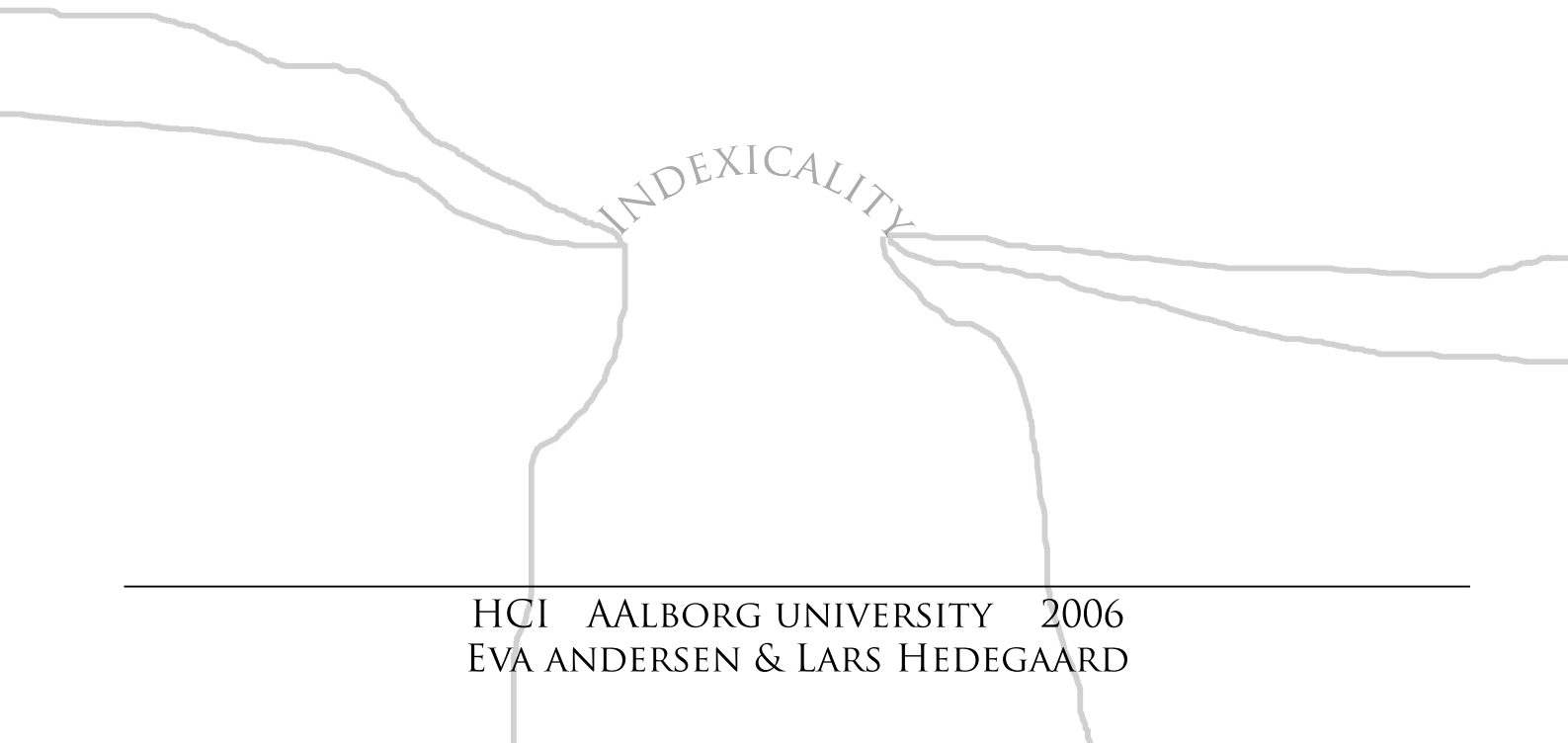
Bridging the gap

How can indexicaltiy provide design principles
for user interaction design?



HCI AAlborg university 2006
Eva andersen & Lars Hedegaard

CONTENTS

PART 1

Part one introduces the research subject and motivation as well as describes the thesis structure. The initial motivation for this thesis was an interest in mobile context-aware user interfaces. The first activity was a study of the use of an actual mobile context-aware system that motivated us to make a literature study of research into mobile context-aware computing within the last five years. The study revealed a gap in the research concerning development of HCI principles. Little research is focused on generating HCI design principles for mobile context-aware user interfaces, and the research is often very case specific, or on a general level, so that the actual application of the design principle is not obvious. This motivated us to do further research in HCI design principles that were generally applicable, yet also concrete in relation to applying them in user interface design.

1 INTRODUCTION

1.1 PROJECT MOTIVATION

The recent years have seen an increased use of mobile IT such as PDA's and mobile phones and mobile computer systems are becoming an increasingly important part of our professional as well as personal lives. Great attention is being paid to the design of small elegant mobile phones and to fit as many functions as possible into a single device [175].

Wireless networking has become more common in public spaces, and this means that the users of mobile devices can utilise their devices in more ways, and in a larger variety of places, than what was earlier possible. Examples are trains, cafés and public libraries. However, when using mobile devices on the move, there are often many distractions, such as walking and navigating in physical space or talking to a companion, and the user cannot give the device her full attention. This is complicated by the fact that the user interface of a mobile device usually is much smaller than that of a desktop computer, and that the kind of interaction styles commonly and currently used in user interfaces for small mobile devices are often quite similar to the ones used for desktop systems with bigger screens and input devices. Thus, a mobile device shows a smaller amount of information on each screen, meaning that the necessary information often is distributed over several screens. This increases the cognitive load of remembering what is shown on the different screens, and where to find the needed information. This way, the user may need to move backwards and forwards between screens several times to accomplish a task and spend more time on interacting with the device. Furthermore, a mobile device has smaller and fewer input devices such as buttons or widgets on a touch-screen, and small buttons or screen elements can be difficult to hit accurately. The difficulties that arise with adopting interaction styles developed for desktop and terminal systems onto the user interface of small mobile devices, calls for a change in interaction styles and the design of the user interface must support this. [30] and [173]

The mobile devices impose several challenges to both user interface designers and the users. How can the basic functionality of a desktop computer be delivered on a device with a reduced keyboard, no mouse and a screen that is at best 1/10 the size of the screen of a desktop computer? There are established workarounds to the input problems, like using a stylus on a touch screen on an onscreen keyboard but fitting the necessary information on the screen is still a big issue. Context-awareness is a way of changing the interaction with a device and a potential approach to making mobile devices easier to use. Context-awareness adapts the information on screen to what happens in the context, but these systems still need to make the connections between the device and the context clear to the user. Whether it is actually possible to create a context-aware device that knows exactly how and when to communicate with the user, has been a continuous area of research in the last years and is not a trivial question [34]. Even though a context-aware mobile device to some degree should be able to handle the needs of the user without contacting the user it would still need to present information to the user. This raises the problem in what way context-awareness should be implemented in the user interface and if it is possible to identify generalised design principles for designing context-aware user interfaces for mobile devices. Context-awareness in this way is not simply offering a solution but it also raises new issues regarding the implementation and the use. We had the opportunity to explore the use of a context-aware, mobile system at the IWS 2005 conference in Aalborg in September 2005 [176], where a prototype of a context-aware system for mobile phones was tested. We also had the opportunity to interview some of the attendants at the conference who used the system and study the way the system was used.

1.1.1 USER STUDY AT THE IWS 2005 CONFERENCE

We were present at the conference for three days to study the use of the Bluetooth Conference System. The system could be used free of charge during the conference at Aalborg Congress & Culture Centre, where the conference took place and at selected hotels in Aalborg and at Aalborg Airport. This study gave us insight into real users' experiences with a context-aware mobile system and the problems that occurred during the use.

The system was developed in collaboration between Blip Systems [177], N'Volve [178] and the research group of databases and programming technologies at the department of computer science at Aalborg University. Its purpose was to deliver context dependant information related to the conference as well as relevant tourist information. A front-end application was installed on the user's mobile phone, and Bluetooth access points, a so-called Blip Nodes (Figure 2), was put up in the conference centre, at selected hotels and at Aalborg Airport. The application required a mobile phone that could run Java 2 applications and had Bluetooth technology. When it was running on the phone and near a Blip Node, any new updates since last connection would be pushed to the phone. Figure 1 shows the start screen with the main menu of the application. Part of the content, such as the conference programme and the tourist information, was static.

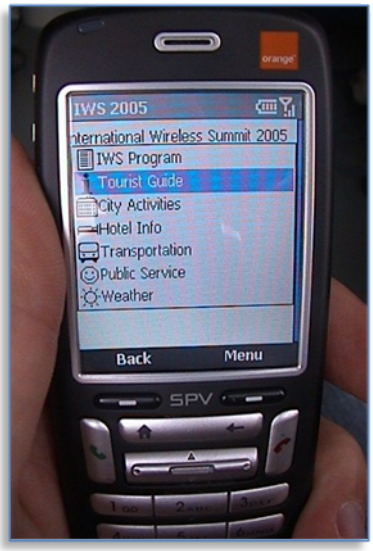


FIGURE 1: THE BLUETOOTH CONFERENCE SYSTEM MAIN MENU

FIGURE 2: BLIP NODE AT THE CONFERENCE CENTRE

During the conference we helped prospective users with installation and information about the system. In this way we had the possibility to create a general impression of the users' reactions and to contact users for later interviews. We conducted qualitative interviews with four users who all had used the system for two to three days[1]. Besides doing interviews we also analysed data from the database of the system in order to identify how many users had used the system during the conference.

1.1.1.1 RESULTS OF THE STUDY

The following numbers was extracted from the database of the system which we had access to during the conference. 69 of the 625 attendants at the conference signed up for the system. We observed that it was not possible for all who had signed up to install and get the application running on their phone. The system obtained a Bluetooth address necessary to transmit updates

[1] The questions can be seen in appendix section 0

and messages on 28 of the 69 persons but 10 of these were from the development team at Blip Systems. This left us with 18 users who could potentially benefit from the system's full functionality during the conference. Out of these 18 nine received updates during the conference; we don't know what happened to the remaining nine. We were able to contact four of these nine for interviews. Figure 3 illustrates the distribution of the users.

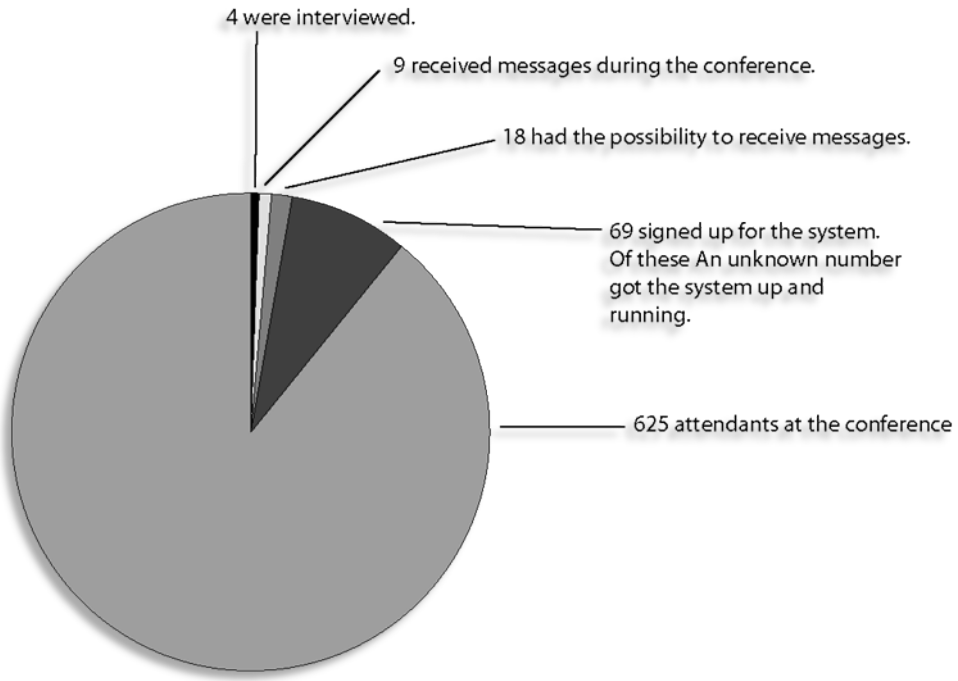


FIGURE 3: DISTRIBUTION OF USE OF THE SYSTEM DURING THE CONFERENCE

From the study we learned that it is very important that the technology functions properly in order to get a decent evaluation of a user interface, as we could only find four people who had actually used the system out of potentially 625. The users do not necessarily have an incentive to go through a long installation procedure and many of them will stop if it is not kept simple. In relation to the use of the system we found that it is important to notify the user of any changes in the interface caused by the system reacting to new input, such as pushed messages. Several users noted that they had not noticed any changes until it was too late, because the phone was lying in their pocket. It is also a good idea to have some static content that works even though the system is not connected to its network, as a backup if the connection fails. This way, the system is still of use to the user.

Major obstacles in the test were technical and practical problems as described above, and these problems were so dominant that they, to a degree, hindered the evaluation of the interaction, which was our focus. In spite of this the study piqued our curiosity concerning mobile context-aware systems and how the user interfaces of these could be improved. For example the users got confused the system was updated, did not notice the messages delivered to the phone, and some simply gave up using the system because it was too complicated. In short, there seemed to be many obstacles concerning the users' interaction with the interface, especially in relation to context-awareness. This inspired the focus of this project on how to improve the interaction with a mobile context-aware device.

1.2 PROJECT FOCUS

As described in the introduction, screen area real estate is in high demand on mobile devices, so it is important to consider how the necessary information can be presented to the user in an intuitive and easily accessible way. Given the physical size of the user interface of mobile devices and their changing context, any interaction with device should be brief and not place a heavy cognitive load on the user. Indexicality is a promising new concept in relation to interaction design of mobile, context-aware user interfaces. By using indexicality in the user interface it is possible to refer to the information already present in the context and thereby minimise the amount of information that is shown on the screen. This opens up the possibility for simpler and more intuitive user interfaces. [173]

1.3 PROJECT STRUCTURE

The following is a description of the structure of this project, and how the different activities are motivated and related. The scope of this project covers two semesters. This means that some of the chapters in the report were originally written during our ninth semester, where the foundation of the project was established. These chapters are:

The introduction.
The literature study.
The theoretical indexicality chapter.
The user requirements study.

The chapters have been rewritten and restructured during the tenth semester and are now part of this thesis. Figure 4 below illustrates the structure of the thesis and how the individual activities and sections are related.

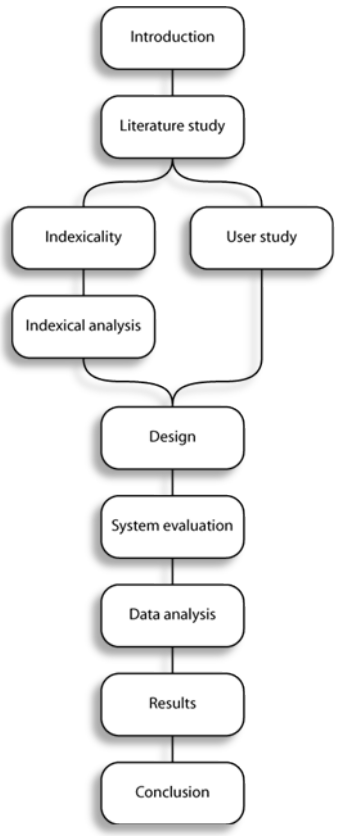


FIGURE 4: PROJECT STRUCTURE

The *introduction* describes the initial motivation for this thesis project, which was to study the usability of user interfaces of mobile, context-aware devices. This motivated the *literature study* that explored current research in mobile, context-aware computing. The literature study revealed a gap in research concerning HCI design principles. Most papers that presented design principles were concerned with either very general ideas and concepts or proposed very specific guidelines for specific kinds of mobile, context-aware systems. This gap provided our main motivation for this project, which was to research the possibility of developing more generally applicable design principles for mobile, context-aware user interfaces. The literature study also provided us with a body of knowledge about current research that we have been able to utilise throughout the project.

We chose the semiotic concept of indexicality as a possible theoretical foundation for a set of design principles. Thus it was necessary to study and define indexicality and identify methods that could be used to explore the indexical references within the use domain of the case and facilitate the design of indexical user interfaces. This part of our study resulted in the sections about *indexicality theory* and geosemiotics, and an *indexical analysis* of the use domain that supported relating the theory to this project. The use domain came from a case, which would give us a real-life situation in which to evaluate the design principles. The case was inspired by the TramMate project [159] and developed for use on city buses in Aalborg with university students as our primary user group. We conducted a *user requirements study* of the user group and explored how the users currently obtained information that aided undertaking a bus journey. With foundation in the results of the user study, and on indexicality theory, a mobile, context-aware system, intended to run on a dedicated device with a user interface based on indexical design principles, was *developed* and *evaluated*. The development process focused on implementing and testing the indexical representations in the user interface, rather than on

satisfying user needs, as exploring the concept of interaction design principles related to indexicality was the primary goal. The evaluation of the system resulted in data about how the test users reacted to the indexicality of the user interface. These data was analysed in *an analysis* with focus on how well the indexical representations worked. The final chapter of this thesis *conclusion* presents the result of the validation of the design principles.

1.4 RESEARCH QUESTIONS

The introduction of the project brings us to the aim of our research. We sought to obtain a theoretical understanding of the research area as well as undertaking research into HCI design principles for mobile context-aware computer user interfaces. The following research questions have guided the work of this project.

> *What characterises the current research in design principles for mobile context-aware HCI?*
> *How can design principles with foundation in the concept of indexicality be developed and verified?*

2 A REVIEW OF CURRENT RESEARCH IN MOBILE CONTEXT-AWARE COMPUTING

In this chapter we conduct a study of the current literature concerning mobile context-aware HCI to determine what kind of mobile HCI design principles the current research presents, and how they are derived. The chapter contains a description of the background of the study, the approach to the study, the selection of literature, and an analysis of the findings that will form a base for a discussion of principles in general.

2.1 INTRODUCTION

The field of mobile context-aware HCI is has been a subject of research in the last five to ten years, as opposed to the HCI field in general, which has been an established research area for roughly three decades. As more research within a field is conducted the field is defined and redefined and every aspect is elaborated.

The aim of this study was to classify current research within the field of mobile context-aware HCI. We therefore sought to study the notion of context and context-awareness, and identify different research approaches. This gave an overview of the focus of current research and thereby led to indications of which research approaches were most frequently applied and which areas that had yet to be explored. Our starting point was to establish the current status of HCI design principles in relation to mobile context-aware computing. In order to do so a review of the current literature within the field of HCI related to mobile context-aware computing was conducted.

2.2 METHOD

The literature study forms the foundation of our research and provides an overview of what kind of research approaches, and ways of relating to context, that are prevalent in current context-aware mobile HCI research. The method was inspired by previous literature studies within the field of computer science mainly [157] and [158]. Both of these studies aimed at giving an overview of current research practices. They used a classification scheme in the form of a two-dimensional matrix. The earliest of these studies, performed by Wynekoop and Conger [157], was concerned with the use of research methods in relation to research purpose, to understand current research and to propose future research in the use of CASE[2]. The second study, by Kjeldskov and Graham [158], reused the classification scheme from the first, but studied the field of mobile HCI instead to identify how research is done in this field. As in the two examples above, the present literature study was based on scientific papers that describe the latest research within the field.

The study was done by classifying the papers into two different matrices. The first matrix was designed to illustrate how definitions of context relate to research approaches in order to understand in what way context is perceived within the HCI field and how the definitions are handled. The second matrix was designed to illustrate how research purpose relates to research approach, and in this case especially to identify the development and use of design principles for interaction design. Using two different matrices gave a more elaborated view of research in the HCI field and reflected the focus on both context-awareness and design principles.

[2] Computer Aided Software Engineering

2.2.1 DEVELOPING THE MATRICES

Instead of using pre-defined categories as used in [157] and [158] a bottom-up approach was chosen to find appropriate categories for classification of papers in the first matrix. In this way the categories grew out of the literature. The reason for using this method was that the categories would fit the empirical material and thus the papers would not be forced into a pre-defined framework. By tailoring the categories to the literature, the more subtle variations in the literature could also be depicted.

The categories were found by reading 32 randomly chosen papers concerning mobile context-aware HCI from journals and conference proceedings[3] published from the year 2000 until the end of October 2005. The focus was on identifying research approaches, definitions of context and ways in which context was perceived. Furthermore any papers with principles for interaction design were noted for later use.

It was found that nine of the papers included explicit discussions of the definition of context and context-awareness. Four of these were devoted explicitly to conceptual discussions about context and research on context-awareness [1], [143], [61] and [62]. A significant number of the papers concentrated on engineering aspects of design and implementation of a system. The research approaches could be divided into three main sections; an engineering approach divided into a *technological* and a *user-centred* approach and a reflective approach that focused on *conceptual discussions* of context-awareness. These three sections were the basis of the categories in *the research approach dimension*, which is developed further in section 2.2.2.

Two main ways of understanding context and context-awareness were identified. Three papers specifically discussed context using a *phenomenological* perspective; [61], [62] and [143], which contrasted with the perspective that was found in the rest of the papers. The second perspective was identified as *positivistic*; using Dourishs' definition:

"Positivist theories derive from the rational, empirical, scientific tradition … positivist theories seek objective, independent descriptions of social phenomena, abstracting from the detail of particular occasions or settings, often in favour of broad statistical trends and idealised models." [62].

These two perspectives; phenomenology and positivism, formed *the worldview dimension* of the classification scheme. In section 2.2.3 the two categories based on this is developed further.

[3] The same conference proceedings and journals that will form the base for the literature study. They are listed in section 2.3

		Research approach		
		Technological approach	User-centred approach	Conceptual discussion
World-view	Positivistic			
	Phenomenological			

TABLE 1: FIRST MATRIX: ILLUSTRATING THE RELATIONSHIP BETWEEN CONTEXT DEFINITIONS AND RESEARCH PURPOSE.

For the second matrix the *research approach* dimension, as used in the first matrix of the literature study, was related to the *research purpose* dimension. The category 'research purpose' was inspired by the categories used in [157] and [158] but changed to reflect our focus on design and design principles. We joined the engineering, the description and the re-engineering categories, as they all could be seen as parts of an implementation process, and defined the 'interaction design' category to hold papers especially concerned with HCI. The design principles category was for papers that specifically explored design principles for HCI by explicating them.

		Research approach		
		Technological approach	User-centred approach	Conceptual discussion
Research purpose	Understanding			
	Implementation			
	Interaction design			
	Interaction design principles			
	Evaluation			

TABLE 2: SECOND MATRIX: ILLUSTRATING THE RELATIONSHIP BETWEEN RESEARCH PURPOSES AND APPROACHES

2.2.2 RESEARCH APPROACH

The three categories of the research approach dimension reflected different approaches to research in the field of mobile context-aware HCI. The categories were *technological approach*, *user-centred approach*, and *conceptual discussions*. We defined key issues in each approach to ease the classification. These served as a means to ensure that the classification was done properly, and to aid in ambiguous cases.

2.2.2.1 TECHNOLOGICAL APPROACH

This category described papers that were concerned with the development of a context-aware mobile system or parts of such. A technological research approach was characterised by a focus on development and/or optimisation of the technical parts of a system. The papers could also contain research in user requirements or evaluation of systems, but the focus was on the technological parts of the system. As an example, a paper describing the development of a system where a user evaluation forms a base for a discussion of the technological aspects of the system [22] would belong in this category as the focus was on technology.

Key identifiers of the papers with a technological approach:

Research in technical solutions that support context-awareness.
Descriptions of devices that measure the condition of the user or the environment; e.g. temperature, time, movement or position in space.
Code and/or algorithms.
Technical descriptions.
Pictures or drawings of technical units.
Drawings of models.
Implicit understanding of the concepts 'context'; often very little discussion about what context is.
Little direct interest in users and their requirements.

2.2.2.2 User-centred approach

This category describes papers that focus on users and principles for design of mobile and context-aware systems. There is typically focus on the user interface; either in general or in a specific case. The user was central for the research carried out in papers in this category. There was focus on user requirements and development of principles for design that centres on the user. An example was the project described in [84] where potential users act out use-situations with a dummy-device, or the evaluation with users described in [88] where user needs for location-aware mobile devices were studied. The evaluation of a system or a set of design principles would also be in this category

Key identifiers of the papers with a user-centred approach:

Descriptions of user studies.
Principles for design of user interfaces if they origin from user centred research.
Guidelines for finding user requirements.
Research on how the user deals with context-aware mobile technology.
Focus on modelling the user.
Usability.
The technological aspect of units and computers used for a study are not described in detail.
Pictures and descriptions of user interfaces.
Discussion about users and their needs.

2.2.2.3 Conceptual discussions

This category describes papers whose aim was to discuss, define or re-define a central concept; especially context and context-awareness. It also included papers that compared and discussed previous studies and systems, and papers that studied and discussed research methods in the field of HCI concerned with mobile context-aware HCI. Papers in this category were usually not concerned with the development of a system, though it might be used as an example.

Key identifiers of the papers with conceptual discussions:

Definitions of context and context-awareness that are discussed in depth.
Discussion of concepts.
Methodological studies.
Comparing of previous systems and studies.

Philosophical discussions.
Discussion of scientific methods on a meta-level.

2.2.3 WORLDVIEW

As our main interest of research was mobile context-aware HCI, we were interested in context and context-awareness as concepts and the definition of these in relation to users. This therefore guided the way papers were classified in this dimension; how was context and context-awareness understood and defined and what worldview was expressed in the research methods. In many cases this was only implicitly expressed in the papers.

The worldview dimension reflected two different worldviews: a *positivistic worldview* and a *phenomenological worldview*. This was inspired by some of the 32 papers read in order to develop the categories of the first matrix namely [61], [62] and [143]. Defining the worldview was interesting because it affects the way research is carried out and as the field of HCI is concerned with humans as well as computers. It thus draws upon humanistic research as well as computer science. This dimension was especially concerned with how context and context-awareness was understood and defined in the papers, i.e. what kind of worldview was expressed in the definitions of context and how context was understood in relation to users. It is also concerned the worldview that lay behind the kind of research that was carried out. By actively relating to the worldview that forms the basis of research, it gave a more nuanced understanding of the user's situation, as HCI research draws upon humanistic and sociological theories in order to understand users.

2.2.3.1 POSITIVISM

We define positivism as a broad definition of a scientific method, which serves as the foundation of natural science. *"Positivist theories derive from the rational, empirical, scientific tradition."* [62]. Positivistic thinking is based on positive knowledge or hard facts that are observed and sensed by human beings or logically calculated. Positivists believe science must be limited to what can be *positively* recognized, that is, science is a systematic description and organisation of empirical data. [166]:

"…, positivist theories seek objective, independent descriptions of social phenomena, abstracting from the detail of particular occasions or settings, often in favour of broad statistical trends and idealised models. Positivist theories are often … quantitative or mathematical in nature." [62].

As positivism is based in a traditional scientific understanding of the world, its understanding of how the human consciousness works follows the concept of *dualism*. Dualism is a philosophical tradition where the view is that reality consists of two different parts. The one is material substance, or the body, which essential property is that it has physical presence, and the other is mind substance, or the consciousness, that has no physical presence and which essential property is to think. These two different kinds of substance can causally interact, e.g. the mind can cause the body to act. The body does not 'do things' on its own, i.e. the body can be understood as a kind of container or machine that houses the consciousness and is controlled by it. [167]

From this follow a worldview that has a mechanistic understanding of human behaviour as governed by cause-effect rules and a belief that it is theoretically possible to make 'true' or complete models that describe human behaviour.

In relation to the notions of context and context-awareness this means that the papers that were classified as positivistic were the ones that had a mechanistic understanding of context and

human behaviour. This implied an understanding of context as the surroundings of the user and the device. This understanding could be explicitly or implicitly expressed in the paper. The focus was on the parts of the context that affected the system or the interaction with the system, and the understanding denoted that this context could in some way be sensed, measured, calculated or otherwise derived by the device. It could furthermore be put to use by the system, so that the system achieved context-awareness. If the user was described in the paper as part of the context or the representation of the user was based on rules or generic models of the user, either static or dynamic, in order to understand and predict the user's behaviour, it was classified as positivistic. Another indicator that a paper had a positivistic worldview was the way empirical data concerning users was handled. If the results were processed and presented using statistics, it was a significant indicator that the worldview was positivistic.

