art and related ambient displays, which are highlighted below with italic letters after each lesson.

7.1 What information is suitable to show?

In the theoretical material it was not clear what information that ambient displays are suitable to display. Rather, this has been pointed out as a problem when designing ambient displays, e.g. by Schmidt et al (1999) and Wisnesky et al (1998). The practical work did not provide a set of possible information sources, but gave experience about the information properties and how they can affect the display.

7.1.1 Rate of change

The prototypes of informative art have been based on dynamic data, but the update rates have varied in each prototype. The results from the empirical work shows that it is important to have a suitable rate of change where the display changes often enough for users to perceive it as dynamic, but not so often that it becomes a source of distraction.

In the evaluation of the weather forecast, the results showed that it was sometime perceived as being static. The display only changed a few times a day, when a new forecast became available. People would thus sometimes believe that the display was "broken" since there was no perceivable change. With a low change rate there is also no urgency to look at the display. In the case of the weather forecast, it was actually only sufficient to look at it once per day to get all information that it had to offer.

The bus visualization is based on real-time data that changes more often. It also provides time-critical information that directly helps the users to accomplish an everyday task – to catch the bus. Since the buses runs very frequently during daytime, some people stressed that they would walk directly to the bus without checking the display. Since buses come less frequent during the evening, it is expected that the visualization will be used more during these hours.

Although the rate of change in the information source is not under control by the developer, the update rate of the display is. If data that is seldom changed, there is a need to make users aware that the display is not broken. A way to achieve this could be to add a minimal animation. On the other hand, data that has a very high rate of change e.g. a stock market index, might be suitable to slow down, so that the display will not attract to much attention.

Adapt the update rate so that they necessarily do not attract the users attention, but indicate that the display is regularly updated.

7.2 Designing the understandable aesthetics

The dangling string was made by an artist, whereas the look of InfoCanvas is intended to be designed by users themselves. In other cases, such as the Digital Family Portrait and the water lamp, the researcher themselves created the aesthetics. The appearance of informative art however, are borrowed from an artist. Either way might be suitable, depending on the skills of the user and the designer, of course. However, using already existing artistic style, does not need to hinder the readability or the comprehension of the display. Below the use the style of Mondrian as a template.

Even though several artistic styles have been used, one is especially prominent and common among the prototypes –the style provided by Mondrian.

In all Mondrian prototypes, mapping from some of quantitative data to the size of the color fields have been used. This mapping has worked well, even though it was not ideal for temperature (in the design of the weather forecast). This is due to the fact that the centigrade value for the freezing point is zero, and there is no simple way of making the area of a square indicating a negative value.

When using the Mondrian template the designer is forced to carefully design the mappings to make them fit the style. This has lead to simplified visualizations that all use bold and quite easy- to-read encodings, which are possible to view from a distance, even in busy environments. This might not have been the case if the design had started from scratch, when the designer could have been tempted to cram too much information into the display.

Another issue that is relevant for the aesthetics is taste. If a display is private, it might be suitable to let the users design the aesthetics, as long as they feel comfortable enough. However if the aesthetics are of importance e.g. in a setting with several users, it might be benefiting to use an already existing template or let an artist design it.

An already existing artistic template can provide useful design constraints, without the need for artistically talented users or designers.

7.2.1 Inconsistency

In some prototypes, all graphical objects act as information carriers whereas in others there is only a few that carry information. In the case of the soup clock, all items on the display reflect information, but for the Mondrian prototypes there are several graphical objects that do not. The email display and both weather displays, (weather in six cites and the local weather forecast) have squares that reflect information and lines that do not. In the bus visualisation all squares except for the river represents real-time dynamic data. Even if it represents information, acting as a visual clue, it does not carry any dynamical information.

Even if the Mondrian style have been used in several prototypes, it is only in the bus visualization that some of the lines also represents information, which could be said to not follow Mankoff et al´s (2003) heuristic of “consistent and intuitive mapping”. The two lines represent the direction of the buses. Thus, in the same visualisation similar graphics may represent information or only be part of the aesthetics. This did however not seem to be a problem in the first evaluation of the bus visualisation. One of the subjects in the evaluation of the bus visualisation said that she found it annoying that she did not know what all the lines

meant. However, she was still able to use the display for its intended purpose. The others that could read the display did not say anything about the lines.

We find that when using an artistic display, there will always be a trade off between readability and the aesthetics. But, from what the study has indicated at this point, such inconsistency does not necessarily have to be a problem. Even though, it was pointed out as a potential problem in the heuristic evaluation made by Mankoff et al (2003.

Inconsistency does not have to constitute a problem.

7.3 Physical metaphors

We believe that incorporating geographically based metaphors can support the comprehension of a display.

In the Mondrian examples several strategies was used for the spatial layout of the colored squares. In the evaluation it was found that the arbitrary spatial mappings, used in the local weather forecast tended to be harder to remember than the ones where geographical metaphors have been used as a basis for the spatial layout. This was also the case for the email display, that also had arbitrary mappings.

