Usability in Mobile IT Systems

Johansson, Niklas [Ж]
Nylander, Stina [Θ]

[Ж] Department of Information Technology, Human Computer Interaction, Uppsala University, Sweden

[Θ] Swedish Institute of Computer Science

ABSTRACT

In this report we give an overview of usability aspects applicable to mobile devices and systems. A number of research projects from three different application areas are presented and experiences from the projects are discussed.

To successfully design usable products, services and systems both for leisure and for mobile work practice has turned out to be a difficult undertaking. Many systems fail because of a number of reasons. Some systems do not fail, but remains difficult and cumbersome to use.

A certain immaturity can be observed since developers and designers do not fully utilise the benefits and assets provided by today's technology in design of mobile systems. For mobile systems, the varying contexts of use become more important. When only relying on existing knowledge of design for stationary systems, important possibilities are often lost and the system has gone astray.

KEYWORDS

Usability, Mobility, HCI, Mobile work

ISSN 1404-3203 2005-029

This report is part the Technical reports series from the Department of Information Technology at Uppsala University and is available on the address: http://www.it.uu.se/research/reports/

TABLE OF CONTENTS

1. INTRODUCTION 3

2. MOBILE CHARACTERISTICS 3

2.1 CONTEXT 4
2.2 CONDITIONS OF USE 7
2.2.1 Professional use 7
2.2.2 Varying frequencies of use 7
2.2.3 Reliability 8
2.3 SOCIAL CHARACTERISTICS 8
2.4 TECHNICAL ASPECTS 9
2.4.1 Input 10
2.4.2 Output 11
2.4.3 Security 12

3. CASES 13

3.1 POSITION-BASED MESSAGING SYSTEMS 13
3.2 ROUTE GUIDANCE SYSTEMS 14
3.3 TOURIST GUIDES 15
3.4 HOME HEALTH CARE 16

4. USABILITY ASPECTS 16

4.1 SHORTCOMINGS IN THE SOFTWARE DESIGN PROCESS 16
4.2 FRAGMENTATION AND POORLY SHARED DATA 17
4.3 INEFFICIENT USE OF AVAILABLE TECHNOLOGY 18
4.4 DEDICATION OF HARDWARE BUTTONS. 18
4.5 THE SIZE PARADOX 19
4.6 VARIABILITY 20
4.7 INTERFACE INTERACTION 20
4.8 PRESENTATION OF INFORMATION 20

5. CONCLUSIONS 21

6. REFERENCES 22

1. INTRODUCTION

We are now experiencing mobile computing in many areas of our daily lives, with the most common manifestation being mobile phones that are ubiquitously present in Sweden today. Mobile technology is applied for leisure as well as for professional use in various degrees. By providing new ways for communication and information access, the technology offers means for entertainment and can facilitate a more effective work, economical savings etc.

Possibilities with mobile computing brings not only new devices that are small, personal and wireless, but also new types of services and applications, along with new types of usage settings and usage conditions. The most frequently used services are arguably the phone calls and text or image messages that the mobile phone offers, but personal information management (PIM) applications, web surfing, and location-based services like for example Telia Sonera's friend finder are getting more common. The portability of the new computing devices makes it possible to use them in contexts where desktop computers can not be used, for example in buses, cars, in the subway, in cafés and restaurants, in streets and squares, and many other public places where people are moving around.

In this paper, our intentions have been to investigate the state of the art in usability for mobile computing. We have adopted a two-part approach and studied both literature concerning mobile computing and usability for mobile computing, as well as user studies of working mobile systems, both commercial services and research prototypes. The approach has been data driven to some extent, since both literature and applications in this area are somewhat immature. It has also turned out to be very difficult to find usability data on commercial devices and services, since manufacturers and providers usually do not make their own testing-results public.

Below we discuss mobile characteristics and focus on four important aspects that separate mobile computing from desktop computing: *context*, *usage conditions*, *social aspects* and *Technical aspects* such as hardware and security. The discussions are followed by an analysis of four groups of mobile applications: *position-based messaging systems* (PBMS), *route guidance systems*, Tourist guides and *home health care systems.* The application groups cover several aspects of mobile computing, tourist guides and PBMS systems involving handheld devices, tourist guides being used by moving users, route guidance systems used by moving pedestrians or installed in mobile environments (cars). A discussion is thereby following about *usability aspects* and to what extent there exist some kind of usability guidelines for mobile computing, how usable existing applications really are, and some design guidelines are given, based on the experiences from this work.

2. MOBILE CHARACTERISTICS

'Mobile computing' is a term with many meanings, interpreted in many ways. Weilenmann (2003) points out the importance of defining *what* is mobile. Whether it is *the individual, the setting, the technology,* or *the information* that is mobile makes a difference when talking about mobility. In that way, ‘mobile’ can refer to users that are actually moving while interacting with a device such as a cellular phone (mobile) or a personal digital assistant (PDA). It can also refer to a class of devices that are considered mobile, mostly handheld devices but often devices like laptops are included since users carry them around and use them in different places. A third meaning is that of computing that is performed in mobile settings, i.e. environments that are moving, for example cars, trains or buses. Finally, information can be mobile in the sense that it is accessible from many different places and devices. Using the meaning of mobility, presented by Weilenmann (ob cit.), our studies has led us to focus mostly on the aspects of mobility that concerns *mobile users*, and *mobile devices*. *Mobile settings* have been treated to some extent, while *mobile information* has not been treated.

Luff and Heath (1998), and subsequently others (Pinelle, 2003; Fagrell, 1999) describes the extent of devices (or ‘artifacts’) mobility in three ways; Micro-mobility, local mobility and remote mobility. *Micro-mobility* refers to when the distribution of an artifact is rather limited. The artifact is movable, but is only used within a limited space like an office or hospital aisle. *Local-mobility* is when the area for use of the artifact is enlarged to e.g. a building or construction site. The most unlimited dispersion is described by the term *remote-mobility*. Here the artifact is used by individuals moving around distant physical locations, also at a global scale. We find this division useful when, among other things, describing use of mobile artifacts, which is also essential to clarify when making the choice of technology used in the device.

Another important aspect when choosing technology for the mobile artifact is whether it is to support *tight mobility* or *loose mobility*, a distinction described by Churchill and Wakeford (2001). Tight mobility provides *real-time synchrony* for communication and information sharing. What is written in one device is immediately accessible in another. Loose mobility is the opposite where information and communication is available *asynchronously*. This makes some kind of synchronisation a decisive action for the system.