2.2.3.2 Phenomenology

Phenomenology is, as well as positivism, a very broad term, and there are many definitions of phenomenology as a scientific method and worldview. Our definition of phenomenology was inspired by three papers discussing definitions of context [61], [62], [143] and the phenomenology of Maurice Merleau-Ponty [164].

Phenomenology is the theory about *the phenomena* and the name means 'that which appear [to the human consciousness]'. As opposed to dualism, phenomenology believes that there is no mind/matter division and that the consciousness cannot choose not to be conscious; it is always directed towards something. There is no subject (the mind) that observes the object (the matter), nor is the body only a container for the mind. [167]

The phenomenology of Merleau-Ponty is focused on an understanding of the body and a turning away from dualism that sees the body as an object. According to Merleau-Ponty the human is an embodied existence, i.e. human existence is a unity of body and mind and the 'body-part' of the human is a property of the human at the same level as the 'mind-part'. The process of sensing the world is an active process that involves the body as well as the mind. The body is not a passive receptacle of sense stimuli, but is actively involved in the meaning construction process of understanding the world. [143]

This means that context can not be viewed as something that is outside the user, i.e. that the user or the device is the subject that observe and direct objects in the world. The user and device and their actions are all parts of the context.

Compared to positivism, phenomenological theory has a subjective and qualitative nature. Phenomenology does not believe that 'social facts', i.e. fact about humans and human action, has any inherent objectiveness. Social facts arise out of human interaction; they are negotiated and contested in a continual and ongoing process of interpretation and reinterpretation. Thus, the human experience of the world becomes something that can not be quantified or measured except as a consensus of interpretation. Abstract theories and models that describe human action do not exist a priori, i.e. human action is contingent upon the *specific* situation. Thus it is not possible identify *the* model that describes human action in a certain situation or to create models that take all aspects into consideration. [62]

An explicit understanding of context was the most direct way of identifying a potentially phenomenology-founded paper. Papers were classified as phenomenological if they shared the understanding of context as being more than what can be mechanically sensed in the surroundings, and thereby recognised that the context is dependant on human interpretation. An example could be a criticism of a positivistic view of the perception of context, backed up by a phenomenological discussion. A secondary criterion for classifying papers as phenomenological

was the way that the subjects of the study were perceived. Papers focused on the individual users and their perception of the context or the use-situation, were classified as phenomenological if they did not seek to generalise upon the user interaction, and if the understanding or interpretation of the user data was based on humanistic research.

2.2.3.3 *Comparison of the positivistic and the phenomenological worldview*

The following list shows our perceived pros and cons of adapting the different worldviews when doing research. It is based on our understanding of the worldviews as described above, and can be read as an elaboration of the above.

Strengths and benefits by adopting the positivistic worldview

The positivistic view of context is easily converted to fit a computer system.
Tests results from a sufficient number of users it will be representative for the entire user group.

Disadvantages

It is difficult to give a precise and operational definition of context, because all the subparts such as time, location, temperature and so on cannot be listed [62].
The positivistic view of context has little room for special cases or exceptions in the normal use of system.

Strengths and benefits by adopting the phenomenological worldview

Context can be fairly easily defined as everything in the situation including the user and his history.
A phenomenological view can support an understanding of the user based on humanistic theories. We take the view that a human-based theory is preferable when studying humans rather than a mathematically-based theory.

Disadvantages

A phenomenological understanding of a situation is difficult to transfer directly into a system that can be implemented in a computer system.
Each user makes sense of the system and the surroundings in their own way, so the understanding of the context is hard to generalise upon.

2.2.4 Research Purpose

The research purpose dimension described the goal of the paper, or the results that were the outcome of the paper. The categories of this dimension are described below.

Understanding was papers concerned with exploring technology, concepts, use cases etc. The papers typically presented a theoretical framework or constructed a theory to describe the findings, or concluded by describing a change in the way that the research subject should be perceived.

Implementation was research where a system was designed and implemented, or an existing system was re-engineered, or improved. It could also be the development of a system that used an experimental technology to design a practical system. In the papers classified as

implementation-related there was a strong focus on technological aspects as opposed to focus on users.

Interaction design described the development process of a system with special focus on user interaction during the design and implementation of the system, as opposed to focus on technological aspects. The category also included papers that described only the interaction related parts of a system

Interaction design principles described papers that presented interaction design principles explicitly. It can furthermore be research where one or more systems, or a theoretical foundation, form a base for guidelines that can be applied within the field of mobile context-aware HCI. This could be a survey of context-aware system that concludes why some are successful and others fail, and summarising in a list of properties what the successful have in common [58].

Evaluation holds papers focused on validating an existing system or theory with some sort of test or inspection. This could for example be a usability test of a system, or a practical comparison of different usability evaluation methods.

2.2.5 SELECTING PAPERS

To get a wide variety of subject matters of papers, and to gain insight into the most recent research in mobile context-aware HCI, papers were selected from a variety of sources and from the most recent years. The papers were selected from a number of journals and proceedings of conferences. The journals and conference proceedings reflected a wide variety of research on mobile context-aware HCI within the field and gave a representative section of the current research to found this literature study.

The criterion for choosing papers was that they should be concerned with *mobile* and *context-aware* HCI. This ruled out papers concerning stationary context-aware systems, as well as mobile systems that were not context-aware. If we found several papers with the same content from different publications the earliest published would be picked. The journals and conference proceedings were reviewed by reading abstracts from all papers. After reading an abstract the paper could usually be identified as relevant or irrelevant to the study, if this distinction could not be established, the paper was read until a clear distinction was made.

2.2.6 CLASSIFICATION

The classification was done with the help of a general description of the category combined with the list of key identifiers listed in sections 2.2.2.1 - 2.2.2.3 that define the category. For ambiguous cases we also applied a general rule, which was to determine what the aim of the paper was, what research question the paper wanted to answer, and what the underlying worldview was of the research carried out. For papers equally concerned with implementation and evaluation of a system, in many cases this rule was the deciding factor.

The definition of context was especially important for the determination of worldview, but other factors such as the way the subjects of the study were perceived and how the study in general was carried out, also contributed to determining worldview.

In order to decide the category of a paper, the paper should contain a substantial number of identifiers and concepts from a certain category besides also complying with the general rule. In the sorting process for the first matrix, the papers were read through by either one of us and classified accordingly. If there were doubts about the classification, we would discuss the focus

of the paper to find the proper category. In the sorting process for the second matrix the classification was done by both of us at the same time, and we would discuss the research purpose and classify accordingly. The classification of research purpose from the previous matrix was kept.

The papers were classified based on the general rule of thumb; to determine the aim of the paper and the research described therein. In most cases this was easy to do, but a few papers were concerned equally with answering questions belonging to several categories of the research approach dimension. This could be a paper discussing the definition of context and using this as a platform for the development of a context-aware system. This paper would be placed in both the technological and conceptual discussion categories. Another example could be a description of a technical implementation that was tested and inspired a special way of studying users, or some guidelines concerning user studies. As papers in this way could be placed in more than one category, the percentage-wise distribution in some of the following tables will not always sum to 100. Because the worldview dimension categories were defined as mutually exclusive it only happened along the research approach dimension.

2.3 RESULTS

A total of 156 papers were found in the conference proceedings and journals.

The papers were selected from publications from the beginning of the year 2000 until October 2005, and from the following selection of journals and proceedings of conferences, as they gave a representative view of the field because they presented a wide variety of research concerned with context-aware mobile computing within the field of HCI.

The literature study contained papers from the following sources:

Conference on Computer-Human Interaction, CHI, ACM
Human-Computer Interaction Journal, ASP/EBSCO
Conference on User Interface Software and Technology, UIST, ACM
Conference on Computer-Supported Cooperative Work, CSCW, ACM
Mobile HCI, Springer-Verlag (2000-2004), ACM (2005)
Symposium on Designing Interactive Systems, DIS, ACM
Symposium on Interactive 3D Graphics, Si3D, ACM
Transactions on Computer-Human Interaction, TOCHI, ACM
Journal of Personal and Ubiquitous Computing, Springer-Verlag
Journal of Computers and Graphics, ScienceDirect
Computer Supported Cooperative Work, Kluwer Academic Publishers B.V.

The table below gives an overview of which papers and how many per year were found in each publication.

	2000	2001	2002	2003	2004	2005	Total no. per publication
Conference on Computer-Human Interaction, CHI, ACM	1	1	1	8	5	7	23
Journal of Human-Computer Interaction, Laurence Erlbaum Associates Inc. (ASP/EBSCO)	0	17	0	0	0	0	17
Conference on User Interface Software and Technology, UIST, ACM	1	3	1	0	1	-	6
Conference on Computer-Supported Cooperative Work, CSCW, ACM	0	-	0	-	4	2	6
Symposium on Human-Computer Interaction with Mobile Devices, Mobile HCI	-	*	10	19	11	14	54
Symposium on Designing Interactive Systems, DIS, ACM	2	-	1	-	1	-	4
Symposium on Interactive 3D Graphics, Si3D, ACM	-	0	-	1	-	0	1
Transactions on Computer-Human Interaction, TOCHI, ACM	2	0	0	0	0	2	4
Journal of Personal and Ubiquitous Computing, Springer-Verlag	-	10	7	7	7	4	35
Journal of Computers and Graphics	0	3	0	2	1	0	6
Total no. per year	6	34	20	37	30	29	156

TABLE 3: THE DISTRIBUTION OF PAPERS BY YEAR AND PUBLICATION

- No publications

* Covered by “Journal of Personal and Ubiquitous Computing”, Springer-Verlag 2002[4]

[4] According to [174]

The Following table presents the distribution in the first matrix.

	Technological approach	Human-centred approach	Conceptual discussions
Positivistic	4, 6, 7, 9, 11, 14, 16, 19, 22, 25, 26, 34, 36, 38, 39, 40, 42, 44, 47, 54, 58, 59, 67, 68, 69, 73, 76, 77, 78, 79, 80, 81, 82, 85, 93, 94, 98, 99, 109, 110, 112, 114, 115, 124, 127, 128, 129, 130, 131, 134, 137, 139, 140, 141, 142, 145, 147, 149, 150, 151, 153, 155	2, 5, 8, 10, 12, 13, 17, 18, 22, 23, 24, 27, 28, 29, 30, 31, 32, 35, 41, 43, 45, 46, 48, 49, 50, 51, 52, 53, 56, 57, 63, 64, 66, 70, 72, 75, 77, 79, 83, 84, 86, 87, 88, 91, 92, 95, 96, 97, 100, 101, 103, 105, 106, 110, 111, 113, 116, 118, 119, 120, 121, 122, 123, 125, 126, 133, 135, 136, 142, 148, 152, 156	1, 21, 55, 56, 60, 67, 89, 90, 102, 104, 132, 138
Phenomeno-logical	15, 154	117, 144, 146	3, 20, 33, 37, 61, 62, 65, 71, 74, 107, 108, 143, 146, 154

TABLE 4: CLASSIFICATION OF THE PAPERS ACCORDING TO WORLDVIEW AND RESEARCH APPROACH

Of all the 156 papers, 64 (41%) were classified as having a technological approach, 75 (48%) as having a user-centred approach, and 26 (17%) as conceptual discussions. The 146 (94%) reflected a positivistic worldview, and 19 (12%) a phenomenological worldview. In all we encountered nine papers that were classified as belonging to more than one category in the first matrix.

It can be seen, that 86% of the papers found were based on a positivistic worldview, and aimed to explore technology, design, or use of context-aware systems[5], and the distribution among these two was relatively even. Furthermore, among the 17% of the papers that were concerned with conceptual discussions, there was an almost even distribution between the two categories of the worldview dimension, so there was a greater part, percentage wise, of the phenomenological papers (74%) that were using this approach, as opposed to the positivistic papers (8%).

As the positivistic worldview proved predominant, only 8 % of the positivistic papers had central concepts as main focus of their research. This was a sign that the prevailing definition of context is positivistic. Of the 12 % of all papers that were identified as phenomenological, 74% were concerned with the definition of central concepts, and very few used this as a base to build or design systems, so in the phenomenological research there was more focus on the concepts and less on the technology. If the first matrix of the study is compared with the list in section 2.2.3, where the advantages and drawbacks of the different worldviews versus the research approach are listed, there is a clear relation between the advantages and the focus of the papers, meaning that the current research is focused on the areas where there are advantages. It seems sensible to do research in areas where one can identify some clear advantages as opposed to choosing areas that have more implications, but some important aspects might be missed. Some of the

[5] Categories Technological and Human-centred

few papers that focused on the more problematic areas have therefore received a lot of attention, e.g. [56] and are continuously discussed within the research field.

The table below illustrates the findings in the second matrix.

		Research approach		
		Technological approach	User-centred approach	Conceptual discussion
Research purpose	Understanding and frameworks	14, 34, 52, 67, 82, 98, 154	2, 18, 41, 48, 50, 56, 72, 86, 101, 103, 117, 120, 146	1, 3, 20, 21, 33, 37, 55, 56, 60, 61, 62, 65, 67, 71, 74, 89, 90, 102, 104, 107, 108, 132, 138, 143, 146, 154
	Implementation	4, 6, 9, 11, 15, 16, 19, 22, 25, 26, 36, 38, 39, 40, 42, 44, 47, 54, 58, 59, 69, 73, 77, 78, 79, 81, 99, 109, 110, 112, 114, 115, 124, 127, 128, 129, 130, 134, 137, 139, 140, 141, 142, 145, 147, 149, 150, 151, 153, 155	8, 17, 22, 51, 57, 64, 75, 77, 79, 100, 110, 111, 118, 123, 126, 136, 142, 148	
	Interaction design		5, 10, 13, 23, 24, 28, 29, 30, 31, 32, 35, 43, 46, 49, 53, 66, 83, 84, 87, 92, 95, 96, 97, 106, 113, 116, 119, 122, 121, 125, 135, 144, 152, 156	
	Interaction design principles	47, 58, 79, 85	12, 91, 105	20, 33, 107
	Evaluation	7, 68	27, 45, 63, 70, 88, 133	

TABLE 5: CLASSIFICATION OF THE PAPERS ACCORDING TO THE RESEARCH APPROACH AND THE RESEARCH PURPOSE

In the second matrix we encountered eight papers that belonged to more than one category. The table showed that of the 156 papers, the purpose of the 46 (29%) were understanding and frameworks, 50 (32%) concerned implementation, 34 (22%) concerned interaction design, 10 (6%) gave explicit design principles, and eight (5%) concerned evaluation.

68 % of all the papers were classified into three of the 15 different boxes, and these three represented the perceived primary purposes of the three research approaches: 78% of the papers with a technical approach were focused on implementation, 45% of the papers with a human-centred approach were focused on interaction design and 90% of the papers concerning conceptual discussions were focused on understanding and frameworks. The variation was smallest in the user-centred approach where all research purposes are represented, this meaning that the user-centred approach was frequently used in a vide variety of research purposes.

There was a relatively even distribution among the three first categories of the research purpose, but the evaluation category only held eight papers, so very few papers had evaluation as their main focus. In four of the possible combinations, there were no papers represented. In the case of conceptual discussions related to implementation evaluation respectively, it does not make sense to conduct an evaluation or a conceptual discussion in order to implement a system. We believe that for the two remaining combinations interaction design related to technological approach and conceptual discussions, it is possible that papers that fitted these combinations could have existed, but we found none.

2.4 DESIGN PRINCIPLES

This section relates the results from the literature study to the field of HCI in general. We adopted a qualitative approach to classify the design principles that were found in the study in relation to design principles for HCI in general.

2.4.1 HCI DESIGN PRINCIPLES

The field of Human Computer Interaction has long been concerned with generally applicable rules for interaction design. The design principles deal with almost every possible aspect of the field and are concerned with a lot of different issues, ranging from specific rules such as how a radio button should look, to very general goals e.g. how a user should feel while using the system. Furthermore many large companies, such as Apple[6], IBM[7], Microsoft[8] and Sun[9] have their own principles for software running on their systems [169].

The existing HCI design principles were categorised, to see how the design principles presented in the papers were distributed. This led to an indication of where the focus in the current mobile context-aware HCI research was and where the focus on establishing new guidelines should be concentrated. We identified the following three major categories of design principles:

Different levels of design principles

1. ***Usability Goals*** e.g. easy to use, satisfying e.g. [179]
2. ***General concepts*** e.g. gestalt laws (proximity, colours), affordance, user feedback (background/foreground interaction, mediation, help, push/pull strategies, mapping)

[6] OS Human Interface Guidelines [169]

[7] Ease of Use: Articles, News, Training and Tools [169]

[8] Usability information from MSDN [169]

[9] Sun's Java Look and Feel Design Guidelines [169]

3. ***Specific guidelines and rules*** e.g. exit button should be in upper right corner, …

These do not constitute a complete list of principles, but are examples that serve to illustrate the different ways in which design principles are described. The ten papers that were found to present design principles are described below and the design principles are classified into one of the three categories above to establish the level of these design principles.

2.4.2 PAPERS FROM THE LITERATURE STUDY:

Context Information in Mobile Telephony [12], Barkhuus L. (2003)

This paper describes how relevant aspects of context are drawn from a qualitative case study of mobile phone use. This is continued by a discussion of how other areas may have other relevant aspects of context. The paper concludes that the definition of context should be tailored to the context of use and gives vague rules concerning mobile context-aware telephony. These belong to category one.

Intelligibility and Accountability: Human Considerations in Context-Aware Systems [20] Bellotti V. and Edwards K. (2001)

This paper comments on the anchor paper of a publication with focus on context-awareness [56], and the definition of context described therein. Based on a discussion it presents the idea that it is not possible to sense the human aspects of the context, and that systems will therefore not be able to act on behalf of the user. We should therefore build: *"… context-aware systems that respect human initiative, rather than attempting to supplement it."* [20]. A framework that enables these, and the following guidelines to support intelligibility and accountability are presented. They are limited to a very specific and small area of systems and are therefore put in category three.

Building a Context Sensitive Telephone: Some Hopes and Pitfalls for Context Sensitive Computing [33] Brown B. and Randell R. (2004)

Based on examples of use the paper argues that a context-aware telephone will probably never be able to 'guess' right every time, and that this should be seen as a premise when designing systems. From this discussion, rules concerning context-aware systems are presented. As they give overall goals for the system, they are categorised as belonging to category one.

The design of a handheld, location-aware guide for indoor environments [47] Ciavarella C. and Paternò F. (2004)

A mobile museum guide is developed with the technological choices that have been made as foundation in the description. The design criteria are listed, but it is not clear how they are derived. The developed system is evaluated and the conclusion holds lessons learned from the entire process, which serves as guidelines. These are very case specific and therefore belong to category three.

Designing Mediation for Context-Aware Applications [58] Dey A. and Mankoff J. (2005)

The paper is concerned with how ambiguous context information from sensors should be handled. Different issues concerning ambiguous sensor input are highlighted. The term mediation[10] is also discussed, and it is concluded that asking the user could solve the problem with ambiguous input. Based on this, some guidelines on mediation are described as an extension to the "Context Toolkit" described in [56]. An application, the Communicator, is implemented with mediation techniques.

The guidelines are focused on the term mediation, and therefore belong to category one and two.

Foreground and Background Interaction with Sensor-Enhanced Mobile Devices [79] Hinckley K., Pierce J., Horvitz E., and Sinclair M. (2005)

This paper discusses a variety of cases, with focus on fore- and background interaction, and gives lessons learned for the systems based on user tests. The lessons learned belong to category two but are only concerned with handling foreground and background interaction.

Acquiring In Situ Training Data for Context-Aware Ubiquitous Computing Applications [85] Intille S. S., Bao L., Tapia E. T. and Rondoni J. (2004)

This paper draws an analogy to speech recognition where a number of different methods, including trained models, are combined to find the most plausible interpretation of a word. In the same way context-aware devices should have more than a one-to-one mapping of sensor input and context, including the same sort of trained models. The users should furthermore be able to train their devices, so their recognitions of context could improve. Design observations to be used in systems that can be 'trained' are very specific on learning systems and are categorised as belonging to category three

"Just-in-Place" Information for Mobile Device Interfaces [91] Kjeldskov J. (2002)

The paper concerns how context-awareness enables less complicated interfaces, and how the information presented in the interface of a mobile context-aware devices can be improved by increasing spatial and temporal Indexicality. The principle is presented on a high level and the paper is therefore categorised as belonging to category one.

Pedestrian navigation aids: information requirements and design implications [105] May A. J., Ross T., Bayer S. H. and Tarkiainen M. J. (2003)

The paper describes a study where two approaches to guiding pedestrians through a route in a city were compared. The first was a guide made by recording a person looking on a map. The second guide was made by walking the route, while recording the user's verbal directions. The

[10] *"Mediation Techniques are interface elements that help the user to identify and fix system actions that are incorrect, or potentially involve the user in helping the system to avoid making those mistakes in the first place."* [58]

frequency of reference points was then compared and the findings are summarised in guidelines. These are on a case specific level, and belong in category three

On Typologies of Situated Interaction [107] McCollough M. (2001)

"*This essay explains typology as a design philosophy, toward which it suggests possible steps forward from current developments in context-aware applications of computing.*" [107] The paper presents a different line of thought that can be used when building context-aware systems. It is on a high level of abstraction so it is put in category one.

The following list shows the distribution of the ten papers according to their guidelines

1. **Usability Goals:** [12], [33], [58], [91], [107]
2. **General concepts:** [58], [79]
3. **Specific guidelines and rules:** [20], [47], [105], [85]

In comparison to the field of HCI in general the literature study revealed very few guidelines concerning mobile context-aware interaction, and those that did exist, was either concerned with a special type of systems – [12], [47], [85], [105], a subpart of the interaction – [58], [79], [20], or was on such an abstract level that they can be used as 'rules of thumb', or goals when designing – [33, 107]. Placed in the categories of design principles that were identified in the HCI field in general, they concentrate on small areas of the design, and present no framework for interaction design. There is a gap between the kind of abstract general rules stating that a system should possess a certain quality on one hand and the specific guidelines that concern only a small section of context-aware systems on the other hand.

2.5 Summary

The aim of this study was to identify the focus of current research within the field of mobile context-aware HCI. Furthermore we sought to identify interaction design principles, and different research approaches within the field.

2.5.1 Research approach and Research purpose

We found that the majority of the current research is concerned with the developing and designing new systems, while less focus is on generalising the findings of the research, in order to understand the field. The study showed that there was much focus on developing systems from new concepts, not on evaluating or understanding to the same extend. This explorative approach may be predominant, because the area of this study is still a young and not yet established field of research compared to other research areas of computer science, so researchers are still pushing the borders of the field rather that going in-depth in established research. The two worldviews that were identified raise another possible distinction in the research: the understanding of the context of mobile computing devices.

2.5.2 Worldview

The positivistic approach was identified as the most frequently applied within the publications, though in most papers it was not explicit. This brings up the question whether it is based on an obvious and implicit understanding of positivism as the predominant worldview in computer science, or whether the worldview is not a general concern when doing research within this field. The positivistic view is appealing since it is directly applicable to computer systems and enables

the devices to interpret the context and give fully functioning context-awareness. The phenomenological approach easily provides a broad definition of context, and one that can explain things about human behaviour that cannot as easily be described with positivism. But this definition is not directly applicable in computing, as all perception is based on a human interpretation of the situation; the context. The way that the phenomenological approach can contribute to the field is by a critical understanding of the capabilities of the devices. The device can never share the understanding with the user, so the user will have to decide what the device should do in some cases.

The two worldviews clearly have different strengths and weaknesses, but we seek to combine them to get a better understanding of context, and at the same time be able to implement a context-aware system. As previously explained we think that since HCI is concerned with humans as well as machines, it makes sense to include humanistic theories when analysing and designing this interaction, as well as including positivistic theories to understand the capabilities and limitations of the computers.

2.5.3 HCI Design principles

Ten papers included principles for interaction design. Most of these were only applicable to specific kinds of systems and many were on the level of 'rules of thumb' or on the other hand only stating general desired properties of a system. Only few usable and applicable design principles for interaction design were found.

The mobile devices have some limitations compared to stationary computers, but they also have advantages. The context of a device holds a lot of potential information that can be used to a wide extend. Not to be presented to the user in the interface, but to allow information that can be easily derived by the user to be removed, so the interface will have less information to present, and thus can be simplified. This line of thought is elaborated in the next chapter.

PART 2

Part two describes the theory about indexicality that was the foundation for the development of interaction design principles for mobile context-aware devices and the motivation for bringing the concept into this project. On basis of the theory and by applying it on the relevant aspects of the context of the use domain, which was decided by the case, a set of HCI design principles were developed. The second chapter of part two concerns an indexical analysis of the context of the system where the design principles were applied. This analysis resulted in knowledge about the indexical properties of the context that could be used for the design of the user interface.

3 THEORETICAL FOUNDATION

3.1 INDEXICALITY

The concept of indexicality comes from the academic field of *semiotics*. It is concerned with how people assign meaning to things and concepts in the world and thus make sense of their surroundings. Semiotics is describes how things and concepts are assigned meaning through *signs*. In the simplest sense, a sign is basically something that 'stands for' something else, i.e. it is not the thing or concept itself, but something that represents it. This is not only 'signs' in every-day sense like road-signs, letters or displays, but a broader definition is in effect: *"signs can take the form of words, images, sounds, gestures and objects."* [162, p. 2]. A letter is a sign and a group of letters, a word, can also make up a sign. The word 'stands for' the object that the word means, i.e. 'cat' in English means a specific kind of animal. Other examples of signs are the sound of an ambulance siren or a handshake. The sound means that the ambulance is nearby and the handshake means a greeting.

Signs are mainly studied in the context of other signs, i.e. sign systems, such as a genre or a medium. A sign or an assemblage of signs is a 'text' that can be 'read'; that is, one is 'reading' the gesture of a handshake as a greeting. Signs are thus a way in which the material of the physical world is represented and can be interpreted in a meaningful way, i.e. read. This process of meaning-assignment and reading is what make humans able to act in the world and to interact with other humans. [162]

3.1.1 PIERCE'S SIGN MODEL

Pierce's sign model [Figure 1] is a framework for understanding what signs are and how they relate meaning to the objects in the physical world or objects as concepts. The model illustrates the relationship between the uninterpreted information, the representation and the reader. The *object* is the uninterpreted information, i.e. a concept or a physical thing. The object is represented by some kind of sign, the *representamen*, which could be for instance, a symbol or a word, a gesture or a sound. The *interpretant* senses, and thus reads the sign. By reading a sign it is assigned meaning and thus the object becomes 'something' that is different from 'everything else'. Signs differentiate the object and make it possible for humans to interpret and understand and ultimately make sense of the world. Object, representamen and interpretant together make up a sign. [162]

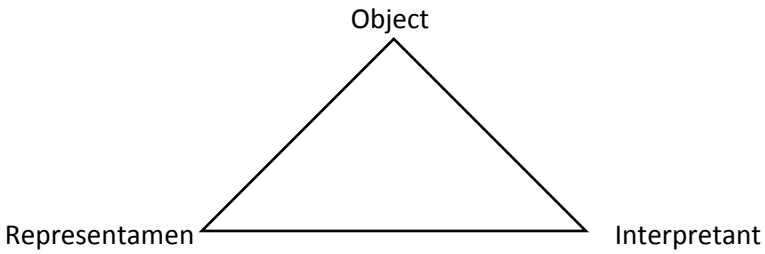


FIGURE 5: PIERCE'S SIGN MODEL

Pierce's sign model operates with three kinds of relationships, called *modes*, between the object and the representamen; *symbolic, iconic* and *indexical*. In the symbolic mode there is an arbitrary, conventional relation between the object and the representamen. Examples are alphabetical letters, sentences or traffic lights. The relation between representation and object is not necessarily obvious. For instance is it not immediately obvious that the letters 'C', 'A' and 'T' forms a sign 'CAT' that can be interpreted as a specific kind of animal, or that the colour green in a traffic light means 'go'. That is something that has to be learned by the interpretant. [162]

In the iconic mode, the sign resembles the object; the sign imitates the object in some way, e.g. it could look or sound like the object. Examples on iconic signs are pictograms, computer icons, imitative gestures, metaphors or sound-effects. [162]

As opposed to the symbolic and iconic mode, an indexical sign has a physical or causal connection to the object. The sign's physical or temporal place in the world, its context, directly affects its meaning, i.e. the meaning of the sign is relative to its placement in the world. The indexical sign indexes, or refers, to something, a concept or an object, and that reference is the link between object and representamen. The link can either be directly observed or inferred. An example of a directly observed link is a sign above a shop with the name of the shop. The sign indexes directly to the shop as the name of this particular shop because of it's placement and relative nearness to the shop.

