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Disabled Persons as Lead Users in Mobile User Interface Design

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| <p>In order to understand user needs, traditionally only current users of a product are examined. Classical research on problem solving shows, however, that current users are strongly constrained by their real-world experience, an effect called functional fixedness. Von Hippel's lead user method takes a totally different approach as it is not based on current users but lead users. Lead users face needs that will be general in a marketplace – but face them months or years before the bulk of that marketplace encounters them, and they are positioned to benefit significantly by obtaining a solution to those needs.</p> <p>The purpose of this study was to investigate if disabled persons could be seen as lead users in mobile user interface design. Another goal was to evaluate the suitability of the selected research methods on the examined user groups.</p> <p>An able-bodied user may suffer from a “situational disability” caused by the environment. In this study the user needs of disabled and “situationally disabled” users were compared. The examined user groups were deaf, blind, and “ordinary” users, who see and hear well. The methods used were photo diary based on a theme, and contextual inquiry combined with an open-ended discussion. The “ordinary” users were examined in situational disability conditions, and disabled users in their ordinary environment, such as home.</p> <p>This research shows that “ordinary” users do face difficulties when using their mobile phones in special situations, i.e. they in fact are situationally disabled. The user needs partially overlap with the needs of disabled users in ordinary situations. Both visually and hearing impaired participants showed innovative and leading edge behaviour. It was concluded that there is a strong indication that disabled persons could be seen as lead users.</p> <p>Photo diary was found to be an effective and easy method for self-documentation – also when studying blind users. No other equipment is needed for documentation, as long as the photos are later reviewed in a separate discussion. No major difficulties occurred in carrying out the contextual inquiry and open-ended discussion. All applied methods were found suitable for all examined user groups.</p> <p>It was recommended that disabled users would be included in mobile user interface design.</p> | | |
| Keywords: | lead users, disabled users, user interface, mobile phone, usability, photo diary, contextual inquiry | |

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1 Introduction

It is broadly acknowledged that when trying to develop successful new products understanding user needs is essential. Traditionally this means exploring the needs of the targeted customers of the product. Several methods for the assessment of current customer needs exist.

Traditionally we examine current users of a product in order to obtain information on user needs that can then be utilized to develop improvements on the current product or new products. Methods, such as observation and interviewing are often used. Classical research on problem solving shows, however, that current users are strongly constrained by their real-world experience, an effect called “functional fixedness” [1, 12]. Thus, those who use an object or see it used in a familiar way are blocked from using that object in a novel way. A screwdriver, for example, is a tool for handling screws but as it is long and sharp it could also be used as a crowbar or chisel. Or if a person is asked to perform a task that requires the use of a wire, he is less likely to unbend a paper clip if he is given the clip attached to papers than if he sees the clip loose [12]. What comes to the use of completely unknown objects or materials, “they cannot imagine what they don’t know about emergent technologies, new materials, and the like” [48]. A current user of a product is *functionally fixed* and therefore not able to broaden his perspective on its use – not able to think out of the box.

It appears extremely difficult to determine the demands of tomorrow’s markets via traditional market research methods. Von Hippel’s lead user method [50, 51] takes a totally different approach as it is not based on current users but lead users. Lead users are users whose present strong needs will become general in a marketplace months or years in the future. Lead users also profit strongly from innovations that provide a solution to those needs.

Lack of functional fixedness makes lead users very appealing to product development – lead users do not base their views on existing products but on their needs. Since familiarity with existing product attributes interferes with the ability to think of novel attributes and uses, the representative target market customers, users

of today's products, seem to be poorly situated to envision novel needs or solutions. In contrast, lead users seem to be better positioned in this respect – they “live in the future” relative to representative target market users, experiencing today what representative users will experience months or years later. [27] Developing products to meet the needs of lead users allows a firm to anticipate trends and to leapfrog competitive products [47]. Lead users found outside of a target market often encounter even more extreme conditions on a trend relevant to that target market. They may, therefore, be forced to develop solutions that are novel enough to represent “breakthroughs” when applied to the target market. [27]

All new things diffuse through a society over time – often over many years – and that is why there are always users whose present needs foreshadow general demand [43]. The main problem in the lead user approach is, however, to identify these users. **In this study I explore the possibility of disabled persons being lead users in mobile user interface design.**

Traditionally mainstream consumer product design has not explicitly considered the needs of older or disabled people. Instead, their needs have been considered in the design of niche products, e.g. disability aids, providing separate, often stigmatising solutions for these user groups. [20] Yet in many ordinary circumstances we all suffer from a “situational disability”. When there is no light, we cannot use our eyesight, for example. When there is a lot of noise, we are not able to hear. When driving a car, we should not use our hands for anything else than driving nor look away from the road.

I argue that if a mobile user interface is designed based on the user needs of the target market, i.e. the majority of consumers that are people who hear and see well, we end up leaving out everyday situations, where the use eyesight and hearing is limited or completely prevented. Yet it is a significant advantage for a mobile phone, for example, to work well in all possible situations. I suggest that if a mobile user interface was designed based on the needs of disabled persons, the special disability situations would be covered as well. In this study I investigate, if the needs of a disabled user in an “ordinary” situation correspond to the needs of an “ordinary” user

in a special situation. In other words, are specifications derived from an actual disability equal to those derived from a situational disability?

In addition to the fact that users who do see and hear undergo moments of situational disability, it should not be forgotten that up to 25 % of population in industrialised countries are older people or people with a disability [20]. The target market of mobile phones being virtually all consumers means that the aging population should not be shrugged aside, as it continues to fill an ever-increasing part of the target market.

This study was carried out by comparing three different groups of users: deaf, blind, and “ordinary” users, who see and hear well. The methods used were photo diary based on a theme, and contextual inquiry combined with an open-ended discussion. **In this study I also evaluate the suitability of the selected methods on the examined user groups.**

Deaf and blind groups were selected to represent disabled persons, because of the clear definition of these groups, and the fact that it was rather easy to access these groups. The “ordinary” users were examined in situational disability conditions in order to compare the appeared needs with the needs of the disabled groups.

Concepts essential to this study are defined in Chapter 2, and Chapter 3 describes the relevant background of this study. Chapter 4 provides a theoretical introduction to the applied methodology, and describes the execution of the methods being used in this study. Results are presented in Chapter 5, followed by discussion and conclusions in Chapter 6. Chapter 7 summarises this study in short.

2 Definitions

This chapter provides definitions relevant to this study. First product development is shortly introduced. In the end of the paragraph it is also explained where the lead user approach fits in product development. Lead user theory and method are explained in the following paragraph. The third paragraph of this chapter presents user interface and specifically mobile phone user interface. This chapter ends with an explanation of different usability definitions.

2.1 Product Development

According to Ulrich & Eppinger [47] product development should be understood as all the activities beginning with the perception of a market opportunity and ending in the production, sale and delivery of a product. Otto & Wood [39] break it down to separate processes: product development process, design process, manufacturing process and research and development (R&D).

A product development process is the set of activities that includes everything from the initial inspiring new product vision, to business case analysis activities, marketing efforts, technical engineering design activities, development of manufacturing plans, and the validation of the product design to conform to these plans. Often it even includes development of the distribution channels for strategically marketing and introducing the new product. [39]

A design process is the set of technical activities within a product development process that works to meet the marketing and business case vision. It includes refinement of the product vision into technical specifications, new concept development, and embodiment engineering of the new product. [39]

The *manufacturing process* follows the product development process, although the design of the manufacturing process is generally considered part of the product development process. If the product design process and the design of its manufacturing system are carried out simultaneously we talk about *concurrent engineering*. [39] The term concurrent engineering is also used, when different design activities are carried out concurrently. [23]

The *research and development* phase of new product development is when new technology is developed for subsequent incorporation into products. Nowadays many companies try to separate the R&D process from the product development process. This means that new technology is developed by R&D teams to the point where the technology is encapsulated into a new system and is then ready for immediate adoption by the product development teams. This arrangement is similar to outsourced subsystems and ideally makes product development a very rapid process where technologies are tailored into new systems that meet changing market needs. In the real world the transfer from R&D to product development is not necessarily smooth. The technology passed on to the product development teams may not function well in the new product concept. This may result from social causes, such as different cultures between R&D corporate research and product development business units, or from the fact that the new technology is used in ways not foreseen by the R&D group. One general problem is also miscommunication of specifications. [39]

The set of activities preliminary to the actual product development is sometimes called the *fuzzy front-end*. This includes the decisions on what products to consider for development. These decisions derive from the determination of what technologies are to be used and in which markets a company should compete. Forecasted customer markets and business trends can also impact these decisions. The fuzzy front-end also includes development decisions on what the underlying portfolio architecture should be for set of products that may be offered by a company. [39] Von Hippel's lead user approach [50, 51] that is considered in this study is one of the methods used to identify unarticulated customer needs in the fuzzy front-end.

2.2 Lead Users

2.2.1 Lead User Theory

There was a time when nobody needed a mobile phone. At least nobody had one. Now almost everybody has one (or even two) and they all claim it would be impossible to live without it. In 1990 less than 10 % of Finns had a mobile phone, in 1998 already 55 %, and in 2003 more than 90 % [46]. According to EMC World Cellular Database [13] global penetration of mobile phones was 41,5 % in the end of 2004, and 91,5 % in European Union. Today there is a clear *need* for a mobile phone.

Rogers [41, 42] talks about diffusion of new ideas through a society, and the fact that a considerable time lag exists from the introduction of a new idea to its widespread adoption. The main elements in the diffusion of new ideas are: (1) an *innovation* (2) that is *communicated* through certain *channels*, (3) over *time* (4) among the members of a *social system*. In spite of the fact that the communication of most innovations involves a time lag, there is certain inevitability in their diffusion. Most attempts to prevent innovation diffusion over an extended period of time have failed. For instance, the Chinese were unsuccessful in their attempt to maintain sole knowledge of gunpowder. And today, the secret of the nuclear bomb is no longer a secret. [41, 42, 43]

According to the diffusion model, an innovation is completely diffused when it has been adopted by 100 % of the members of the social group to which it has been introduced. Rogers divides the adopters into five categories (see Figure 1) [42]:

- *Innovators*: the first 2,5 % who adopt a new technology. They are “venturesome” almost to the point of obsession, and willing to absorb high costs and uncertainties for the reward of being first to adopt new technologies.
- *Early adopters*: the next 13,5 % to adopt. They find it easy to imagine, understand, and appreciate the benefits of a new technology. By many they are considered as “the individual to check with” before using a new idea. The highest number of “opinion leaders” is found among the early adopters.