The first prototype that used a geographical mapping was the world weather visualisation. Although no visual cues were given to the mapping, it is possible that it helped the viewers to remember the mapping. The users still had to learn which cities that were represented. Once this was done however, it would work both ways, since the mapping work as a mnemonic, indicating which areas of the world that the cities were located in.

In the bus visualization actual geographical landmarks were be represented in the visualisation, which has been given the best results so far. With the representation of the river as a point of reference, the viewers could easily derive which direction each bus went. This way the display would act as an abstract map of the bus stop, still keeping the visual style of Mondrian. This abstract map also relates to the displays geographical relation to a place, which will be presented next.

Physical metaphors can help comprehension of the display

7.4 Information Scope and Relation to Place

The section about ambient displays reveals that the display may have different complexity. However, when designing informative art, other aspects that relate to the information shown in the display has been found – its scope and relation to place.

In the case of InfoCanvas, the displays are only created for one user and thus the scope of information only have to suit one person, rather than several in a place. It seems like this display is meant to be situated in someone's office and the information that is shown, is usually something that the person otherwise would look up on his or her desktop to be aware of i.e. traffic information, the weather and stock change. The information scope in the Digital Family Portrait is relevant for a whole family, or people caring about someone's health.

We believe that information should be designed so that the scope of the information is clearly linked to the placements and the possible users of the display. Informative art has usually been designed for several people in a specific area. Designing for several users can make it more complicated to find a relevant scope, that is considered valuable for the people in that space. The scope of informative art range from covering the office (e-mail traffic) to encompassing the entire world (world weather). The bus visualization is somewhere in between as it reaches outside the user's immediate surrounding, but concerns something that potential users are very likely to be familiar with.

The email example is only relevant for the people who are working in that particular group whose email is visualized, whereas world weather has relevance to users form all over the globe (or at least in the cites that are visualized). This made it suitable in an exhibition situation, were visitors were likely to come from many different countries. Both of these examples were suitable to present the concept of informative art, but not enough compelling to evaluate or to see continued real world use.

The bus visualization on the other hand is relevant to a place, in this case the area around the university bus stop. This means that all visitors to the place are potential users of the display. The weather forecast is relevant to the local city area, the inhabitants of the city as well as its visitors. Such displays can be situated in more than one place being useful for several people, and thus having a broader scope.

The information scope, the relation to a place and the placement of the display all affect each other.

7.5 Graceful degradation

One aspect that is not covered in the heuristics by Mankoff et al (2003), is that the system preferably should let the user know when there is a breakdown. When evaluating the weather forecast, some perceived the visualisation to be static. How would they then be able to know whether the visualisation had frozen or if it was displaying actual data? This also relates to the previously discussed rate of change, suggesting that a data source with a slow rate should have something that indicates that it still is working. Thus, a clear notification of when the system has broken down could prevent the user from misinterpreting the data or feeling like they cannot trust the system. When evaluating the use of the bus visualisation, it was found that the users directly interpreted that the display was not working, when all squares turned black. This happened occasionally when the local transit authority server broke down.

Provide the users with feedback whenever the display does not work as expected.

7.6 Evaluating ambient displays

7.6.1 Actual use

The preliminary evaluation focused on if the participants could read the display and what they thought about it, rather than if they actually used it. Thus, rather than evaluating the displays as part of the everyday life of the people in the place, the aim was to understand how people perceived it and if they could read it. The first evaluation is thus somewhat related to the heuristic evaluation performed by Mankoff et al (2003), that does not involve a long-term use situation. However, in our case, the users were involved in the evaluation, which usually not is the case in a heuristic evaluation.

The evaluation of the bus visualisation, involves more about the actual use of the display. This was also the focus in the field test performed by Mynatt et al (2001) and in the upcoming evaluation that will be performed by Miller et al (2003).

We find that the bus visualisation is more compelling to evaluate during an extended time, than the weather display. Providing a display that engage in people's daily activities of catching the bus, means that it is more directly used than occasional glances on a weather forecast. This should preferably make it easier to conduct an evaluation that focuses on the use of the display.

Field tests are suitable to use to understand the how real users employ the technology in a specific setting.

7.7 Informing Users

Ambient displays present information in an environment, where users might not even be aware of that it is an information display. The first evaluation focused on if it would be possible that the participants (that spend much time in the setting) eventually would know what was visualised. However, it was clear that unless someone provides you with the correct decoding information, it is impossible to understand what is visualised. Several would not even guess that the graphics were conveying information at all. This could imply that it is possible to display any kind of information in a public area, where only some will know that it is information and be able to ”decode” it. Those who do not have the decoding knowledge will only be able to perceive it as decoration. This benefit of abstract information has also been mentioned by Miller et al (2003), which suggest that this can be seen as a way of protecting privacy. The intended users however, need some description of what is visualised. For the first evaluation a presentation was held, and for the second text-based information was provided, close to the display and by email. The second option; textbased information, has been considered to be the best, as it makes it possible for the users to get more detailed information if they would forget how to read the display after some time. This will also be further investigated in the initiated long-term evaluation.