FIGURE 6: A SIGN ABOVE A SHOP

FIGURE 7: GRASS MOVED BY THE WIND

An example of an inferred link could be seeing the wind move strands of grass from inside a house. The wind cannot be seen or felt, but from seeing the grass moving, it can be inferred that the wind is blowing, i.e. the moving grass indexes blowing wind.

There are several types of indexical signs; *natural* signs (footprints, thunder, smoke, pulse-rate), *signals* (a knock on the door, flare), *pointers* (a directional signpost), *recordings* (a photograph or film) and *indexical words* ('that', 'this', 'here' and 'there'). The indexical sign is thus very context specific and only makes sense in a particular situation, i.e. at a certain location or at a certain time. [162]

The modes are not finitely assigned or mutually exclusive, which is why it is preferable to refer to them as modes instead of types. Most signs are a combination of modes with one mode as the dominant. Which mode, is determined by the context of the sign. A photograph (the sign) of a cat can be presented in a way that means the picture represents 'cats' as a broad category and the dominant mode would be iconic. It could also represent a specific cat or cat breed, in which place the sign would be primarily indexical. The modality of a sign can change historically, e.g. the letters in the Roman alphabet was derived through Greek from Arabic letters that originally were iconic signs that represented certain physical things. Today they have become symbolic signs and their original meanings has disappeared [163, p.27]. [162]

In a sense indexicality is property of all signs, because the representamen refers, or index, to the object. In the case of a sign that is predominantly symbolic, the indexing is arbitrary and something that has to be learned. In the case of a predominantly iconic sign, the likeness of the representamen indexes to the object and only requires that the interpretant knows what the object looks like. [163]

3.1.1.1 *Examples of indexical signs*

Figure 8 shows footprints on a sandy beach. You cannot see a person, but the footprints index that a person has walked here. Furthermore the look of the footprints index to more than just that a person was here, e.g. whether she was running or walking, if she was wearing shoes or not, and in what direction she was moving etc.

Figure 8: Footprints on a sandy beach

Figure 9 shows an exit sign. It is indexical because it indexes to a specific road, or way out. It is also iconic as the shape of the sign and the black shape that emphasize the shape resemble an arrow. Furthermore it is symbolic as the text on the sign only has an arbitrary relation to the concept of an exit in the mind of the interpretant.

Figure 9: An exit sign

3.1.2 Indexicality in language

Indexicality in language is expressed through the choice of words. Indexical words in language are used to index a thing or a concept in the world. Often the words are accompanied by gestures or speech in order to make clear to the listener what exactly the speaker talks about. In addition, it might be necessary for the speaker to contextualise the indexing, i.e. elaborate the statement with the use of several indexes. This could be viewed as levels of indexicality where the listener is clued in to the correct understanding by the talker indexing from a general level to a very specific level. Also several indexes can support each other, for example pointing and saying 'look at that' at the same time. The following paragraph summarises the main groups of indexical words in English. Other languages might have different structures, for instance in Spanish is it possible to use both a 'there' that means something that is close to the hearer or speaker or a 'there' that means something far away, while only one kind of 'there' exists in English. [163]

Demonstratives are words like 'this', 'that', 'these' and 'those'. These are words that specify or singles out the person or thing that is referred to. *Deictic adverbials* are adverbs that refer to words that point out something; like 'here' and 'there'. While demonstratives and deictic adverbs mainly indexes space, *personal pronouns* are words like 'you', 'I' and 'them' index people and social relations. *Tense* and *time adverbs* index 'when', i.e. what time, 'now' or 'not quite ready' and tense; past, present and future. [163]

Indexicality in language is important because it describes the patterns in language, i.e. grammar, which people use to make sense of the world in relation to each other.

3.2 GEOSEMIOTICS

This section describes the theoretical framework of *geosemiotics*. It is relevant to this project because of the use of indexicality as a fundamental principle in understanding of human action in the physical world. We are interested in using indexicality as a foundation for design principles for user interfaces for mobile context-aware devices. Geosemiotics is concerned with the interaction between human action, visual spaces and physical spaces, and uses indexicality as an all-pervasive principle that ties it together. With the focus on the meaning on signs in place and humans as *social actors* in these places using the signs and participating in discourses, geosemiotics is useful as a tool for analysing and designing design principles.

In their book "Discourses in place" [163], Scollon and Scollon introduce geosemiotics which use indexicality as a fundamental principle for analysis of discourses in the physical world. The book is about the meaning of signs and discourses and the meaning of human action in and among those discourses. Where the action takes place, is an important part of the meaning. Signs then become parts of discourses when they are situated 'in-place', i.e. they are made relevant by their placement and the way they are linked to the physical world. Besides indexicality, there are two other fundamental principles; *dialogicality* and *selection*. Dialogicality is the notion that all signs operate in aggregate. There is a double indexicality with respect to both their placement in the world and to other signs in their context. The sign is both part of an indexical discourse with its placement and with other signs. Selection means that any action a social actor makes, selects a subset of meanings for the actor's attention. I.e. some meanings come to the foreground of the action and are of particular meaning to this action, while others are of less importance to the social actor and kept in the background of the action. Geosemiotics is thus the study of indexicality of the physical world with focus on human action and signs in relation to human action. It is a study of discourses as they reveal themselves in the physical world. [163]

Scollon and Scollon's definition of their view of human action and the social actor can be understood as phenomenological. Human action arises: *"largely unconsciously, out of prior experience, habits, and prior actions within the particular places we inhabit."* and *"…we see human action as part of a continuous flow of process…"* [163]. The social actor does not have much conscious knowledge about the sources of her actions, but the actions arise out of the actor's prior actions, knowledge, dispositions, history of experience, etc. This standpoint is in opposition to the positivistic view (see section 2.2.3.1), where the viewpoint is that actions arise from conscious thought, and that the actor is in full conscious control of her actions. Humans as social actors are positioned in relationship to other social actors as well as to other discourses with the place where they are positioned. [163]

Besides the social actor, the overall structure of geosemiotics consists of three main semiotic systems; *the interaction order, visual semiotics* and *place semiotics*. These systems are interconnected at sites of social interaction. Together they can be used as an analysis tool to reveal social relationships that are usually invisible to us, because they are implicit and embedded in everyday life and thus taken for granted. The semiotic systems each reveal different things about social interaction. Combined, they form an organising framework for the meanings of 'places' and the impact of the social actors. Indexicality, dialogicality and selection are the fundamental principles that anchor the different kinds of analysis methods used in each of the three semiotic systems. [163]

3.2.1 THE INTERACTION ORDER

The interaction order is a concept inspired by Goffman. It consists of sets of social relationships that exist between social actors in a certain place. The focus is on social interaction and interpersonal communication. As human beings we are anchored by our bodies in the physical world. Whether or not we are trying to communicate something, we 'give off' information to other social actors and project some kind of social relationship that indexes us as belonging to some social groups and not to others. Language is a large part of this indexing; e.g.: "Let us go." where 'us' implies a set of social actors, or "Look at that!" where the position in space, of the speaker, the listener and the object that is seen, is implied. [163]

There are two main parts of the interaction order; *resources* and *units of the interaction order*. Resources are the semiotic resources that the social actors use to enact social performances by constructing entities of the interaction order, that is, create and maintain discourses in place. The resources are:

Sense of time
Perceptual spaces
Interpersonal distances
Personal front

The four sections below explain the resources in detail.

3.2.1.1 SENSE OF TIME

The sense of time is most relevant in relation to the notion of urgency which means that time *seems* to pass slow or fast and to the notion of Monochronism versus polychronism. Monofocal activities means doing one thing at a time and polyfocal activity is multitasking.

A sense of time is an internal psychological state. These states can be indexed through signs. In language, the choice of descriptive words can make a big difference. E.g. the words stroll, walk, march and pace conveys different levels of urgency. Body language can also express whether the person feels like she is in a hurry or have all the time she need. This can also be seen in signs as illustrated by the two pictures to the left. The picture on the bottom shows more urgency than the picture on top. Thus the states are embodied in the world by body language. [163]

3.2.1.2 PERCEPTUAL SPACES

Visual space, auditory space, olfactory space, thermal space and haptic/tactile space. The spaces are different semiotic zones of the senses of the social actor, i.e. each of them tells the social actor something about the space she is in. For example "It's dark.", "It smells funny here." or "It's hot." all index to a certain semiotic zone for interpretation. Perceptual spaces are closely tied to the physical world as they index a certain kind of state in time at a certain place. [163]

3.2.1.3 INTERPERSONAL DISTANCES

The distances, or zones, that separate people in face to face communication. There are four types; going from intimate to personal to social and finally public distance. The distances describe how close we allow other people to come to us, and the closeness is a sign that indexes the psychological closeness between two social actors, i.e. the differences in social and interpersonal relationships. For example close family is usually allowed closer than people we do not know. [163]

3.2.1.4 PERSONAL FRONT

The personal front is any perceptible aspect, like look or smell, that a social actors present to others, whether they are intentional or not. The personal front indexes personal information about the social actor that others can 'read'. [163]

Units of the interaction order are the units or social groups that are made up by one or more social actors. The main indexes of units are location; 'here' or 'there' and social presence; 'they' or 'us'. The definition of units comes from Goffman's concept of 'with': *"A party of more than one whose members are perceived to be 'together'."* [163, p. 61]. The 'with' was developed into 'interaction arrangements' or social groups that makes up the interaction order. Examples of these social groupings are; 'singles' (a person who is by herself in a social space), 'service encounters', 'queues', 'ritualised celebrative events' or 'withs' (two or more people together in a group).

3.2.2 VISUAL SEMIOTICS

Visual semiotics is a system for analysing and understanding the visual components of social interaction and describes a: *"…grammar of visual design…"* that is used to decode the meaning of visual signs. It is adapted from Kress and van Leeuwen [163, p. 17][11]. Scollon and Scollon deal with three aspects of visual semiotics: how images represent the real social world, how visual images index the real world in which they are placed or how they have a certain meaning because of their placement, and how social actors index images in the real world while constructing ongoing social performances. The culture that produces and consumes visual designs has great impact on the meaning. So while individual examples may or may not convey the same meaning in different cultures, the general structures remain the same according to Kress and van Leeuwen. [163]

The definition of the medium of visual semiotics, a *picture* (semiotic display), is that it is designed and put together in a conscious way, e.g. art, a scientific model or an advertising photograph, as opposed to a snapshot which is mainly unintentional. A 'picture' is defined in a broad sense; it is all kinds of intentionally designed and generated images. A poster, a label on a can, a painting, a road sign or an advertisement are all examples of pictures in the definition of Kress and van Leeuwen. [163]

Scollon and Scollon divides visual semiotics into four subsystems:

Represented participants
Modality
Composition
Interactive participants

They are explained in detail in the sections below.

3.2.2.1 REPRESENTED PARTICIPANTS

Participants within the picture carry the meanings of the picture. The participants are construction elements used in the picture and can be both images of persons or texts or iconic signs. The elements can be either *narrative*; they show an unfolding of events or processes of change, or *conceptual*; and show abstract, comparative or generalised elements. Vectors, such as gaze or direction of movement within the picture connect narrative elements, while

[11] The system described in "Discourses in place" [163] is adapted from Kress and van Leeuwen's work on visual semiotics, particularly their book "Reading Images: The Grammar of Visual Design" [163]

conceptual elements are marked by an absence of this kind of vectors. Narrative relationships between elements borrow from representations of natural movements such as motion, paths or traces, degree of balance, heat that is rising, etc. These representations carries over from the real world into the picture as vectors that can be read by the viewer of the picture. They become signs that index the real world to the picture. [163]

3.2.2.2 MODALITY

Modality refers to the truth-value or credibility of the picture. I.e. is the picture seen as a 'true' and 'real' representation of reality? This is closely tied to the culture that produces the picture. In the Western world the default modality that is seen as most truthful, is the naturalistic representation. It is the one that comes closest to what can be seen in the real world. The main indicators of modality are: colour saturation, colour differentiation, colour modulation, contextualisation, representation, depth, illumination and brightness. What is seen as high modality and what is not, is dependent on the culture that produces and consumes the picture. [163]

3.2.2.3 COMPOSITION

Kress and van Leeuwen have put together *models of information structures* (Figure 10 and Figure 11) that illustrate the overall systems of composition of a picture. The structures illustrate how elements of the pictures are placed in relation to each other and how they are combined with elements that index the real world. *Centred* and *polarised* are two basic information structures. The centred structure can be either circular, triptychal or centre-margin placement. Polarised are divided into two systems; left/right and upper/lower. 'Given/new' and 'ideal/real' indexes what people (are supposed to) think when the text/picture-part is placed like that. An example could be that if a company wants a product to be represented as 'natural', the favoured positions in a picture should index to 'real' and 'new', i.e. the lower right would be the position that would seem most 'correct' in order to convey the message of the product being 'natural'. The structures are combined with *salience* and *framing* to make a full system of composition. They can be overridden in cases where the physical reality demands it, for instance in the structure and placement of fire exit signs that can be directed by the demands of the material world. [163]

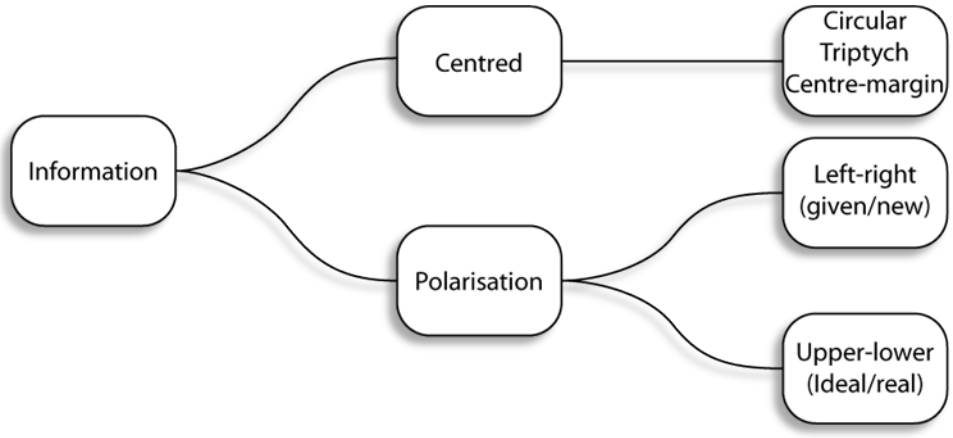


FIGURE 10: INFORMATION STRUCTURE MODEL A [163]

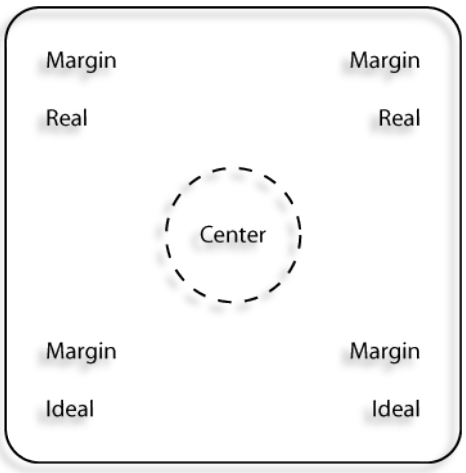


FIGURE 11: INFORMATION STRUCTURE MODEL B [163]

3.2.2.4 *INTERACTIVE PARTICIPANTS*

There are three types of interactive relationships between participants. The first type is between the producer of the picture and the represented participants within it, the second between the represented participants within the picture, and the third between the represented participants and the readers or receptive participants of the picture. The third one is the most interesting in relation to geosemiotics as geosemiotics is interested in the social relationships created in the physical world and created and maintained by indexicality. The relationships go on simultaneously between the participants that take part in or create visual signs. [163]

There exist three kinds of relationships between represented participants and viewer; *contact*, *social distance* and *attitude.* They can be most distinctly recognised when the represented participants are pictures of people.

Contact is represented by eye gaze and eye contact from represented participant to viewer; is it a direct demanding look or a downward look that is avoiding attention. Social distance is represented by the size, cut and cropping of the represented participants and the picture. E.g. a large close-up indicates closeness and focus on feeling. Attitude is mainly seen in a combination of contact and social distance and the total composition of the picture; i.e. how does the picture address the viewer and what impression or feeling does it seek to convey. [163]

3.2.3 PLACE SEMIOTICS

The interaction order and visual semiotics are focused on actions and activities of social actors in the world in a higher degree than place semiotics, which is concerned with the material world itself and the signs therein. The world we live in can be seen as a semiotic space. Everywhere we go there are signs that can be read, and we use those signs to locate ourselves in the world and to position ourselves, i.e. we use indexicality to position the sign and ourselves in relation to it. *Code preference*, *inscription* and *emplacement* are three concepts that describe dimensions of the indexicability of signs. [163]

While the theory about code preference, inscription and emplacement are mainly focused on the interaction between spaces and visual semiotics, *discourses in space* are concerned with the intersection between spaces and social interaction. [163]

3.2.3.1 CODE PREFERENCE

Code preference is the problem of which codes or languages that has been chosen to represent language in a sign placed in a particular place in the world. The problem of multiple codes within a single sign or picture is especially interesting. An example of multiple codes is road signs with the information written twice in two different languages. For signs with multiple codes there is a preferred and a marginalized code. The preferred code is placed top, left or centre of the sign. The marginalised code is placed on the bottom, right or margin. Code preference can also be embodied in the space-time dimension. The preferred code would be earlier/first and the marginalised later/second. Code preference is related to culture. In some cases codes and conventions are borrowed by other cultures and used in ways that would not be immediately recognisable for a person from the original culture. Cultural knowledge makes the viewer able to index the signs correctly. [163]

Preferred	Marginalised
Centre	Margin
Top	Bottom
Left	Right
Earlier/first	Later/second

TABLE 6: CODE PREFERENCES

3.2.3.2 INSCRIPTION

Inscription is the meaning systems that are based on the physical materiality of codes and code systems in the world. The range of systems is wide; from the difference between surface materials to icon design. Scollon and Scollon concentrates on four meaning systems that are associated with the presentation of language in the material world; *letterform*, *material*, *layering* and *state changes*. Letterform conveys meaning through their design. The shape of both the individual letters and the words allow us to index certain kinds of emotions and messages to the sign. For instance handwriting is usually seen as more personal and intimate than typewritten letters. Material is the material substance from which the sign is produced. The meaning of the sign is indexed through the properties of the material. These properties are *permanence*, *temporality* (oldness/newness) and *quality*. Different materials index different degrees of the properties; is it new or worn, cheap or expensive, etc. Layering happens when signs are added or removed to other signs over time, thus remodelling the original sign. That parts of the sign is 'old' and other parts are 'new' indicate a change; that something is happening, and to a degree keep up the 'newness' of the sign. State changing signs are signs that indicate their reading through different changing states. Two examples are traffic lights and the red light in a recording studio. [163]

3.2.3.3 EMPLACEMENT

The concept of emplacement describes where in the physical world the sign is located. Several issues are connected with location; *whether or not signs are expected, decontextualisation, transgression and situatedness*. The first issue concerns places where the cultural conventional aesthetics prohibit signs. Examples from the Western hemisphere are natural areas and older urban areas. In the Western world an absence of signs is generally considered more aesthetically pleasing. This influences the number, placement and size of signs. Decontextualised signs are sign that may appear in the same form in different context. The Nike logo or the Red Cross flag are examples of such signs. Transgressive signs are signs that are in the 'wrong' or unauthorised place; a place where it is not supposed to be by cultural convention. Examples are graffiti or a price tag that has fallen of the item it was put on. Situatedness means that the meaning of the sign is closely related to the place of the sign, such as in directional signs or a display with a shop name put directly on the building.

Emplacement is in many ways tied with culture. Different cultures have different conventions and expectations of aesthetics. Without these differences we would not be able to index signs as belonging to different places and cultures. [163]

3.2.3.4 DISCOURSES IN SPACE

Social interaction take place in spaces and the social actors participate in discourses that organise, and are constrained by, the spaces in the physical world. Signs in place indexes discourses that can be used by social actors. Discourses in spaces can be viewed in relation to Goffman's interaction order that describes how people organise social interaction [Section 3.2.1]. [163]

In public spaces there is a continuum from open and socially available spaces such as public parks to relatively closed and tightly defined public spaces such as elevators. There is also a continuum of space design from almost all-purpose to narrowly, intentionally designed spaces with a very narrow use specification such as court rooms, where the social actors must follow tightly defined roles. Thus social actions have preferred time and space requirements and are in many ways determined by the space that it takes place in, and places are often designed in ways that encourage or determine what kind of activity that takes place. Scollon and Scollon have identified some general types of public spaces:

Exhibit/display are spaces whose function, by the public, are to be looked at, but not 'used' by the public in any other way. Examples are display windows, flower beds and walls in public space.

Passage spaces are used by people to travel in from one point to another such as stairs, sidewalks or elevators.

Special use spaces are spaces that are reserved for special uses such as café seating arrangements or smoking areas.

[163]

There will exist multiple discourses in a space that engage in multiple intersections with the interaction order. This is termed *semiotic aggregates*. Within a semiotic aggregate the discourses co-exist and may influence each other. Signs in place are indices of the discourses, i.e. the discourses can be recognised and identified through the reading of signs. Scollon and Scollon term the occurrence of multiple discourses *interdiscoursive dialogicality*. In a semiotic aggregate the discourses themselves becomes signs in physical space. The 'interdiscoursiveness' goes beyond the most commonly understood definition of interdiscoursivity, in that each single discourse in the aggregate is not necessarily influenced by other discourses, but can operate semiotically independent of each other. I.e. some discourses may influence each other, while others coexist without doing it. [163]

4 INDEXICALITY IN USER INTERFACES

Indexicality and the framework of geosemiotics present tools to understand how people communicate and how they relate and refer to the context in which they act. This thesis focus on how to improve mobile context-aware user interface interaction and seek to extend the work described in the Indexical Interaction Design (IID) project [173]. The IID project is concerned with research into using indexicality as a design principle for interaction design for mobile and context-aware computer systems. In the IID project Kjeldskov proposes the use of indexicality as a design principle for the design of context-aware user interfaces for mobile systems. As pointed out in the theoretical indexicality chapter, the context of a user holds a large amount of information that can be used to adapt the user's device to the specific use-situation by using context-awareness. Indexicality can then be used to make sense of the information by indexing from the user interface to the context; i.e. using indexical signs in the user interface is a way of structuring and emphasising the connection between user interface and context.

An example of this could be using the dimensions of context that is place and time. Then context-awareness would mean that the device presents only what is relevant for the user in the specific time and place. If the user e.g. is at a conference and is going to a talk at a certain place and at a certain time, the device could provide information about this exact lecture based on the current time and the user's location. This means that in a user interface in a context-aware-device, the work of finding the information that is meaningful at that specific time, has already been done. The connection between the sign and what it indexes to, is central to the way people makes sense of the world and by utilising this fact, we can make user interfaces easier for people to understand. Thus information that is not relevant in the current context does not have to be shown. All the information that needs to be presented can be sorted in relation to the context it is presented in. In relation to time, information concerning for example buses that left two hours or 15 minutes ago is irrelevant, as you just need to know when the next bus you could take will arrive. The challenge in the user interface design is to determine exactly what information in the context should be referred to and what should not, and in what way it should be presented to the user. By using theory about indexicality as related to people as social actors and physical space, we believe that it is possible to utilise the communication tools of people in order to make a person's interaction with a device smoother and more intuitive.

4.1.1 INDEXICALITY IN RELATION TO THIS PROJECT

The purpose of this project was to develop and evaluate a set of design principles based on indexicality. This was done by designing an indexical system inspired by the TramMate project [159]. One of the goals in designing the user interface was to cut down on the information that the system provides to the user and utilise indexical signs as a connection to the context. Based on this we sought to relate the theoretical description of indexicality to the chosen use domain, to operationalise the presented theory, and formulate indexical design principles.

4.1.1.1 INDEXICALITY IN RELATION TO CONTEXT-AWARENESS

The following discussion on context and context-awareness focus on defining context and context-awareness in order to help identify the indexical properties of the context. This information was needed for the design of the user interface.

As pointed out in the literature study in section 0, context-awareness has been an established area of research for quite a while. A part of this the definition of context has been debated heavily. One approach is to define context as 'everything surrounding the system', as different aspects of context continually interact and affect each other [143]. This seems reasonable as it is

difficult to decide that something does not in some way affect the system and thus is not context. As discussed in the literature study, this definition is not easily applied from a system perspective. As we sought to understand and clarify the relationship between context-awareness and indexicality, and thus not take a system development perspective yet, we found it relevant to start with the following widely acknowledged, though not easily operational, definition of context:

"Context is any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves." [55].

This definition was further specified to fit the scope of this project, but firstly, we sought to determine the concepts of context-awareness in relation to indexicality. One of the classic examples of a context-aware system is a tourist guide that uses the context of the user to deliver information about the surroundings. In this case context-awareness is a technology that enables the system to deliver information to the user. The way that this information is presented is indexical, because the time the information appears and the physical location in which the user receives the information, index to the current surroundings, and the user then acknowledges that the change in the information is due to the surroundings. In this way we believe we can argue that all context-aware systems are indexical if they supply the user with meaningful information that index to the surroundings. But if this is the case, if indexicality is just a basic property of all context-aware systems, why is it then an interesting field of research? The exciting thing about indexicality in context-aware systems is how to make sure that the indexical clues that the user receives work as well as possible. Consider the way that the user reacts to the changes in the information on the screen of the tourist guide. If the user is notified each time the system registers that her location has changed it might be too much, but if the system does not give any indication as to whether the text on screen has changed, the user might be confused. The same can be applied to the information on screen where the right level of indexicality is essential for the user to make sense of it.

4.1.1.2 Definition of context

As we are working empirically, we seek to ground our work in empirical data in a bottom-up approach. We started with a broad definition of context that was not easily operationalised and from this we sought to go back to the case and define context in relation to this project. We had chosen Deys's definition of context as basis for our definition of context. This definition is so broad that we would not unintentionally cut off relevant context, but too broad to be of practical use for implementing a system. The definition of context for the system that was developed is based in the user study, which provided us with information about the behaviour and information needs of the users, i.e. what kind of information they needed for undertaking a bus journey successfully and how they sought to get that information.

From the general definition of context, we can look at different aspects of the context, such as the user's location, other people around the user, the weather, the user's current activity and so on. The user study served as means of isolating the essential aspects of the context enabling us to focus on these. During the study, the users sought information in their surroundings – the physical environment (mainly streets, buildings and buses), the 'informational environment' with emphasis on the information services provided by Nordjyllands Trafikselskab in Aalborg such as signposts by the bus stops, and finally they needed to know what time it was. Things that also affected the users were time and place of departure from e.g. home, time and place of arrival at the final destination/appointment, their prior experience and general knowledge with using the buses in Aalborg. The behaviour of the users showed that the parts of context that was relevant

to the task were concerned with time and location, and they were defined as the context of the device. We therefore implemented spatial and temporal context-awareness in the system.

4.1.1.3 *Absolute and relative indexicality*

Indexing to something can be done relatively or absolutely. So-called *relative* information is information that indexes to something relative, e.g. a place in time or space. Examples of this are phrases like 'over there' or 'in 10 minutes'. *Absolute* information is information that always is the same; for example an address, or a time, e.g. '10 p.m. the first of May 2006'.

When relating to time, the indexical word "now", is easier for a person to relate to her current circumstances than "11:45 o'clock" given the time is 11:45. In relation to space it is easier to relate to information such as "Just walk straight ahead, it is right by the big white church" because it indexes to information in the surroundings that is easily obtained by looking around, instead of "it's at 102, Union Street, New York, US", which would require the person to either have obtained that information beforehand or seek it out. Much information does not even make sense before it is related to something that is not present in the information. In the example above, the address is useless, unless the person knows the streets or is able to find out what the street is called.