- *Early majority*: the next 34 % to adopt. They adopt new ideas just before the average member of a system. They follow with deliberate willingness in adopting innovations, but seldom lead.
- *Late majority*: the next 34 % to adopt. They are sceptical about innovations and often adopt only because of the peer pressure those who have already adopted. They often have relatively scarce resources, which means that most of the uncertainty must be removed, before they feel safe to adopt.
- *Laggards*: the final 16 % to adopt. They are traditionalists and tend to be suspicious of innovations. They possess almost no opinion leadership. The point of reference for the laggard is the past. [42]

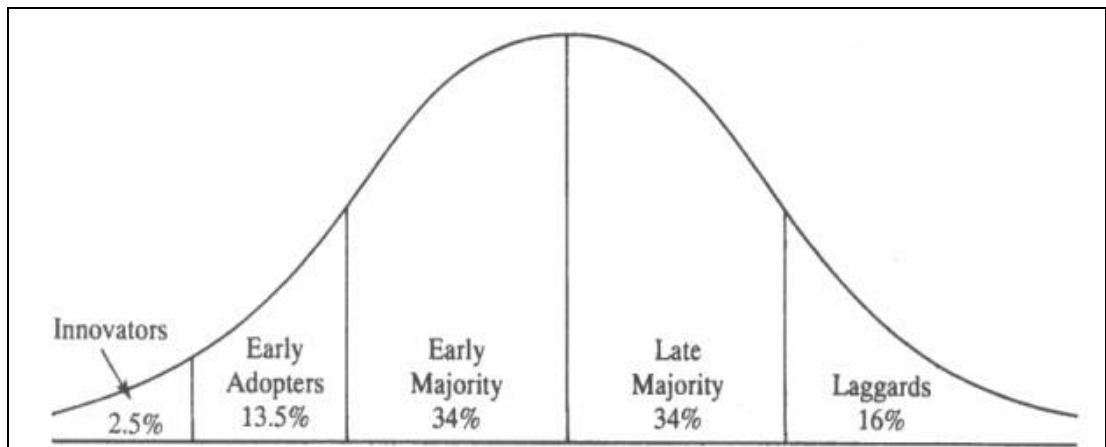


Figure 1 Rogers's diffusion curve [42]

The theory of *lead users* relies on the idea that there is always somebody who has the need first, and that the rest of the marketplace will have the need later. As all new things diffuse through a society over time, *there are always users whose present needs foreshadow general demand* [43]. Von Hippel [50] introduced the term 'lead user' in 1986. He defines lead users of a novel or enhanced product, process, or service as those displaying two characteristics with respect to it:

1. Lead users face needs that will be general in a marketplace – but face them months or years before the bulk of that marketplace encounters them, *and*
2. Lead users are positioned to benefit significantly by obtaining a solution to those needs [50].

According to the first lead user characteristic there are users who experience new needs and are prepared to generate innovations that substantially differ from existing market offers. The second characteristic reflects the possibility of the users initiating the development of a new solution if the solution would bring them significant benefit. [51] In other words, lead users are well ahead of market trends and have needs that go far beyond those of the average user. [55]

The main question is *how to find a lead user*. Lead user is often somebody who is trying to improve his way of working rather than consciously trying to invent. Like the developer of World Wide Web Tim Berners-Lee says: “it was something I needed in my work” [6]. Berners-Lee wanted simply to solve a problem that was hindering his efforts as a consulting software engineer at CERN, the European particle-physics laboratory in Geneva. Mainly to become more efficient, he developed a system that provided easy-to-follow links between documents stored on a number of different computer systems and created by different groups. He expanded the idea he had developed at CERN and made it available on the Internet in the summer of 1991. [6]

Very often lead users will have already invented solutions to meet their needs. This is particularly true among highly technical user communities, such as those in the medical or scientific fields [47]. Developers of open source software are a clear example of lead users. They profit by using the software improvements that they develop. [52]

Innovations in sporting equipment are often developed by lead users. Shah [44] shows that innovations in skateboarding, snowboarding and windsurfing have typically been developed by a few early expert participants in those sports. The innovating users are in their teens or early twenties and technically unsophisticated. They develop their innovations via learning-by-doing in these novel and rapidly evolving fields.

Lead users can also be found among those who function in harsh conditions. Innovations by lead users can take place among professional athletics, aerospace, or military solutions, for example.

The idea for the heart rate monitor was originated by professor Seppo Säynäjäkangas already in early 1970's. He enjoyed cross-country skiing, and he started wondering what methods could be used to monitor the development of his condition. Suomen Hiihtoliitto (Finnish Ski Association) soon became interested in the idea and started developing a prototype with professor Säynäjäkangas. Later this invention has been utilised by all competitive athletes, and nowadays the heart rate monitor has been diffused to serve a big part of people who enjoy recreational sports. [58]

The energy bar was invented by Olympic marathoner Brian Maxwell. He conceived of the idea of an endurance-boosting bar for athletes after “bonking” (what runners call the point at which the body runs out of carbohydrates and starts burning muscle) in a 1983 race. Working with his girlfriend Jennifer, a nutritionist, the pair came up with an energy bar that athletes could eat before and during events. In 1986, they began making PowerBars in their kitchen.

When 3M, a diversified technology company, was trying to develop cheaper and more effective infection control in the area of surgical drapes^a, they went to gather information outside the target market, in order to find lead users. They travelled to hospitals in Malaysia, Indonesia, South Korea, and India, and learned how people in less than ideal environments attempt to keep infections from spreading in the operating room. They interviewed veterinarians who had great success keeping infection rates low despite cost constraints and the fact that their patients were covered with hair and didn't bathe. They interviewed Hollywood makeup artists who had learned effective ways to apply non-irritating, easy-to-remove materials to skin – which is important to the design of infection control materials. With the help of lead users, 3M was able to create three new product-line concepts. [55]

It is to be noticed that lead users are not just individual consumers but they can also be large companies. For example, an auto company might have a need for a novel machine tool. The auto company is the user of products supplied by a machine tool

^a Surgical drapes are thin adhesive-backed plastic films that are adhered to a patient's skin at the site of surgical incision, prior to surgery. Surgeons cut directly through these films during an operation.

manufacturing firm, and it is also much bigger than the machine tool manufacturer. A single firm can then function both as a user innovator and a manufacturer innovator. If an airplane manufacturer develops a tool to help build airplanes, it has developed an innovation as a user. In contrast, when it develops an innovative new aircraft to manufacture and sell, it has in that case developed a manufacturer innovation. [54]

When trying to identify a lead user, it should be remembered that lead users can be found from a totally different branch of industry than the one of the possible application. If a manufacturer of materials used in autos identifies a trend toward lighter, higher strength materials, he may find the lead users at the front of this trend are aerospace firms rather than auto firms, because aerospace firms may be willing to pay more than auto firms for improvements of these attributes. [50]

If an automobile manufacturer wanted to design an innovative braking system, it might start by trying to find out if any innovations had been developed by drivers with a strong need for better brakes, such as auto racers. Next, it would look to a related but technologically advanced field where people had an even higher need to stop quickly, such as aerospace. And, in fact, aerospace is where innovations such as antilock braking systems (ABS) were first developed: military aircraft commands have a very high incentive to stop their vehicles before running out of runway. [55]

It is important to distinguish lead users from the categories defined by Rogers [42]. Lead user acts solely on his needs, when innovators and early adopters are driven by their interest in the new technology. In other words, as stated by von Hippel [52]: “Note that **lead users are not the same as early adopters** of an innovation. They are typically ahead of the entire adoption curve in that they experience needs before any responsive commercial products exist – and therefore often develop their own solutions.” See Figure 2.

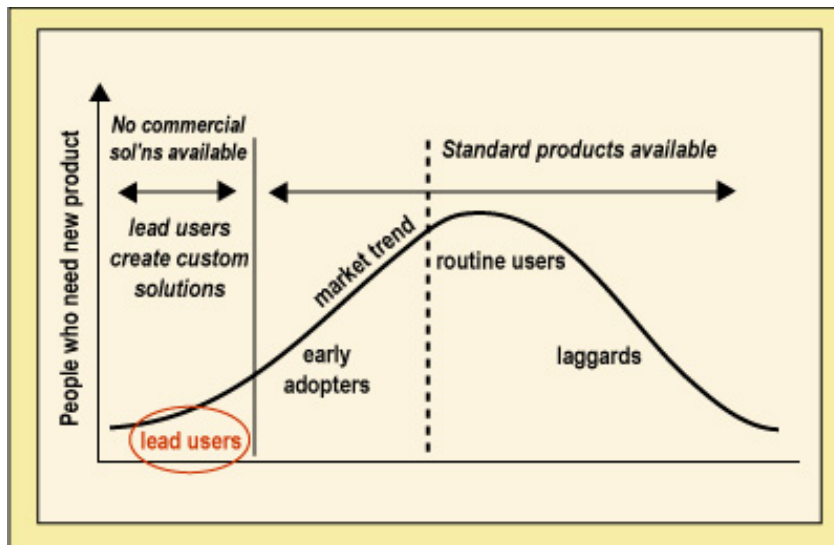


Figure 2 Lead users' position on a market trend [53]

What makes the lead user concept interesting is the hypothesis originally proposed by Duncker already in 1945: Problem solving may be inhibited by the functional fixedness of solution objects [12]. His example on a chimpanzee using a stick describes the term quite well: “A stick that has just been used as a ruler is less likely to appear as a tool for other purposes than it would normally be.” This means that if we examine users that are already familiar with the product, we might find them not to be able to generate new ideas for its use. They are *functionally fixed* and then not able to think out of the box. The functional fixedness however is seen to decrease with increasing time following initial use of the object, i.e. lapse of time following the use of the object weakening the association between the object and the specific function [2]. Lack of functional fixedness makes lead users very appealing to product development – lead users do not base their views on existing products but on their needs.

As lead user's present strong need will become general in a marketplace, but it will take months or even years for that to happen, lead users can be used as a need-forecasting laboratory for marketing research. In addition to the need data, they can provide valuable new product concept and design data, because of their attempt to fill the need they experience. [51] Developing products to meet these needs that are still latent for the majority of the market allows a firm to anticipate trends and to

leapfrog competitive products [47]. Analysis of data from lead users can improve the productivity of new product development in fields characterized by rapid change [50].

2.2.2 Lead User Method

The lead user methodology was proposed by Urban and von Hippel in 1988 after their prototype lead user market research study in the field of CAD products. The method that was used to identify lead users and test the value of the data they possess in the CAD field involved four major steps: (1) identify an important market or technical trend, (2) identify the lead users with respect to that trend, (3) analyze lead user data, and (4) test lead user data on ordinary users. [51]

Later the same year Urban and von Hippel introduced more general methodology for concept development and testing consisting in the following 4 steps [49]:

1. *Specify lead user indicators*

- A. *Find market or technological trend and related measures*

Lead users are defined as being in advance of the market with respect to a given important dimension which is changing over time. Therefore, before one can identify lead users in a given product category of interest, one must specify the underlying trend on which these users have a leading position, and must specify reliable measures of that trend.

- B. *Define measures of potential benefit*

High expected benefit from solving a need is the second indicator of a lead user, and measures or proxy measures of this variable must also be defined. In work to date, we have found three types of proxy measures to be useful. First, evidence of user product development or product modification can serve as a proxy for user benefit because, as we noted previously, user investment in innovation and user expectations of related benefit have been found to be correlated. Second, user dissatisfaction with existing products (services and processes) can serve as a proxy for expected benefit because it is logical that the degree of dissatisfaction with what exists will be correlated with the degree of expected benefit obtainable from improvements. Finally, speed of

adoption of innovations may also serve as a surrogate for high expected benefit. Early adoption and innovativeness have been found often correlated with the adopter's perception of related benefit [43].

2. Identify lead user group

Once trend and benefit indicators are specified, one may screen the potential market based on the measures specified above via questionnaire and identify a lead user group. This is accomplished by a cluster analysis of the survey-based lead user indicators to find a subgroup which is the leading edge of the trend being studied and displays correlates of high expected benefit from solutions to related needs.

3. Generate concept (product) with lead users

The next step in the method involves deriving data from lead users related to their real-life experience with novel attributes and/or product concepts of commercial interest. This experience may include modifications to existing products or new products which they have created to meet their needs. Creative group sessions can be used to pool user solution content and develop a new product concept. In some cases the user solution may represent not only a concept but a fully implemented product.