2.1 Context

Unlike traditional desktop computing, mobile computing exposes users, their services and applications as well as their computing devices to different situations and varying contexts to a much higher degree. How, when and where the use occurs is not to take for granted for mobile systems. Therefore, when designing mobile IT systems, the precise context where the user, technology and interaction between them will occur cannot be foreseen. The varying context is recognized as an important quality for use of mobile devices. Context is something inherently variable, and therefore somewhat difficult to define (Dourish, 2004). Environmental variations like rain, wind and traffic noise might also be different from time to time as well as differ during the time a task is performed. As a part of the context of use, these variations are also an innate part of the nature of mobility and are not to ignore when developing mobile technology. We will latter discuss some areas effected by the various contexts of use.

As in the case of mobile computing there are many definitions, and the majority of context definitions are descriptive. The one that is most often used is perhaps that of Dey et al. (2001):

> *[context is] any information that can be used to characterize the situation of entities (i.e. whether a person, place, or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity, and state of people, groups and computational and physical objects. (p. 106)*

A more operationally oriented way of looking at context is provided by Winograd (2001):

> *... something is context because of the way it is used in interpretation, not due to its inherent properties. (p. 405)*

This provides a way to exclude some of the information that would be considered in the definition of Dey et al. Neither of these two definitions gives very much tangible support to designers. This has two main reasons. First, context, context adaptation, and context awareness are rather new research areas and new application areas. The technology used is new, many times unstable, and always quickly changing. During these circumstances it is very difficult to establish design principles and guidelines for the area. Secondly, it is in the nature of mobility that context is changing, otherwise something would not be mobile. Guidelines on how to incorporate or handle context in services and applications for mobile computing will therefore never be direct instructions on "how to do", but rather guidelines on "what to think about", and "what to test".

A common mantra of frequent occurrence today's research and development is to design for ”access anytime anywhere”. The meaning of this is to provide a mobile device that always can be carried along (anywhere) and that always (anytime) contains proper information.

Perry et.al (2001) stresses the importance of to carefully take the aspects of context into consideration:

> *"The need to support flexibility is why the notion of access anytime, anywhere has become such an important mantra in the developing of mobile technologies." (p. 342)*

However, designing for anytime, anywhere is not enough for the mobile user. It is not sufficient to be able to access information from a mobile device if the information is not adapted to the device used for access. Many web pages are shrunk to illegible miniature size on a small device, and scrolling through a long document on a small screen can be both cumbersome and time consuming. The anytime, anywhere need to be complemented with anyhow, where information and interaction techniques are adapted to the current access device (Shneiderman, 2002; Trewin et.al, 2003; Myers et.al, 2000; Perry et.al, 2001). Otherwise, the opportunities of mobility risk burdening users more that helping them by for example forcing them to use different applications for the same activities (Shneiderman, ob.cit.).

If the mobile device is used exercising a profession, it is also important to consider adaptation to the work process. Mobile work never occurs totally isolated from stationary work, and the two processes need to be smoothly connected and synchronized. This must be fully supported by the technology, in a way allows information to flow within the whole system. When designing mobile technology, the whole process of work must be considered, not only the specifically mobile parts:

> *"…we can see both the mobile aspects of the work and how its everyday or non mobile aspects intrude into the mobile component of work. The two appear indivisible, and technology that only supports the mobile component will not support a large component of its users needs."* (Perry et.al 2001)

In all usage situations, the attention of users needs to be divided between the IT-system and the surrounding environment. In some situations the environment only requires a fraction of the user's attention, for example when a user works alone in an office, while in other situations almost 100% of the user's attention must be focused on the environment instead of the application, for example while driving a car during rush hour. Mobile services introduce a new aspect of the attention problem, since they move between different contexts that poses different demands on users' attention. The same service can be used both in situations where users can focus all their attention on the interaction with the service, and in situations where the environment demands a large part of the attention.

Bad design of mobile services and its requirements of the user's attention can result in various consequences. A map application in a car must for example require very little attention to make it possible for the user to effectively and safely acquire the information necessary to navigate while driving. Furthermore, a mobile museum guide (see the section Tourist guides, pp.15) must provide a carefully balanced interaction that gives the user interesting information in the device but does not compete with the museum itself. The choice of interaction techniques can here be crucial. If for example the visual attention is of great importance for the user, voice and audio interaction and can be preferred when it requires less attention then interaction with a keyboard or buttons.

Technology for detecting physical position is getting more and more common, most frequently represented by GPS. The possibility of knowing where a mobile device is has opened up for new types of services, for example SMS-services providing you with information about the nearest mail box, route guidance systems in cars and tourist guide systems that gives information on the sights nearby the current location. Even if technology keeps improving, location aware services share some problems that need to be dealt with.

All location aware systems need to be able to deal with situations where the positioning technology does not give an accurate position or any position at all. Regardless of which positioning technology that is used, interference, weather conditions, hardware malfunction or other factors will occasionally put the system out of order, and it is important that these situations are handled in a suitable way.

It is preferable that the system can retrieve the positioning without help from the user, and tell the user what is going on in the mean time. The route guidance systems handle the loss of positioning in the same way as they handle driver deviations from the suggested route; at the next reliable position a new route is computed. Obviously, it is not a good solution to let the service black out and demand a restart when the positioning is lost.

Users of a location based system must be able to interpret the behavior of the system. If users do not have a good understanding of how exact the positioning is and what system behavior is linked to the position, it does not matter that the position technology works excellently. Orientation is a frequently reported problem for different types of services (Burrell, 2002; Cheverst, 2000). Even if the system have the exact position of the user and displays relevant information about the location, users can be very confused if the object or building that the information concerns is behind their back. In this case, it is not obvious that users understand that the information from the system actually is relevant to their position.

2.2 Conditions of use

The conditions of use have great impact on usability requirements. With systems that are designed for leisure or pleasure, users are free to choose if they want to use them at all, and if they do, when and in which situations. This implies that services that are experienced as difficult to use might not be used at all, or might only be used in situations where users can spare the extra time and effort needed. It also implies that if users do not find the provided service interesting enough and worth the effort to use, the service probably will not be used at all.

2.2.1 Professional use

The situation is different with systems that are used in professional activities. Here users' work practice can be highly depending on the system. An IT system at a work place can be an obligatory tool to perform the work, with no chances to refrain from using the tool because of for example poor usability. A route guidance system can, for example, be linked to the planning and delivery for a transport company. Each driver is forced to use the route guidance system when driving to delivery destinations, both to keep track of the distance each vehicle travels, and to get notified about new pick up points.

Mobile IT systems can be implemented in order to transform a stationary work and make it a mobile work. It is then important to carefully consider how the new work is to be carried out. Already mobile work can also be supported by a mobile IT system, as in the previous example with the driver in the transport company or as in the case of home health care nurses (Johansson, 2006).