With context-awareness, information can be presented using relational spatial indexicality. This information takes the current context into consideration, and describes the destination in relation to the current location, easing the understanding for the user. When the two aspects, absoluteness and relativeness, of the context are combined they become even more powerful at sorting and presenting the information. [91] Examples of indexical properties in this example are the mentioning of 'the big, white church' and 'straight ahead'.

4.1.2 Indexicality to be tested

This section gives a summary of how indexicality could be used in the interface. This served as a starting point for the following indexical analysis of the current information, as it aided the application of the design principles.

4.1.2.1 *Spatial indexicality*

Spatial indexicality is about indexing from the device to its physical surroundings. In this case it is indexing to locations such as bus stops and the location or destination of the user.

Relational spatial indexicality

This is indexing between two locations in space, and thereby describing the location of one in *relation* to the other. An example is another location in relation to the users' current location, or a location in relation to an absolute location. A description of a journey can in this way be presented with relational indexicality. E.g., "Turn left and walk 100 m to the bus." The relational indexicality is in the words 'left' and '100 m', as these are related respectively to the direction the user is currently facing and her current position.

Absolute spatial indexicality

An absolute place in space is a landmark, such as a street or a place. This can be indexed to as a reference to a specific place such as "The train station", "Boulevarden" or "McDonalds". This requires that the mentioned place, as well as the used name for it is meaningful for the user. We believe that indexes to landmarks are more meaningful if they are close by and can be seen, while places the user know, like 'home' or 'the university' can be indexed to from anywhere.

4.1.2.2 *Temporal indexicality*

Temporal indexicality is indexing to a certain time, either a fixed/absolute or a relative time. This is highly relevant for the purpose of the device.

RELATIONAL TEMPORAL INDEXICALITY

Relational temporal indexicality is indexing from the 'now' to a future time; e.g. 'in five minutes' or from one point in time to another. Examples could be time until the bus departs from, or arrives at a specific location. When using relational temporal indexicality the user does not have to translate information about a given absolute future time, e.g. 14:43 and put it in relation to the current time.

ABSOLUTE TEMPORAL INDEXICALITY

Absolute temporal indexicality is indexing to certain, fixed times. Examples are current time or expected time of arrival. The absolute time at which the bus arrives is just a representation of what the time will be when the action is due. We believe that absolute time makes little sense for the user as it is, and she will usually have to relate it to other times and places, i.e. translate it into relational information.

4.1.2.3 INDEXICALITY IN LANGUAGE

Indexicality in language describes principles for how people use the indexical properties of language. This would lead to an understanding of the communicative means in spoken and written language that makes the most sense to the users, and thereby how the device should communicate its indexical information to the users through language. It is not only certain 'indexical words' like 'here' and 'there' (see section 3.1.1) that can index to something. Words that belong to a certain linguistic discourse will index to that discourse and if it stands out from its context the indexing will be easy to recognise. For example, if a word from a specialised discourse such as a military discourse is used in another discourse, it will index to its original discourse. Using words that belong to a certain discourse (the use domain) can help a user to index to that discourse.

4.1.2.4 VISUAL SEMIOTICS

Visual semiotics is a grammar of visual design. It can be used both to analyse existing pictures and to design new. Scollon and Scollon [163] mainly concentrate on pictures containing images of people, as social interaction between people is their main concern. But all kinds of 'pictures', like the interface of a computer program, can utilise the visual semiotic system. This can be used to understand how the visual indexical clues should be placed and designed to make sense to the user. One part of visual semiotics is analysis of how the elements relate to each other as well as the context, i.e. internal and external indexing.

4.1.2.5 PLACE SEMIOTICS

Place semiotics is important in relation to research into the use of indexicality in interfaces. It gives an understanding of the focus of the users on different screen elements in relation to their placement on the screen. Furthermore it provides ways understanding the users' interaction with and in the physical spaces. An interesting aspect is how this interaction is affected when augmented by a device.

4.1.3 PROVISIONAL DESIGN PRINCIPLES

The above sections indicate how an analysis focused on indexicality can lead to a design with basis in the way that people make sense of and refer to their context. We therefore conducted an analysis based on the following three provisional design principles that are a summary of the section.

The domain of the system is very important for the users' understanding of the indexical interface, so it is important to identify the right discourse. Furthermore the users are familiar with the signs from the use domain as well as the concepts that are used, so these make a lot of sense to the user. Context-awareness enables information to be tailored to the surroundings and thereby referring to this when presenting information. This enables a more human-like way of communicating that is easier for the users to understand. This forms the following provisional design principles:

Index to colours and graphic elements from the relevant context.

Index to names and words that are used in the context.

Index to relative time.

5 INDEXICAL ANALYSIS OF THE USE DOMAIN

The indexical analysis of the use domain identified its indexical elements. It was necessary to identify the signs in the real world that could act as indexical cues that the user could recognise. The purpose of the analysis was to gain insight into the indexical properties of the existing system for planning and undertaking a bus journey in Aalborg. This provided information about how to index from our device to the real world in the user interface as well as served to operationalise the provisional design principles in relation to the domain.

The user study showed that the participants often looked for visual cues when searching for information to find out what to do, where and when. For example, they looked out of the window of the bus when trying to figure out where to get off the bus or to identify the right the bus. The information the participants in the user study needed was related to time and place and they used a combination of this to solve issues about missing or ambiguous information by indexing to information about either. This meant that the analysis focused on the indexical properties of the time and place aspects of the context. Another important thing was that they used both relative and absolute information such as 'in seven minutes' and 'at 7:41 a.m.' respectively 'next stop' and 'by the central bus station'.

5.1 USE DOMAIN

The elements of the use domain are the buses (city buses and metro buses), the central bus station, maps of bus routes displayed in various places, bus stops, signposts with electronic or printed timetables, the printed bus schedule book and the website of Nordjyllands Trafikselskab (NT). All these elements are in some way part of a system, provided by NT, that can aid the user in getting from one place to another. Besides NT's system, other relevant parts of the use domain are the user's home and Aalborg University. The following sections describe the different parts of the system

5.1.1 THE BUSES

The bus routes in Aalborg are divided in a number of different types that all service the citizens of the city and the surrounding area. These four main types are city buses, metro buses, night buses and regional buses. Besides those, there a number of variants of city buses that provides services such as running on outside hours or to outlying areas. The relevant types for our user group are the city buses and metro buses. City buses are yellow and service Aalborg and Nørresundby with eight bus routes. The metro buses are red and service four routes in the same area. What makes metro buses different is that they have larger number of departures, five or ten per hour, where the city buses have two to four departures per hour. The number of the bus route is displayed on the back and on the front of the bus. The name of the terminal bus stop for that particular bus route is displayed on the front of the bus. In some buses, the number and terminal bus stop name is displayed on the side of the bus as well.

The yellow and red colours of the buses are distinct features that are easy to recognise. The colours are also used in the printed schedule book and on the maps to index to city and metro buses respectively. The bus number and terminal bus stop name, indexes to the timetables and printed schedule and makes it possible for a bus traveller to recognise a specific bus. The name of the terminal bus stop of a route also indexes to a certain physical location. This in turn can tell the traveller in what direction the bus, and the name then becomes an index to the direction.

The user needs to be able to recognise the right bus. The right direction of the bus is taken care of by getting the user to the right bus stop and is not relevant here. Thus the user needs to identify its number and type. The bus colours are very obvious and easy to recognise and likewise the bus number. Also time of arrival/departure, which signifies a certain departure, can help the user to identify the right bus.

5.1.2 THE CENTRAL BUS STATION

The area with the central bus station and the train station, placed at Kennedy Square in Aalborg, is the central place of transfer between regional buses, city buses and trains, and a large number of people have to move from one place to another. A number of displays are found in and around the central bus station. The placement of bus stops index to a degree in what direction the bus goes but this requires that the traveller is acquainted with the system.

FIGURE 12: MAP OF AREA AROUND "BUSTERMINALEN", THE CENTRAL BUS STATION

5.1.3 MAPS OF BUS ROUTES

At the central bus station there are maps showing overviews of the area and the city of Aalborg. These are displayed inside the building and on the shelters outside the building. The same maps can be found on NT's web site and in the printed bus schedule. The maps indexes bus routes and physical locations in and around Aalborg. The maps used in different mediums, i.e. the website, a bus shelter and the printed schedule, are alike and that gives them, as signs, a symbolic as well as indexical quality that means that the 'reader' of the maps automatically will index between these mediums and to NT.

That the maps use the same 'sign language' as the rest of the elements, index them to buses. As the screen of the device is small and the users in the user study did not use these maps, we do not think that using them for giving direction will help the user.

FIGURE 13: MAP AT A BUS SHELTER

FIGURE 14: MAPS AT THE CENTRAL BUS STATION

5.1.4 BUS STOPS AND SIGNPOSTS

Bus stops are comprised by a number of elements; signposts that identify the place as a bus stop, electronic and printed timetables, and possibly a shelter with route maps. A bus stop has a name that identifies it. The name is taken from somewhere in the physical surroundings, often the name of the street it is placed by, or the name of some physically salient feature that is close

by, e.g. the name of a square or a school. This name is used to uniquely identify the bus stop in other parts of NT's system, most notably in the printed bus schedule.

5.1.4.1 *Signposts indicating the presence of a bus stop.*

Figure 15 and Figure 16 shows signposts with a stylised bus in black on a yellow rectangular background. The shape of a bus is distinctive and easily recognisable as an index to buses. The yellow colour indexes city buses. The signpost can be read as a sign that is a combination of both symbolic, iconic and indexical modes. The yellow colour is the symbolic mode and the picture of the bus is iconic. Taken together they strongly index to city buses, as city buses are yellow and resemble the icon. By being in a certain place the signpost indexes not only to city buses, but also to the place of the sign. I.e. to a reader of that sign, the meaning of it is that something about city buses is happening here. What that is exactly, is something that has to be learned, and that gives the signpost yet another symbolic quality. What we are interested in is primarily the indexical qualities of the sign, i.e. that it is a sign that indexes that this place is a bus stop. Many stops have some sort of shelter. These shelters are signs that in their symbolic mode indicates a bus stop and in their indexical modes indexes to that the stop is 'here'. Together with the signpost, the shelter supports the indexical qualities telling a person that 'this is a bus stop' and together they make a more visible sign than only the signpost.

Figure 15: Shelter with Signpost

Figure 16: Signpost

Electronic timetables.

A number of bus stops have electronic timetable displays as seen in Figure 17 and Figure 18. These provide real-time information about how many minutes there are until the next bus will arrive at the bus stop. As the other signposts, these also have a picture of black bus on a yellow background that indexes to city buses. The information on the display is bus number and terminal bus stop name and time to departure. The times given on the display are relational time, i.e. how long until the next bus leaves from here as opposed to the absolute times given on the printed timetables. The electronic displays provide on-the-spot real-time information. The bus numbers and terminal stop names indexes the displays on the bus, the printed timetable on the signpost in Figure 18 and the printed schedule book in Figure 21.

FIGURE 17: SIGNPOST WITH ELECTRONIC TIMETABLE

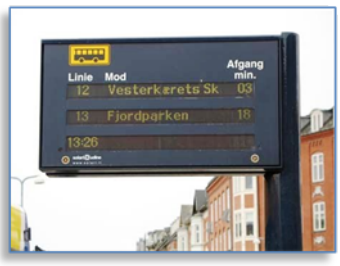


FIGURE 18: ELECTRONIC TIMETABLE

FIGURE 19: PRINTED TIMETABLE

5.1.4.2 *Printed timetables.*

Figure 19 shows the timetable has information about the arrival times of a specific bus that stops at that particular spot. The information on the timetable indexes to that particular bus stop because it is in that particular place, and like the electronic timetable signposts, it also indexes to a certain bus and the printed schedule book. The yellow frame of the sign indexes to the colour of the city buses. In cases where the printed timetable is placed on the signpost that also has an electronic timetable, the bus numbers and time of arrival index the other timetable.

INDEXICAL QUALITIES OF SIGNPOSTS

The information is the bus stop name, bus number, time of departure, terminal bus station and time to departure (electronic). The device should index to the bus number and time of departure. As not all signposts are electronic and indexing to the time to departure could be confusing if there were only a printed timetable. Since the unique identifier of a bus stop is its name, the device should index to that. If it is a bus stop that the user is familiar with, such as the one closest to her home, it could be possible that the user used some other name that was personally relevant. In this case it might be necessary to give user the possibility to name the bus stop herself.

5.1.4.3 *ELECTRONIC TIMETABLES AT THE CENTRAL BUS STATION*

The electronic displays at the bus terminal seen in Figure 20 shows real-time information about departure times and delays. Like the electronic timetables, they index to certain buses and the time they leave. In addition the specific bus stop is indexed by a letter indicating where it is. This letter indexes to small signs by the bus stops at the bus station and to the map of that area. The placement of the timetables for regional and city/metro buses is respectively closer to the doors that lead from the waiting area and to the bus stops, and the placement indexes to which bus stops the signs hold information for and in what direction the bus stops are.

FIGURE 20: VARIOUS ELECTRONIC TIMETABLES AT THE CENTRAL BUS STATION

5.1.5 PRINTED BUS SCHEDULE BOOK

This is a book that contains information about all buses and routes in and around Aalborg. The different types of buses are identified by colour codes. The colour code for the city buses and the metro buses are also the colour of the bus. The colour yellow indicates city buses. It is a commonly used colour for city buses, also in other cities than Aalborg, which means that as well as being indexical, the colour as a sign also has a symbolic mode, i.e. indexes city buses in general. Yellow is also used on the signposts that indicate the position of a bus stop as seen in Figure 16. The colours and style of the text and graphic elements in the printed schedule is distinctive and used consistently throughout the plan. Each type of bus has a colour code that is used to identify the section in the schedule book – see Figure 21 .For city and metro buses the colours are the same as the buses; yellow and red respectively. The bus numbers are identified by icons that look like a rectangle with rounded ends and the number and the colour of the bus with white text. The colours of the buses are also used to identify the bus routes depicted on a number of maps. These maps are the same that can be found by the central bus station and on the bus shelters. Besides colours used to identify buses, NT uses a dark blue on the front of the book and as accent in details throughout.

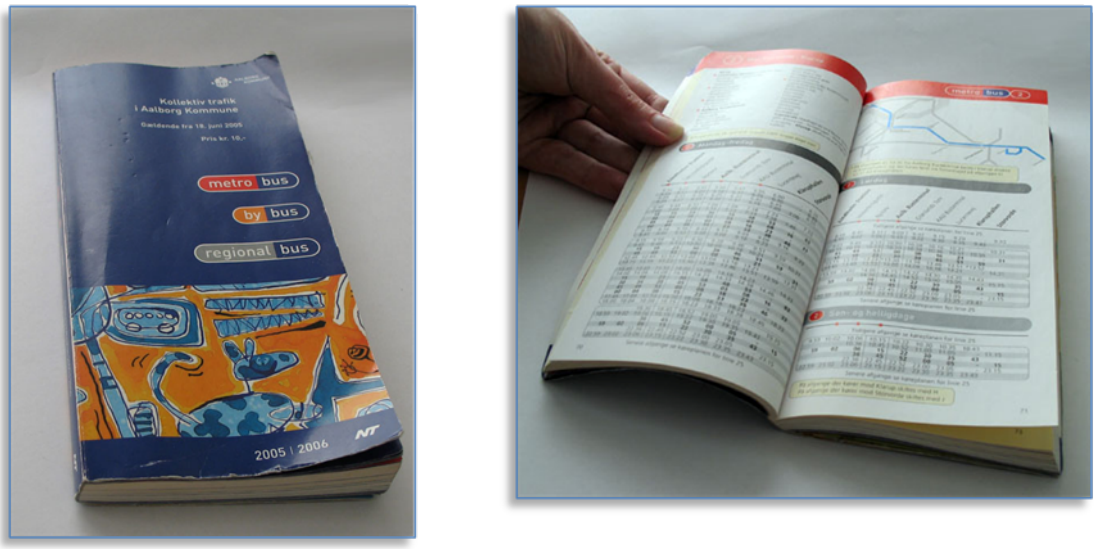


FIGURE 21: PRINTED BUS SCHEDULE

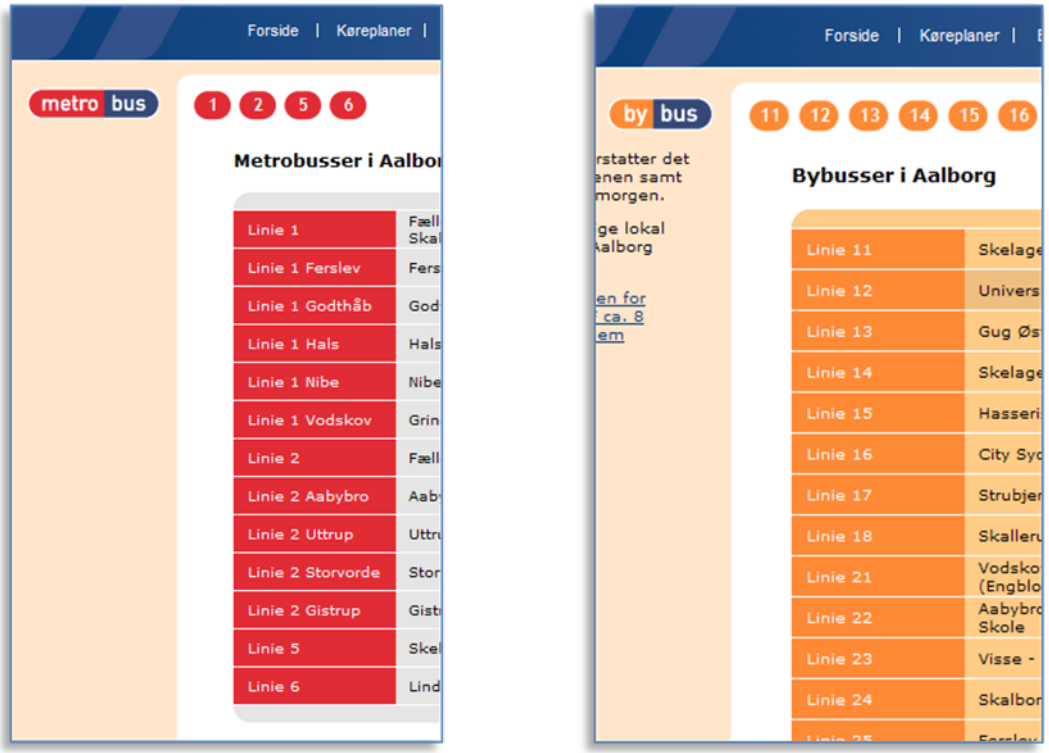


FIGURE 22: COLOUR CODING OF BUS TYPES

5.1.6 NT'S WEBSITE.

The web site [180] provides a number of services to the users. The services that are interesting in relation to this project are time tables, real-time information about delays on city and metro buses and a link to Rejseplanen.dk. The users of the website can find information about which buses they should take, when they leave from where and real-time information about possible delays. The visual theme of the printed schedule is continued in on the website with rounded corners and blue and orange colours. Most of the information that can be found on the website is the same as in the printed schedule book. The main difference is that the website also offers

interactive services, such as a search function and real-time maps and tables that show any current delays. The graphic format is also the same as used in the printed schedule book.

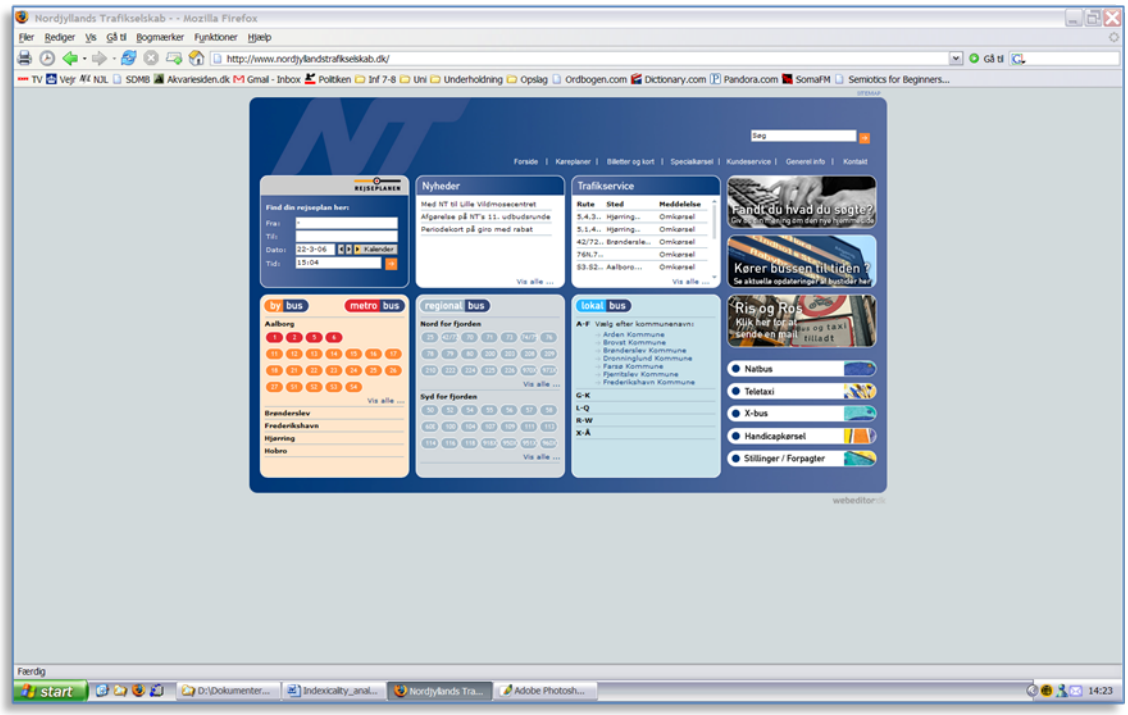


FIGURE 23: THE MAIN PAGE OF THE NT WEBSITE

5.1.7 OTHER ELEMENTS OF THE USE DOMAIN

5.1.7.1 THE UNIVERSITY

Since this is a key part of the journey we find it important that university can be identified by the users of the system. The university is generally referred to as “the university” or “AAU” in the existing information system, as well as by the users.

5.1.7.2 THE USERS HOME

When travelling by bus the users refer to home, but naturally this is not used by NT. As a concept we find it interesting as it uniquely identifies the users home. Therefore we will try to find elements that can index ‘home’ to the user.

5.2 SUMMARY

The main parts of the current information system are all connected to NT and to a large extent the same colours and graphics are used in the different elements. I.e. NT has a special sign language that indexes between the different elements, such as maps on displays, the website and the printed schedule book. A set of colours and shapes are used as codes to identify the different elements. The use of certain colours is also pervasive in the existing system in the way that buses and bus stops are indentified by certain colours and or numbers. The bus traveller identifies which bus to take on the basis of a number. In this way much of what is found in the context is something the user has learned to index to beforehand. If we use this in the user interface, a user should be able to index from the user interface if she is already aquatinted with the existing system.

5.2.1 PROVISIONAL DESIGN PRINCIPLES IN RELATION TO THE DOMAIN

The design of the system was based on these to form the interface that was used to evaluate them. The indexical analysis served to fit the provisional design principles to the domain. Below the provisional principles are presented along with the implications for the interface design.

Use colours and graphic elements from the relevant context.

Buses

The buses should be identified by their number in the same way that it is done in the NT system, by the icon, where the colour, number and shape of the icon are the exact same. We do not think that the end station is particular important to identify a specific bus, as the location from where the bus departs will aid the user in getting on the right bus.

Use names and words that are used in the context.

Bus stops and other locations

The bus stop should be identified by the most commonly used place name such at the university and the bus terminal. Even though each place name means a different thing to each user we think the users will understand it from their own perspective.

Index to relative time.

Time

The user requirements study we learned that the users often referred to relational time and in general more often referred to time rather than location. The fact that the buses run according to schedules enables us to relate the temporal information to spatial and thereby describe a location by how many minutes it takes for the bus to get to the users destination. In cases of delay this conflicts with the absolute temporal representations that are the basis of the bus schedules.

PART 3

Part three of the thesis describes a user requirements study. Four users were interviewed and studied while they undertook a bus journey. The data was analysed with affinity diagramming. The results of this study described the needs of the users and were used in the design of the user interface.

6 USER REQUIREMENTS STUDY

This chapter describes a user study conducted in December 2005. The aim of this study was to specify user requirements for the mobile context-aware computer system that is developed in order to aid the development of interaction design principles.

The user requirements study was inspired by the TramMate project [159]. TramMate was designed to aid business employees, who during a typical workday have to attend appointments at different physical locations in a city, with using public transportation, primarily buses and trams, to get around in Melbourne. TramMate is a program designed to run on a PDA and is a route planning tool that supports the user in getting to the place where he or she is supposed to be, at the right time, using public transportation. The system is context-aware and keeps track of relevant context information concerning the user and the city, such as the time and place of the user's appointments, timetables for buses and trams, and where and when the user is at a certain moment. It is then able to alert the user when to leave for an appointment and how to get there. Field studies that involved the potential users were performed in order to collect data for developing user requirements for TramMate.

Likewise, a system aiding people in using public transport in a city was developed for this project. In this case, the potential users were university students from Aalborg University and the means of transport city buses. The first phase of the development process was a field study, studying students using the city buses, as described in the following sections.

6.1 MOTIVATION

For most people travelling by public transport entail a number of implications. Whether by bus or train some of the common problems are knowing when and where to get on and off, knowing what line to change to, where to find it and how long time you have to and wait. A traveller will have to gather information before and under the journey in order to carry out the task of the journey successfully. Signs at the central station, by the bus stops and in the buses are used to ease the journey by providing the traveller with information. But much of the information that is provided is static, i.e. not context-dependent and does not take into consideration any changes in the physical reality of the traveller, like delays or platform changes. The information that is context-dependent such as calls over a speaker system and electronic displays that can take changes into consideration are delivered to the travellers as one-to-many communication. Thus a traveller must be attentive to a large amount of information in order not to miss anything that might be necessary for the further journey. As travellers all have individual needs they could be better supported by information tailored to their needs; something a device like TramMate is designed to offer [159].

The user requirements study therefore explored how people carried out the task to get from one place to the other using public buses; what kind of tasks they did and which obstacles the current way of transportation presented. This provided us with knowledge about what kind of information that is useful for travellers before and during a bus journey and when, where and how it should be provided.

6.2 METHOD

The method for collecting empirical user data followed the structure for data collecting in the TramMate project [159]. It consisted of a qualitative field study with three phases, an *interview,* an *observation of the current practice of the user* and an *acting out session* enacting imagined

future practice. This study was carried out with four participants each going through the three phases and data was collected by recording all sessions on video. An interview provided background information and an opportunity for the participant to talk about thoughts and ideas, while observation provided us with an opportunity to find out what the participant actually was doing including the things that she did not think about while doing the task. Acting out was a method for letting the participant develop new ideas for technology. A description of how the three phases were conducted is presented in the following sections.

The study was carried out in the same way for all four participants: first the interview, secondly the observation session, and thirdly the acting-out session. The schedule was made to accommodate the participants own time schedule. Thus the observation and acting-out sessions were carried out at different times during the day. The participants were recruited among university students and chosen to represent a variety of students from different locations in the city. The bus route that the participants followed was from their home to the university, with a change at the central station. We chose users with different levels of experience with using the bus system in Aalborg and made sure that the users lived in different places and had to take different lines. This provided us with more varied data, because they planned, arranged and carried out their travels in different ways.