4. Test lead user concept (product)

The needs of today's lead users are typically not precisely the same as the need of the users who will make up a major share of tomorrow's predicted market. Indeed, the literature on diffusion suggests that, in general, the early adopters of a novel product or practice differ in significant ways from the bulk of the users who follow them [41]. One therefore next assesses how lead user data are evaluated by the more typical users in the target market. This can be done by employing traditional concept (product) test procedures after segmenting lead and non-lead user responses.

2.3 User Interface

2.3.1 General Definition

Several definitions for user interface can be found in literature.

Moran [30] defines user interface as:

“Those aspects of the system that the user comes in contact with.”

Maddix’s [28] definition conforms with Moran’s:

“...the parts of the system with which the user comes into contact physically, perceptually, or cognitively.”

Chi [8] translates Moran’s definition into:

“an input language for the user, an output language for the machine, and a protocol for interaction”

Preece et al. [40] go further into detail:

“The totality of surface aspects of a computer system, such as its input and output devices, the information presented to or elicited from the user, feedback presented to the user, the system’s behaviour, its documentation and associated training programmes, and the user’s actions with respect to these aspects.”

To evaluate the quality of a user interface Nielsen [35] lists ten general principles that he calls “heuristics”:

1. **Visibility of system status.** The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
2. **Match between system and the real world.** The system should speak the user’s language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

3. **User control and freedom.** Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support “undo” and “redo”.
4. **Consistency and standards.** Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
5. **Error prevention.** Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.
6. **Recognition rather than recall.** Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
7. **Flexibility and efficiency of use.** Accelerators – unseen by the novice user – may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
8. **Aesthetic and minimalist design.** Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
9. **Help users recognize, diagnose, and recover from errors.** Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
10. **Help and documentation.** Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

2.3.2 Mobile Phone User Interface

The mobile phone represents a new type of user interface domain that differs from the desktop computing environments:

- The devices are small so the user interface only has a small physical footprint available.
- The input and output capabilities, and the processing power and available memory are limited.
- The mobile and social usage context and the reasons for use pose new requirements and design challenges.
- Mobile phones are mechanical devices, and in order to give enough time for the industrial and mechanical design in the development process, control keys must be decided earlier in the process than when designing a desktop software system. [24]

Ketola [23] divides interaction components of a mobile phone interface into user interface, external interface, and service interface (see Figure 3).

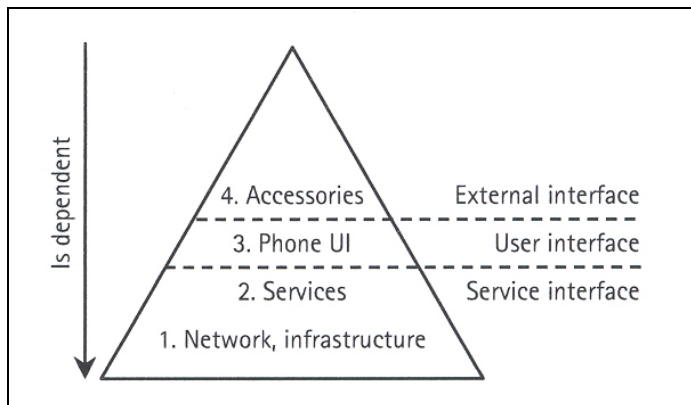


Figure 3 Interface hierarchy [23]

The external interface is not physically part of the device. It includes user support materials, such as manuals, accessories e.g. chargers, and support software, such as downloadable applications. The service interface is the user's view of the available mobile operator's or service provider's mobile services visible through the mobile phone user interface. [23]

Kiljander [24] reminds that some accessories may be able to access the service interface without the mobile phone in-between, and presents the interface interdependencies as seen in Figure 4.

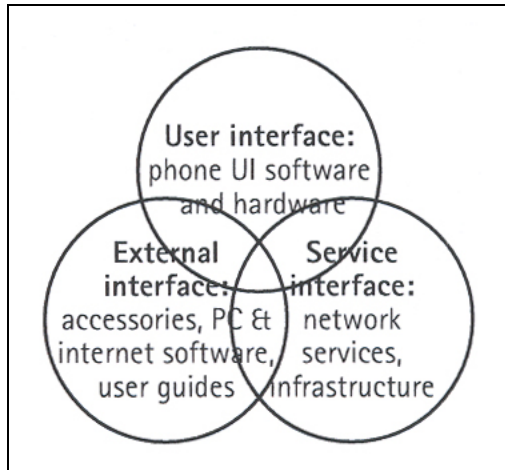


Figure 4 Interface interdependencies [24]

2.4 Usability

“When you have trouble with things – whether it’s figuring out whether to push or pull a door or the arbitrary vagaries of the modern computer and electronics industry – it’s not your fault. Don’t blame yourself: blame the designer. It’s the fault of the technology, or, more precisely, of the design.”
(Donald A. Norman [36])

There is no generally agreed upon definition of usability nor can usability be expressed in one objective measure. Several definitions and categorisations have been presented, and they agree at least on the concept of usability. In the more detailed level the definitions vary, but one common attribute seems to be *learnability*. Nielsen’s [34] and Shneiderman’s [45] definitions go hand in hand. Dix, Finlay, Abowd, and Beale [11] propose a categorisation that focuses more on the concrete elements that influence usability.

In ISO 9126 [22] usability is defined as a software quality attribute. Usability is seen as a set of “attributes that bear on the effort needed for use, and on the individual assessment of such use, by a stated or implied set of users”. ISO 9126 defines usability in terms of *understandability*, *learnability*, *operability*, and *attractiveness*.

ISO 9241 [21] gives a rather abstract definition in terms of effectiveness, efficiency, and satisfaction:

Effectiveness: Measures of effectiveness relate the goals or sub goals of the user to the accuracy and completeness with which these goals can be achieved.

Efficiency: Measures of efficiency relate the level of effectiveness achieved to the expenditure of resources. Relevant resources can include mental or physical effort, time, materials or financial cost. For example, human efficiency could be measured as effectiveness divided by human effort, temporal efficiency as effectiveness divided by time, or economic efficiency as effectiveness divided by cost.

Satisfaction: Satisfaction measures the extent to which users are free from discomfort, and their attitudes towards the use of the product. [21]

Dix, Finlay, Abowd, and Beale [11] present usability principles that are divided into three main categories:

1. *Learnability*: The ease with which new users can begin effective interaction and achieve maximal performance
2. *Flexibility*: The multiplicity of ways the user and system exchange information.
3. *Robustness*: The level of support provided to the user in determining successful achievement and assessment of goals.

The principles of each category are presented in Table 1.

Table 1 Usability categorisation by Dix et al. [11]

| Learnability | Flexibility | Robustness |
|---------------------|--------------------|-------------------|
| Predictability | Dialog initiative | Observability |
| Synthesizability | Multi-threading | Recoverability |
| Familiarity | Task migratability | Responsiveness |
| Generalizability | Substitutivity | Task conformance |
| Consistency | Customizability | |

Nielsen [34] defines usability with five attributes:

1. *Learnability*: The system should be easy to learn so that the user can rapidly start getting some work done with the system.
2. *Efficiency*: The system should be efficient to use, so that once the user has learned the system, a high level of productivity is possible.
3. *Memorability*: The system should be easy to remember, so that the casual user is able to return to the system after some period of not having used it, without having to learn everything all over again.

4. *Errors*: The system should have a low error rate, so that users make few errors during the use of the system, and so that if they do make errors they can easily recover from them. Further, catastrophic errors must not occur.
5. *Satisfaction*: The system should be pleasant to use, so that users are subjectively satisfied when using it; they like it. [34]

Shneiderman's [45] definition is essentially identical to Nielsen's definition, and only differs in terminology: *time to learn*, *speed of performance*, *rate of errors by users*, *retention over time*, and *subjective satisfaction*.

Nielsen's definition of usability must be the most famous one, as his name is rarely left unmentioned whenever usability is discussed. Nielsen's five usability attributes are here presented in detail:

Learnability

The most important attribute is learnability, since the first experience the user has with the system is that of learning to use it. In most cases systems need to be easy to learn, although there are systems for which one can afford to train users extensively to overcome a hard-to-learn interface. [34]

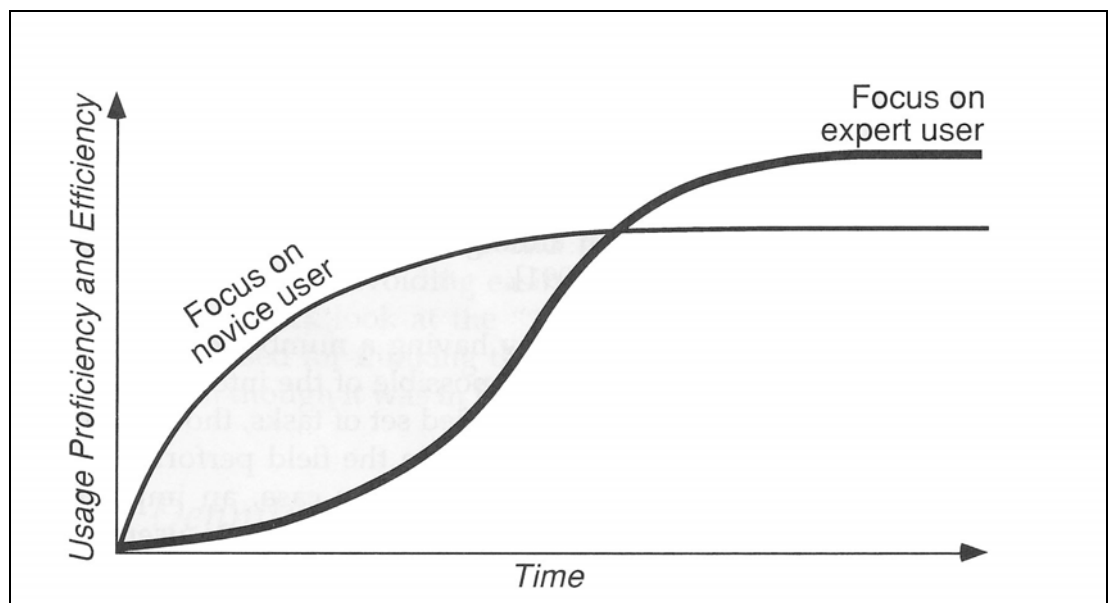


Figure 5 Learning curves for a hypothetical system that focuses on the novice user, being easy to learn but less efficient to use, as well as one that is hard to learn but highly efficient for expert users. [34]

Learning curves of a novice user and an expert user can be used to visualise learnability and efficiency of a system (Figure 5). Ease of learning refers to the novice user's experience on the initial part of the learning curve. Almost all user interfaces have learning curves that start out with the user being able to do nothing at time zero. There are, however, systems that are intended to be used only once, like information systems in public places, and therefore need to have zero learning time. In case of a system upgrade, users are transferring skills from previous systems and the standard learning curve does not apply. [34]

Initial ease of learning is perhaps the easiest of the five usability attributes to measure. One picks users with zero knowledge of the system and measures the time it takes them to reach a specified level of proficiency in using it. Albeit measuring learnability seems relatively simple, it should be kept in mind that users often jump right in and start using a system without thoroughly mastering it. Besides measuring how long it takes to achieve complete understanding of a system, it is then reasonable to measure how long it takes to achieve a sufficient level of proficiency to do useful work with the system. [34]