Most of the systems here examined in the overview below are leisure systems where the use is highly optional and the user has the option to stop using the system any time.

2.2.2 Varying frequencies of use

Different systems are created for different frequency of use. Systems that support tasks or situations that users encounter frequently, such as common work routines, will soon have quite experiences users, while systems that support activities that users perform once or twice in a lifetime will always have novice users.

The route guidance systems are created to be permanently installed in cars, and thus used continuously by drivers. Even if the systems are not used for every trip to the grocery store they have good possibilities to get used frequently. The tourist guides must assume that most of the users are novices. Even if it is not unusual that people spend their holidays at the same place many years in a row, such a system must be designed primarily to accommodate first time users. The PBMSs are also designed for long term use, but temporary users that visit a location should be able to benefit from the information available in the system without prior training.

2.2.3 Reliability

The use of mobile technology is still characterized by insecurity and unreliability to a certain degree. Mobile artefacts are mostly a part of a larger system and they handle information that is stored somewhere else in the system. A common problem with the mobile devices is still bad network connections. Many mobile systems store their data on a remote server and are thereby completely dependent on a functioning network connection. When the connection is bad, the whole system mostly fails. Much too few systems store data locally and use a network connection when available to update and refresh data. In the same way, if a power supplies fails, the whole device mostly becomes unusable. Compared to a ditto paper based solution this is a major disadvantage.

> *”one of the characteristic difficulties of mobile work is that there is less predictability and more access to information and artifacts”* (Perry, 2001)

Perry (ob.cit.) explains how this insecurity generates a, what he call, “planful opportunism”. We, as users of mobile systems, make plans for the unexpected.

> *”When people know that they are going to encounter situations in which they cannot know exactly what is required, they can plan by collecting and carrying particular technologies, documents and resources.” (pp 334)*

The insecurity in use of mobile systems makes us prepare for a failure in the system. It forces us to bring paper copies of documents, to prepare OH-slides for a presentation and the most foresighted user keeps a paper backup of the address book in the mobile phone.

2.3 Social characteristics

Use of mobile devices involves not only technical aspects of the mobile device, but also social. The surplus values that mobile technology provides us with in terms of improved communication abilities and information access are just not simply positive, but also provide social effects that are not to ignore. Using the mobile device has to be socially accepted in many aspects to succeed and gain the users confidence for the device and the IT-system. In the literature we find a number of examples:

Physicians using a PDA in their contact with patients describe different effects (McAlearney et.al., 2004). In the beginning they felt afraid of using the device in front of the patients in order to appear as incompetent when they not manage to handle the device properly. But soon they found that was not a problem. Instead they experienced respect from the patients for using a “trendy” device and modern technology.

Bornträger and Cheverst (Bornträger, 2003) reports of tourists using a mobile tourist guide system consisting of a PDA equipped with headphones. When walking around in a large town while using the mobile guide system on the PDA, the tourists did not fancy using the headphones in order not to look strange or to be recognised as tourists. When it comes to a similar field of application, Ciavarella (2004) describes a mobile museum application for museum visitors. This device was also equipped with headphones, but the visitors and users disliked using them in order to be able to share the information from the device with others.

Another perspective on the mobile technology to reflect on is that the technology makes the personal privacy exposed in a greater extent. Communication means, information access and management facilitated by mobile technology makes it hard to separate private activities from professional in many circumstances. The day-care teacher can call in the middle of a business meeting, colleges can interrupt a private lunch with a mobile phone call. Private and personal emails are often mixed up and a laptop tends to contain both work related content as well as private since it is easy (and made for) to use both at home and at work.

Mobile computing also provides the possibility to carry out work in *virtual teams* (Andriessen, 2006). A team that jointly perform a work does not by necessity need to be located on the same place or even really know each other, through use of mobile technology,. Also the important role of management for the teams changes in the very same way. Relation to the manager becomes “mobile” and is virtually detained through the mobile IT system. Design of such mobile IT systems implies careful reflections and awareness of the possible effects.

2.4 Technical aspects

Due to the nature of mobile devices the device it self has to be small and easy to carry along. That affects its over all performance to a large extent. Today, the performance of mobile devices is almost technically comparable with a ten years old stationary computer. A numbers of constraints for the hardware in mobile IT systems limit the performance of the system:

- Network connections are generally slow since most mobile devices today relay on network technology such as WAP or GPRS. This limits data transfer rates when sending larger sets of data, e.g. in more demanding multimedia applications. The speed improves with 3G, and some devices (PDAs) even have built in WLAN cards which can give them considerable bandwidth. However, WLAN is still only accessible in restricted places and the technology still suffers from problems when moving between different access points.
- **CPUs** are slower in the interest of being inexpensive, small and less power consuming.
- M**emory** size is limited as well as the speed.
- **Battery** life is short, also in order to reduce price, size and weight. Routines (that are not always desirable) for screensavers, device standby and hibernate modes and network disconnections has been developed in order to prolong battery lifetimes.

- The **network connections** are today unpredictable and far from geographically complete.
- The **screen size** is small. Even if screen resolution can be improved, the form factor of mobile devices sets limits. The OQO, which is a full-fledged PC only millimeters larger than an Ipaq, has a screen resolution of 800 * 400 pixels (www.oqo.com). At that resolution, most UI widgets and text get very small so higher resolution for that screen size can decrease usability rather than increase it.
- As a consequence of the small screen, **interaction with GUI elements** in a small screen application become very limited compared to a stationary computer with a significantly bigger screen and more comprehensive interaction means. This results e.g. in bad readability and is one of the most treated issues about mobile usability, the design for mobile graphical user interfaces (GUI) (Weiss, 2002; Nielsen and Ramsay, 2000).

The physical and environmental limitations create restrained interaction possibilities for the mobile device. Input as well as output from the device has to be carefully designed, consider all the limitations and meet up to all the different requirements.

2.4.1 Input

The input interaction with mobile phones meets challenges like entering text while on the move, write longer messages smoothly, or just answer the phone while bicycling. Input interaction methods have two characteristics to a greater or less extent; They are navigation means, i.e. a way for the user to interact with the software in the device. They supply data input, i.e. allows the user to input data in the device and the application.