6.2.1 INTERVIEW

Interviews were conducted with each of the participants in order to understand their information needs and their perception of the bus-journey. They were interviewed either in their home or in a room at the university; wherever that would be most convenient for them. Both are places that are familiar to the participants and therefore places were they would be able to relax more while being interviewed and filmed than in unfamiliar surroundings. The interviews were conducted as semi-structured and qualitative interviews, and structured around a number of questions that were prepared in advance. The questions were used to keep focus on relevant topics and to ensure that we covered as many possible topics concerning using the bus-system, but they were not intended to dominate the interview. The interviews were scheduled to last approximately 20-30 minutes. Techniques from “Contextual Design” [161] were used to keep the participants focused on what they actually do, i.e. keeping their answers grounded in the real world. The general ideas behind the techniques are to be attentive to the interviewee’s use of words and body language. E.g. using words like ‘generally’ or ‘usually’ or looking away and leaning back can indicate that she is generalising and presenting an abstraction. A strategy for dealing with this is to ask specific questions about specific details and draw the attention back to the specific instead of the general. [161]

The interview questions[12] had two main areas of focus. Firstly what the participants actually do; their perception of the task, and secondly what things they would like to change if possible and any new ideas for improvements of the present method of travelling. The first was done to capture what the participants thought and felt about travelling by bus. Combined with the observation session, this would give a richer understanding of the task than only doing observation. The second was partly to identify the enablers and constraints in the present way of travelling, i.e. what makes the journey easier and what irritates the traveller and feels like hindrances, and partly to gather ideas for possible functions of the device.

[12] These can be seen in section 5

6.2.2 CONTEXTUAL INTERVIEW

The second phase of the study was the contextual interview carried out while the user undertakes a bus journey using her current practice. It was carried out using Contextual Design methods for learning about the situation from the user. This would bring forth implicit information, i.e. the hidden 'work' structure that the user would not likely think about, either when explaining it in the interview or when actually carrying out the task of undertaking a bus journey. [161]

Contextual Design is a framework for a design process for developing computer systems. It supports finding out how people actually work and how to design the computer system so that the work process is supported in an optimal way. Contextual Interview is the first part of the Contextual Design process. It is used for gathering user data and user requirements and supports understanding the needs and desires of the users their and approach to the work task. [161]

Contextual Interview is build upon four principles:

> ***Context:*** The interviewer should be physically present while the user does the work task. This will enable the interviewer to learn about the task as an ongoing experience rather than a summary that might leave out important information. It will also insure that the interviewer learns about concrete and real work experiences rather than abstract and ideal situations. [161]
>
> ***Partnership:*** The partnership principle is to use techniques that make the interviewer and the interviewee take on roles that makes them collaborate and encourages the interviewee to share her knowledge and take an active role in the interview. The master/apprentice model is the ideal partnership model for achieving this. [161]
>
> ***Interpretation:*** Interpretation means assigning meaning to observations. It is important to understand what is going when a work task is carried out. Therefore the interviewer must try to interpret and form hypothesises about the work while observing and confirm these with the interviewee during the contextual interview. [161]
>
> ***Focus:*** Focus is the point of view an interviewer chooses when studying a work task. Awareness of focus makes the interviewer more alert about the direction of the conversation and thus able to change focus if it is necessary to understand a situation from several angles. [161]

A central idea of the Contextual Interview is the use of master/apprentice relationship roles during the interview. The observer acts like an apprentice, who seeks to understand the practice of the research subject, the user, by observing and trying to understand the work task of the user by asking questions to the actions of the user. This approach was used, because it kept the participants close to the real world and thus avoided that the understanding of the task became too abstract, and also kept the interviewer focused on observing and learning about what the participants were doing. Being in context also encouraged the participants to think and talk about the task in a more concrete way, than at a traditional interview by letting the participants show and explain tasks as they are done instead of imagining them while explaining. A contextual interview differs from a traditional interview as the one conducted in the first phase, as it takes the form of observation accompanied by asking questions concerning the current actions of the user in the context. The approach supported that implicit information concerning the task was made explicit, i.e. that the interviewer asked questions to some part of the task that the participant did automatically without noticing. The focus was mainly kept on the information needs of the participants before and during the journey. This also provided

information on how often participants needed information, and how they usually acquired that information. [161]

6.2.3 Acting out future practise

The last phase was conducted as an explorative approach to designing systems. The purpose of this phase was to gather knowledge about what the participants would feel was the ideal support of planning and undertaking a bus journey. E.g. how often should an ideal mobile device provide information, in what situations should the different kinds of information be presented to the user of the device and what kind of functions was interesting. Furthermore the phase was a way of letting the participants come up with ideas for functions for a mobile device, and to identify problems that might occur in some use situations.

The approach is inspired by the scenario-based design described by [160]. Instead of actors to perform the acting out, the participants from the previous phases were chosen for this phase too. The acting out was done in context during a bus journey meaning the scenario was not staged, but a part of a normal bus journey enhanced with support from a fictive mobile device. The participants were given a device prop; an object that was used to act as a mobile device but designed so it did not resemble a traditional device – see Figure 24. There were three different shapes for the participants to choose from and they were painted bright blue. This was done to the keep the participants from thinking of the device as a specific device and thereby limiting its functions to those of that device. Based on a short introduction to the idea of acting out with a device prop, the participants acted out with the prop during a bus journey, while explaining the imaginary functions and answering questions from the interviewer. The role of the interviewer was to support the participants in acting out and to help them to make explicit the information that the device delivers and how and when it was presented on the device.

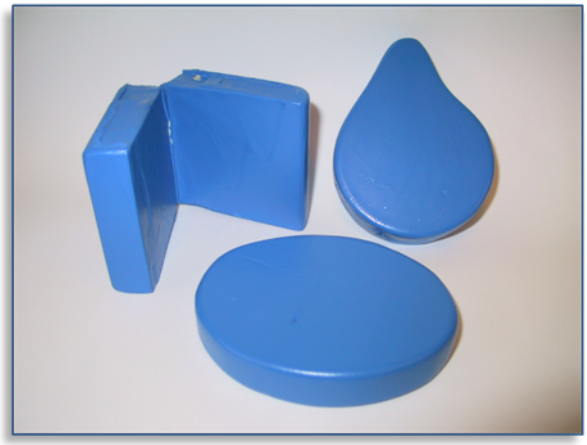


Figure 24: Device props

6.3 Data analysis

The data was analysed using *Affinity Diagramming* [161, p. 151-163].*"The affinity shows the scope of the customer problem: it reveals in one place all issues, worries, and key elements of work practise relevant to the team's focus"* [161, p. 154] It is a method that works bottom-up by using empirical data as the foundation for understanding the needs of the potential users. Instead of forcing the data into predefined categories, the categories are defined by working inductively with the data and identifying patterns and themes in concrete, real data. [161]

In affinity diagramming, empirical data is sorted by grouping findings and linking them with each other. The method is based on notes, so-called *affinity notes*, either captured during the contextual interview, or in this case written by reviewing the videotapes from the sessions with the participants while noting their statements and actions. Everything that had any kind of relation to the bus journey was written down. Examples of affinity notes are: *"Is looking for the bus to see if it is coming.", "Walks over to the bus stop on the other side of the road in order to check departure times for his return journey"* and *"Reads a news paper in the bus in order to make time pass."* The aim of affinity diagramming is to identify common themes and patterns between the notes by grouping them based on affinities between them. The groups should preferably not be larger than three to five notes, as the aim is to identify as many aspects of work as possible. The groups are then given labels with a statement that summarises the individual points of the notes. These groups are then grouped in larger groups and areas of concern and themes emerge by abstracting more and more over the initial notes. In an inductive way the initial statements from the users will reveal the structure of the task. The result is an affinity diagram with three to four levels that gives a picture of the entire problem build solely from the user data, as everything in the picture has origins in the notes. [161]

The finished affinity diagram from the user requirements study consisted of four levels that can be seen in Figure 25 . The number before the level is the number of different categories or notes in that level.

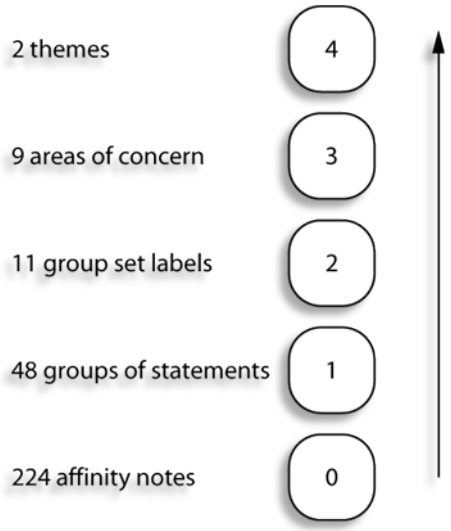


FIGURE 25: LEVELS OF THE AFFINITY DIAGRAM

The group set labels was used to divide areas of concern that consisted of six or more groups, which is why the label has not been applied to all areas of concern. The affinity note group labels and the group set labels describe the content of the groups by using a statement such as one that could be stated by a person. An example is: *"On unknown routes I need information on where the bus is"*. This was done because it kept our knowledge rooted in reality and concrete understanding of the problem. Level three 'areas of concern' identifies a number of different tasks that emerge during a bus journey and level 4 describe the two themes that emerged concerning the tasks that needed the user had to do as well as the things affecting the participants during a bus journey.

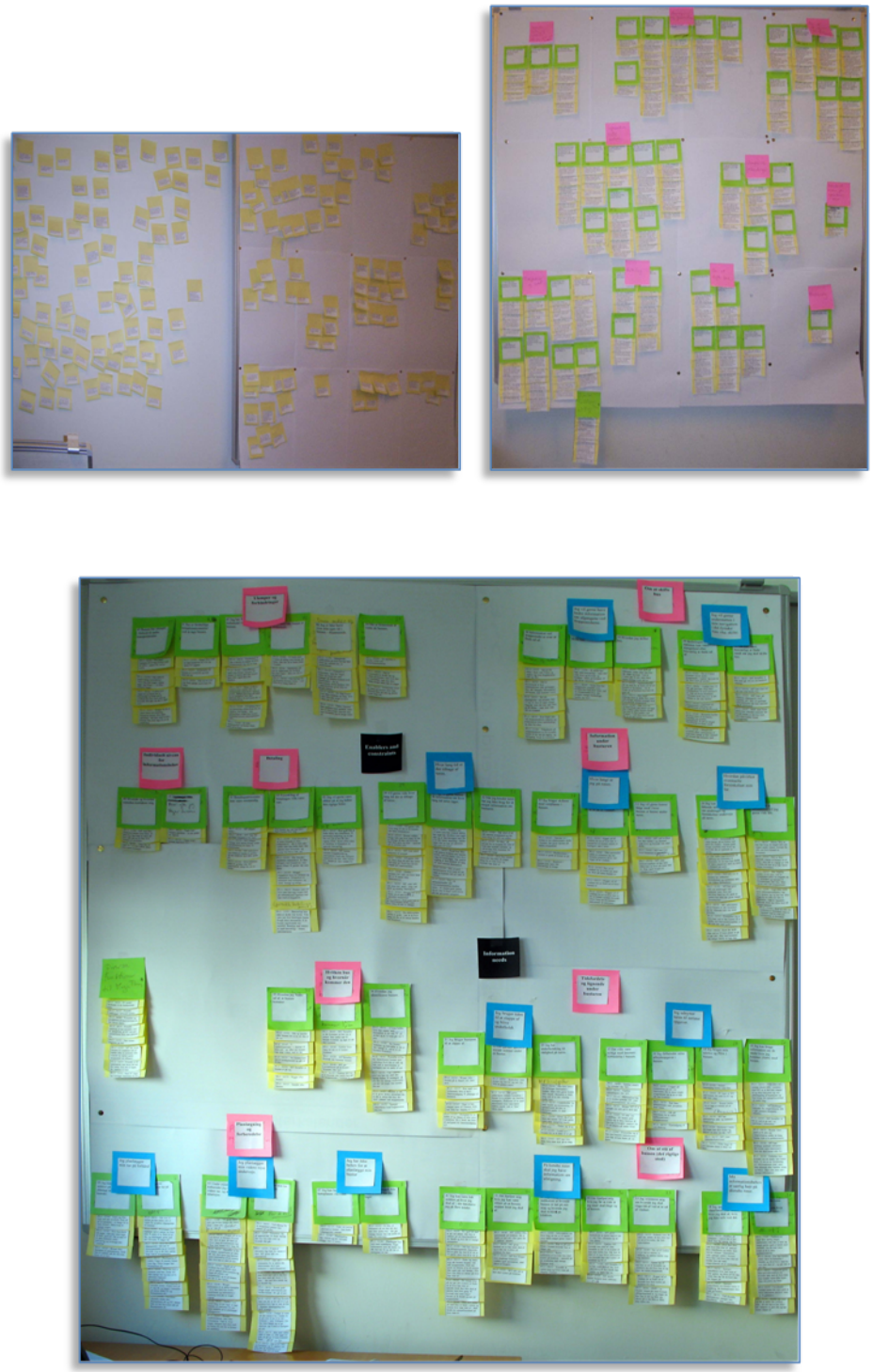


FIGURE 26: A. THE AFFINITY NOTES ARE GROUPED WITH SIMILAR NOTES. B. THE NOTES ARE ORGANISED BY CATEGORIES AND SUBCATEGORIES. C. THE FINISHED AFFINITY

6.4 RESULTS

The following table shows level one to four of the affinity diagram and how the different levels of notes are related. It formalises the participant's actions and understandings of the bus journey and explicates the different situations that the participants undergo and gives insight

into how they get the necessary information and resolve problematic situations during a bus journey.

Level 4: Themes	Level 3: Area of concern	Level 2: Group set label	Level 1: Affinity note group label
Information needs	Planning and preparation	I plan my trip in advance	I am not sure that I have planned my journey right
			I want to plan my journey in advance
		I plan my trip ad hoc	During my journey I plan my further journey – my next step
			I adapt my journey to the current situation
		I don't plan my trip at all	I have the timetable in my head
			I don't plan what bus to take
	Getting off the bus (at the right place)	On known routes I want information on when to get off the bus	It is helpful if I know that the bus stops at every stop
			I am missing an indication of when I should ring the bell and when the bus is at my stop
			An indication on when to ring the bell would be helpful
			I figure out when to ring the bell by looking out the window
			I can have some doubts as to where to get off. I deal with that in several ways
		My information need is higher on unknown routes	I ask the bus driver or the other passengers if I don't know the route
			On unknown routes I need information on where the bus is
	What bus and when		How I identify the right bus
			How I find out that the bus is arriving
			How I find out when the bus arrives
	Bus change	I want better information about departures at the stops	The information at the stops is hard to understand
			It is troublesome to change bus
			How I change the bus
		I want my navigation in the physical space to be supported better by use of signs	The information at the station can be flawed and is hard to understand
			It is hard to find the next bus when changing at the station
	Information during the bus ride	How much time is left of the journey	I would like to know the duration of the bus journey
			When I know the route I need less information
			I would like to know how much time is left of my bus journey
		How far am I on the route	I find out how far the bus is on the route by looking out the window
			I would like to be able to se the bus' progress on the route
			I look at the route signs in the bus
		How does delays influence my journey	I would like to get updated information on delays and changes during the journey
			I want to be notified when the bus is delayed
	Individual information needs		How often I take the bus
			When and how the device contacts me
Enablers and constraints	Passing the time during the bus journey	I want to be entertained and to relax	I relax during the journey
			Some special social norms are in effect during the bus journey
			I have entertainment at my disposal during the journey
		I use the journey to work on small tasks	I prepare for the things I do at the university
			I can use information on the things I see on the journey
			I use my phone and my PDA
			An internet connection would be useful
	Downsides and constraints		It annoys me to wait for the bus
			The bus has some downsides compared to other means of transportation
			The bus journey annoys me
			I take the bus with some reserve
			Crowded busses annoy me
			It is frustrating that I have no influence on the duration the journey
	Payment		Paying the fare can be troublesome
			Simplification of the payment process would be helpful
			I want to make sure that I have bought the right ticket

6.4.1 THEMES IN THE AFFINITY DIAGRAM

We identified two major themes that describe the areas of concern that affected the participants in relation to a bus journey. These were *Information needs* and *Enablers and constraints.* They will be described in the following and their influence on the further course of this project will be explained.

6.4.1.1 INFORMATION NEEDS

This theme describes the situations and circumstances in which the participants needed information. They can be seen as areas of concern where a system should assist and ease the task for the users.

There are a number of critical times during a bus journey where a traveller needs information about certain things.

Planning and preparation

When people plan to go on a bus journey they prepare. The first thing they do is finding out which bus to take and when they should leave home. Either they plan their route by asking other people, using an online route planner, a printed bus schedule, or they have done the journey many times before and can remember the schedule, or they do not care to prepare and just take the next bus that comes to the stop.

What bus and when

No matter what they are always adapting to the situations trying to optimise the journey en route. When waiting at the bus stop they want information on when their bus arrives and they want to be ready when it does.

Information during the bus ride

On the bus they need information on when they reach their destination, how long it takes before they have to get off and furthermore they want to know whether the bus is delayed and for how long time.

Getting off the bus (at the right place)

If they are not familiar with the destination they are going to they need more information during the journey, maybe a map of the area or the bus route, and they want to be certain that they get off at the right location. The participants want to be reminded when they should hit the stop button and especially when getting off at unknown locations they would to feel more secure if the bus stops at every stop it passes, so they have time to see whether they should get off the bus or not. This is preferable as it also ensures that their bus actually stops were they are supposed to get of the bus.

Bus change

When changing between bus lines participants are often in doubt, because they receive little to no information as they move. The participants think that the signs at the central station are not sufficient, and they do not know when and from where the bus that they are moving to is leaving.

Individual information needs

When they grow accustomed to using a certain bus route or a combination of buses their information needs lessen. They keep the schedule in their head and they do not seek as much information during the journey.

6.4.1.2 *Enablers and constraints*

This theme describes the benefits of taking the bus, the benefits that a system could provide, and the perceived annoyances and constraints that a system might be able to ease. It was not as important as the information needs theme in relation to indexicality because it did not give insight into how the dynamic context-aware information should be presented. But the theme did provide knowledge about the functionalities that the participants felt they needed. Furthermore it present a number of problematic issues to which the solutions are beyond the scope of this thesis.

Downsides and constraints

Taking the bus is a second choice for most participants, and they usually do it when they are not able to use other means of transportation such as bicycle because it is too cold outside, or a car because it is in use. There is some drudgery associated with the bus journey such as crowdedness, payment and unreliability. Still there are the benefits of being able to concentrate on other things or sleep while being transported.

Payment

Payment is seen as somewhat troublesome, e.g. the traveller needs to remember having money ready or to buy a travel card beforehand.

6.5 Summary

The findings in this user study served as the foundation for the design of the mobile system supporting university students making bus journeys between their home and the university. By mapping out their approach to the task and their thoughts of it we achieved an understanding that enabled the design of a system that delivered the information that the users requested. This contributed to the project of designing the system that explored design principles for mobile context-aware user interfaces by providing user requirements based in a real, concrete use situation.

6.5.1 User requirements and system functions

The user requirements study provided us with the user's understanding of the journey and how the required information was acquired and how it should be presented. Based on the user study the following functions, elements and tasks that are associated with taking the bus were identified and the system design was based on them.

Planning the journey, i.e. finding the right bus route and when and where to get on the bus.

- Possibility to plan ahead and to schedule a journey.
- The user must feel reassured that it is correct and the best route.

Alerting the user when to leave home to catch the bus.

- An indication of when to leave home or university. The walking distance and time to the stop should be included.
- A countdown timer to the bus leaves.
- Displaying alternative routes if the bus is missed.
- A signal that alerts the user when the bus arrives.
-

Guide the user from home to the right bus stop and from the bus stop to the final destination of the user.

- A guide that can help the user to find the relevant bus stop.
- A guide that can help the user to find his final destination.

Automatic ticket payment functions when the user gets on board the bus.

- Should buy the cheapest ticket type, and notify the user (and the bus driver) of the payment.

When on the bus provide the user with information about the duration of the journey and where the user is at the moment.

- Displaying an indication of time left of the journey and estimated time of arrival.
- Displaying an indication of delays and, if the journey involves shifts, these shifts and alternatives.
- Possibly a map displaying the current location

Alert the bus driver that the bus should stop and alerting the user shortly before the stop.

- Alert when to ring the bell and present a possibility to ring from the device

PART 4

Part four of the thesis describes the design of the user interface. The task description is based on the user requirements and on the indexical properties from the indexicality analysis of the use domain. The focus of the design was to incorporate as much indexicality as possible. The design went through two iterations; a paper prototype and an implemented prototype, which are both described in this part.

7 USER INTERFACE DESIGN

In order to evaluate and validate the indexical properties of the user interface, we developed a system for a user evaluation. The system was intended to run on a PDA, which was used for the user evaluation. We named our system Buster and in the following sections we refer to the system either as 'Buster' or 'the device'.

The design of the user interface was based on provisional indexical design principles and functional requirements from the user study in sections 4.1.3 and 6.5.1 The user requirements study focused on identifying the information needs of a potential user carrying out the task of undertaking a bus journey in Aalborg. A number of tasks that the device should handle for the user were identified, and central tasks that could be enhanced with indexicality were chosen for the design.

The design went through two iterations; a paper prototype and an implemented prototype. The paper prototype was developed to explore how the potential tasks that were identified could be supported with the indexicality that the users applied during the user study, and how this could be implemented in an interface. The indexical qualities that were implemented in the user interface were identified through an application of our provisional indexical design principles on an indexical analysis of the use domain. The focus of the design phase was therefore not only to design the system, but to make sure that the user interface was designed to explore to what extend indexicality could be used to minimize the information presented on the device, while still presenting the user with a sufficient amount of information to derive all needed information for undertaking a bus journey. In this way, the design of the user interface was a balance between supporting the functions identified in the user study, and implementing the functions according to the provisional design principles presented in the indexicality chapter.

7.1 TASK SPECIFICATION FOR THE USER INTERFACE

The overall functionality that was implemented, supported the user in getting from one place to another, at the right time, using the city buses in Aalborg. The primary user group was students at Aalborg University. The affinity diagram from the user requirements study informed the task specification for the user interface, and this was what the device should be capable of in order to evaluate the indexicality, which was the main goal. The task specification is an assessment of each function in relation to how much indexicality we could implement, how difficult it was to implement, and how it would affect the system if the function was not available. We sought to avoid functions that were not indexical if their absence did not impact the primary functions of the system. The main function of the device was to support the tasks that arose during a bus journey. These tasks were centred on the theme 'Information needs' from the user study. This meant that the primary goals for the device was to deliver the right information to the user at appropriate times, primarily by displaying information on screen, but also included notifying the user via sound.

The theme 'Enablers and constraints' from the user study identified things that were related to tasks that might be irritants or enhancements of the bus journey, but were not necessarily directly connected to the user's information needs. This theme is secondary in relation to solving the task of planning and doing a bus journey, so the possible tasks from within this group were not prioritised in relation to implementing indexicality in the user interface when deciding what the device should support.

7.1.1 COMMUNICATING WITH THE USER

As the device is supposed to support the user during a bus journey, by supplying her with information, the user and the device would need to establish a means of communication where the user can obtain information from the device. As seen in the study at the IWS 2005 conference described in section 1.1.1, information can be pushed to a user who is not in constant contact with the device in a situation where a user does not need constant information from the device. The opposite of 'pushing' information is 'pulling'. That is, the user deliberately chooses to obtain information from the device. An established separation between push strategy and pull strategy separates the way that information is retrieved. Information that is pushed is automatically provided to a passive user, while a user that pulls actively looks for information by interacting with the system. Whether to use push or pull strategy is a difficult choice, as different users might prefer different strategies, and as well as being a choice between either one, it is also a choice of how much information should be pulled and how much should be pushed. Cheverest et al. [*Exploring Context-aware information Push: Keith Cheverst, Keith Mitchell and Nigel Davies*] points out that the chosen strategy should reflect the primary task of the system. In our case, the system is not very information dense, as the small amount of information that the user interface displays does not requires the user to read more than a few lines at a time. This means that the user is highly 'disruptable', in the sense that, in most cases, the user can be interrupted if the device wants to display some new piece of information[*Exploring Context-aware information Push: Keith Cheverst, Keith Mitchell and Nigel Davies*]. Therefore there is little need for the user to look for information that is not specifically updated for the situation. On this basis, push strategy would suit the system best and the device used mostly push strategy to notify the user according to the context. On some occasions pull strategy could be used, for instance when the user needs information already in the system, such as details on an upcoming appointment.

7.1.2 TASKS BASED ON USER REQUIREMENTS

This section describes the tasks that the device should handle, based in the user requirements study. The main, general tasks of the user were identified and served as headers for the description in the sections below.

7.1.2.1 PLANNING THE JOURNEY:

The user plans either in advance or ad-hoc during the journey. In the case were the user has a specific appointment sometime in the future, it should be possible to create a journey plan in advance. Otherwise the device should provide the user with context-aware information about when the next buses that leaves.

A journey plan is created in accordance to the information the user puts into an electronic calendar when creating an appointment, and the information the device has, by being time- and location-aware. During a journey, the plan might need to be altered according to delays, or if the user changes her mind about the destination. The first part of the task is to create an appointment in the calendar. An appointment is information about where the user wants to go, i.e. the location, and when and for how long it will last. The system will find the best possible bus or buses for the journey. A plan is then created on the basis of this information, and information about the location of the user immediately before the journey starts.

7.1.2.2 GETTING ON THE BUS:

The task covers getting on a bus at the beginning of a journey and change during a journey. The user needs to identify the right bus and needs to know the line number and time of arrival. The device should notify the user about time of arrival and any delays, and give information about

how to identify the bus. An extra functionality belonging to the 'enablers and constraints' theme is to let the device take care of payment automatically. A related task is guiding the user to the bus stop or between two buses during a change if she is not in a familiar place. As before, the user needs to know how to identify the right bus and how to find the right bus stop. This is especially important where there are several bus stops close to each other in one place, for instance at the central bus station. The user should be able to identify where she is and how to get to the departure bus stop. Time to departure is also relevant, so the user will now whether she is in a hurry or not. Finding and identifying the correct bus stop and correct bus involves being able to recognise it using visual clues. A possibility is to index from the device to physical space, for instance by the use of signs that index to certain physical locations or things.

This task is primarily related to spatial indexicality. As for temporal indexicality, the primary concern is to be at the bus stop right before the bus arrives. In other words, the user is at a certain point 'in time' in relation to the time of departure and this relative time indexes the point of departure. It is more useful for the user to know that the bus leaves in five minutes rather than knowing it leaves at 10.22 o'clock. This entails indexing between elements in the user interface, as well as indexing to timetables and bus schedules.

7.1.2.3 GETTING OFF THE BUS:

The user need to know when and where to get off the bus. This functionality includes informing the user about how much time that is left, notifying her shortly before the stop, so that the user is ready, and finally activating the stop signal in the bus. When the task of being aware of when to get off the bus and press the stop signal is left to the device, the user can relax more. As the device takes over most of the task of getting off the bus; i.e. stopping it and alerting the user, the user has to do very little herself. By telling the user to 'get off the bus now', the system indexes to current time and location, giving the user a clear message.

7.1.3 SCENARIO

The following scenario is a walkthrough of how the system could be used typically. It's purpose is to describe aspects of the system from a user-perspective as it will give further insight into what functionality the system will actually provide for a user [181]. The scenario was written to support decisions concerning functionality during the development, such as whether a function could be left out because it contained no indexicality, or if it was a central that the user would need. The scenario will serve as a guide for the functionality, while the user interface will be developed based on the information needs discovered from the user study, and by means of indexicality as described in the chapter.

> *David puts in an appointment in the calendar about a meeting, with his study group, in two days time. The system automatically creates a journey plan that includes the time when David should leave home and until he arrives at the bus stop at the university. By pressing the appropriate fields in the calendar, he can watch the details of his appointment and the bus journey plan. Five minutes before David should leave home for the bus, the system alerts him via a pop-up message and a sound indicating that message. He hears the notification and acknowledges it by pressing the screen-button 'OK'. A timer has also started to count down the minutes until David should leave home to be in time for the bus. When David leaves home, the timer starts counting down to a new event in the future, namely the time when the bus leaves from the bus stop. All the way from home and until David reaches the university, the system provides him with information about what actions, with relevance to the bus journey, he should do next. This is done mainly via pop-up messages. If he needs to change between bus lines during the trip, the device alerts him and guides him to the correct bus.*

Besides the functions described in this scenario, the device also provides a separate functionality, which is 'Next bus'. This function display when the next bus departs from a location for certain bus lines, chosen by the user. It is relevant when the user does not have a fixed appointment, but simply need to know when the next buses from the nearest bus stop leaves for desired destination.

7.2 PAPER PROTOTYPE

The first iteration of the design process was the development of a paper prototype. The functionality is centred on an electronic calendar, where the user inputs her appointments. When an appointment is created, the program will then automatically create another special appointment with information on what bus she should take and when it departs. Furthermore, it will alert her when it is time to take action.