Efficiency of Use

Efficiency refers to the expert user's steady-state level of performance at the time when the learning curve flattens out (see Figure 5). It can be measured by measuring the time it takes an expert user to perform a test task. The problem however is to define the level of expertise. Informally an expert user can be defined as somebody who has used the system a certain amount of time, such as a year. This applies to systems that have been in use for some time. More formally the expertise of a user can be defined in terms of number of hours spent using the system. This definition is often used in experiments with new systems without an established user base: Test users are asked to use the system for a certain number of hours, after which their efficiency is measured. [34]

Memorability

Casual users do not use a system regularly but intermittently. These users are the third major user category besides novice and expert users. Casual users do not use a system as frequently as expert users but they are not completely new to a system

either as novice users are, so they do not need to learn it from scratch. Typical example is a system that is not part of user's primary work and therefore not regularly used but comes in handy every now and then. Memorability is important also when a user stops using the system for some reason, such as a vacation. Improvements in learnability often also make an interface easy to remember, but in principle, the usability of returning to system is different from that of facing it for the first time. [34]

There are two ways of measuring memorability, although it is rarely tested as thoroughly as the other usability attributes. A standard user test can be performed with casual users who have been away from the system for a specified amount of time. This means measuring the time they need to perform some typical test tasks. Alternatively, it is possible to conduct a memory test with users after they finish a test session with the system and ask them to explain the effect of certain commands or to name the command that does a certain thing. The interface's score for memorability is then the number of correct answers given by the users. [34]

Errors

An error is defined as any action that does not accomplish the desired goal, and the system's error rate is measured by counting the number of such actions made by users while performing some specified task. Error rates can thus be measured as part of an experiment to measure other usability attributes. It should however be seen that all errors are not alike. Some errors can be corrected immediately by the user and have no other effect than to slow down the user's transaction rate. Other errors are more severe in nature, either because they are not discovered by the user, leading to a faulty work product, or because they destroy the user's work. Special efforts should be made to minimize the frequency of such catastrophic errors. [34]

Subjective Satisfaction

Subjective satisfaction refers to how pleasant it is to use the system. For systems that are used on a discretionary basis in a non-work environment, such as home computing and games, the entertainment value is often more important than the speed with which things get done. For measuring the subjective satisfaction some psycho-physiological measures such as EEGs, pupil dilation, heart rate, etc. can be

used. Alternatively, it may also be measured by simply asking the users for their subjective opinion. Since the entire purpose of having a subjective satisfaction usability attribute is to find out whether users like the system, it seems highly appropriate to measure it by asking the users. [34]

3 Background

This chapter presents research related to this study and provides information about visually and hearing impaired mobile phone users.

3.1 Related Research

No research reported on disabled persons seen as lead users can be found, but there are some notions proposed in the field of “situational disability”.

Newell [31] proposes the concept of “Ordinary and Extra-ordinary human-machine interaction”. This draws the parallel between an “ordinary” (able-bodied) person operating in an “extraordinary” environment, e.g. high work load, adverse noise, or lighting conditions, and an “extraordinary” (disabled) person operating in an ordinary environment. He introduces the concept of considering a ‘user’ as being defined by a point in the multi-dimensional space, which specifies their functionality and the relationship of that functionality to the environment in which the user operates. In other words this means that otherwise fully functioning people can be seriously handicapped by hostile environments

Newell & Gregor [33] show situations where people are using standard equipment, but not in standard locations, and are therefore effectively disabled: If a laptop or palmtop computer has to be operated while the user is standing and cannot rest the system on a ledge, then effectively the user is one-handed. In a noisy environment communication systems which are designed for deaf or speech-impaired people may be appropriate. Using technology designed to provide access for people with visual impairments should be considered in darkness or in situations when there is smoke. Many industrial situations require wearing protective clothing which reduces sensory input as well as manual dexterity. Newell & Gregor [33] also note that Norwegian Telecom developed a large-key telephone keyboard specifically for people with poor manual dexterity, but found that it was very useful in outdoor locations where users tended to wear gloves.

VTT Building and Transport department of VTT Technical Research Centre of Finland conducted a research project called NAVITarve that concentrated on user

needs for personal navigation services [3]. This study consisted of three parts that were reported separately. The objectives of the third part were to investigate in detail the information needs of different users in different travelling situations, and to explore the problems and information needs of users in different events of everyday life not just limited to travelling situation.

Mainly two methods were used in data collection in NAVITarve study: personal diaries and group meetings. In addition, a limited (48 respondents) conjoint analysis was carried out. 85 users participated in the group meeting or filled in a personal two-day diary. Most of the users studied were “typical” users that were interested in information content, not so much in the technology that would provide the information to them. Among other groups, three groups of “critical” users were studied: visually impaired people, people with memory disorders, and mobility impaired people. [3]

It was assumed that these “critical” users would provide essential information about user needs not only for themselves, but also for others in “critical” situations of use: dark or unfamiliar environment, stressful use situation, or moving with luggage, pram, or bicycle. The results from “critical” user groups revealed that “critical” users often need information that is similar to all other users. Approximately 50 % of those information needs expressed by “critical” users were same as those information needs expressed by “typical” users. It was concluded that majority of these information needs can be seen to facilitate travelling for anybody in less than ideal situation, such as unfamiliar environments, travelling with luggage, etc. [3]

Newell [31], Newell & Gregor [33], and NAVITarve [3] show several examples of “situational disability” but they do not link their findings to the lead user theory.

3.2 Visually and Hearing Impaired Mobile Phone Users

According to World Health Organization (WHO), globally in 2002 more than 161 million people were visually impaired, of whom 124 million people had low vision and 37 million were blind [56]. WHO estimates that in 2002 there were 250 million people in the world that had disabling hearing impairment [57].

There are estimates that 15 % of adult population in Finland would be hearing impaired. The number of all hearing impaired persons in Finland is estimated to be circa 740 000, of whom 290 000 need rehabilitation. Use of hearing aid is supposed to assist 85 % of the hard of hearing. 8 000 people are deaf, of whom 5 000 have sign language as their native language. [26]

There are circa 80 000 visually impaired in Finland, of whom 10 000 are blind. Great majority of the visually impaired, possibly even 70 000, is more than 65 years old. [38]

Kuurojen Liitto (Finnish Association of the Deaf) believes the penetration of mobile phones among the deaf to be at least as high as among the general population of Finland. It can be assumed that the penetration of mobile phones among the blind correlates to the general population respectively. According to EMC World Cellular Database [13] the mobile phone penetration in Finland in the end of 2004 was 93 %.

4 Methodology

The first part of this chapter provides theoretical background to the methods used in this study. The second part explains in detail the methods being used.

4.1 Methods Background

4.1.1 Probing

The word ‘probe’ suggests an automatic recording device that is sent to unknown territories where human researchers cannot go to collect samples, and to send these back to the researchers [29].

Probes Approach

The probes approach was first applied by Gaver et al. in 1999 [14]. They used *cultural probes* to inspire the design of new technologies. The work was part of European Union-funded research project called Presence looking at novel interaction techniques to increase the presence of the elderly in their local communities, and it was executed in three different cities or towns around Europe. The cultural probes package (see Figure 6) included material that was designed to provoke inspirational responses from elderly people in diverse communities. The purpose of cultural probes was not trying to reach an objective view of the elders’ needs, but instead a more impressionistic account of their beliefs and desires, their aesthetic preferences and cultural concerns. The goal was to gather inspiration, not information. Hemmings et al. [17] and Crabtree et al. [10] propose that probes and probes hybrids could also be used to gather not only inspiration but ethnographic information from “socially sensitive settings”.

The core of the probes approach is to give people (possible future users) tools to document, reflect on and express their thoughts on environments and actions. Probes are specially designed material packages for self-documentation and they contain different documenting assignments and reflective parts. These packages can contain disposable cameras, stickers, diary-booklets, pre-stamped postcards with open questions etc. In the cultural probes package used by Gaver et al. there were also maps with an accompanying inquiry exploring the elder’s attitudes toward their

environments (see Figure 6). Including separate playful items in the package can affect the motivation of starting the documentation. The ambiguous stimuli that allow expression verbally, visually and through action enable the participants to express their emotions easier. Having several items in the package provides a possibility to the participant to select the tasks that they think are relevant and they feel comfortable with. The probes packages are often purposefully designed to provoke, reveal, and capture for analysis the motivational forces that shape an individual. [14, 17, 18, 29]



Figure 6 A cultural probe package containing maps, postcards, booklets, and a camera. [14]

Besides cultural probes, the probes approach has been applied as domestic probes, technology probes, and mobile probes. *Domestic probes* have been applied to address both what role technology might play in the home of the future and, specifically, how it can support existing domestic values. *Technology probes* are simple, flexible, adaptable technologies with three interdisciplinary goals: the social science goal of understanding the needs and desires of users in a real-world setting, the engineering goal of field-testing the technology, and the design goal of inspiring users and researchers to think about new technologies. Results from technology probes have given insights into practical needs and more playful desires but have also provided

real-life use descriptions. The pilot study of *mobile probes* was based on dual band mobile phones with GPRS connections and an external accessory digital camera. As cultural probes often seem to work in a retrospective mode, mobile probes captured the fresh sense of context and action. The system was dynamic and interactive. Since all material was collected in digital form, data sharing and analysing was easier. [15, 17, 18, 19]

Photo Diary

Self-photography has been used in various disciplines. In social sciences it is one possible technique for field observations. As disposable cameras are often included in a probes package, self-photography can be used also in probing. The subjects are given cameras and asked to take photographs either with or without specific assignments. In self-photography the observed has thus the control and as Ziller [59] says “the understanding begins with the view through the eyes of observed”. [18]

The disposable camera included in the cultural probes package was repackaged to separate it from its commercial origins and to integrate it with the other probe materials. On the back of the camera there was a list of requests for pictures, such as: your home, what you will wear today, the first person you see today, something desirable, something boring. About half of the pictures were unassigned, and the elders were asked to photograph whatever they wanted to show the researchers before mailing back the camera. [14]

An example of a theme-based photo diary is touch diary. The subjects are asked to take a photograph every time they touch something. [9]

Another example of the use of self-photography was reported by Brown et al. [7]. The subjects were equipped with digital cameras to use over the course of 7 consecutive days (covering on average 5 working days and 2 days at home). Subjects were asked to use the camera whenever during the course of each day they felt the need to “capture” some information either at work or at home. It was emphasized that they should use the camera as a diary tool rather than as a conventional camera. They were told to take a picture whenever they actually captured some information in the course of their day, or whenever they would have like to have captured

information but did not have the means. The advantage of this method was in gathering data during action. The users found photographing easy and less laborious than writing notes in diaries. The photographs themselves were used later as illustrations and as memory joggers in semi-structured interviews that followed the documenting period. The interviews were tape recorded and fully transcribed, producing a large corpus of information. [7]

4.1.2 Contextual Inquiry

Contextual design is a full front-end design process that takes a cross-functional team from collecting data about users in the field, through interpretation and consolidation of that data, to the design of product concepts and a tested product structure. Contextual design process can be divided into seven parts: Contextual Inquiry, Work modelling, Consolidation, Work redesign, User Environment Design, Mock-up and test with customers, and Putting into practice. [4]

Beyer and Holtzblatt [4] define contextual inquiry as follows:

“Contextual inquiry is a field data-gathering technique that studies a few carefully selected individuals in depth to arrive at a fuller understanding of the work practice across all customers. Through inquiry and interpretation, it reveals commonalities across a system’s customer base.”