Some established methods are here presented:

- Write directly on the screen, over the whole screen or in a dedicated area, with a type of pen, also known as "**stylus**". The software for hand recognition translates the written sign to a character, possible for the computer to recognize.
- Mobile and smart phones also uses the **buttons 0-9*#** for input of text. Each button is assigned 3-4 letters which can be switched between by pressing the same button repeatedly. The T9 algorithm offers a quicker way where the button that represents the 3-4 letters only has to be pressed once for each letter in the word. In the end of the word the algorithm compares the possible combinations with a dictionary and finds the right word, or if several, gives proposals of possible words.
- Devices with a stylus can often offer a **virtual keyboard**, a keyboard displayed on the screen where the user can tap with the stylus on the preferred letters. On a research level there exists systems for example for gestural text input where the stylus is dragged over a virtual keyboard to compose the words (Kristensson, 2004), but they are yet far from commercial launching.

- Some devices offer a small **hardware keyboard** (that makes you retardate back to the hunt and peck system) with traditionally QUERTY keys. OQO and the Sony Ericsson P900 phone are good examples.
- Researchers are interested in **tactile interfaces** and on how to use them for both output and input. Linjama and Kaaresoja (2004) demonstrate how a tactile interface can be used for input interaction. A ringing phone can for example be shut off when it is still lying in the pocket, simply by a gentle tap with the hand on the outside of the pocket, or by sensing that the user is holding the phone (Hinckley, 2001). Series of taps on the pocket or purse can also be used as login identification (Patel, 2004). Tilting the device can be used as a means for scrolling the screen content (Hinckley, 2000), and even as a way of entering text on very small devices (Partridge, 2002).
- When realising that adding a button for each function is not a durable solution, the **dynamic soft key** becomes handy and is frequently used. An area of the screen nearest the soft key informs the user of the key's function. When navigating in the interface or using a certain application, the soft key can easily change its function. This implies that the same key can be used for several things, which if it is bad designed and implemented can be very frustrating for users.
- **Speech** as input modality already exists, but is sparsely used and mostly in mobile phones to call persons in the user's contact list. Seldom speech input is used in other applications.

Regardless of several new techniques for entering text in mobile devices, a stationary computer with a traditional keyboard is still faster and provides more potential interaction means in a more effective way. Even in an ergonomically point of view, the use of a larger, stationary, computer is mostly the most beneficial device to use for longer periods of work. This is sometimes forgotten when rashly trying to produce new mobile technologies and create mobile work.

As recognized in the HCI area concerning stationary computers, the need for input in order to perform a task should be minimized to achieve effectiveness and efficiency (Preece, 2002). In a mobile environment this is even more important when the context is various and interaction sometimes has to be carried out quickly while focusing on something else.

2.4.2 Output

The channels for output have not evolved much from the simple ring signal used in the infancy of the telephone. Today, 130 years later, just a few numbers of ways are used by mobile devices to get the users attention or communicate information back to the user.

- The traditional **sound** and ringing tones has developed and sound better and in several channels (polyphonic) on the latter phones. However, context sensitive and in other ways sophisticated variations in volume and intensity of the sound is still very moderately used. Today a lot of effort is instead laid in making it possible to listen to the favourite song as a ring tone on a mobile phone.

- On today's mobile artifacts the **screen** is mostly the most important output channel, except for the telephone ring tones. Information that requires more than a ring signal or an indicating lamp can be displayed here. The screen is also used for soft keys, to "increase" the number of buttons a device can contain.
- Attention can also be drawn to the artifact by other **visual** means than the screen, mostly a lamp or the screen blinking. A visual signal can be used as an alternative to sound when the artifact is in some kind of silent mode, but requires the phone to bee in the user's line of sight. During a meeting or when driving a car listening to music a blinking mobile phone can be quite effective as a substitute (or complement) to sound. Lights can also be used as feedback when for example pressing a button (the button illuminates) or as an indicator (a small indicating lamp is blinking when a message is waiting or when the battery is low).
- **Tactile** interfaces are today implemented for output to some extent. Some mobile artefacts use a vibrator for interaction, mostly as a complement to the ring signal or as a kind of force feedback for games. In the research community there are attempts to use tactile feedback to facilitate user interaction, for example Popyrev et al. that have used vibration feedback to help users perform scrolling tasks (Poupyrev, 2002).
- Some mobile devices can be **connected to a stationary computer** and in some extent synchronize and exchange information. A few devices can interact with the user in a greater extent through the computer.

2.4.3 Security

Several aspects can be mentioned regarding security for mobile systems and or devices. Here we will focus on security from a user perspective, i.e. what effects security has on usability. We will not discuss technical solutions to enforce security, as for example encryption.

The properties that make mobile devices useful and practical, i.e. the small size, the light weight, and readiness to use, are also potential security risks. It is easy to forget the device, for example on a bus or at a train station, and the devices' expensive technology make them attractive for thieves.

The most commonly discussed security aspect is the access to information and services. It is important to keep unauthorized users from accessing information such as medical information, and services such as telephone or internet banks. Even in more personal cases, it is important that only the right persons get access to information. Most people do not want strangers to read their text messages or listen to their voice mails for example. To ensure that only authorized users get access to information and services, different types of login procedures are applied. Mobile phones use PIN codes when the phone is switched on, PDAs have screen locks that can be activated, and telephone banks demand user names and passwords. These procedures can sometimes disrupt usage and annoy users to the point that they switch the security functions off or never use the device or service. For example, doctors using PDAs for drug information during hospital rounds have reported that it is too annoying to have to log in to the PDA each time it has switched to power saving mode, so they do not use the login feature at all (McAlearney, 2004). This means that if the device is lost, anyone can access all the information it contains.

Mobile computing adds to the security problems by being used in different situations. The simple fact that mobile phones, PDAs, and other small devices often are used in public spaces creates security problems that never occurred with desktop computing. We have all heard people sharing personal, or even confidential, information with a whole bus or train car while speaking on a mobile phone. Preece at al. (2002) gives a good example of how difficult it can be to offer secure access to a telephone bank that could be used in public: To avoid that by passers can get hold of users' phone bank password by eavesdropping, British banks often ask callers personal questions like their mother's maiden name, and instead of letting people say the password they ask about the fifth character in the password. Different questions are asked every time, and they are asked in different order, to be sure by passers cannot get hold of someone's login information. However, a login procedure like this is time consuming, and the variation of the questions and the order of them can be very confusing.