7.2.1 INDEXING TIME AND LOCATION

We have chosen to focus on temporal and spatial aspects of context, as these were identified as the central aspects of the context of the use domain in section 4.1.2. This means that the system will be adapting to changes in the current location and time of the user. When the user is in a certain place at a certain time, she might be aware of this, but whether the system is aware of this too, might not be necessarily clear to her. Even more important is, whether the user is aware that the system is knows of this. We chose to make the time explicit to the user, providing her with knowledge of the understanding of the device, of this aspect of the context. The understanding of the device of the location, is on the other hand not explicit to the user, but only becomes apparent to the user through functions that rely on location. While the implicit approach to the understanding of the location saves space in the user interface, the explicit knowledge of time, gives the user more clues about how the system works.

7.2.2 DESCRIPTION OF THE USER INTERFACE

This section describes the user interface. The section is divided into the three main windows of the system, and is mainly focused on the indexical properties of the interface.

7.2.2.1 SYSTEM OVERVIEW

The system has a menu on top, which is always accessible, and from where the three main functions is accessed. The area below the menu displays different content, related to the chosen functionality. The menu has three options: Buster, Calendar, or Find bus as illustrated below. The start screen is 'Buster', and from the menu, 'Calendar' or 'Find bus' can be chosen.

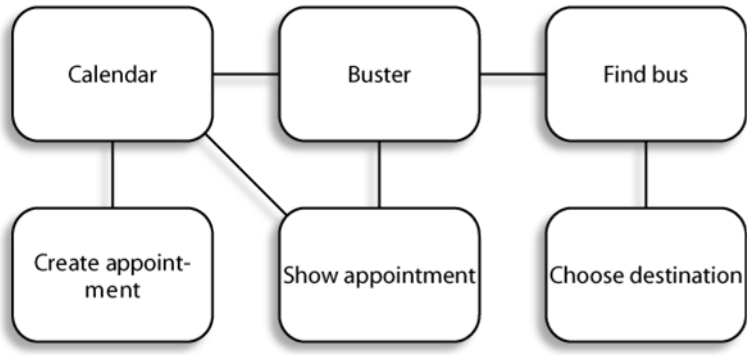


FIGURE 27: SYSTEM OVERVIEW

The start screen is the 'Buster' screen, with a dynamic bar at the bottom showing the next action that the user should take. The screen has a plan where the user can tap on an item to see the appointment. In the *Calendar* it is possible to see an appointment or create a new one. The screen, *Find bus*, provides functionality for quickly finding the next bus that leaves from the nearest bus stop. Apart from the directly accessible content, there are push messages that are triggered by events outside Buster. They cover most of the content screen, and can be closed by accepting them. Below is an in-depth description of the different windows.

7.2.2.2 BUSTER SCREEN

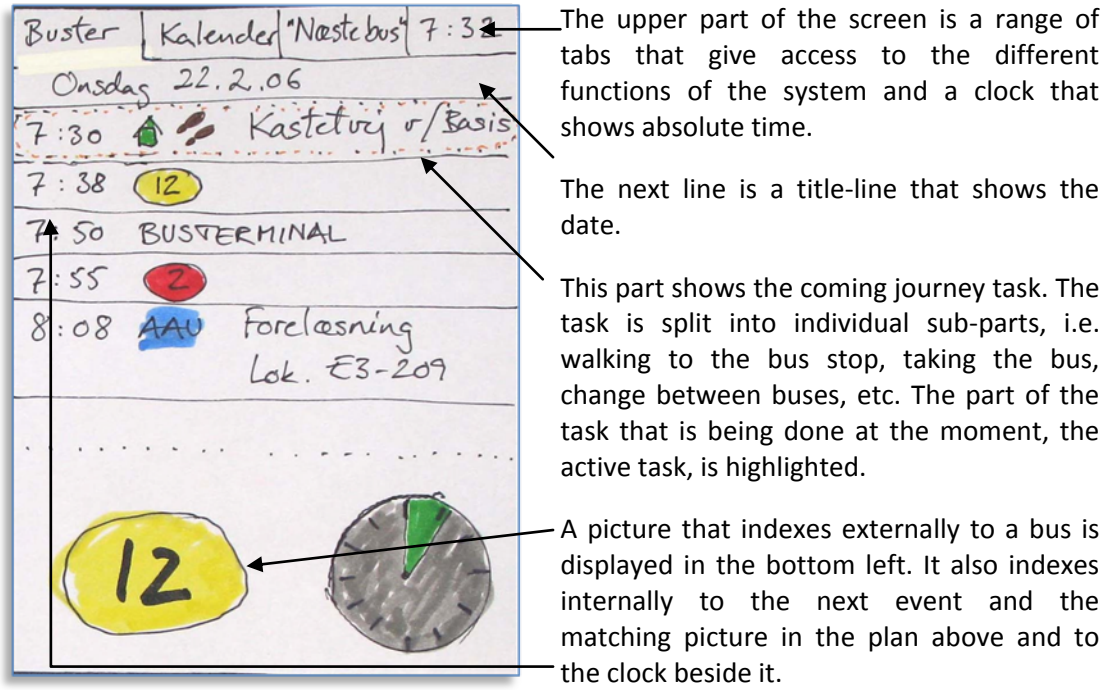


FIGURE 28: THE BUSTER MAIN SCREEN

The timer shows relative time and is counting down - indexing to the next event where the user must take action, e.g. leave home, get on the bus, get off the bus when it stops, etc, and the picture signifies the *next* event that the timer is counting down to, hereby indexing internally to the item in the plan with the matching symbol. The timer indexes internally in the interface to the difference between the current time shown in the upper right corner and the time of the next scheduled action shown in the plan. The green part displays the amount of time to count down. The colour changes to yellow and then red, the closer it gets to zero.

Each item in the plan consists of an absolute temporal index, a picture that is a graphic representation of either the event or the location in which it takes place, and a textual description of the location or the event depending on the pictures. These were designed as a kind of rebus that conveys the information in less space than a textual expression because of their iconic, symbolic and indexical properties. Furthermore the pictures can be used to index internally in the interface. As an example, the following numbered lines contain the information that is conveyed in this example of the main screen of Buster.

1. You have to walk from your home at 7:30, which is in five minutes.
2. To catch the city bus number 12 at 7:38.
3. It arrives at the central bus station at 7:50 where you have to get off the bus.
4. You are changing to metro bus number 2 that departs at 7:55

5. This bus arrives at your bus stop at the university at 8:08
6. Your lecture is in room E3-209

Buster will display this information in the following way:

Line 1 corresponds to the first line in Buster in combination with the timer at the bottom. Buster will show the information in the following lines, and push pop-up messages to the user when she has to get off the bus, when changing to the next, and finally when she has to get off at the final destination. In this way, we sought to minimise the information that is shown in the user interface, by replacing some of the textual descriptions with graphics, leaving some information out and simplifying the expressions, such as only keeping the most central words. The graphics that are used in the interface are explained in further detail in the following sections.

GRAPHICS AND PICTURES IN THE USER INTERFACE

The pictures were chosen to represent certain places and events, i.e. they index to something in place, except for the footprints that indexes to a certain action. They were chosen because they would be easy to recognise when glancing at the screen, while moving about and using the device. The pictures has symbolic and iconic properties, identified in the user study, which should make it possible for the users to index correctly. As well as indexing to locations and actions outside the user interface, they are used throughout the interface and will then index to each other because of their likeness. The pictures and graphics will be referred to as icons in the following sections and chapters.

Bus icon of metro bus line number five. The red colour index the colour of the buses on this bus line and the colour used in the printed schedule, as well as on the metro buses. The same icon is used in Buster, as we believe the user will recognise as a bus line because of previous experiences with the colours of the buses and the bus numbers.

This is a depiction of a house that is used to identify the user's **Home Location**. We have chosen to make it green as this colour stand out in the user interface and is not used by NT. The house shape was chosen, because it is commonly used in Internet browsers to signify the start or home page, and we believe that the user will understand the picture as a location, as it is used in the context of other locations in the user interface.

This icon represents the user's bus stop at Aalborg University. The colour was chosen because Aalborg University use that colour for their logo. The logo is used on official letters from the university and on their website, and we believe that student will be able to index the colour to Aalborg university. The same is idea is behind the use of the name 'AAU', which is used commonly in the university as an abbreviated name for Aalborg University. In Buster, this picture is used to identify the university as the location of the bus stop where the user has to get off.

The Central Bus Station is a central location in the city where the buses stop and where the users change between buses. This is used as a location in the system and the name indexes to that location.

Footprints indicate a walking distance that the user should travel. The user should be familiar with this symbol as it is used in systems that provide functionality somewhat similar to that of buster, e.g. www.rejesplanen.dk.

7.2.2.3 CALENDAR

When pressing the calendar tab, this screen becomes visible. The interface shares many similarities with the 'day' interface for MS Outlook for PDA. The line below the menu shows the relevant date. This example shows a day view with two appointments and two accompanying travel plan appointments. They have different colours in order to differentiate them into two different types. Each appointment is given an amount of space that reflects the length of time it takes. In order to create a new appointment, the user taps the screen on the relevant time slot. This opens a pop-up window where the user defines type, location, time and if a travel plan should be created. The finished appointment can be viewed by tapping the appointment.

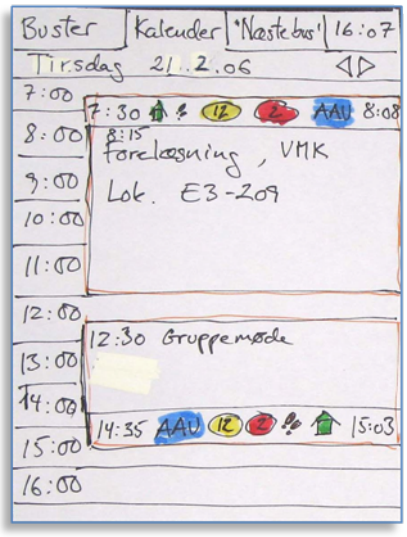


FIGURE 29: THE CALENDAR SCREEN

The position of the time slot indexes to the start time of the appointment and the size for an appointment indexes the time span. The icons in the special bus plan appointments are the same as the ones used on the main screen. On the main screen they are shown in vertical order, but here a simplified version is shown horizontally, where only the icons and no explaining text is shown.

7.2.2.4 NEXT BUS

The third major functionality is 'Next bus'. It shows a continually updated list of the next buses from a bus stop nearest the user's current location going to a destination that the user chooses. This functionality is useful if the user does not have to be at the destination at a certain time, but only wants to know when she should leave her current location to be on time for a bus departure at the nearest bus stop. This functionality is indexical, as it is based on the user's current location and the current time. The information it shows is thereby tailored to the place and time. The user's current location is not shown, as we want to explore if the user makes this connection by herself.

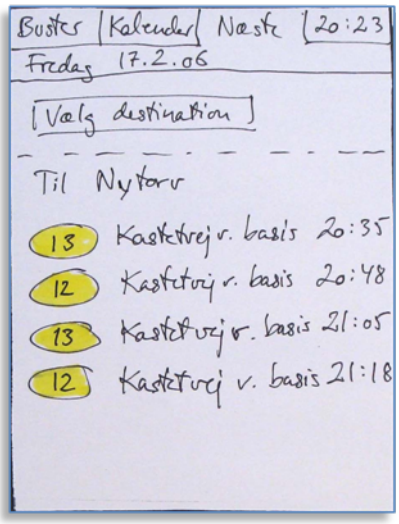


FIGURE 30: THE FIND BUS SCREEN

7.2.2.5 NOTIFICATIONS

There are a number of notifications on pop-up messages that alerts the user when something is about to happen that the user should be aware of. A notification is accompanied by a sound to alert the user. The user can choose close the notification or let it stay on the screen. It closes automatically when it is no longer valid. The notifications will be shown as pop-up messages that cover most of the screen as seen on the picture. The pop-up messages are triggered by events in the context such as the bus arriving at a stop, or the user getting off the bus.

FIGURE 31: A POP-UP

THE NOTIFICATIONS

The following pop-up messages are either conveyed to the user at certain times where she should take action, or messages that the user can get by interacting with the system.

Travel plan; plan showing the entire trip, when and where.
Before leaving; what (the appointment), where the bus leaves and when to leave the current location.
The number of minutes until the bus arrives. The information is updated dynamically if the user leaves the notification open.
The bus arrives now – and shows a confirmation that the trip has been paid for.
Notification that the bus will soon arrive at the user's destination.

7.3 FUNCTIONAL PROTOTYPE

This section describes the program and the user interface of the functional prototype. The indexical properties of the user interface and basic functionalities are explained in the following sections.

7.3.1 FORM FACTOR

The application is intended to run on a dedicated digital device. Since the evaluation was done on a standard PDA, the application was run in full screen, to hide the traditional PDA functionality from the user and imitate a dedicated device. The user will interact with the device by using the standard pen of the PDA on the touch sensitive screen. Some of the widgets on screen were furthermore made large enough for the user to hit them by using the fingers only. This was done as we assumed it would be practical to be able to use only one hand to interact with the device, in situations where the bus is moving and you have to hold on to something. Like the paper based prototype, the program has a static menu on the top and dynamic content below. The static menu consists of three menu buttons and a clock. Each button selects one of the three main screens of dynamic content. Right below the menu buttons is a status line displaying the current menu, and the current weekday and date. The screens are described in detail below.

7.3.2 REVISED GRAPHICS AND PICTURES IN THE USER INTERFACE

The graphics in the user interface have been adjusted to ease the reading on screen. The "Busterminalen" picture was removed, as there were not a well established graphic representation for this location that could index to it. This left the following:

The AAU logo indexes to the location of the users bus stop at the university.

This icon indexes to the user's home.

The icon used for bus number 13 by NT. It is the same colour as the bus.

The icon used for bus number 2 by NT. It is the same colour as the bus.

A symbol informing the user that she should walk.

7.3.3 SCREENS

The description of the program is divided according to the three main screens in the program: Buster, Calendar and Find bus. On the left are the paper prototypes and on the right user interface of the running program.

7.3.3.1 MENU

The text on the two first buttons in the upper menu has been replaced by pictures, as the text on the buttons proved to be too small to read. The iconic representation on the buttons is furthermore supported by a status bar displaying the current menu instead of using tabs. This was done to ease navigation and to give the interface a coherent feel. The orange and blue colour scheme was chosen because it is colours used by NT in the information they provide. It was used to make the users index to the information of the use domain when seeing the colours.

7.3.3.2 BUSTER

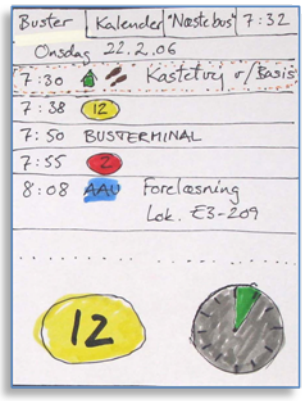


FIGURE 32: PAPER PROTOTYPE BUSTER SCREEN

The information, that the screen holds, has been elaborated in the description of the prototype, but with a change so that it does not display information about when the bus arrives at an intermediate station, only when the next bus departs from it. The timer was also changed slightly in order to make it look more like a real clock. The symbolic green/-yellow/red colour was not implemented. Instead, digits were added to show the time in numbers, to support the understanding and precision. This would improve readability and make the indexicality explicit between the time in the upper right corner, the highlighted task, and the timer. It would thereby help the users to understand the connection between the three kinds of information by use of internal indexicality.

FIGURE 33: FUNCTIONAL PROTOTYPE BUSTER SCREEN

7.3.3.3 CALENDAR

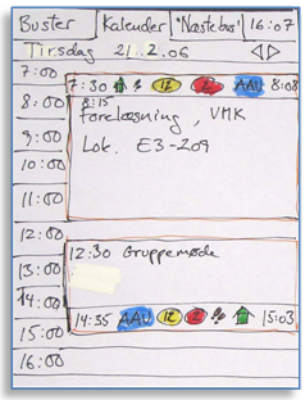


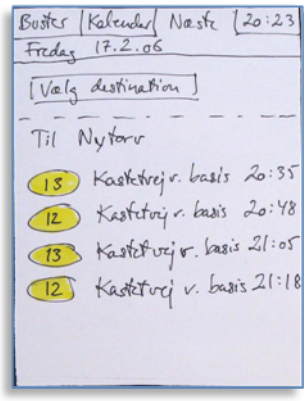
FIGURE 34: PAPER PROTOTYPE CALENDAR SCREEN

The finished calendar is like the prototype, except that the bus journey is not represented by a series of pictures that explicates the journey. Instead there is bar above the appointment that can be activated and links to a screen that shows detailed information about the appointment. Because the bars are resized according to how much time the bus journey takes, it was too small to fit the journey information on the bar itself as it is done in the paper prototype. Like the journey, the special travel plan appointment can be pressed and this will display information about the appointment on a separate screen. The calendar interface has also been limited to show only the relevant day and it is not possible to leaf through the days as in the paper prototype.

FIGURE 35: FUNCTIONAL PROTOTYPE CALENDAR SCREEN

7.3.3.4 NEXT BUS

This screen has been changed to reflect



the systems knowledge of the user's position. The user selects a destination from the drop down menu and it is shown next to the drop down button. The current location is then shown and the three next buses that depart from this location towards the selected destination are then shown. This is the only screen where the understanding of the system of the location is expressed explicitly.

FIGURE 36: PAPER PROTOTYPE FIND BUS SCREEN

FIGURE 37: FUNCTIONAL PROTOTYPE FIND BUS SCREEN

7.3.3.5 POP-UP MESSAGES

The pop-up messages is controlled by a so-called wizard application running on another PDA with wireless connection to the PDA used for the evaluation. This application can trigger pop-up messages in the system according to the user's context and thus imitate context-awareness. These use the push strategy that is further described in section 7.3.4 below. They can be seen in Figure 38,Figure 39,Figure 40,Figure 41,Figure 42,Figure 43,Figure 44Figure 45. Most are similar to the prototype pop-up messages but the one that guides the user from where she gets off the first bus and gets on the second is different (Figure 43). We have used a photo of the bus at the stop where the user should get on the bus instead of a map of the area with a route drawn on it. The photo is taken from the location where the user gets off the first bus. This was done to index to the physical environment by using a photo from the user's current location and also depicting a dominant landmark in the surroundings, such as the train station. Furthermore a pop-up message about eventual delays were added (Examples in Figure 44 and Figure 45) that displays the number of minutes the bus is delayed and how this affects the appointment.

FIGURE 38: POP-UP MESSAGE NO. 1

FIGURE 39: POP-UP MESSAGE NO. 2

FIGURE 40: POP-UP MESSAGE NO. 3

FIGURE 41: POP-UP MESSAGE NO. 4

FIGURE 42: POP-UP MESSAGE NO. 5

FIGURE 43: POP-UP MESSAGE NO. 6

FIGURE 44: POP-UP MESSAGE NO. 7

FIGURE 45: POP-UP MESSAGE NO. 8

7.3.4 TECHNOLOGY

The Buster application was developed in Macromedia Flash 8 and the networking components were developed in C#. Flash was chosen because it enabled us to quickly and easily manipulate the interface to fit our exact needs. The Flash application was developed using Actionscript to manipulate on screen objects and trigger events. The problem with Flash is that a standalone Flash application such as Buster is "sandboxed" and therefore not allowed to save files to the system on which it runs. This was the reason for using C# applications to edit, save and transport the XML files. The modular construction is furthermore an advantage if the system needs to be updated or ported to different hardware. The Flash application was executed on the PDA with Macromedia Flash Player 6 for Pocket PC and FlashAssist 1.3 to enable standalone and full screen execution. As Flash 7 or 8 are not available for PDAs the system is using Actionscript 2.0 for Flash 6.

7.3.5 WIZARD OF OZ SYSTEM DESCRIPTION

The evaluation system is specially designed for the evaluation process and needed to simulate context-awareness and the Wizard of Oz technique was used. It was developed as a client-server system where the user's system continuously searched the server for updates provided by the wizard application. The following is a schematic description of how the two applications simulate the context-awareness.

FIGURE 46: WIZARD

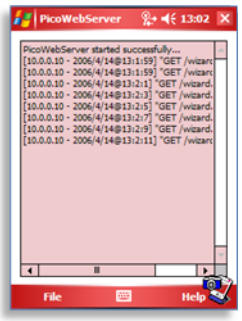


FIGURE 47: WEBSERVER

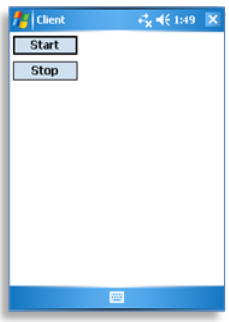


FIGURE 48: CLIENT APPLICATION

FIGURE 49: BUSTER

The system runs on two PDAs; a wizard PDA, which is used by the evaluation observer, and a client PDA that is given to the user. The first two screenshots, Figure 46: Wizard and Figure 47: Webserver are from the wizard application while the latter two, Figure 48 and Figure 49, are from the client application. A model can be seen in Figure 50. The wizard runs a custom wizard application that allows him to change different variables to an XML file. These variables

represent different context-triggers that the wizard can activate. Each will trigger a different action on the Buster client.

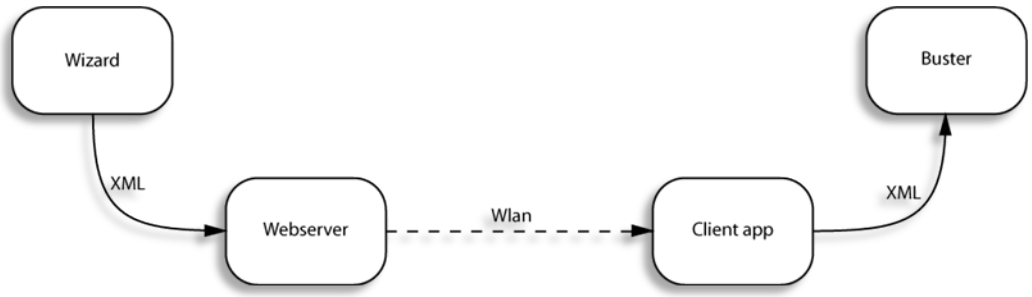


FIGURE 50: WIZARD SET-UP

The XML file is offered by a standard web server, also running on the wizard's PDA. Because it runs as a web server, there is no permanent connection between the wizard and the client, and the connection is opened and closed each time the client requests an update. This is an advantage because of the low stability of the wireless network in the sense that the PDAs can loose connection and find it again without problems.

The client PDA runs a custom-made application that downloads the XML from the web server and saves it locally to the client every two seconds. This was done to put a minimum of networking workload on the client flash application. The XML file that was saved by the client application is checked for updates every two seconds. This is done by comparing the variables from last time the file was read with the new ones. If there are updates, the flash application acts accordingly.

PART 5

Part five describes the evaluation of the user interface and system. The evaluation was conducted as a think-aloud field evaluation sessions with 11 test users who undertook a bus journey in Aalborg and during the journey used the system. The data from the evaluation sessions was recorded on video for the analysis. The analysis was separated into an analysis of the usability problems and indexical issues and the results of the analysis were knowledge about how the test users understood and used the indexical properties of the user interface and this was related to the design principles. The test users had in most cases used the indexicality as expected and this validated the design principles.

8 METHOD

After the system was designed an evaluation was conducted. This chapter describes the evaluation method as well as the considerations behind the chosen method.

8.1 EVALUATION METHOD

The design of the user interface was based on key requirements from the user study. It was the intent to evaluate the proposed design principles by exploring indexicality as much as possible through evaluation of the indexical qualities of the user interface. Hence, use of indexicality was also a guiding factor when deciding the evaluation and analysis methods. The primary interest of this evaluation was to find out whether the indexical interface could provide the necessary information to the user and if the test users could understand it.

8.1.1 EVALUATION TYPE

The evaluation was carried out as a think-aloud test where the user was given a task and asked to carry it out while using the device and talking about what she was doing. This way of testing has been extensively used in laboratories since it was first described by Lewis and Reiman in 1993 [182].A think-aloud test is a qualitative study that yields a high amount of information about the use of a computer system. The user is given a number of tasks and encouraged to talk about what she encounters during the test. The evaluation session is recorded either by writing notes or recording sound or video. A think-aloud test is usually used when evaluating usability, but we chose it as it is a direct way of capturing the users immediate understanding of a system, whether this is the understanding of the interface and the information it provides, or the general usability usually evaluated. This test therefore differed from a usability test in the way that we focused specifically on indexical issues in the system as opposed to a usability test, where the system is scanned through to discover areas where the user encounters problems.

8.1.2 LABORATORY VERSUS FIELD

It was central to the design of the user interface that elements in the design indexed to elements in the context. This way, the user interface was dependent on the context in order to be fully meaningful to the user. Some parts of the context can be simulated in a laboratory and in the paper [183] it is pointed out that while the field offers conditions that are close to a real use context, conditions in a lab are much easier to control and data collection is both easier and renders data of a higher quality. The authors also argue that usability testing in a lab can render data that is as useful as data collected in the field.

On the other hand, simulating field conditions in the lab can be difficult when the system is mobile and the user is supposed to use it in a number of different settings where the physical environment changes. As pointed out in [184], a strong connection between the system and the context means more implications for a laboratory test with regards to imitating context. In this case, a situation such as the user waiting for the bus or getting off the bus could be hard to imitate. The context is very complex, as it is constantly changing and there are a number of unknown and unpredictable factors such as delays caused by the weather or traffic jams and the presence or absence of information in the user's surroundings. Hence, we were dealing with a use situation that could be very difficult to replicate meaningfully in the laboratory. If we only wanted to evaluate the general usability, using a laboratory could be preferable, but in this case, where indexicality is the very property of referring to the context, the user interface is only

meaningful in context and so heavily dependent on it that it is not possible to evaluate the system in a laboratory.

8.1.3 TEST USERS

The prospective user group for the device was university students, which made it easy to find the 11 test users who participated in the evaluation. Since field evaluation becomes more complicated because the users are moving, and adding the unpredictable nature of the environment, the risk of anything going wrong is greater than in a laboratory. Thus, we chose a larger number of test users than the suggested six for qualitative think-aloud tests [179]. This was also done to enable a more quantitative comparison of the different indexical functions of the system, as the evaluation is centred on validating design principles, i.e. specific functions of the interface and not to search the system for bugs as in a usability evaluation.

8.1.4 IMITATING CONTEXT-AWARENESS

A central part of the use context is the city buses. The system is designed to act context-aware in relation to the current time, the users' location and to the city buses, which ideally require the device to have access to information such as delays or other changes to the 'bus-system' and information about where the device is in relation to the buses. As this is currently not feasible to implement, a 'Wizard of Oz' [185] technique was used as a substitute for real context-awareness. This requires the system to be able to handle a large number of possible events during the evaluation. As the context is complex it is difficult to predict all possible instances of what could possibly happen. An obvious example is delays. While evaluating in the field, it is not possible to have access to real-time information about delays, and there would be a difference between what the user experiences and what the device informs her.

8.1.5 DATA CAPTURING

The evaluation required collection of the data. The test user used a PDA where the application for evaluation was installed. In order to record the user's interaction with the screen, a wireless miniature camera was mounted on the PDA and the data recorded on a video recorder connected to a wireless receiver. The context and the test user in the use-situation including relevant context was recorded with a handheld digital video camera. Two observers were present at the test. One acted as main test leader and interviewer whose job was to keep the test user talking and thinking aloud. This person also made the video recording of the user and the context. The other observer was in charge of the recording of the users PDA and also acted as wizard. As the main interviewer had the task of filming the test user, the second observer was also supportive interviewer in case an elaboration of a comment was needed. The observer who carried the wizard PDA triggered events such as "the bus arrives now" and delays when the bus had not arrived at the specified time.

The pictures below illustrate the test setup. Figure 51 shows the evaluation, where the interviewer videotapes the user and the other observer acts as wizard and carries the wireless video recorder. Figure 52 is a graphical illustration of this that matches the right hand picture in Figure 51. The dashed line symbolises the wireless video transmission.