Contextual inquiry includes one-on-one interviews with customers in their workplace. A contextual interviewer observes users as they work and asks about the users’ actions step by step to understand their motivations and strategy. Through discussion, the interviewer and user develop a shared interpretation of the work. [5]

The first and most basic requirement of contextual inquiry is the principle of *context*. Staying in context enables us to gather ongoing experience rather than summary experience, and concrete data rather than abstract data. Gathering data on an ongoing experience means that the interviewer is present when work is being done. If you are asked, your answers tend to be summarised. It is very difficult to go into detail and describe exactly what happened. The job of the interviewer is to recognise the actual work structure, which arises out of details of mundane work actions. In order to

discover concrete data instead of abstract data it is very important talk in concrete terms. When the customer says “generally I do this” or “usually...” the interviewer must pull the customer back to real experience. To gather concrete data you need to ask questions like “what did you do last time” instead of “what do you do usually”. [4]

The principle of *partnership* means that the interviewer and the customer are collaborators in understanding the customer’s work. The only person who really knows everything about his work is the one doing it. The traditional interviewing relationship model tilts power too much toward the interviewer, because the interviewer controls the questions, the discussion, and how long is spent on a topic. Instead of the relationship of interviewer and interviewee, expert and novice, or guest and host, the interviewer and the customer should be partners. [4]

The interviewer must constantly check his *interpretation* of the event with the customer. What matters is the interpretation of the facts, not the facts themselves. To ensure the interpretation is true it is important to create and maintain the right relationship with the customer. When the interviewer pays close attention to the customer, and really takes in interest, the customer becomes invested in making sure the interviewer gets it right and sees everything that is relevant and important to him. [4]

Focus defines the point of view interviewer takes while studying work. The interviewer needs to guide the customer in talking about the part of the work that is relevant. Each interviewer sees a different aspect of the work, all of which are “true”, but which may be more or less relevant, depending on what is being designed. [4]

Contextual inquiry helps us to understand the real environment people live in and work in, and it reveals their needs within that environment. It uncovers what people really do and how they define what is actually valuable to them. [25]

4.2 Methods Used

4.2.1 Overview

Three members of three different groups of mobile phone users were studied and compared: deaf, blind, and “ordinary” users who see and hear well. Deaf and blind groups were selected to represent disabled persons, because of the clear definition of these groups, and the fact that it was rather easy to access these groups. Blind and deaf persons were contacted through several associations and societies, such as Näkövammaisten keskusliitto (Finnish Federation of the Visually Impaired) and Kuurojen Liitto (Finnish Association of the Deaf). My announcement of this study was published on the electronic bulletin boards of the societies, after which the volunteers would contact me directly by e-mail or by phone. One deaf person was found through personal contacts. Also the “ordinary” users were found through personal contacts. The three deaf persons were deaf since birth. Two of the blind participants were congenitally blind, and one had lost his eyesight in his adulthood.

The methods used were photo diary based on a theme, and contextual inquiry combined with an open-ended discussion. There were two meetings with every participant. The first meeting was a short 30-minute meeting where participants were given the photo diary assignment. Approximately two weeks later in the second meeting the contextual inquiry and the open-ended discussion were carried out. At the same time the photo diary results were talked through and used as inspiration in the discussion. An outside interpreter from Pääkaupunkiseudun Tulkkikeskus took part in the meetings with the deaf participants.

The study was piloted with one “ordinary” user. The photo diary was carried out as planned. The pilot revealed that the use of flash on the disposable camera was a bit complicated. This problem was addressed by giving the participants step-by-step instructions on the use of the disposable camera. The tasks to be performed by “ordinary” users in special situations were shaped up during the pilot study.

In addition to the nine participants presented above, two open-ended interviews were carried out. First interview included two persons who have progressively lost a major part of the eyesight in their adulthood. The second interview included one person

who had a similar visual disability but who suffered also from a severe hearing impairment. Two of these persons were found through personal contacts. One was a volunteer found through a society of the visually impaired. The purpose of these interviews was to gain a wider perspective on disability in general, since these persons had seen both worlds. Besides, all three had tried out a variety of mobile communication devices.

All participants are listed in Table 2. (See also Appendix 2.)

Table 2 List of participants and their mobile phones

| user | sex | age | mobile phones |
|--------------------------------------|------------|------------|---|
| blind 1 | female | 34 | Nokia 8310 (personal), Nokia 1100 (personal) |
| blind 2 | female | 58 | Nokia 3660 (personal) |
| blind 3 ¹ | male | 36 | Nokia 6600 (personal) |
| deaf 1 | male | 25 | Nokia 6100 (personal), SonyEricsson Z1010 (personal), Nokia 6600 (work) |
| deaf 2 | male | 33 | Nokia 9110 (personal), SonyEricsson Z1010 (personal), Nokia 6310i (personal), Nokia 9110 (work) |
| deaf 3 | female | 28 | Nokia 6820 (personal) |
| ordinary (pilot) | female | 27 | Nokia 3510 (personal) |
| ordinary 1 | male | 29 | Siemens ST60 (personal) |
| ordinary 2 | female | 30 | Nokia 6600 (personal) |
| ordinary 3 | male | 60 | Nokia 9210i (personal, work), Nokia 6230 (personal, work) |
| severe visual impairment | male | 43 | Nokia 6600 (personal, work) |
| severe visual impairment | male | 37 | Nokia 6600 (personal, work) |
| severe visual and hearing impairment | male | 57 | Nokia 9300 (personal) + Nokia LPS-4 inductive loop set |

¹ Not congenitally blind. Not able to read braille.

4.2.2 Photo Diary

The photo diary assignment consisted of a disposable camera and a stamped return envelope. Instructions to use the camera were given verbally in the first meeting, and also on paper or by e-mail depending on the person's choice. The theme of the photo diary was to take a picture of "everything you use for communication, or use for receiving and transmitting information". Some general examples were given:

- If you read a newspaper, take a picture of the newspaper.
- If you listen to the radio, take a picture of the radio.
- If you check the temperature, take a picture of the thermometer.
- If you use a mobile phone, take a picture of the mobile phone.

The time frame within which the photo diary was supposed to be carried out was one day starting from waking up in the morning until going to sleep in the evening. The participants could choose the day themselves. (See pictures in Figure 7.)

The blind participants were advised in practice on how to use the disposable camera. Since the pilot study had showed that there might be problems with the flash when using a disposable camera, step-by-step instructions were given to all participants on paper or by e-mail.

No additional equipment was required – just the disposable camera.

It was possible to take 28 pictures with the camera, but participants were advised not to worry, if in the end of the day they have taken only 10 photos. The important thing was to document all possible things and equipment that is used according to the given theme. After finishing the photo diary, the camera was to be sent back to me (within two weeks) in the stamped return envelope, for me to develop the pictures.



Figure 7 Photo diary pictures

4.2.3 Contextual Inquiry and Open-ended Discussion

In the second meeting the pictures taken in the photo diary assignment were discussed one-by-one. The participant explained the meaning of each picture in the order they were taken. Each object in the pictures was discussed in detail: how many times it was used during the day, why, and for which purposes.

The use of mobile phone was discussed according to the principles of contextual inquiry. What have you done with your mobile phone today? Show me how you do it. What devices have you used this week? For which purposes? Why? Show me.

The disabled users were observed when using their own mobile phones in their ordinary environment, such as home or work environment.

The “ordinary” users were observed when using their mobile phones in special situations that included complete darkness, and noisy environment. These special situations were created in the participant’s home. Complete darkness was achieved in a walk-in closet or in a bathroom. Noisy environment was created by using an industrial hearing protector headset that included total noise-cancelling and an FM radio (see Figure 8). All sounds from surrounding environment were blocked out and replaced with music.



Figure 8 Hearing protector headset

To assure total cancelling of surrounding sounds, disposable foam ear plugs were used under the headset (see Figure 9).



Figure 9 Disposable foam ear plugs

The special situations were chosen to be such that really simulate a possible everyday disability situation. Therefore the “situational blindness” was not simulated by concealing user’s eyes. It is highly unlikely that a person ends up in a situation where his eyes are concealed but there is a strong possibility that his eyesight is limited by lack of light.

In these special situations the “ordinary” users were asked to perform basic tasks, such as calling, receiving a call, sending a text message and receiving one. The starting point of the tasks varied: the mobile phone was to be found in the pocket, in the bag, or in the surroundings in proximity of the user. The use of mobile devices was studied also in the ordinary environment in the same manner as was done with the disabled users.

After going through the pictures of the photo diary, and the contextual inquiry, the participants widely expressed their views on their current mobile devices, their expectations, and desires. They told about problems they have faced, and shared their visions on what kind of devices they would like to use and how.

5 Results

5.1 Photo Diary

The photo diary assignment resulted in nine sets of pictures. Each photo diary consisted of 4–24 pictures. Seven participants had taken all pictures within one day, as advised. Two participants had stretched the time frame into two days. The objects photographed fitted well the given theme, although one participant had expanded the definition of “everything you use for communication, or use for receiving and transmitting information”, and had photographed also paintings, cooking ware, and other objects with less distinct role in communication and information sharing.

Due to the limited performance or disposable cameras, there were a few photos left unexposed. The flash had to be manually charged, which for some participants was slightly complicated. That caused for some photos to lack in brightness, and made recognising the photographed object difficult. Majority of the photos turned out well.

The blind participants had been advised to first press the flash light button and then direct the lens on the chosen object in arm-length distance. This worked out well, since the quality of photographs ended up being practically the same as the photographs taken by sighted participants. Only aiming at the target was slightly inaccurate, but it did not impede recognising the photographed object (see Figure 10).

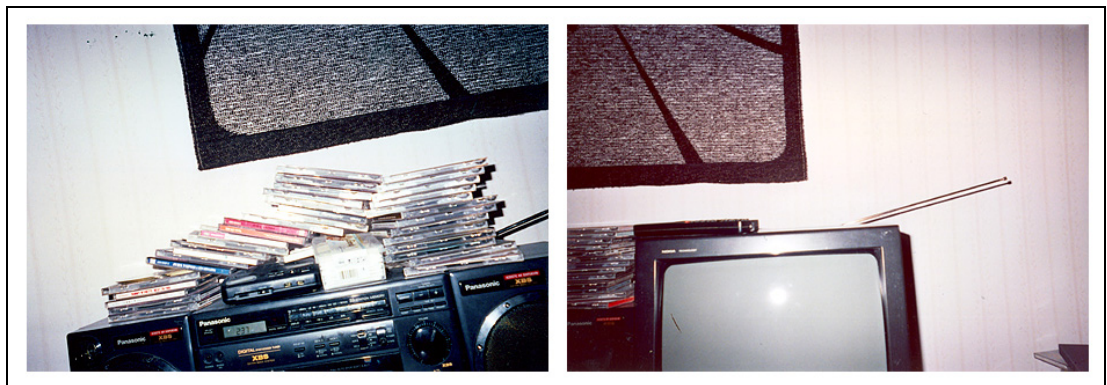


Figure 10 Photographs taken by a blind person

Even if the participants had concentrated on the assignment and followed the given theme and instructions, there were moments, when they had forgotten to take picture.

When the pictures were talked through one-by-one, many participants realised they had forgotten to photograph some objects they had used during the day. In some cases they remembered having taken a picture, but due to the quality problems of the disposable camera, the picture had not come out in the development. Despite of all, the missing objects were equally discussed and analysed, even though there was no picture of the object available.