3. CASES

3.1 Position-based Messaging Systems

A PBMS system allows users to post electronic messages that are tied to the current physical position. Other users of the system can read the messages when they come to a position where messages were posted. All the content of the system is provided by end users. The main idea is to use a physical position as the "information hub" instead of people. A posted message is available to anyone that passes by the place where the message was posted, not only to a list of recipient as email or other instant messages. This approach has been implemented and tested in several systems with smaller variations. The Geonotes system (Persson, 2002) allows users that post messages to be anonymous, but all posted messages are public. Messages can only be posted from users' current position, and only be read from the position they were posted; no remote access to messages is allowed. The e-grafitti system (Burrell, 2002:1) allows remote posting but not remote reading, and messages can be addressed to a specific recipient. Geonotes and e-grafitti are designed for general communication, while Campus Aware (Burrell, 2002:2) uses the PBMS approach for a more specific purpose. Campus Aware is a guide to a university campus, where students familiar with the surroundings can post information messages to newcomers.

All of the PBMSs had problems with their contents. It is always difficult to launch a system that relies on user input, since the system by default is empty at the launching time. Both Geonotes and E-grafitti had difficulties taking off, and the majority of the messages were posted in the very beginning of the study period. Users did not post enough messages to create activity in the community. As a consequence people did not find the systems very useful and did not use it. A Geonotes user reported that the system could not be very useful since so few people posted messages to it (Persson, 2002). That way, a vicious circle is quickly created when there is not a critical active mass using the system. Apparently, it is very important to find the right community and the right purpose for such a system to take off. The study of Campus Aware seemed to have found a purpose that motivated people to contribute content to a much higher degree than in the case of Geonotes and E-grafitti. The students that participated in the study posted a lot of messages and reported that they had wanted the information they posted when they were newcomers.

Users' motivation to use the system can also be due to system usability. The PBMSs are designed for leisure use, i.e. there are no other enforcements to use the system besides the actual value of using it. This means that users can drop the system if it is difficult to use or hard to understand. Both Geonotes and E-grafitti were in the test phase implemented on laptop computers which did not allow the always-on property that is fundamental for the intended use.

A position based messaging IT system used in a work context is MobiSIR, used by Banverket, the Swedish National Railway Administration. The International Railway Federation (UIC) has specified the requirements for a mobile train traffic radio communication system based on the GSM-R standard. Through deployment of this system a complete interoperability has been obtained for European train traffic systems. In Sweden the MobiSIR system covers all 7 500 km of railway tracks. The system is not for public use but intended only for train traffic operators and train drivers. The MobiSIR system has implemented several specific messaging services such as emergency calls, calls to train numbers, group calls and position based messaging. One example is the possibility to define a message as accessible only in a defined geographical region. When a train enters the specific region the message is activated in form of an incoming call.

3.2 Route guidance systems

Route guidance systems are usually installed in cars to give driving directions to a destination that the user has entered (Eby, 1997; Kostyniuk, 1997; Tijerina, 1998). Some systems use keyboard for entering the destination, and a screen (sometimes with a map) for driving directions, while other systems rely on speech both for input and output. This kind of systems has been commercially available for several years and are considered quite mature. Route guidance systems for pedestrians are a more recent phenomenon that mostly exists in the form of research prototypes (Tarkiainen, 2001; Kray, 2003) but there are commercial examples, see www.citycompanion.de Rout guidance for pedestrians is usually based on text or graphic output on cell phones or handheld computers.

Route guidance systems for driving pose special restrictions on testing and evaluation, since the normal usage situation can be highly risky for the user. This kind of systems is either tested in a natural situation (where users drive on public roads) but they are not forced to use or interact with the system if the traffic situation demands their attention (Eby, 1997) or in an artificial setting where users drive on a test track (Tijerina, 1998) or in a car simulator.

The route guidance systems are unique both in terms of having to settle with a small amount of the user's attention, and the risk that comes with sharing the attention between the environment and the service. Most of the user's attention needs to be directed to surrounding traffic, and there is a very real risk of personal injury when directing a part of the attention to a route guidance system, especially if the system demands visual attention. For example, it would not have been ethic to conduct the study of mental workload when entering destinations to different route guidance systems in authentic traffic situations (Tijerina,ob.cit.). In that study, the system that only allowed input of destination by voice (and did not provide a graphical user interface at all), caused by far the least problems in terms of involuntary lane changes, or wobbling on the road.

Even though route guidance systems are intended for long term use, and often are used by professional drivers as taxi drivers, their use normally is optional. If drivers know where they are going they can choose not to input the destination to the system, or if they find the system to difficult to use they can use other means to find their way (maps, asking other people etc). This means that the systems can get away with some usability problems as difficult input of destination, especially when users are driving in a familiar area as they did in (Kostyniuk, 1997) and (Eby, 1997).

3.3 Tourist guides

Tourist guides are systems that provide information about sights and landmarks at the user's physical location. The information goes beyond orientation and navigation information that are provided by route guidance systems, and aims at enhancing the users' experience of the place. The system can cover larger outdoor areas like a city or a part of a city, or be restricted to a museum or university indoor area. The information in the systems is usually authored by professionals in the field, and the systems included in this overview did not allow end-users to contribute (even if that of course could provide a valuable addition to the system). The GUIDE system (Cheverst, 2000) provided tourist information on different sights in the historical centre of Lancaster, and the Cararra (Ciavarella, 2004) system provided information about artefacts of the Cararra marble museum.

When attending a museum or visiting a new city, user's primary focus of attention are the artifacts on display or the city surroundings. The purpose of the guide system is to provide information that enhances the experience of the exhibition or the city visit, not to replace it or compete with it. In that respect, the museum guides can be compared to the route guidance systems. However, there is little risk of personal injury if the guide attracts too much of the user's attention. Besides bumping into other museum visitors, or the artifacts on display for that matter, there are few dangerous consequences of not paying attention to the environment in a museum. But even if there is little risk of injury when the guide demands too much attention, the purpose of the museum visit is destroyed if the user has spent all the time looking at the guide.

Tourist guide systems are primarily designed for first time use, which poses high requirements on usability. Even if it is not unusual that people spend their holidays at the same place many years in a row, such a system must be designed primarily to accommodate first time users. Both systems described above used web-similar user interfaces to draw on users' previous experiences, which seemed to work.

The GUIDE system used the connectivity symbol of cell phones to indicate when the system was on line or not (Cheverst, 2000), and it seemed like users had no problem understanding what was happening. GUIDE also had some off line functionality that was available even when the network connection was lost. In the user study of the GUIDE system, a very long startup time for the positioning technology was reported. This was handled by having an extra person that started the system while study participants received information about the study (Bornträger, 2003).

3.4 Home health care

There are few truly mobile systems that are extensively used in the health care sector (Johansson, 2005:1; Lindh, 2004). The reason is yet concealed, but research points out a number of likely causes. Scandurra et.al. (2003) argues the importance in health care of sharing the same information, but on adapted interfaces and devices for different occupations. Other studies (Johansson, 2006:2) describes a case where the way of working, proposed by the used mobile IT system, is overridden by the personnel at a home health care service center in order to perform theri work as well as possible. Pinelle and Gutwin (2003) make a similar reflection in the same work context.