FIGURE 51: PICTURES FROM THE FIELD EVALUATION

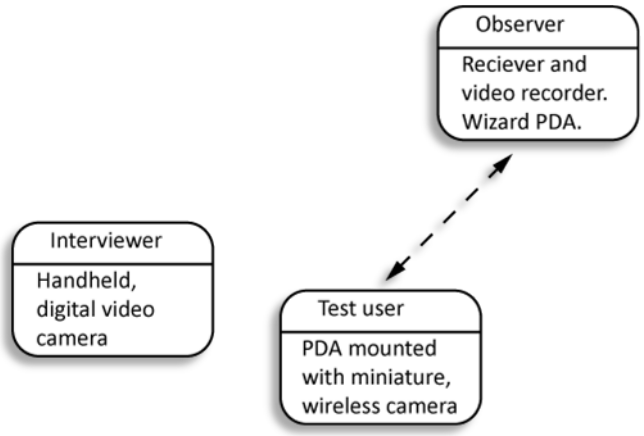


FIGURE 52: OVERVIEW OF THE TEST SETUP

FIGURE 53: PICTURES FROM THE EVALUATION. THE VIDEO FROM THE PDA MOUNTED CAMERA CAN BE SEEN IN THE LOWER LEFT CORNER.

After the evaluation sessions recordings were mixed into one picture and recorded to a DVD in order to ease the analysis. Figure 53 shows the technique of mixing the pictures from the recording of the context, and the recording of the users PDA screen which can be seen in the

lower, left corner. This was done so we could compare the user's actions with the context. In this way we could also capture both the action and the context if the users pointed to the screen during an explanation of an issue.

8.1.6 TEST SCENARIO

One of the observers acted as interviewer during the test. The interviewer's role was to keep the user thinking aloud and to ask questions to the user's actions in the same way as during the user study described in. In a traditional think-aloud test the interviewer also gives the user the tasks that are planned in advance to explore the functionality of the system but this test was based on a single scenario instead of the tasks.

The scenario was the task of getting from the users home to the university in time for a meeting. This was done instead of a task-based set-up because the main function of the device was to serve as guide and information tool for an entire bus trip. The dependency of the device of time and place could not be fully tested with short, five to ten minutes tasks. Instead we sought to keep the user talking, and instead of giving separate assignments, the user was continuously asked if she had noticed any changes in the system, and to what might have caused them. During the session, the test user was furthermore encouraged to use and comment on the device as much as possible. For each session, the goal was that the test user should have tried out all functionality of the device.

For this study we used a basic scenario were the user took the bus from one of two locations in Aalborg to the university with a change at the central bus station. A map of the routes can be seen in Figure 54. Routes one and two are the routes from user's home to the central station while route three is the route from the central station to the university common for all users. The decision to use only two routes and not start from each user's home was based in partly the necessity for being able to compare the results and partly the results from the previous user study described in section 0. It revealed that users who were put in situations where they did not know exactly what to do, or had little prior knowledge of the context generated more data than the ones who knew what to do without consulting anyone or seeking information. As the test participants in several cases used the city buses as primary daily means of transportation to the university, they knew the route a little too well. Both routes went from locations in Aalborg through the central bus station. Having only two routes also simplified the wizard setup and thus minimised the possibility of technical complications as well as enabled the observers to concentrate on capturing data.

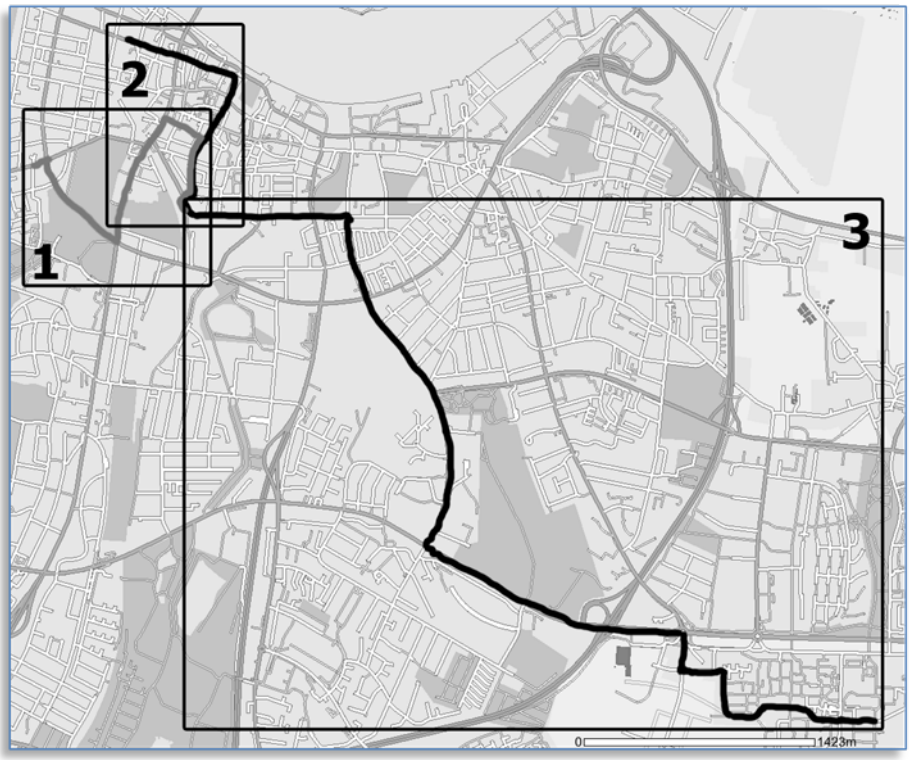


FIGURE 54: MAP OF THE ROUTES

Instead of a number of smaller sub tasks as is usual with think-aloud tests the evaluation session consisted of one large task with a number of subtasks. The test participant was asked to use the functions whenever possible and thus guided through all functions in the user interface. In this setting, a subtask is then defined as an action that the test participant has to carry out in order to make the device do something. Three examples of subtasks are hitting the 'OK' button on pop-up messages to close it, opening, reading and closing a travel plan in the calendar and reading and interpreting the travel plan correctly. A goal for the user interface was that it should be efficient; it was important that a subtask should not take a long time for the test participant to carry out. In the context of mobile computing, a subtask should be solved almost immediately as the test participant often are distracted by e.g. walking and navigating the physical surroundings and also do not have time to concentrate on the user interface. Consequences of not accomplishing subtasks are not always great, though the subtask itself may not be solved or test the participant may have gotten it completely wrong. In relation to Buster this could be that the test participant did not see a pop-up message. In this case the user completed the subtask, though not with any help from Buster. Doing the task of seeing and acknowledging the message went wrong, yet the user solved the problem using other means. If the user was completely stuck, or asked the interviewer for help she was given guidance from the interviewer.

8.2 ANALYSIS METHOD

The data from the evaluation was analysed through affinity diagramming [REF. user study]. The approach allows the data to speak for itself and reveal issues that might not be found if we used predefined categories. The affinity notes were separated into the two overall categories of usability and indexicality issues, which were then analysed separately. The results of the affinity diagrams were analysed using relevant theory; usability severity raking and indexicality theory respectively.

8.2.1 INITIAL CLASSIFICATION

The data from the evaluation sessions was reviewed with a focus on indexicality and usability, and notes were written on relevant actions and statements made by the test users during the evaluation sessions. During the review, the notes were classified into the two main categories, 'indexicality issues' and 'usability problems'. The reason for separating these was that in this project we were primarily interested in how the test users utilised the indexical properties of the user interface, but it was possible that other kinds of usability issues could veil or complicate indexical issues. For example if an element on the screen was too small and the test user did not notice it, it would hinder the user trying out that particular function. Thus, it was necessary to isolate usability problems that were not directly indexical and identify where they collided with indexical issues. Ruling out the misunderstandings caused by usability problems, would give us a better understanding of the user's perception of the indexicality.

8.2.2 USABILITY ANALYSIS

Notes were placed in this category if the test user had a problem with using the device and it was not specifically an indexical issue. A usability issue would be primarily focused on performing a task. A usability problem was if the user did something wrong, misunderstood the user interface, was hindered in doing something, or failed to perform a task successfully. Often the problem would be expressed as confusion or irritation with the device.

The first part of the usability analysis was creating an affinity diagram[13] from the notes on usability problems. This was done because the test users were not put through a number of very specific tasks as with a traditional think-aloud test and it was necessary to identify what sub-tasks and functions that gave the user trouble. The affinity diagram was created with focus on the tasks and related actions that the test user had problems with. The affinity diagram of the usability notes has two levels.

Besides grouping the usability problems into affinities, the notes were also classified using a set of categories based on usability classification categories by Jeffrey Rubin [186] for think-aloud evaluation for stationary IT systems. This was done in order to assess the severity of the problems. The categories were predefined and further defined in relation to this evaluation based on a number of usability goals. These goals were based in that the device is mobile, and as such, there are certain requirements for use that are not issues with stationary systems. The main purpose of the device is to make a bus journey easier to plan and undertake; thus it is important that the device is efficient and quick to use. The device is supposed to be used on the go. Therefore it should be easy for the user to read the screen and input data while being distracted by other things happening around her. The user should be able to understand what is going on, on the screen, and know intuitively how to react to that.

[13] See section 6.3 for a description of affinity diagramming

8.2.2.1 USABILITY PROBLEM SEVERITY RATING

The definition of the usability problem categories are based in a list of problem severity ranking from Rubin, p. 278 [Rubin], and further defined in relation to this project. This can be seen in the table below

Severity Ranking	Severity Description	Severity Definition
4	Unusable	*"The user either is not able to or will not want to use a particular part of the product because of the way that the product has been designed and implemented."* [186] The user cannot do what she wants to do or the device does something that is completely different from what the user expects. The user does not understand the device.
3	Severe	*"The user will probably use or attempt to use the product here, but will be severely limited in her ability to do so. The user will have great difficulty in circumventing the problem."* [186] Problems in this category are when the user needs more than about 30 seconds to solve, needs to concentrate on it and is so confused by the user interface that it takes some time to figure it out. The user may also need outside information in order to solve the task, e.g. looking at the time tables at the bus stops. The user may be very confused because of a discrepancy between the device and what information the user knows herself or can gather from the context. It is very difficult to solve the task successfully and will mostly remain only partially solved.
2	Moderate	*"The user will be able to use the product in most cases, but will have to undertake some moderate effort in getting around the problem."* [186] The user will need to think a bit in order to figure out a problem in this category, but should not use more than about 30 seconds and should be able to handle a little distraction as well. It could mean that the user is uncertain about the information provided by the device and needs to think about to figure it out. The difference between expectation of the result and outcome should be notable.
1	Irritant	*"The problem occurs only intermittently, can be circumvented easily, or is dependent on a standard that is outside the product's boundaries. This could also be a cosmetic problem."* [186] Problems in this category are something that may bother or slightly confuse the user, but is otherwise easily solved. The user should be able to very easily and quickly (up to 10 seconds) work out how to deal with it without having to think about it too much. The user is slightly confused and/or irritated. The user stumbles over something, but quickly understands and is able to complete the task successfully. There should be little to no difference between the expectation of the result and the actual outcome.

The severity of a usability problem is not always as clear-cut with context-aware, mobile systems. As the context changes, the test user is able to pick up information from the context. In this case it was also what the user interface was supposed to help the user to do, which meant that the test user could solve even severe problems with using information from the context. Another aspect that also played a part was that during the evaluation sessions, the test users were helped when they got stuck or possible tasks were pointed out to them. This was done in order to gather as much data about indexicality as possible. Thus a usability problem could not be rated only with basis in whether the test user successfully carried out the task, as it would at some point be solved in order to move on with the test. We were interested in keeping the usability issues separate from the indexicality issues, because we needed to indentify usability problems with the user interface that might have interfered with the indexical properties of the user interface. Therefore the severity of a problem was ranked without taking indexical issues into consideration. For example, if a test user was not able to solve a problem without using information from the context, then the rating reflects only that the test user could not solve the problem successfully.

The last part of the processing of the usability problems was relating the usability problems with the affinities in the indexicality issue analysis in order to identify where usability problems affected indexicality issues. The severity rating was used as a guideline for the severity of the influence on the indexicality issues, but as the interviewer/observer interfered in severe cases, a rating of 4 did not necessarily mean that the user was unable to utilise the indexicality. This means that a problem that was given high ratings on some of the affinity notes could have little influence on the indexicality evaluation.

The severity assessment was ranked and put into three groups in relation to how much the usability issues influenced the test.

1. Little or no influence. The problems did not interfere with indexical issues.
2. Medium influence. The interviewer had to interfere, but the problem was quickly solved.
3. Great influence. The interviewer had to interfere and explain and the test user was hindered in fully utilising the indexicality.

8.2.3 INDEXICALITY ANALYSIS

As with the usability evaluation, the notes were analysed by use of by affinity diagramming. This way, we could let the different kind of themes and uses of indexicality emerge without forcing predefined categories upon the data. The finished diagram has four levels. The affinity notes were sorted into the indexicality category if they indicated that the test user indexed from something in the user interface to the surroundings or other elements in the user interface. An example is, when a test user indexes from an element on the user interface to something in the surroundings. The note could say: "The user notes that the red bus icon refers to a 'metro bus', and the yellow icon to a 'city bus'." or "The user sees the 'bus arrives' pop-up message and looks for the bus to verify the message." The notes were then grouped with similar statements from other users to form more general terms that one or more of the users relate to. These statements describe a number of issues related to indexicality and make up the first level of the affinity diagram. Examples of such notes were:

> The user matches the colour on 'bus' icons to the colour of the bus when she is not previously acquainted with NT's sign language
>
> The green colour of the home icon signifies something 'homely'.
>
> The user double checks the info she get from the device by matching with her surroundings.
>
> The user checks her position in relation to the current time. She uses the plan presented by the device.

The group statements were then grouped into sets of groups (second level) that again were grouped into more general sets (third level). The top-most level divided the groups into internal and external indexicality.

While the affinity diagram revealed different issues concerning how the users utilised the indexical qualities of the user interface, we still needed to connect and compare the results to the provisional design principles developed on the basis of indexical theory and the indexical analysis of the use domain in section 0. In order to do this, the results were discussed with focus on a comparison with the indexical aspects and aspects of context identified in the indexicality analysis. The discussion is divided into the two fourth level groups, internal and external indexicality. The design principles are based on the findings from the indexical analysis. Since they are concerned with how to index to the surroundings, they are about how to implement external indexicality in the user interface and does not deal with internal indexicality. Thus the part of the affinity diagram that concerns internal indexicality is not directly of interest in relation to our research questions.

8.2.3.1 INTERNAL INDEXICALITY

The term internal indexicality is used to describe relations between elements in the user interface such as similar colours, or icons that indicate that two instances of these are co-related.

It is furthermore used to describe other relations, such as those that exist between the timer, the clock and an appointment, where the timer indicates the difference between the clock and the relevant line of the timetable in the plan.

The term is closely related to the terms mapping [noget norman] and the gestalt laws[Molich] which are described below

MAPPING

Mapping refers to the relationship between different elements of a system. In relation to user interfaces especially the relationship between the widgets and the events that these trigger. Good mapping is a natural and clear relationship between the layout of the widgets, and the effect in the interface. For example, it can be argued that the Calendar in buster uses good mapping when entering an appointment, as the point where the screen is pressed is where the appointment starts, and the point where the screen is released is where the appointment ends, as illustrated in Figure 55. The middle picture illustrates the pen movement on the screen.

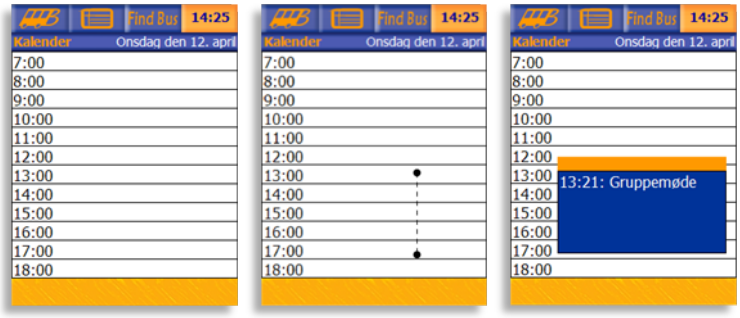


FIGURE 55: THE PROCESS OF ENTERING AN APPOINTMENT IN THE CALENDAR

In relation to internal indexicality mapping can be described as a widget-oriented equivalent, as the used definition of internal indexicality also concerns elements on screen that cannot be manipulated by the user.

9 USABILITY EVALUATION

While the central part of the data analysis centred on evaluating the indexical properties of the interface design, it was also necessary to look for usability problems as they might hinder the use of the prototype system in the first place and making use of the indexical qualities of the interface. Whenever the user was confused about how to interpret the device or did not know how to deal with some specific information, it could be a usability problem as well as an issue with the indexical properties.

The results are presented in the following Table 7. The leftmost column is the second and highest level that describes the nature of the problem. The middle column contains first level of the affinity diagram and includes the usability severity rating in parenthesis for each of the affinity notes in relation to the rating system defined in section in 0. For example: (1,1,1), means that there were three affinity notes that all have been given a rating of 1. The column to the right is comments on the rating of the influence of the usability problem on the indexicality related to the task. For each affinity on level two the column contains a summary and notes about how the problem may have interfered with indexical issues. The table is sorted according to influence level; with the great influence assessment at the top of the table.

Level 2 – task/action and issue	Level 1 – task/action and issue	Comments
Problems related to information needs finding the right bus stop when changing to bus 2 at the central station.	Test user has problems with finding the right bus stop when changing between buses. (1,1,1,1,1,2)	**Great influence.** A large part of the problem was that the users did not notice the photo on the bus 2 pop-up message. Without help from the interviewer or prior knowledge of where bus 2 left, the users were stuck. This problem interfered with the evaluation the indexicality of the picture.
	Test user does not notice the photo on the bus 2 pop-up message. (4,4,4,4,4)	
	Test user cannot identify from where the bus leaves. (1,2,2,4)	
Problems related to the device not giving correct information about context (out of synchronicity).	The device cannot handle information about delays (no update of plan). The test user becomes confused and uncertain. (3,3,3,3,3,3,3,3,3,3,3)	**Great influence.** When the user interface does not index the context correctly, the users were not able to utilise the features as they should. On the other hand, we also saw that they were very creative in trying to find the right information and determine what information that was wrong and how great the difference between the device and the context was.
	Confusion caused by the device not being updated and out of synchronicity with the context. (1,1,1,2,4)	
Problems related to noticing the pop-up message. They did not hear the alarm or could not read the message.	It is difficult to hear the alarm and/or notice that it comes from the device. In all cases the test user does notice the message shortly after. (1,1,1)	**Medium influence.** Not hearing the alarm and/or not noticing a pop-up message was a common problem. The test users would have been stuck if they had not been guided and the message pointed out by the interviewer. Had they received no help, they could not have utilised the indexicality. That the interviewer had to interfere could have influenced the way the test users used the device. On the other hand, it was not all users who experienced this problem and it was not greatly disturbing for the user when the message was pointed out.
	Test user does not see pop-up message. (4,4,4)	
	Confusion and misunderstanding of pop-up messages. (2,4)	
Problems related to the graphical elements of the user interface. The test users had problems seeing what were buttons and what were not or some elements were difficult to see – they did not stand out.	Test user is confused by the graphical elements – things that looks like buttons are not and vice versa. (1,3,4,4)	**Medium influence.** Several functions was difficult to use, as the test users could not see if they were buttons or not and in some cases could not see what the icon was. This interfered with their use of the device and made some functions more difficult to use. In the instance with the 'house' icon, several users had problems with understanding what it indexed and that it was too small to see what it could have played a part. In general, the design of some of the graphical elements impaired some of the users' ability to read and understand them correctly.
	The 'house' icon is difficult to see and identify. (2,2,3,4,4)	
	Orange highlight in bus plan is difficult to see. (1,1,1,1,1)	
Test users expected a journey plan to be created like in the calendar. This was not implemented.	Test user wants to see journey plan when pressing the bus icons in "Find bus". That function was not implemented. (4,4,4,4,4,4,4,4,4,4,4,4,4)	**Little/no influence.** All test users were given the task of finding the next bus that left from the university and two also tried it out during the journey. In all cases they expected the system to present them with a journey plan. This was not implemented and the system behaved very differently from what they expected, but as the function was never meant to be implemented, it did not have any influence on the evaluation.
Orange bar is not immediately intuitive and the user has to spend some effort to understand it fully.	The information in orange bar is a little difficult to interpret. Not intuitive. (3,3)	**Little/no influence.** Only two users had severe difficulties with understanding the information in the orange bar. In the other case, the problems were a few moments of confusion. In both cases, when the confusion was cleared the users had no problems with interpreting it correctly for the remainder of the session.
	Test user misunderstands the timer. (1,1,1)	
Problems related to information about time spent 'between buses'.	Test user is confused about time of arrival (when) and would like more info. (1,1,1)	**Little/no influence.** The users were slightly confused but not hindered in doing the task. It is possible that more data could have been gathered, had the user interface had these features.
	Slight confusion about graphical representation of time between bus change. (1,1,1)	
Comments indicating that the user was uncertain if he/she could trust the device.	Test user does not trust the device. (1,1,1,1,1)	**Little/no influence.** The users were sometimes uncertain whether they could really trust the device, but they went on with the task anyway.
Reflections of sunlight on the screen, etc.	Miscellaneous minor technical issues. (1,1,1,1)	**Little/no influence.** Did not influence the use of indexicality in any noticeable degree.

TABLE 7: USABILITY AFFINITY DIAGRAM

9.1 SUMMARY

Two problems had great influence. The first problem was that the users had difficulties with noticing and using the “change to bus 2” pop-up message seen in Figure 56. The users received the pop-up message as they got off a bus and had to change to the next.

FIGURE 56: THE "CHANGE TO BUS 2" POP-UP

The second problem was that the device could not handle delays and the information thus easily became obsolete in respect to indexing correctly to the context. This occured if a bus was delayed and the user arrived too late at the bus station to catch her bus. Buster would then show information concerning the bus that the user had missed and not update the plan.

Two problems had medium influence. The design of the graphical elements in the user interface and several users’ problems with noticing the push messages.

The remainder of the problems had little influence on the use of the indexical elements in the user interface.

10 INDEXICALITY EVALUATION

The aim of this analysis was to generalize the findings by grouping similar findings and reveal which issues were common for the users, and which where unique cases. We sought to understand what the indexical understanding behind an utterance was, how the indexicality that was in the involved part of the interface was perceived by the user, and on the basis of this we found out how many other users shared this understanding.

10.1 RESULTS OF THE INDEXICAL ANALYSIS

The affinity diagram is shown in Table 8. It lists the issues encountered and how many users that shared the issue. The indications of how many of the users encountered the issue are based on how many users that explicitly described the issue. The indexicality notes were basis for the creation of an affinity diagram in four levels. The first level (level 1) is groupings of affinity notes into statements describing common themes of all issues that the users experienced. These themes emerged during the first revision of the affinity notes. The next two levels are generalisations over the first level groups. The top-most level divides the notes into two groups, internal and external indexicality. Internal indexicality describes the areas where the user in some way indexed between the graphical elements within the user interface. External indexicality describes how the user indexed to her surroundings.

Level 4	Level 3	Level 2	Level 1	No	Encounters
External indexicality	Indexing from the icons to the surroundings.	Bus icon.	The user matches the colour of the bus icons with NT's sign language, with which she is already acquainted.	9	5
			The User matches the colour on 'bus' icons to the colour of the bus when she is not previously acquainted with NT's sign language	10	1
		Other icons.	Common place names are too broad a reference to uniquely identify the location. The user has difficulties to match the AAU icon, and "Busterminalen" to specific location.	11	6
			The 'walk' icon is matched with the idea that the user is supposed to walk from one place to another.	12	3
		House icon.	The user matches the 'home' icon with the notion of 'home' because it looks like a house.	13	6
			The home icon is confusing and difficult for the user to match with anything specific.	14	3
			The green colour of the home icon signifies something 'homely'	15	1
	Indexing from other graphical elements of the user interface than the icons, to the surroundings.	Identification of a place in the surroundings from a picture	The user finds it easy to index from the picture on the 'bus no. 2' pop-up message to a physical location.	16	7
		Index between other graphics and external things	The user suggests that because the picture used for the button for the start screen looks like a bus, this means that the 'Find bus' function is here.	17	1
		The users figure out the meaning of the orange highlight by indexing between the plan and current time and place.	The orange highlighting on the plan indicating the next action is initially confusing, but the user is able to make sense of it by comparing what she is currently doing with the plan though It is not intuitive.	18	4

	Indexing to the surroundings to solve issues about degree of correctness of information and making sure that the user can trust the device.	Double checking information by matching with the surroundings.	The user double check the information she get from the device by matching to the physical environment. (Checks that the device is correct by matching).	19	6
			The user checks the information from the device by matching it with NT information on the displays.	20	7
			The user checks her position in relation to the current time and place. She compare with the plan presented by the device.	21	3
		Information conflicts causes uncertainty and confusion.	The user misses information from the device and is uncertain whether it handles everything correctly and can be trusted.	22	4
			Conflict between the physical environment and what information the device provides confuse the user. The user becomes confused and uncertain.	23	3
			The user is missing detailed information about which no. 2 bus to catch and becomes confused and uncertain.	24	4
			If the user has enough clues as to why information on the screen does not match the surroundings she is able to make use of the information it provides.	25	4
			If the information from the device conflicts with the surroundings, the user is more ready to trust the information in the surroundings.	26	4
			The user matches pop-up messages with the current time and place. If the match between message and surroundings fit, the user immediately understands the message.	27	10
		Matching pop-up message with the surroundings.	The user understands the implicit information from the device about the current location (that the device knows) – feedback to the user about location.	28	5
		Matching general information from the device with the surroundings.	The user trusts the device also when there is little information (while there is no information conflicts the device does not need to inform the user about this).	29	3
Internal indexicality	Internal indexing in the calendar interface.		The user understands the connection between the placement and size of an appointment in the calendar. Respectively, she index to starting time and duration of the appointment.	1	2
	Indexing between elements on the front screen.	Indexing between elements in the plan on the front screen.	The user notices the orange highlight and that it shifts. She indexes between the clock, the time indication and icons and figures out why something is highlighted.	2	7
			The user understands the connection and internal indexing between the icons and names in the plan.	3	4
		Indexing between orange bar and the plan.	The user connect the information in the orange bar with the information in the plan and the clock (absolute time) in order to make sense of it.	4	7
			The user match the orange highlight with the orange bar by their similar colour	5	5
		Indexing between elements in the orange bar	The orange bar is easy to read. The user connects the timer with the icon.	6	8
			The timer explains itself as the clock gives meanings to the digits, and the digits make sense when comparing with the plan and the current time	7	2
	Indexing between internal graphic elements on pop-up message.		The user finds it hard to connect the picture with the text on the message. The picture was seen as decoration.	8	1

TABLE 8: AFFINITY DIAGRAM OF INDEXICALITY ISSUES

10.1.1 EXTERNAL INDEXICALITY ISSUES

This section describes and discusses the external indexicality issues in relation to indexicality and usability problems. It is sorted into affinity groups levels as in the following example. The discussion in this sections concerns mostly level 1. In section Summary10.1.3, Summary, the issues are discussed on level 2 and 3.

Example of the structure of the section:

level 3

Level 2

Level 1 (no. of users who encountered the issue)

Description and discussion of the issue.

Indexing from the icons to the surroundings.

Bus icon.

Group note 9: The user matches the colour of the bus icons with NT's sign language, with which she is already acquainted. (5)

Most users were already familiar with the design of the bus icon, a coloured ellipse with the bus route number written on it. The same symbol is used by NT in the printed bus schedule and on displays that the test users were acquainted with beforehand. This suggests that they indexed from the symbol on the user interface to actual buses and bus routes. We believe that in this domain, there is a well-established connection between a one or two digit number and a bus route, as this is a conventional way of referencing to bus routes in the same way that road names are used for tram routes, and station names for train routes. This underscores the initial suggestion that existing sign language should be explored and reused.

Group note 10: The user matches the colour on 'bus' icons to the colour of the bus when she is not previously acquainted with NT's sign language. (1)

Here the user indexes the colour in the device to the bus in the physical environment. Even though the user was not familiar with NT's distinction between city and metro buses, the fact that the symbols of the buses have different colours was noticed by the user, and this was furthermore given a lot of attention by the user. After careful consideration by the user she concluded that because the first bus she travelled with was yellow, and the symbol in the plan was yellow, the next bus she should catch should be red as the symbol in the plan is red.