Photo diaries documented rather well the course of the participant's day, and the objects and devices that had been used during the day. The number of devices that are in active use for communication and handling information per each participant is presented in Table 3.

Table 3 Devices actively used by the participants

| | Deaf 1 | Deaf 2 | Deaf 3 | Blind 1 | Blind 2 | Blind 3 | Ordinary 1 | Ordinary 2 | Ordinary 3 |
|----------------------|--------|--------|--------|---------|---------|---------|------------|------------|------------|
| Mobile phone | 3 | 4 | 1 | 2 | 1 | 1 | 1 | 1 | 2 |
| Television | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| Computer | 1 | 1 | | | 1 | 1 | 1 | | 1 |
| Laptop computer | | | 1 | 1 | | | | 1 | |
| Webcam | 1 | 1 | 1 | | | | | | |
| MP3 player | | | | | | | 1 | | |
| Text phone | | 1 | | | | | | | |
| Electronic magnifier | | | | | | 1 | | | |
| Memona Plus | | | | | 1 | | | | |

Blind 2 and Blind 3 are users of TALKS^b speech output software that speaks out the words and letters that are shown on the screen. Blind 1 is not a TALKS user, but uses the mobile phone just by touch. Blind 1 has a limited access to mobile phone functions since she has to memorise the menu structure.

Blind 1 and Blind 2 read Braille and therefore have a Braille display attached to the computer (see Figure 11).

^b SpeechPAK TALKS™ converts the display text of a cellular handset into highly intelligible speech, making the device completely accessible for blind and visually impaired people. SpeechPAK TALKS runs on Symbian-powered mobile phones to speech-enable contact names, callerID, text messages, help files, and other screen content. (<http://www.scansoft.com/speechworks/talks/>)



Figure 11 Braille display

Examples of photo diary pictures are shown in Figure 7 and Figure 10. Complete listing of all pictures can be found in Appendix 1.

5.2 Contextual Inquiry

Contextual inquiry for disabled users was carried out in ordinary situations, such as home or work environment, and for “ordinary” users in special situations that included complete darkness and noisy environment. This was done to set situational disability against actual disability.

5.2.1 Situationally Blind vs. Blind

The comparison of the ability to perform basic tasks between **situationally blind** and **blind** is shown in Table 4.

Table 4 Ability to perform given tasks (situationally blind vs. blind)

| Task | Situationally blind (complete darkness) | | | Blind | | |
|--|--|------------------|------------------|--------------------------|--------------------|--------------------|
| | Ordinary 1 | Ordinary 2 | Ordinary 3 | Blind 1 (no TALKS) | Blind 2 (TALKS) | Blind 3 (TALKS) |
| Can he find the silent phone, when not holding it, and make a call? | no | no | no | no | no | no |
| Can he find the ringing phone, when not holding it, and answer the call? | yes | yes | yes | yes | yes | yes |
| Keypad locked, can he unlock it and make a call? | yes ¹ | yes ² | no ³ | yes ² | yes ⁴ | yes ⁴ |
| Keypad unlocked, can he make a call? | yes ⁵ | yes ⁵ | yes ⁵ | yes ⁶ | yes | yes |
| Keypad unlocked, can he send a text message? | yes ⁵ | yes ⁵ | yes ⁵ | yes ⁶ | yes | yes |

¹ Pressing one determinate key lights the screen and makes the instructions to unlock the screen visible. *User knows the determinate key by heart.*

² Pressing two determinate keys is needed to unlock the keypad. The screen is not lit until unlocked, i.e. the instructions to unlock the screen not visible. *User knows the determinate keys by heart.*

³ Pressing two determinate keys is needed to unlock the keypad. The screen is not lit until unlocked, i.e. the instructions to unlock the screen not visible. *User does not know the determinate keys by heart.*

⁴ TALKS speaks out the instructions to unlock the screen.

⁵ The screen is lit.

⁶ *User knows the menu structure and keys by heart.*

As is presented on the Table 4, neither situationally blind nor blind users were able to find a silent phone if it was placed in an unknown location. If the phone was ringing, both situationally blind and blind users found it easily guided by the sound. Situationally blind users also perceived the blinking screen and were able to use that to locate the phone.

Two of the three situationally blind users (Ordinary 2 and Ordinary 3) had such phones that require pressing two determinate keys to unlock the keypad. The screen

of the phones will not be lit until the keypad is unlocked, i.e. the instructions to unlock the keypad that are shown on the screen cannot be seen. The other of the two knew the needed two keys by heart but was not able to find the keys without taking off the protective cover (see Figure 12). The other situationally blind user did not remember the combination of keys to unlock the keypad. Ordinary 1 had a phone that requires only one determinate key to be pressed in order to light the screen. He knew that key by heart and was then able to read the instructions to unlock the keypad on the lit screen.



Figure 12 Nokia 6600 in a protective cover

All three blind users had a phone that requires pressing two determinate keys to unlock the keypad. Blind 1 knew these keys by heart. Blind 2 and Blind 3 were able to listen to the instructions on the screen through TALKS.

Situationally blind users could easily make a call, since the screen was lit. Blind 1 could make calls, because she knew the menu structure and the keys by heart. Blind 2 and Blind 3 could make calls with the help of TALKS. Same applies to sending text messages.

5.2.2 Situationally Deaf vs. Deaf

The comparison of ability to perform basic tasks between **situationally deaf** and **deaf** is shown in Table 5.

Table 5 Ability to perform given tasks (situationally deaf vs. deaf)

| Task | Situationally deaf (noisy environment) | | | Deaf | | |
|---|---|------------------|-----------------|--------|--------|--------|
| | Ordinary 1 | Ordinary 2 | Ordinary 3 | Deaf 1 | Deaf 2 | Deaf 3 |
| Can he find the ringing phone, if not holding it? | no | yes ¹ | no | no | no | no |
| Incoming call, can he find the phone, if the phone placed in a pocket or a handbag? (phone vibrating) | no | yes | yes | yes | yes | yes |
| Incoming text message, can he find the phone, if the phone in pocket or handbag? (phone vibrating) | no | yes | yes | yes | yes | yes |
| Can he make a call... | yes | yes | yes | yes | yes | yes |
| ...and communicate the message? | yes ² | no ³ | no ³ | no | no | no |
| Can he send a text message? | yes | yes | yes | yes | yes | yes |

¹ User notices the blinking light on the screen.

² User notices when the call is answered, and then speaks out the message on the phone.

³ User does not notice when the call is answered. User speaks out the message on the unanswered phone.

As presented in Table 5, only one situationally deaf was able to find a ringing phone when not holding it. Ordinary 2 noticed the blinking lit screen in the corner of her eye. Other users did not notice the ringing phone.

When the phone was placed in a pocket on in a handbag, only Ordinary 1 did not notice the vibrating phone. This applies to both ringing phone and incoming text message.

All users were able to select a number and make a call, but only Ordinary 1 was able to communicate a message. Deaf users were naturally not able to speak. Ordinary 2 and Ordinary 3 could speak the message on the phone, even though they could not hear the person in the other end, but both users were not able to realise if the call had been answered or not. Both Ordinary 2 and Ordinary 3 spoke the message on an unanswered phone. The symbol that indicates calling changes on the screen, when there is a ring tone. Both users were mistaken by this symbol change and interpreted it to indicate that the call had been answered.

Both situationally deaf and deaf users could easily send text messages.

5.3 Critical Attributes for Visually Impaired Users

Examining altogether six blind or visually impaired users (see Table 2) gave information on attributes that are critical for these users to be able to successfully use a mobile phone.

Good Keypad

Good keypad is essential. Since blind users are not able to perceive the keys visually, they need to rely on the tactile feeling of the keypad. There are a few attributes that define a good keypad:

Keys need to be separate from each other. When the keys are clearly separate from each other, it is easy to know when your finger is on a key.

Good tactile response when pressing a key. The sensation of “click” signals the user that a key has in fact been pressed. For example, a feather-touch switch is not a good choice.

Keys in straight rows, no strange arrangements, such as U-shape. If keys are not arranged in straight rows and columns, it is not easy to know which key is which key. In a U-shape arrangement (see Figure 13), for example, when you go to the left from the 5-key, you can accidentally end up on the 7-key instead of the 4-key.



Figure 13 U-shape keypad in Nokia 3660

Tactile cue on the 5-key. To facilitate the positioning of fingers on the keypad, there should be a tactile cue on the 5-key. The cue needs to be on the key, not beside the key (see Figure 14 and Figure 15).



Figure 14 Tactile cue beside the 5-key



Figure 15 Tactile cue on the 5-key

Surface of the key not slippery. For better touch, the keys should not be slippery. A rubber-like surface, for example, was preferred by the research participants.

Three visually impaired, one hearing impaired, and one “ordinary” participant were users of Nokia 6600. They all found the keypad (see Figure 16) unsatisfactory because the keys are not separate, they are not in straight rows, and their surface is slippery.

Classic Nokia 6110 keypad (see Figure 17) was mentioned several times as an example of a good keypad: the keys are separate, they are in straight rows, and their surface is not slippery but rubber-like.



Figure 16 Nokia 6600 keypad



Figure 17 Nokia 6110 keypad

Not Many Changing Functions on One Key

If one key has changing functions depending on what is shown on the screen, the use of the keypad becomes complicated for users who cannot see the information shown on the screen. Softkeys^c like the NAVI™-key^d, for example, was mentioned as problematic.

Logical Menu Structure

For visually impaired users that are not using speech output software like TALKS, the logical menu structure is essential. When you are not able to see the screen, you must be able to make a mental model of the menu structure.

^c A multi-function key usually positioned beneath the mobile phone display with the corresponding textual or graphical function label shown on the display. [24]

^d Navi™-key: Nokia's one-softkey interaction style; first applied in the Nokia 3110 phone model. [24]

5.4 Critical Attributes for Hearing Impaired Users

Since a mobile phone interface relies heavily on visual information, there are not as clear critical attributes for hearing impaired users as there are for visually impaired users. As long as the interaction with the mobile phone is based on text, symbols, or images, a hearing impaired user is able to use the phone. Use of course rules out talking on the phone. For two-way communication, deaf users can apply two-way video calls.

For hearing-aid users an inductive loop set^e (see Figure 18) is essential. Even with severe hearing impairment, the use of inductive loop set enables calling on a mobile phone. Without the loop set, the user would have to rely on the use of text-messages only.



Figure 18 Nokia LPS-4 inductive loop set

^e All hearing aids support the induction loop technology. When hearing aid is on the T-mode, it captures the signal supplied from the loop.

5.5 General Findings

For most participants mobile phone was the primary timekeeper and alarm clock. Two deaf users have replaced the vibrating alarm clock specially designed for the hearing impaired by a vibrating mobile phone which they place under their pillows.

Only one user had his primary calendar on the mobile phone. This user was visually impaired and used the calendar through TALKS. Most users used calendar alerts, even if their primary calendar was a traditional paper calendar.

E-mail, internet, and MMS were not much used although most of the users had those features in their mobile phones. Pricing of these services was generally seen as too high.

Two blind users had modified the keypad by adding a small “lump” on the 5-key or all keys in order to make the keypad more tactile.

One blind user actively uses Navicore Personal^f navigation software through TALKS.

Even though TALKS was generally appreciated it was mentioned that using it in a public place is not necessarily convenient without headphones. It was also found rather ironic that nearly all phone models compatible with TALKS come with a camera.