Ambient displays cannot be intuitive, so that users can read them directly. Instead, some additional information will have to be provided so that the users can learn to read it, and eventually get back to, if they forget how to read the display.

8 Discussion and future work

How can we change the way we interact with computers? I believe that we need to look beyond the current interaction of computers, and our view of using them as mainly desktop or handheld devices. As Buxton (1996) describes it, the current ideas of what a computer is have to be put aside, to find out alternative interaction possibilities. This thesis has explored an approach to this by looking into the research field of ubiquitous computing, bringing up new ideas on interaction with computers. This work has focused especially on the design and evaluation of unobtrusive information displays, so called ambient displays. The practical work has involved the design and evaluation of informative art prototypes, which are a kind of ambient displays. Thus, the aim has been to investigate constraints and possibilities with informative art and to compare this with other ambient display prototypes. This work has led to the design and evaluation implications that constitute the result of this thesis.

This thesis touches upon issues that affect the design and evaluation of ambient displays in general. Instead of formulating any general model, important design and evaluation issues have been exemplified with informative art (and compared with the other displays) to guide future design. Hopefully these examples also will inspire others in the design process of various forms of ambient displays.

The evaluation of the prototypes in the design process, especially the involvement of users has been essential in this work. A reason for this is that I want to understand how the current interaction with computers can be less attention demanding to use and instead more peripheral or calm and fit in everyday situations. I also believe that to achieve this, we have to get closer to people's everyday lives and try to understand different habits and ways of living, and how to support those. By implementing novel technology prototypes in people's everyday lives, it is possible to achieve design implications that otherwise are hard to find. Such experience and knowledge should be hard to accomplish in a lab experiment or with heuristics that does not involve users. I also find that if we are really interested in changing the interaction and use of computers, we should also be open for new ways of evaluating technology. Currently, several of the methods that have been described imitate evaluations that previously were used for desktop computer applications.

Trying to create novel or long-term evaluations for ambient displays are not easy however. First of all, it is hard to find out what aspects that have to be evaluated when technology is constantly present and peripheral, rather than off most of the time (like regular desktop computers). Another problematic issue is that technology prototypes often are unreliable, which makes it harder to conduct studies where the technology really become integrated in the surroundings. Server breakdowns, and the risk of imprints in the screen showed to be problematic with the study presented here. The bus-visualisation, has graphical objects that are static and risk "burning" the screen, i.e. causing imprints that cannot be removed. This concern has been shared with the employees at the IT-University, who as a result has turned the screen off a few times during this period. This will of course affect the results of the continuing study, as users cannot use the prototype on the daily basis that first was intended. Still, rather than avoiding the problem by excluding the users and the natural setting from the evaluation (such as in the work by Mankoff et al, 2003), I find it important to involve users as much as possible. With this thesis, several important issues have been brought up only when the users where involved on site, leading to design implications that would not had been discovered otherwise. I also believe that it is an important difference between using a prototype for an hour, a day or for longer periods of time. As Miller (2003) suggests, novelty

effects are reduced by time. I also believe that extended use can bring up even more implications as time passes by, but this will have to be investigated further.

Another concern when conducting long-term studies is that the prototype must be interesting and appealing enough for the users, to be used over an extended period. If the prototype does not appeal to the users, it will most likely not be used at all. In a way, that is also a result, as the reason itself might be an important implication, but some use preferably makes the evaluation more interesting. A concern that was found in the design process was that it seemed easier to conduct a study, when the information is related to some task. In the case of the weather forecast display, the use is usually not directly relevant for a task. This way, users may look sporadically now and then, perhaps without even remembering whether they "used" the display or not. The bus-visualisation however, could be more easily remembered as it helps users to accomplish the task of catching the bus. This phenomenon makes it important to try to find suitable methods that include less explicit task related technology. A possible way might be to use observations in combination with interviews, which will be possible to try out in future work.

The delimitation of scope suggested that the material presented in this thesis would have a research oriented focus rather than give market implications. Many of the prototypes described in this thesis will most likely never enter the market. However, I find that each of them is still valuable. The design and evaluation of prototypes can play an important role as inspiration and help for other researchers, designers and innovators, to think beyond the current use and interaction with technology. Even if not inspired by the work presented here, there is a kind of ambient display that already has entered the market. *Ambient Orb* (www.ambientdevices.com) is a small personal ambient display that indicate stock portfolio changes. Preferably many more or less similar kinds of ambient displays will be used by companies or private persons in the future. My hope is that this small device is only the beginning of a new trend of interaction with computers that slowly is about to change our view of what a computers is and can be used for.

Finally, I would like to comment on how art compositions made by famous artists have been used in this project. Some people might suggest that it is inappropriate to use art this way, for example breaking up Mondrian's well-balanced compositions. However, Mondrian's exact compositions have never been used. Rather, his style has been used as inspiration, allowing us to create appealing displays, that like traditional paintings can fit in an everyday setting.

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