> *" ..workers usually communicate with each other intermittently, and often only when they believe the necessity of communication outweighs the effort required to communicate."*

Communication with colleagues is consequently only carried out when necessary and to share information becomes a secondary task. Again the personnel's first priority is to perform the practical, tangible, work. To use an enforced IT system that does not provides any apparent and useful means is not a welcome work task. A badly designed IT system, requiring lot o effort to communicate, would reduce the communication and information exchange further.

This further call attention to the importance of carefully designing the system based on the work practice. The users, i.e. the practitioners, will prioritize performing a good work before using an IT system.

4. USABILITY ASPECTS

Despite today's access of a quite mature and capable technology, comparatively few IT systems fully use the technology successfully. Our efforts to find research performed on well established, dispersed, IT systems taking advantages of the existing technology have given a poor result. Despite that, based on our studies of the literature and the systems described above, we have identified five problem areas we find need more research and development work in order to help designers and developers to create usable mobile services.

4.1 Shortcomings in the software design process

Established usability criteria raised from the HCI research area are normally based on a standard personal computer platform consisting of e.g. a normal sized screen, a usual network connection and a full sized keyboard and a mouse. These can usually be taken for granted and focus can be directed to the software and basic HCI aspects like how to make it perform the right things, be easy to use and so on.

When designing devices for mobile use, this is not the case. The hardware can here not be taken for granted and is to be treated as a determining factor in the design process. Standards are vague defined for interaction techniques and use of the hardware. Applications for mobile systems consequently have to be individually adapted to a version for each device model to run on.

Software design for mobile technology of today seems to rely on the more established design tradition for applications running on stationary systems, for example a system with screen output and keyboard input that users are supposed to operate while driving a car. Software design for the mobility area appears to be at the same level as the stationary, 15-20 years ago, fumbling to find effective design metaphors and to establish different kinds of standards for how to design and design for mobile software and hardware.

The whole design and usability work performed today with mobile devices seems based on the ditto for stationary systems. The design work must evolve and take into consideration the new prerequisites valid for design of mobile systems. Existing GUI-design guidelines must be extended to handle the technical limitations and possibilities provided by the mobile technology. More effort must be laid into finding out how, where and in what context the mobile device is to be used – and design thereafter. As well as the GUI design must evolve and adopt, the interaction design must develop to the prerequisites for the mobile technology and its use.

4.2 Fragmentation and poorly shared data

In order to compensate for the inevitable disadvantages with mobile devices like small screens and poor input facilities for larger texts, stationary computers can with advantage be used as a complement. The possibility to access the same data from a stationary computer provides for an easier and more effective way of administrating the data also handled by the mobile devise. It also facilitates the integration of mobile tasks and stationary tasks. However, this can be a source of problems. Often applications that handle the data on the various devices come from different providers, and special software is needed to synchronize the information. The synchronizing process is often experienced as complicated to setup and then cumbersome and unstable to use. In addition, an active action often is required from the user (pushing a button, placing the device in a cradle, start an application etc.) to start the synchronization, an action that is easy to forget. As a result it is quite common that users find themselves with different versions of for example their calendar information on different devices, each version containing changes that are not shared with the others. In that situation it can be very difficult to create a synchronized calendar on the different devices, and the possibility to access information from several devices can seem quite expensive in terms of work needed. To free users from this problem, we need device manufacturers and software providers to cooperate to find easier ways of synchronizing information. An alternative could be models that do not primarily rely on synchronization, for example the sView system (Bylund, 2001) that uses a service environment that follows the user in the network and thus gives users the possibility to use the same instance of a service on several devices

4.3 Inefficient use of available technology

Commercial hardware turns out to be very conventional. Our studies has touched upon several good ideas and research projects about innovative technology like tactile interfaces, smart input methods etc., but none of them are even close to be implemented in a industry mass-produced device. Even capabilities of existing products seem to be poorly utilised. Many devices are already equipped with e.g. Bluetooth, large screens and (rather) fast data transfer capabilities but without use of their full potential. Correctly used, a Bluetooth™ equipped cell phone could be able to fully synchronise (for example the address book and calendar) with a stationary desktop computer as soon as the user enters the room, without any interference by the user.

The very competent smart phone P800 from Sony Ericsson disposes a fairly large high resolution screen, but the size of the digits in a dialled phone number is quite small and the size is not possible to change. People with minor vision impairment, which is quite common at the age around 50, have difficulties reading it. The screen could easily display a ten digit phone number with twice as big font as the standard size, without occluding the clock or the name of the telephone network provider, or causing any other changes in the display layout.

Dialing a number on the Sony Ericsson P800 smartphone

It seems like a simple thing to do to improve the user experience for many users, but apparently needs like this it iare hard to discover and realise the importance of. Another feature available in many mobile phones is voice commands; users can record a voice command that is connected to a contact in the phone book and that can be used to call that contact. This functionality is restricted to this particular use. It would be very practical if a voice command could be connected in the same way to another application or function of the phone, for example the alarm. That way, users could create shortcuts to functions that they use often.

4.4 Dedication of hardware buttons.

Mobile devices dispose of a limited number of hardware buttons. Since a device mostly offers a much larger number of functions than the number of buttons, the interaction design becomes crucial when a certain button must be used for different things depending on the active mode or function. Under theses circumstances, a static dedication of a certain function to one certain button is a bold venture and should be thoroughly considered.

What justifies the dedication of a button a certain purpose is when the function should be used often or be available very fast. An example is the camera functionality on certain mobile phones that have a dedicated button on the side that offers quick and easy access to the camera functionality without restricting the use of the standard keys on the key pad. Whether this is one of the primary functions in a mobile phone can be discussed, but the manufactures have in many occasions made these decisions. Manufacturers tend to add hardware buttons that serves their own desires and purposes than the users, or the manufactures have a distorted notion of the actual use of their product.

Dedicated print button

Canon has, for example, on their cameras in the IXUS™ series, dedicated a certain hardware button for printing of pictures using their own Canon printers. We find the "instant print button" questionable whether it is fully motivated to dedicate a single button for this purpose. To print a picture is mostly an action that does not have to be performed very quick or very often and it makes the design decision to use valuable space on the small camera (and risk complications for the user) rather boldly. Further, to print a picture is an action that in greate extent would benefit from being performed from a stationary computer with editing possibilities and a big screen capable to show the picture with all its colours and in a larger size.