Deaf users rely heavily on text messages. This however requires writing in a language other than native, which is sign language. To compensate the missing possibility to make calls, all deaf users have been using MSN messenger^g service on the internet for years. All three used MSN messenger through both webcam and regular chat. Webcam is always preferred to text-based chat, since use of webcam

^f Navicore Personal is a software application that is installed on the mobile phone by memory card, and used together with an external Bluetooth GPS-receiver (<http://www.navicore.fi/>).

^g Internet messaging service by Microsoft (<http://messenger.msn.com/>, <http://messenger.msn.fi/>).

enables communication in sign language. Two deaf users had two separate accounts at MSN messenger: one for work and one for personal communication. Work related use included both in-house communication and communication with customers. The only negative side of communication through webcam was seen to be its intrusive nature. Sometimes a customer does not want to be seen in relaxed clothing at home, for example. In this kind of cases text-based chat is applied, even though both parties share sign language as their native language, and are sitting in front of a webcam.

It is very frustrating for deaf persons not to be able to take care of everyday things by calling. Communicating through e-mail and text messages takes time, and is complicated when trying to book a meeting with a doctor, or trying to call a plumber. One deaf participant still uses text phone^h in such occasions.

Home-made weekly calendar (see Figure 19) was used for internal communication in a family, where the other parent was deaf. It was seen as the best way to check earlier agreed things, when in a hurry.



Figure 19 Home-made weekly calendar for communication within family

^h Text phone enables text-based communication through telephone landline. Both parties need to have a text-phone device. If text phone is used to communicate with a person with normal hearing without a text phone device, text phone service with a middleman is used.

One deaf user also sends her husband photos of products from stores, in order to avoid time consuming text messaging.

Two deaf users used SonyEricsson Z1010 (see Figure 20) for two-way video calls. It was found good that the phone can be placed on a table, in order to make signs with both hands.



Figure 20 SonyEricsson Z1010 mobile phone (pointing to camera used in one-way video messages)

What was found poor was the fact that a thumb can accidentally be placed on the camera (see Figure 21). When sending a one-way video message, you are forced to use the other camera (see Figure 20). This works fine when you are recording other things than yourself. The problem is that when you are recording yourself making signs, you are not able to see your own picture.



Figure 21 SonyEricsson Z1010 (pointing to camera used in two-way video calls)

Blind 1 did not have TALKS, but had been able to memorise the menu structure so well that used mobile phone as primary alarm clock. She was also able to search the address book and to make calls. She was even able to send text messages. The only problem with the text messages was that she was not able to tell when she had written more than 160 letters, which is the maximum size for a regular text-message. When she had tried out TALKS, she had found using it uncomfortable when writing text messages, because the sound was confusing and lagged behind.

As she was not using any speech output software, she was not able to read incoming text messages. In case her friends would have wanted to send her one, she had asked them to call the answering machine directly and to leave a voice message.

Congenitally blind users send text messages using the same three fingers they read Braille with (see Figure 22). Blind 1 (not using TALKS) was able to write text messages extremely fast this way.



Figure 22 Congenitally blind user writing a text message (staged photo)

For blind users the computer is fundamental. One articulated its importance: “*It’s my pen, paper, memory, notebook, calendar, cook book, address book...*” Braille display (see Figure 11 and Figure 23) is more important than speech synthesizer, especially when reading work-related text or text in a foreign language.



Figure 23 Reading on a Braille display

One blind participant still actively uses Memona Plus (see Figure 24) for making notes. Memona Plus is a pocket size electronic, portable note taker that can be connected to a PC or to a mobile phone. It is compatible with Nokia mobile phones of the 6200 and 6300 series. Memona Plus enables both 6- or 8-dot Braille. The storing capacity is 30 A4 pages. The written texts can be checked sign by sign through the inbuilt digitised speech. The notes can be stored as different files and they can easily be transferred from to a PC. Notes can be printed out as normal text, as Braille, or as speech. The keyboard can also be used as a PC keyboard. Through the inbuilt microphone short voice messages can be recorded, such as important telephone numbers. Memona Plus also tells the time and date.



Figure 24 Memona Plus

All “ordinary” users articulated situations, when use of mobile phone is difficult: urban noise, rock festival, library, driving a car. Speaking on the phone when walking in the city centre was found difficult and uncomfortable since it is not possible to clearly hear the voice on the other end. It was said to be “*a rule, not exception*” to lose your friends at a rock festival and then not being able to contact them because of the noise: You cannot talk on the phone and you cannot hear the phone ringing. When trying to contact someone through a text message, it takes a lot of time until the other person even realises he has received one. In libraries you are not allowed to talk on the phone. One mentioned it to be annoying that when going in you forget to turn the phone silent, and it ends up ringing out loud, and when going out you forget to change the sound back to normal, and then end up not hearing the phone ring for the rest of the day. Using a hands-free holder in the car was found useful but it was mentioned to be difficult to push the small buttons, when you are not supposed to take your eyes off the road.

None were satisfied with their current keypad. One “ordinary” user hoped for a keypad with so good tactility that she would be able to use it without watching. She also wanted to wear a protective cover (see Figure 12) on the mobile phone but found using the keypad difficult through the cover. She uses the protective cover on the phone not only in order to protect the phone but also in order to get a better grip when digging out the phone from a bag without watching.

One “ordinary” user used his mp3 player as a memory device, in order to store a document that he would later print out somewhere else. The same user uses the mobile phone sometimes as a small flashlight, since the screen is so luminous.

5.6 Suggested Features

When making two-way video calls or one-way video messages, user must be able to choose, which camera he wants to use in each case. Recording self or recording something else means that the phone turned a different way. In both cases user should be able to see the screen and the image being recorded. There should be a small light source integrated in the phone. Otherwise it is not possible to make a two-way video calls in the dark.

Hands must be freed, in order to make signs with both hands. When sitting down, phone should stand on the table. When standing, user becomes one-handed and cannot make signs with both hands. This should be fixed.

Also the size of current screens was criticised. In order to be able to have a larger screen at times when it is needed, a foldable screen was suggested.

It was suggested that text phone service would be available in the mobile phone. What would be even better than that, would be a mobile interpreting service.

As Braille display is more important to congenitally blind than speech synthesizer, a small Braille display could be integrated on the mobile phone. Ten 8-dot keys would be enough, but *“Even one Braille key would be great!”*.

Hearing and visually impaired user had Nokia 9300 communicator and inductive loop set (see Figure 18). He would like to use communicator + loop set with other devices too, i.e. have a (wireless) connection to the communicator or straight to the loop set. That would mean transmitting sound from computer or from other external memory device to communicator (electronic talking books, for example). When in a meeting, he would like to place a microphone on the table and to have it transmit sounds to the communicator + loop set.

One visually impaired participant described a problem considering routing when outdoors. He is able to see signboards but not able to tell what is written on them. He suggested image recognition as a solution to this problem: User would take a photo of the signboard and have TALKS read out the text.

It was also suggested that signboards, info monitors, and other information devices of that kind could be connected to the mobile phone by Bluetooth. Especially the ticket machines at railway stations should be equipped with Bluetooth, in order to be use the machine through own mobile phone.

One blind user suggested that in order to stop worrying about keys, the mobile phone could be used to unlock the home door. He also hoped that the phone would speak out instructions when walking outdoors.

Two visually impaired users would like to be able to zoom in on the screen.

The blind user, who was not using TALKS but was still able to write text messages, would like to hear a little “beep” when all 160 letters have been used up. She would also like to be able to assign different ringing tones for all persons in the addressbook.

One ordinary user drives a lot and uses a hands-free holder for the mobile phone in the car. He finds it very difficult drive and simultaneously hit the small buttons and search for a number, when phone is placed in the holder. *“Control buttons for the radio are already placed on the steering wheel, why not for the phone too?”* The mobile phone is automatically charged when in the holder, but when at home a regular charger needs to be used. The user finds using a regular charger difficult, since he then needs to crawl under tables to reach a wall socket, in order to plug in the charger. He would like to have a similar holder at home. The mobile phone would never run out of power and would never get lost in the house.

One participant worked as a real estate agent and hoped for a camera of such good quality that he could send the pictures directly to the office were the photos would be used in brochures.

One hearing impaired user hoped for a small mirror on the mobile phone.

It was also suggested that the user could make shortcuts to services he uses the most. It was found frustrating that to send a text message you need to go through a certain path every time.

6 Discussion and Conclusions

Can disabled persons be seen as lead users in mobile user interface design? It was found out that “ordinary” users do face difficulties when using their mobile phones in special situations, i.e. they in fact are situationally disabled. These difficulties include not being able to talk on the phone in a noisy environment, for example. The user needs partially overlap with the needs of disabled users in ordinary situations. This corresponds to findings of Newell [31], Newell & Gregor [33], and VTT’s NAVITarve [3] (see 3.1 Related Research).

The needs of situationally blind do not fully correspond to the needs of blind users, because of the fact that a situationally blind user can benefit from his eyesight, when the screen of the mobile phone is lit. On the other hand, blind users of TALKS are effectively freed from their disability. The blind participant, who was not using TALKS, was then again so trained to use the mobile phone by heart that it is not meaningful to compare this user to an “ordinary” user suddenly taken into complete darkness. Either way, both situationally blind and blind users emphasised the importance of a good keypad.

Situationally deaf users seem to benefit from same features on the mobile phone as deaf users do: blinking light provokes their attention as does vibration.

Both visually and hearing impaired participants showed innovative and leading edge behaviour. Some had modified the keypad to better meet their needs, and some used features like MMS messaging and two-way video calls which “ordinary” users have (not yet) found useful. All participants seemed to have replaced some other devices as clocks, calendars, or notebooks by their mobile phones.

Von Hippel [50] defines lead users by two characteristics (see page 7):

1. Lead users face needs that will be general in a marketplace – but face them months or years before the bulk of that marketplace encounters them, *and*
2. Lead users are positioned to benefit significantly by obtaining a solution to those needs [50].

When we look at the data gathered through this study in reference to von Hippel's definition, it is clear that the second lead user characteristic applies to disabled users: Disabled users surely benefit significantly by obtaining a solution to their needs. Applicability of the first characteristic is not as explicit. We cannot be sure if, for example, the need for two-way video calls already used by deaf users will be general in the marketplace. This happened in case of text messages, but will it happen again with other features? What we do know is that the majority of the target market i.e. "ordinary" users face needs in special situations similar to those of disabled users in ordinary situations. I conclude that **there is a strong indication that disabled persons could be seen as lead users in mobile user interface design.**

Considering Von Hippel's [50] definition of lead users, it could be contemplated if a third lead user characteristic should be added to the definition. I suggest that in addition to facing a need in advance, and being positioned to benefit significantly if obtained a solution to the need, a true lead user should also have developed some kind of solution to this need. For example, the need for a more tactile keypad had driven two blind users to add a small "lump" on some keys. One blind user actively uses Navicore Personal navigation software through TALKS, although Navicore Personal is originally aimed at sighted car drivers who are not TALKS users. Adding a third lead user characteristic to the definition could clarify and facilitate lead user identification.

Interesting observation in terms of usability (see 2.4) is the use of mobile phone without any speech output software by one blind user. She had been able to overcome an extremely hard-to-learn interface. The *learnability* of an interface designed for sighted users is surely not too good, when you are blind yourself. After a training period she had reached a high *efficiency of use*. Even though her goal has been only to be able to use the mobile phone as any other user, her learning curve (see Figure 5) resembles the one of an expert user. As majority of feedback offered by a mobile phone user interface is visual, she had to rely on the *memorability* of the interface. In her case *errors* occur more often than when a sighted person was using the same interface, but nevertheless the *subjective satisfaction* of using the product is high.