Other icons.

Group note 11: Common place names are too broad a reference to uniquely identify the location. The user has difficulties matching the AAU icon, and "Busterminalen" to a specific location. (6)

Several users noted that the names "AAU" and "Busterminalen" are not specific enough to pinpoint the exact location of the bus stop where they should get off or on a bus. As "Busterminalen" is the central bus station where all buses in Aalborg, except for metro buses 5 and 6, pass through, there are many buses and bus stops to choose from. Thus, the user is not certain that she can obtain more specific information about where to find the next bus stop before she is in the process of changing and gets the pop-up guiding her to the right stop. One person noted that there are at least four bus stops on campus, with an estimated span of three minutes between the first and last. This illustrates that the prior knowledge of a person about the environment also can confuse the user, as even though the device displays that there is three minutes until the user should get off, she is getting ready because she knows that she is at the university. It can be derived

that a more specific description should be available, as the users do not know exactly what bus stop the device think is the user's destination. If this knowledge is first established, we think that the user will be reassured that the device knows the right location, even though it only displays AAU as the destination. The indexical lesson learned is that a common place name is in some cases too broad a reference and the user should be able to obtain further and more detailed information.

Group note 12: The 'walk' icon is matched with the idea that the user is supposed to walk from one place to another. (3)

The walk icon was easily understood by three users. We can not know for certain how the rest understood it, but since they did not question it, it is a possibility that they understood it intuitively. A couple of users referred to an icon on www.rejseplanen.dk that was the inspiration for the icon in the user interface of our device and in that respect it indexed the action that we expected it to do.

House icon.

Group note 13: The user matches the 'home' icon with the notion of 'home'. (6)

Half of the users indexed the green home icon with a notion of home. They noted that they could see it was a house, which is a metaphor for home used in other user interfaces such as Internet browsers.

Group note 14: The home icon is confusing and difficult for the user to match with anything specific. (3)

Some users did not understand the home icon, and could not understand how the device could have obtained this information. They could see it was a house but did not connect this with a location. We believe this is partly because the icon had not been introduced in the interface before, and that the users have not had the chance to become familiar with, or have influence on any information in the system. A lesson learned was that the assignment of symbols and icons instead of individually users' specific details should be carried out by the user as she cannot index from a generic picture to something that is very personal to her – her home, unless she has chosen and assigned the icon to that specific herself. In this case, the users were not easily able to index from the house icon to their home and the indexical qualities of the icon were weak. The recognition of the house icon was also influenced by usability issues, as several users had difficulties with seeing what the icon depicted because it was too small.

Group note 15: The green colour of the home icon signifies something 'homely'. (1)

One user noted that the green colour of the home icon stood out in the interface, as most other elements are blue and orange. We interpret this as a hint that a colour is more noticeable when is noticeably different from the surroundings, and furthermore, that more attention is put into the specific colour when it breaks with the overall colour scheme of the interface. The fact that some of the users felt that the green colour supported the "homely" meaning of the icon indicates that specific colours can give hints to the meaning of the icon.

Indexing from other graphical elements of the user interface than the icons, to the surroundings.

Identification of a place in the surroundings from a picture

Group note 16: The user finds it easy to index from the picture on the 'bus no. 2' pop-up message to a physical location. (7)

When receiving the pop-up "change to 2" the majority of the users immediately knew where they had to go. Based on the users' comments on the picture this was because of a combination of the following factors: The picture depicted the train station, which the user recognised as a landmark. The picture was furthermore taken from the same angle the user see the train station from when they get the pop-up message, and for those who had identified the next bus as number 2, the bus in photo had the correct colour. It must be pointed out though, that seven of the test users had problems with noticing the the 'bus 2'pop-up message and it had to be pointed out to them. One user did not notice the picture and considered it decoration. This could have influenced how well they actually were able to index, as we do not know how well they could have done, if they had noticed the message and picture all on their own. As soon as the pop-up message was pointed out, the test users could recognise the place.

Index between other graphics and external things.

Group note 17: The user suggests that because the picture used for the button for the start screen looks like a bus, this means that the 'Find bus' function is here. (1)

A single test user initially tried the 'Buster' button in the top menu as his first option when asked to find the next bus. The picture on the button is stylised bus, and for the user this indexed to 'something' about buses and chose to try this option first. It was clear that the picture was easily recognised as a bus, even though the user was uncertain about where to find the actual function that she needed in the user interface.

The users figure out the meaning of the orange highlight by indexing between the plan and current time and place.

Group note 18: The orange highlighting on the plan indicating the next action is initially confusing, but the user is able to make sense of it by comparing what she is currently doing with the plan though it is not intuitive. (4)

The users initially associated the orange bar with what they were currently doing. Our interpretation is that they understood it as an indication of what the device assumed they were doing currently. When the users then compared their own understanding of their situation with that of the device there, was a mismatch, and they adjusted their understanding of the device accordingly. Here they compared the current time with the action highlighted on the screen and understood that the highlight indexes temporally to a future event. A lesson learned was that the test users' first notion of a highlighted item in a list is read as something related to "currently selected" and thus currently happening.

Indexing to the surroundings to solve issues about degree of correctness of information and making sure that the user can trust the device.

Double checking information by matching with the surroundings.

Group note 19: The user double checks the information they get from the device by matching to the physical environment. (6)

We found that the users usually check the information that they get from the device. An example of this is when the device alerts a user that the bus is coming; she looks up to see if it is really coming. The users index from the device to the physical environment, and make sure that the device is correct by matching. We found that the matching between the physical environment and the device is not done as carefully as it would usually be done as a user later questioned whether he had taken the right bus. He just saw a bus coming and got on it after the device alerted him that it was coming.

Group note 20: The user checks the information from the device by matching it with NT information on the displays. (7)

Even though the user is not in doubt about what he should do, or what is happening next, she matches the information of the device with the information provided by NT. As described in the issue above, this can lead to misunderstandings if the user is not able to index the right information from the device to the right information in the NT timetables. This informs us that extra information from the NT timetables and the electronic dynamic system should be supported by the device, as the user indexes both ways and compare the information to make sure that the plan is right.

Group note 21: The user checks her position in relation to the current time and place. She compares with the plan presented by the device. (3)

The users that knew the area where they were travelling in paid attention to the surroundings that they could see from the bus. They then matched this with the plan and the timer to see if it they can make it to the next action in the plan. They index temporally and spatially from the device to the surroundings and compare time and place to the bus plan of the device. If they know the bus route from prior experience, then they index the time given to the current location in order to check whether the bus is on time. If they do not feel reassured that they will make it to their location in time, they seek information on what they should do.

Information conflicts causes uncertainty and confusion.

Group notes 22-27 were estimated to be heavily influenced by usability problems. This occurred in cases where the device did not deliver correct information and this made the test users confused and uncertain. It hindered them in indexing correctly to the surroundings and made them less willing to trust the device. On the other hand this part of the evaluation also provided information about how the users tried to solve the problems and how much they could do on their own. Furthermore note 23 was estimated as being medium influenced by usability problems as Ten of the test users easily understood how the pop-up messages indexed to the context, but some also had problems with noticing the message. The results are promising, but it is not possible to say if and how much they could be better, if the pop-up messages were easier to notice.

Group note 22: The user misses information from the device and is uncertain whether it handles everything correctly and can be trusted. (4)

Absence of information such as how much time the user need for transfer between buses, a clear indication of arrival times or whether it is alright to take an earlier bus, confuses the users. The missing information means that they are not able to index properly. This indicates that it is important that the user has enough information.

Group note 23: Conflict between the physical environment and what information the device provides confuse the user. (3)

In some cases the information provided by the device did not match the physical environment, for instance if the bus came earlier than it was supposed to. When the user then checked the device immediately after getting on the bus, the timer would still count down to the bus departure, and the user would be confused about whether he was actually on the right bus. It tells us that the user tried to index from the current action in the plan to what happened in the surroundings.

Group note 24: The user is missing detailed information about which no. 2 bus to catch and becomes confused and uncertain. (4)

During the test, the users gathered information from multiple sources. When they were waiting for bus 2 at the central bus station, they matched the information on the device with the information on the electronic signpost. As an example, in some cases the device showed that they should take bus number 2 to AAU in five minutes. The signpost showed that bus number 2J to Storvorde departs in 5 minutes and number 2H to Klarup departs in 10 minutes. This confused the user, as the extra information was confusing. Did the buses not stop at the university, and why did the device not show the letter? Both of the buses actually stopped at AAU, but this was not clear to the user. They clearly tried to index by matching time and place indications.

Group note 25: If the user has enough clues as to why information in the device does not match the surroundings she is able to make use of the information it provides. (4)

During the tests, some users managed to catch an earlier bus than the device had planned for them. They coped with this by subtracting the number of minutes by which the bus was earlier with all the future actions in the plan. Therefore, even though the plan told them that they should get on bus 2 in 3 minutes, they could see that they would be at AAU in 14 minutes. They indexed the time-indication in the plan to the actual time and current action.

Group note 26: If the information from the device conflicts with the surroundings, the user is more ready to trust the information in the surroundings. (4)

Information conflicts means that the users were not able to index correctly and they were aware that the device did not deliver correct information. In these cases (four users) they ultimately trusted the information from NT more than that of the device. This could be influenced by the situation being an evaluation session and not a 'real' use situation.

Matching pop-up message with the surroundings.

Group note 27: the user matches pop-up messages with the current time and place. If the match between message and surroundings fit, the user immediately understands the message. (10)

The users appeared to understand immediately the indexicality of the pop-up messages. Even though the message only read "You are at the right stop." the users had no problem indexing to the bus stop that they were at. Even very scarce indexing such as "now" and "next stop" was clear to the users.

Matching general information from the device with the surroundings.

Group note 28: The user understands the implicit information from the device about the current location (that the device knows) – feedback to user about location. (5)

The users did not question the knowledge of the device about its position when the pop-up messages indexed spatially, but reacted as if they implicitly understood. When the device indexed to a certain location in the surroundings, the user got implicit feedback about whether the device had the correct knowledge and could be trusted.

Group note 29: Users trust the device also when there is little information (while there is no information conflicts the device does not need to inform the user about this). (3)

The user felt reassured that "no news was good news" meaning, that the users thought that the device would warn them if the plan they were following did not hold, and that as long as the device did not do anything there were no problems.

10.1.2 INTERNAL INDEXICALITY ISSUES

Internal indexicality concerns how the user makes sense of the user interface by using internal indexing between screen elements. The following section is discussions on each group statement in level 1 and sorted into level 2 and 3. The issues is presented in the same way as the external indexicality section 10.1.1

Internal indexing in the calendar interface.

Group note 1: The user understands the connection between the placement and size of an appointment in the calendar. Respectively, she index to starting time and duration of the appointment. (2)

While only two users explicitly noticed this, it did not appear to cause any difficulties or misunderstandings to other users; they could easily tell the start and the end time of the meeting. This part of the user interface was not tested extensively because it was not in use during the bus journey. A more thorough test might have shown whether the users actually noticed the placement of the appointment.

Indexing between elements on the front screen.

Indexing between elements in the plan on the front screen.

Group note 2: The user notices the orange highlight and that it shifts. She indexes between the time-indication and icons in the plan and figures out why something is highlighted. (7)

Here, the test users connect the time-indications and icons as separate events in the plan. As the highlight shifts, it indicates that something happens and they could compare the time-indications and notice the progression in time. I.e. they indexed the shift or movement of the highlight to the time-indications in the plan and to the absolute time given in the clock.

Group note 3: The user understands the connection and internal indexing between the icons in the plan. (4)

The plan describes an entire bus journey split up into subparts that described the parts of the journey that was important. Almost all of the users could, when asked to do so, reproduce the intended meaning by reading the plan and telling what information each line contained and how they connected to each other.

Indexing between orange bar and the plan.

Group note 4: The user connects the information in the orange bar with the information in the plan and the clock (absolute time) in order to make sense of it. (7)

When the users see the timer, they try to match the digits and the numbers shown with something else in the interface. They quickly figure out the indexical relation between the highlighted item in the plan, the timer and the clock in the upper right corner.

Group note 5: The user matches the orange highlight with the orange bar by their similar colour. (5)

A few users made the connection between the orange bar and the highlighted item in the plan by relating the orange colours. This was done in spite of the fact that several other elements in the interface were the same shade of orange, and tells us that despite some minor disturbances ,indexing by colour match is a useful tool that the users notice.

Indexing between elements in the orange bar

Group note 6: The orange bar is easy to read (connecting the timer with the icon). (8)

The users quickly relate the icon in the orange bar to the timer, as they can relate the icon to the icon in the highlighted item in the plan, and the timer to the plan via the clock. They index between the icons because they look the same.

Group note 7: The timer explains itself as the clock gives meanings to the digits, and the digits make sense when comparing with the plan and the current time. (2)

Although only two users explicitly described how they assigned meaning to the timer, we experienced that all of them at some point referred to the timer when describing how they knew the time until an action. Although it took a bit of time for most of the users, the face of the timer gave an indication to what the digits meant and the digits made it easier to compare the information with the clock and the plan.

Group note 8: The test user find it hard to connect the picture with the text on the message. The picture was seen as decoration. (2)

The user did initially not pay any attention to the photo in the “Change to bus 2” pop-up message. Despite being the only two things on the pop-up message, their graphic qualities were apparently too disparate and the user saw the picture as decoration. This was described as a usability problem whit great influence, as seven of the test users had problems with noticing the the ‘bus 2’pop-up message and it had to be pointed out to them.

10.1.3 SUMMARY

This section contains discussions of the issues on level 3 in the indexicality affinity diagram shown in Table 8.

10.1.3.1 EXTERNAL INDEXICALITY

INDEXING FROM THE ICONS TO THE SURROUNDINGS.

The use of the bus icons and colours from the NT domain appears to be successful since ten of out the eleven test users who were familiar with this colour coding immediately indexed correctly and the eleventh user was able to reach the same results by indexing from the colour of the icon to the buses. Signs from other domains, e.g. the home icon, were not so easily recognised and the amount of familiarity with the sign language appears to be important. Generally, icons proved to be tricky as different people index from the same icons to different things, and if people do not have a prior knowledge and understanding of the icon they might not understand the meaning. The use of icons to induce a specific discourse to further give the user clues about to how to perceive the interface worked for most users, and they were able to connect the information in the interface with the surroundings.

INDEXING FROM OTHER GRAPHICAL ELEMENTS OF THE USER INTERFACE THAN THE ICONS, TO THE SURROUNDINGS.

The combination of icons and time-indications appeared to be easy to understand. Some icons that usually have a very clear meaning to the user, was not easily understood as the context of use required a more specific definition of these. In this case, the name of the bus stops 'AAU' and 'Busterminalen' in the plan was ambiguous as there a several bus stops in both places and the users could not index precisely enough. These places are usually referred to just by their name, but in this specific use context this was not sufficient, as the users did not see it as a reference. Colours were used in the same way as icons the user interface, both for internal indexing between related information and for external indexing to the NT information system. Several users utilised this indexicality well.

The use of a photo to index to the bus stop of bus 2 did not work quite as well, in the respect that several users did not really notice the picture until it was pointed out to them and they were asked about it. Then they found it quite easy to index from the photo to the surroundings. The main problem was a usability issue that hindered the users in immediately understanding the interface.

The information presented in the user interface such as the timer and the pop-up messages mainly indexed relationally and the users understood the information quickly and intuitively. We believe that the test proved the immediate usability of the relational temporal indexicality, but it was also noticeable that the users used the absolute, current time to check if the relational was right, and that this was the easiest way of assigning meaning to the timer.

The users relied on both temporal and spatial indexicality when indexing to the surroundings. The users often indexed between information in the user interface and the surroundings in order to check whether the information from the device was correct.

INDEXING TO THE SURROUNDINGS TO SOLVE ISSUES ABOUT DEGREE OF CORRECTNESS OF INFORMATION AND MAKING SURE THAT THE USER CAN TRUST THE DEVICE.

The users often indexed between absolute time-indications, e.g. arrival/departure of a bus, and absolute locations in order to check the information. In some cases, there were too little information, i.e. it was not precise enough, and this confused some users. Also, when a user received information from one source that conflicted with another and the information on the device was wrong from the user's perspective, i.e. indexed to actions or places at the wrong times, the users became uncertain about what to do, but was still able to utilise the difference in

information to overcome some of their problems. It is interesting to note that the users can derive the information they need from other information even if it is wrong.

10.1.3.2 Internal indexicality

Internal indexicality concerns how the users make sense of the user interface by using internal indexing between screen elements. Many of the test users did this in order to make sense of things that initially puzzled them. We got a variety of results about how the users made sense of the interface by comparing and relating elements within it. In relation to the design principles, the internal indexicality did not provide sufficient evidence to support any of the existing, but the findings could prove interesting for further research.

Indexing between elements on the front screen

One example is that the orange highlight was difficult for many until they noticed that it shifted according to what time it was, so it was the movement of the highlight that clarified its meaning. The users matched between the time-indication in the plan and the time of the clock. In general, the test users were able to index between the elements of the screen in order to make meaning. Colours and placement in relation to each other were the most used methods, for example group notes 2, 3, 5 and 6. The users indexed between absolute time, time-indications in the plan and the count-down timer in the orange bar. This helped them to understand the meaning of the orange highlight in the plan, for example group notes 4 and 7 in this way the user traces the indexicality to make sense of the interface. In the same way we found that although a single item in the plan does not make sense it can be deducted from the context by comparing whit the other items in the plan. Most of the notes concerned issues with the front screen. This was also the part of the user interface that was used most and the screen with the most indexical elements of it.

Indexing between internal graphic elements on pop-up message

A substantial part of the users did not see the photo that should illustrate where the user should get on the bus. There was very mixed understandings of this photo, but most users needed to be asked explicitly before they noticed that it held useful information. We interpret this as a lack of indexicality between the text in the pop-up and the picture, as the users explained they either did not see it, or did not connect it with the text.

Internal indexing in the calendar interface

This can be explained by the use of good mapping [187], as described in the pictures concerning this particular function in Figure 55

Some users found the graphical elements of the user face a little confusing. This hindered them in utilizing the functions fully or made a task difficult for them. If they, in these cases, became stuck, the interviewer pointed out to them how they should continue. Since it made things difficult for the users, we cannot be certain if it really was that hard for the user to utilize indexicality in some cases.

10.1.4 Other findings

Group label number 25 from the indexicality affinity diagram Table 8, concerning the push-messages in the user interface, indicated a point that we found interesting. This issue concerned the fact that the users to a wide extend accepted the pop-up messages if they were pushed in an appropriate situation. The users' actions to receiving a pop-up message were very similar. Even though the message did not explain itself or in other way reveal why it appeared, the users

acknowledged the messages if they fit the context. In this we saw that the highly relational indexical push messages were interpreted right when in context.

This might be because of the nature of pushing the message that it emphasizes the reason that they appear. In our view, the push message itself incite that something have caused it to appear and in this way it adds information to the message delivered. An example could be the message "The bus arrives now" where the implicit, relational, indexical "the bus" is augmented by the current time in which the message is received, and the relational, temporal "now" is established or manifested by the time it appears on the screen. As a contrasting example, the use of "now" in this thesis is ambiguous, as it not clear whether we mean the time in which the "now" was written, or the time when the "now" is read, or if it has a third meaning.

The relational indexicality of the push messages was very easily accepted, so we think that it could be interesting to work with the users' perception of push and pull information in relation to indexicality. Especially how easily the connection between the object and the representamen is established, as our results indicated that the push strategy strengthens this relationship between the representamen and the object, i.e. the indexicality.

10.1.5 DESIGN PRINCIPLES REVISITED

The indexicality chapter concluded with three provisional design principles that were adopted to the domain, implemented and tested in the user interface of the system. The three principles were:

1. Use colours and graphic elements from the relevant context.
2. Use names that are used in the context.
3. Index to relative time.

The results of the evaluation showed that distinct graphic elements from the use domain were effective in relating the needed information and was also easily understood. Indexing to names in the surroundings was more difficult and the names have to be chosen with care or be decided by the user. Indexing to relative time is also effective.

Below the provisional principles is revaluated in relation to the test results, to clarify whether they held in real use, and to see whether they were applicable in the domain.

10.1.5.1 FIRST DESIGN PRINCIPLE

This design principle was implemented in the system by adopting NT's sign language into the system to index to buses. The majority of the users recognised these signs, and they found them intuitive. Furthermore the signs conveyed a distinct discourse that was an aid in the understanding other aspects of a system.

We believe that the design principle was validated in the present case.

10.1.5.2 SECOND DESIGN PRINCIPLE

This design principle was implemented in the system by using the users' language when referring to bus stops and other locations. The users understood the references, but in two cases it appeared that the reference was too broad, as the users did not know to what part of the place the system referred. Different users have different understandings of for example place names, and these will therefore not necessarily uniquely identify a place.

10.1.5.3 THIRD DESIGN PRINCIPLE

This design principle was used in the system to keep the user notified of the next action. The bus journey was broken into tasks that were used to relate the temporal information to. The users, though initially a bit confused, found this useful, as it minimised the mental work, as well as provided the information needed using a minimum of screen space.

This design principle was validated in the sense that the users found it very useful during the journey.

PART 6

Part six is the conclusion that answers the research questions from part one. The analysis of the evaluation data verified that the proposed design principles could be used for design of mobile context-aware user interfaces.

11 CONCLUSION

The aim of this project was to explore and develop HCI design principles for mobile context-aware systems. We set out to answer the following research questions:

> *What characterises the current research in design principles for mobile context-aware HCI?*
> *How can design principles with foundation in the concept of indexicality be developed and verified?*

11.1 FIRST QUESTION

The starting point was to establish the current status of HCI design principles in relation to mobile context-aware computing. This was done by conducting a literature study of papers published within the field of mobile context-aware computing within the last five years. The study revealed that little research is focused on generating HCI design principles for mobile context-aware user interfaces, and that the design principle that have been developed are often either very case specific, or on a conceptual level. Research into design principles that could be applied more generally to the development of user interfaces was rarer. This discovery provided us with motivation for research into HCI design principles.

11.2 SECOND QUESTION

A study of the theoretical concept of indexicality and the framework of geosemiotics identified central concepts and served as foundation for the development of the design principles. By relating the conceptual ideas of indexicality to temporal and spatial context, the following set of provisional design principles were developed.

> ***Index to colours and graphic elements from the relevant context.***
> ***Index to names and words that are used in the context.***
> ***Index to relative time.***

An evaluation of the design principles was conducted using a mobile context-aware system to support users in the domain of public transportation in an urban area. The user interface for the system was designed by applying the design principles in an analysis of the use domain. The evaluation was carried out as a think-aloud field evaluation.

The data from the evaluation was analysed with respect to how, and to what extend, the test users perceived the indexicality in the user interface. The analysis verified that the users understood and used the indexical properties of the user interface.

The design principles therefore contribute to the current research and constitute our addition to close the gap between the case specific rules and general design principles in current mobile context-aware HCI research.

Furthermore, the evaluation of the design principles revealed findings concerning the use of push-strategy in relation to context-awareness and indexicality. This and the use of internal indexicality in an interface, proved interesting subjects for further study.

12 SUMMARY

This chapter contains a summary of the thesis in accordance with the provisions given by the F-sector Board of Studies. The structure of the summary follows the top-level structure of the thesis.

12.1 PART 1

Part one of the thesis introduces the research subject and motivation as well as describing the thesis structure. The initial motivation for this thesis was an interest in mobile context-aware user interfaces. The first activity was a study of the use of an actual mobile context-aware system at the IWS 2005 conference. The study showed a number of usability problems and motivated us to make a literature study of research into mobile context-aware computing within the last five years. The study revealed a gap in the research concerning development of HCI principles. Little research is focused on generating HCI design principles for mobile context-aware user interfaces, and that the research done is often very case specific, or on a general level, so that the actual application of the design principle is not obvious. This motivated us to do further research in HCI design principles that were generally applicable, yet also concrete in relation to applying them in user interface design.

We set out to answer the following research questions:

> *What characterises the current research in design principles for mobile context-aware HCI?*
> *How can design principles with foundation in the concept of indexicality be developed and verified?*

12.2 PART 2

Part two describes the theory that will be the foundation for developing interaction design principles for mobile context-aware devices and the motivation for bringing the concept into this project. The semiotic concept of indexicality is a promising concept with regards to mobile context-awareness. Indexicality concerns how people can create meaning by indexing from the user interface of a device to their context. This could be utilised to make the user interface easier to understand for a mobile user. On basis of the theory and by applying the theory on the relevant aspects of the context of the use domain decided by the case, namely time and location, a set of HCI design principles were developed;

> ***Index to colours and graphic elements from the relevant context.***
> ***Index to names and words that are used in the context.***
> ***Index to relative time.***

In order to evaluate the design principles, they were applied to a case concerning supporting the use of public transport in an urban environment. The second chapter of part two of the thesis concerns an indexical analysis of the context of the system where the design principles was applied as focus. This analysis resulted in knowledge about the indexical properties of the context that could be used for the design of the user interface.

12.3 PART 3

Part three of the thesis describes a user requirements study. Four users were interviewed and studied while they undertook a bus journey. The data was analysed with affinity diagramming. The results of this study described the needs of the users and was used in the design of the user interface.

12.4 PART 4

Part four of the thesis describes the design of the user interface. The task description is based on the user requirements and the indexical properties on the indexicality analysis of the use domain. The focus of the design was to incorporate as much indexicality as possible. The design went through two iterations; a paper prototype and an implemented prototype, which are both described in this part.

12.5 PART 5

Part five describes the evaluation of the user interface and system. The evaluation was conducted as a think-aloud field evaluation sessions with 11 test users who undertook a bus journey es in Aalborg and during the journey used the system. Context-awareness was imitated by using Wizard of Oz technique. The data from the evaluation sessions was recorded on video for the analysis. The analysis was separated into an analysis of the usability problems and indexical issues. The results if the analysis were knowledge about how the test users understood and used the indexical properties of the user interface and this was related to the design principles. In most cases the test users has used the indexical properties as expected and this validated the design principles.

12.6 PART 6

Part six is the conclusion that answers the research questions from part one. The analysis of the evaluation data verified that the proposed design principles could be used for design of mobile context-aware user interfaces.

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14 INTERVIEW QUESTIONS FOR IWS 2005

1. *Where did you hear about the system / what made you sign up?*
2. *Which parts of the system have you used? (Conference program, Tourist info)*
3. *When and where have you used the system? (Conference, hotel, other)*
4. *Did you notice when/where the system receive information?*
5. *Pro's / con's of the system (strengths/weaknesses/missing functions)*

15 INTERVIEW QUESTIONS FOR THE BUS USERS

1. Hvor ofte tager du bussen når du skal på universitetet?
    a. Hvilke transportmidler bruger du ellers, hvorfor?
2. Hvilke fordele/ulemper ser du ved det at tage bussen?
    a. Irritationsmomenter?
    b. Betaling for rejsen (fx at skulle huske kontanter eller klippekort)
    c. Nogen fordele frem for andre transportmidler?
3. Hvordan planlægger du din busrejse?
    a. Ad hoc? Web? Busplan i papirform? Har busplan "i hovedet"
4. Hvilken billet/kort type benytter du?
    a. Hvorfor?
    b. Er der nogen ulemper/fordele forbundet med det?
5. Hvordan får du den information du skal have under busrejsen? Her menes information der har relevans for rejsen, dvs.
    a. hvor bussen er henne
    b. om det er den rigtige bus du kører med
    c. hvornår du skal ringe
    d. hvornår du skal af
    e. planlægning af bus-skift
6. Hvordan er informationsniveauet på stoppestederne og i bussen?
    a. Er det positivt med de digitale skilte der er på f.eks. stationen
    b. Hvordan kan informationen generelt forbedres
7. Hvordan er din opfattelse af bussens stabilitet? er den altid til tiden, eller er den ustabil?
    a. Hvordan kunne dette afhjælpes?
8. Ser du gå-distancer og ventetider ved stoppesteder og mellem skift som et stort problem, hvis ja, så hvorfor?
    a. Hvordan kunne det afhjælpes?