4.5 The size paradox

A revealed paradox, regarding usability in mobile devices, turns out to be the issue about size of the mobile device. In order to be conveniently mobile, the device has to be small and light. In that way it is easy to carry along, to fit in a pocket or bag, and it is always available without requiring too much effort. On the other hand, entering information in the small device turns out to be a problem. Users call for larger buttons that are easy to press, and bigger keyboards facilitating entering of larger amounts of text. Further, larger screens are sought for in general, but in particular when displaying high resolution pictures, movies and extensive texts. Additional requirements of the technology also come into collision with the size; faster systems, better network coverage and batteries with better performance – all forced to compromise in favour for a smaller size.

This will persist being a problem; a tiny device will never have a large screen and a standard keyboard. The best we can do is to use good design to exploit the capabilities of each device to the fullest. We also need to stop considering mobile devices as alternatives to the desktop computer. All devices will not be good tools for all kinds of use. Cell phones are excellent communication devices, and can be used for taking short notes, sending short messages, and taking pictures (if it is a camera phone). This does not mean that we should equip the phone with software to create and edit large texts, or advances image editing. Even if we did that, those tasks would not be very efficient or enjoyable to perform on the phone. Some tasks just work better on stationary equipment. In time critical situations, or when travelling, a mobile device can do the trick, but it will never replace the desktop computer, just as the Swiss army knife will never replace all the other tools we keep in our kitchens (Norman, 1999).

4.6 Variability

Mobile computing brings the aspect of varying context into design. Devices that are mobile, are carried by mobile users, and thus used in different situations and settings. This must be taken into account when designing services and applications. Traditional desktop design has been very focused on identifying the user and the usage context, using techniques as task analysis and user modeling. With mobile computing there are many usage contexts, of which not all can be identified at runtime. Many of these contexts are also much more intrusive than the traditional office setting of desktop computing.

4.7 Interface interaction

While input of information in mobile devices turns out to be complicated and lengthy, even when many different techniques are available, we propose an design of mobile interfaces that requires a minimum of text input. Fällman (2003) consider text input as a stationary activity which is supported by our findings. Our ongoing studies indicate that in a working situation, input of text is carried out in a minimum extent in advantage for use of a stationary computer with an interface to the same system. Naturally text input should not be totally ignored. A reduction of text input in more advanced mobile devices can be done by, when suitable, using graphical components that are easy and quick to manipulate when entering information, e.g. checkboxes, radio buttons, drop lists etc. When it is necessary to enter free text, the system should offer a quick and easy way to do that, without any demands of completeness of the written text. The same information should be accessible from a stationary computer where the user thoroughly can continue to edit the text or start to enter more complex information.

In some situations, speech input has proved to be effective. In a study of destination input for route guidance systems, the system that relied on speech for input and output caused a significantly lower number of involuntary lane changes, and let drivers keep their eyes on the road almost all the time (Tijerina, 1998). Speech is also frequently used to by mobile phone users to call numbers in the contact list, especially when walking and driving.

4.8 Presentation of information

Old, traditional HCI knowledge must not be put aside when starting to design for the new, mobile, domain. An often occurring “truth” is that design should provide for the right information in the right time in the right way. Due to the previously mentioned aspects of usability in mobile systems, presentation of information is even more challenging and requires in addition that information has to be:

- Short and concise (with no need to read unnecessary information)
- Carefully chosen in order not to be misunderstood
- Quick and easy to read (not to small letters, good layout etc.)
- Effective (suited for the situation and the present task)
- Resource effective (quickly displayed)

Too much information is not good when:

- It takes to much valuable space on the small screen.
- It causes an “information overload” and makes it hard to the user to find and remember the right information when in the same time acting in the setting.
- It takes to much time to read, at a glance when on the move.

The hardware and the physical design might differ a lot between different kinds of mobile devices. The environmental limitations and the nature of mobile use raise the requirements on the device. This entails greater challenges when designing for mobile use. Input as well as output from the device has to be carefully designed, considering all the limitations and meet up to all the different requirements. In design of mobile devices, more attention must be given to the hardware and how to handle its limitations and how to fully take advantage of its benefits.

5. CONCLUSIONS

Again and again mobile products seem to fail, both simple services in the telecom network as well as more advanced mobile IT systems. Research projects are carried out concerning various mobile services, but the results very seldom end up in a commercial product that is successfully used in the intended domain. Moreover, the telecom companies are constantly, and sometimes desperately, looking for profitable services to implement in their networks. With an exception for the SMS-functionality, we can see hardly any successful services in Europe.

From the commercial and industrial life sector, we find very few research projects about mobile IT systems at all. Without claiming that this report is in some way all-embracing, we can denote various problem areas from the mobile it systems sphere. The study also allows us to points out a number of areas to improve in order to create more useful mobile systems.

In general, more effort can be put in the design. Thoroughly studies of how and where the device is to be used are requested in order to uncover the functionality it is to provide its users. Due to the nature of mobility, a mobile device has to be built to manage varying conditions to be successful.

Facing the new requirements the mobile context entails can be done by taking the new opportunities provided by the available new mobile technology into consideration in design and get rid of stationary conventional stationary computer thinking.

6. REFERENCES

Andriessen, E. and Vartainen, M. (2006) *Mobile Virtual Work - A New Paradigm?* , Springer, ISBN: 3-540-28364-1

Bornträger, C. and Cheverst, K. (2003) *Social and Technical Pitfalls Designing a Tourist Guide System*, In Proceedings of HCI in Mobile Guides.

Burrell, J. and Gay, G.K. (2002:1) *E-grafitti: evaluating real-world use of a context-aware system*, Interacting with Computers, 14 (4). pp. 301-312.

Burrell, J., Gay, K., Kubo, K. and Farina, N. (2002:2) *Context-Aware Computing: a Test Case*, In Proceedings of UbiComp 2002, Gothenburg, Sweden.

Bylund, M. (2001) *Personal Service Environments - Openness and User Control in User-Service Interaction*, Licentiate thesis, Department of Information Technology, Uppsala University.

Cheverst, K., Davies, N., Mitchell, K., Friday, A. and Efstratiou, C. (2000) *Developing a Context-aware Electronic Tourist Guide: Some Issues and Experiences*, In Proceedings of CHI.

Churchill, F. and Wakeford, N. (2001) *Framing mobile collaboration and mobile technologies*, In Brown, B., Green, N., Harper, R. (Eds) Wireless World: Social and Interactional Implications of Wireless Technology, New York, Springer-Verlag.

Ciavarella, C. and Paternò, F. (2004) *The design of a handheld, location-aware guide for indoor environments*. Personal and ubiquitous computing, 8 (2). pp. 82-91.

Dey, K., Abowd, D. and Salber, D. (2001) *A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of Context-Aware Applications*. Human-Computer Interaction Journal, 16 (2-4). pp. 97-166.

Dourish, P. (2004) *What we talk about when we talk about context*, Personal and Ubiquitous Computing, 8, pp. 19-30.

Eby, W., Kostyniuk, P., Streff, M. and Hopp, L. (1997) Evaluating the Perceptions *and Behaviors of Ali-Scout Users in a Naturalistic Setting*, The University of Michigan Transportation Research Institute.

Fagrell, H., Ljungberg, F., and Kristoffersen, S. (1999) *Exploring support for knowledge management in mobile work*, In Proceedings of the Sixth European Conference on Computer Supported Cooperative Work (Copenghagen, Denmark, 1999). Kluwer Academic Publishers, Norwell, MA, pp. 259-275.

Fällman, D. (2003) *In Romance with the Materials of Mobile Interaction: A Phenomenological Approach to the Design of Mobile Information Technology*, Doctoral Thesis, Department of Informatics, Umeå University.

Guimbretière, F., Stone, M. and Winograd, T.(2001) *Fluid Interaction with High-resolution Wall-size Displays*, In Proceedings of ACM UIST 2001 Symposium on User Interface Software Technology, 21-30.

Hinckley, K. and Horvitz, E. (2001) *Toward More Sensitive Mobile Phones*, In Proceedings of Symposium on User Interface Software and Technology, (Orlando, FL, 2001), pp. 191-192.

Hinckley, K., Pierce, J., Sinclair, M. and Horwitz, E. (2000) *Sensing Techniques for Mobile Interaction*, In Proceedings of Symposium on User Interface Software and Technology, ACM Press, pp. 91-100.

Johansson, N., Lindh, T. and Sandblad, B. (2006) *Usability in IT Systems for Mobile Work*, In Andriessen, E. and Vartainen, M. (Eds.) Mobile virtual work: A new paradigm? Springer, ISBN: 3-540-28364-1

Kostyniuk, L.P., Eby, D.W., Hopp, M.L. and Christoff, C. (1997) *Driver Response to the TetraStar Navigation Assistance System by Age and Sex*, University of Michigan Transportation Research Institute.

Kray, C., Laakso, K., Elting, C. and Coors, V. (2003) *Presenting Route Instructions on Mobile Devices*, In Proceedings of Intelligent User Interfaces, 117-124.

Kristensson, P-O. and Zhai, S. (2004) *SHARK: A Large Vocabulary Shorthand Writing System for Pen-based Computers*, In Proceedings of Symposium on User Interface Software and Technology, Santa Fe, NM, pp. 43-52.

Lind, T, Sandblad, B, Johansson, N and Utbult, M. (2004) *Vård IT-Kartan*, Sjuhäradsbygdens tryckeri, Borås, ISBN 91-631-6352-7.

Linjama, J. and Kaaresoja, T. (2004) *Novel, Minimalist Haptic Gesture Interaction for Mobile Devices*, In Proceedings of NordiCHI, (Tampere, Finland, 2004), ACM Press, pp. 457-458.

Luff, P. and Heath, C. (1998) *Mobility in collaboration*, In Proceedings of the 1998 ACM Conference on Computer Supported Cooperative Work (Seattle, Washington, United States, November 14 - 18, 1998). CSCW '98. ACM Press, New York, NY, pp. 305-314.

McAlearney, S., Schweikhart, B., and Medow, A. (2004) *Doctors' experience with handheld computers in clinical practice: qualitative study*, British Medical Journal.

Myers, A., Hudson, E. and Pausch, R. (2000) *Past, Present and Future of User Interface Software Tools*, ACM Transactions on Computer-Human Interaction, 7 (1). pp. 3-28.

Norman, D. (1999) *The Invisible Computer*, MIT Press.

Partridge, K., Chatterjee, S., Sazawal, V., Borriello, G. and Want, R. (2002) *TiltType: Accelerometer-Supported Text Entry for Very Small Devices*, In Proceedings of Symposium on User Interface Software Technology, pp. 201-208.

Patel, N., Pierce, S. and Abowd, G. (2004) *A Gesture-based Authentication Scheme for Untrusted Public Terminals*, In Proceedings of Symposium on User Interface Software and Technology, (Santa Fe, NM, 2004), pp. 157-160.

Perry, M., O'Hara, K., Sellen, A., Brown, B. and Harper, R. (2001) *Dealing with mobility: understanding access anytime, anywhere*, ACM Transactions on Human-Computer Interaction, 8 (4). pp. 323-347.

Persson, P. and Fagerberg, P. (2002) *GeoNotes: a real-use study of a public location-aware community system*, Swedish Institute of Computer Science.

Pinelle, D. and Gutwin, C. (2003) *Designing for loose coupling in mobile groups*, In Proceedings of the 2003 international ACM SIGGROUP Conference on Supporting Group Work (Sanibel Island, Florida, USA, 2003). GROUP '03. ACM Press, New York, NY, pp. 75-84.

Poupyrev, I., Maruyama, S. and Rekimoto, J. (2002) *Ambient Touch: Designing Tactile Interfaces for Handheld Devices*, In Proceedings of Symposium on User Interface Software and Technology, (Paris, France, 2002), pp. 51-60.

Preece, J., Rogers, Y. and Sharp, H. (2002) *Interaction Design - Beyond Human Computer Interaction*, John Wiley.

Shneiderman, B. (2002) *Leonardo's Laptop*. MIT Press.

Tarkiainen, M.J., Kauvo, K. and Kaikkonen, J. (2001) *Simple Turn-by-Turn Route Guidance for Pedestrians*. In Proceedings of International Conference on Intelligent Transport Systems.

Tijerina, L., Parmer, E. and Goodman, J. (1998) *Driver Workload Assessment of Route Guidance System Destination Entry while Driving: a Test Track Study*, In Proceedings of 5th ITS World Congress, Seoul, Korea, 1998

Trewin, S., Zimmerman, G. and Vanderheiden, C. (2003) *Abstract User Interface Representations: How well do they Support Universal Access?*, In Proceedings of ACM Conference on Universal Usability, Vancouver, Canada, pp. 77-84.

Weilenmann, A. (2003) *Doing mobility*, Doctoral Thesis, Department of Informatics, University of Gothenburg.

Weiss, S. (2002) *Handheld Usability*. John Wiley & Sons.

Winograd, T. (2001) *Architectures for Context*. Human-Computer Interaction, 16(2,3& 4). Lawrence Erlbaum Associates, pp. 401-419.