Were all applied methods suitable for all examined user groups? The photo diary assignment was very well accepted. Only one “ordinary” participant hesitated when introduced the assignment. Positive comments like “*It was fun.*”, “*It was easy.*” were given after the assignment. One blind person told that the whole concept of taking photographs felt strange: “*After taking the photo, I was left with an empty feeling: That was it?*” None of the participants wanted to leave the pictures unexplained. “*Photos don’t tell all, they need explaining.*” Some participants were so excited by the photo diary assignment that they said they would like to do it again. One “ordinary” user was so inspired by the photo diary that he started thinking of using the camera on the mobile phone as a documentation tool. One blind participant said that if given a choice, she would have wanted to document the day by making notes by Memona Plus (see Figure 24) instead of taking pictures.

There was no big difference in photo quality, whether taken by blind, deaf, or “ordinary” participants (see Figure 10).

Despite the positive comments, there were some problems with the assignment. Two weeks was too short a time for one participant to return the camera, and therefore the second meeting had to be postponed. Several participants found the manually charged flash of the disposable camera difficult to use. One participant expanded the definition of “everything you use for communication, or use for receiving and transmitting information”, and photographed also objects with less distinct role in communication and information sharing. Yet there was no photo of a mobile phone among the 22 photographs, because “*Everybody else has taken a photo of it anyway, so I tried out something else.*” When working with any people, it should be remembered that even the clearest instructions can always be interpreted in a way that was not expected by the one who compiled them.

In spite of all, photo diary was found to be an effective and easy method for self-documentation – also when studying blind users. No other equipment is needed for documentation, as long as the photos are later gone through in a separate discussion. No major difficulties occurred in carrying out the contextual inquiry and open-ended discussion. The only problem was related to interpreting. In one meeting with a deaf participant the interpreter was natively Swedish-speaking, which made understanding

the interpretation difficult. I conclude that **all applied methods were suitable for all examined user groups.**

I recommend that disabled users would be included in mobile user interface design. At times all users suffer from situations, when they are not able to use all senses. As Newell & Cairns [32] point out: “A hostile environment can turn a perfectly fit user into one whose performance is similar to that of a person with severe disabilities.” Users of any devices should not be divided into able-bodied and disabled, since ability level is not a dichotomy but a continuum. Using people with disabilities to evaluate interfaces could also highlight problems that would not be obvious to those without such disabilities.

One key observation on working with visually and hearing impaired participants is the importance of common language. Common language means fluent and more personal communication. Sign language is the native language of the congenitally deaf. It was easier for a blind person to contact me by e-mail or by phone, since he could do it in his native language. Finding deaf volunteers was difficult. In some cases communicating with a deaf participant took a lot of time, since the participant felt uncomfortable and perhaps even shy about sending a written message. It should not be presupposed that a deaf person can fluently write in the predominant language. Having to book a sign language interpreter makes planning more complicated, because the timing needs to fit three people. There is also endless e-mailing and text messaging in case of cancellation.

As a possible limitation concerning this study could be seen that only hearing and visually impaired users were studied. These user groups were selected to represent disabled persons, because of the clear definition of these groups. It was not difficult to construct corresponding situational disability environments. Another limitation could be the low number of participants. Examining more users of each examined group would possibly have given a wider understanding on the user needs.

Future research should include examining users with a physical disability, as it is not difficult to find corresponding situational disability circumstances in everyday life, where use of limbs is not preferred or is completely excluded. Multimodal mobile

phone interaction styles should be further developed. Multimodal interaction ensures that a larger group of in the end very heterogeneous users are able to use it in variety of often fast changing situations, including those that are unexpected. Mobile interpreting in order to facilitate the life of deaf persons should be studied, as the technology enabling it already exists.

7 Summary

In order to understand user needs, we traditionally examine current users of a product. Classical research on problem solving shows, however, that current users are strongly constrained by their real-world experience, an effect called functional fixedness [1, 12]. It appears extremely difficult to determine the demands of tomorrow's markets via traditional market research methods. Von Hippel's lead user method [50, 51] takes a totally different approach as it is not based on current users but lead users. Lead users face needs that will be general in a marketplace – but face them months or years before the bulk of that marketplace encounters them, and they are positioned to benefit significantly by obtaining a solution to those needs.

Lack of functional fixedness makes lead users very appealing to product development – lead users do not base their views on existing products but on their needs. Developing products to meet the needs of lead users allows a firm to anticipate trends and to leapfrog competitive products [47].

The purpose of this study was to investigate if disabled persons could be seen as lead users in mobile user interface design. Another goal was to evaluate the suitability of the selected research methods on the examined user groups.

An able-bodied user may suffer from a “situational disability” caused by the environment: When there is no light, use of eyesight is limited. When there is a lot of noise, it is not possible to hear well. In this study the user needs of disabled and “situationally disabled” users were compared. The examined user groups were deaf, blind, and “ordinary” users, who see and hear well. The methods used were photo diary based on a theme, and contextual inquiry combined with an open-ended discussion. The “ordinary” users were examined in situational disability conditions in order to compare the appeared needs with the needs of the disabled groups.

It was found out that “ordinary” users do face difficulties when using their mobile phones in special situations, i.e. they in fact are situationally disabled. The user needs partially overlap with the needs of disabled users in ordinary situations. Both visually and hearing impaired participants showed innovative and leading edge behaviour. It

was concluded that there is a strong indication that disabled persons could be seen as lead users.

The photo diary assignment was very well accepted. There was no big difference in photo quality, whether taken by blind, deaf, or “ordinary” participants. Although there were some problems with the assignment, it could be seen that photo diary is an effective and easy method for self-documentation also when studying blind users. There were no major difficulties in carrying out the contextual inquiry and open-ended discussion. All applied methods were found suitable for all examined user groups.

It was recommended that disabled users would be included in mobile user interface design.

Working with visually and hearing impaired participants brought out the importance of common language. Common language means fluent and more personal communication. Sign language is the native language of the congenitally deaf, and it should not be presupposed that a deaf person can fluently write in the predominant language.

This study examined only hearing and visually impaired users, and the number of participants was relatively low. These could be seen as possible limitations.

Future research should include examining users with a physical disability. Multimodal mobile phone interaction styles should be further developed. Mobile interpreting in order to facilitate the life of deaf persons should be studied, as the technology enabling it already exists.

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9 Appendices

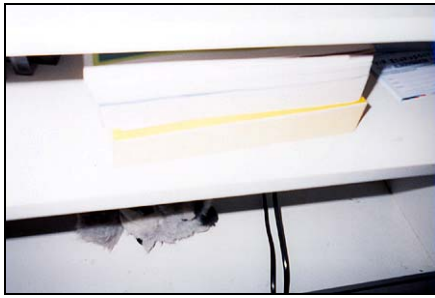
Appendix 1: Photo diary pictures

Appendix 2: Mobile phones

Blind 1



Blind 2

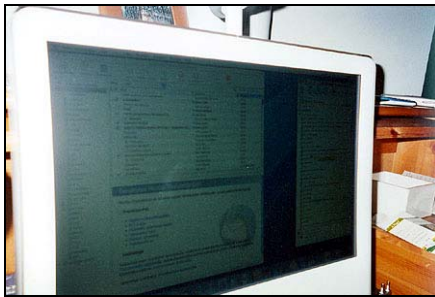
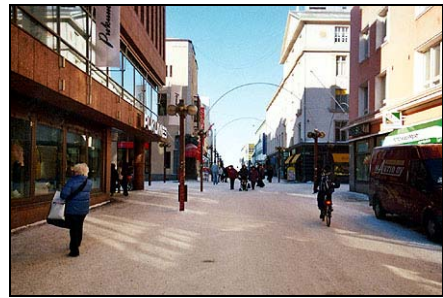
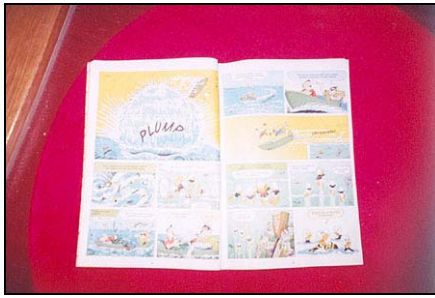


Blind 3

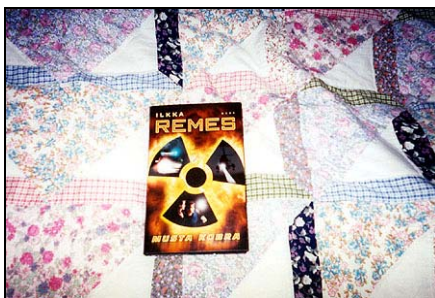
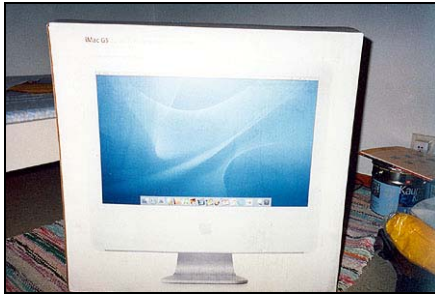




Deaf 1



Appendix 1: Photo diary pictures

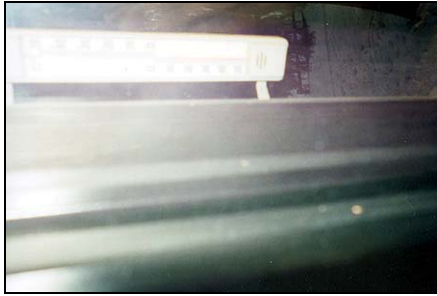




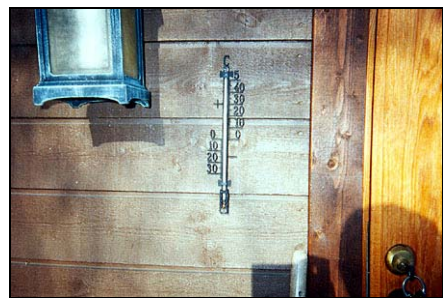
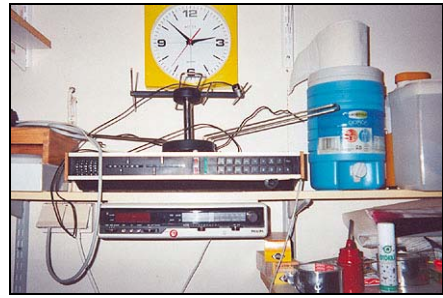
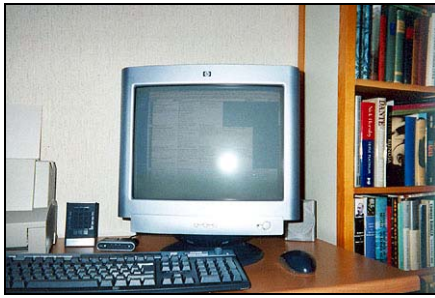
Deaf 2



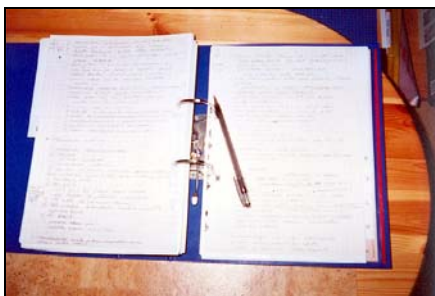
Deaf 3



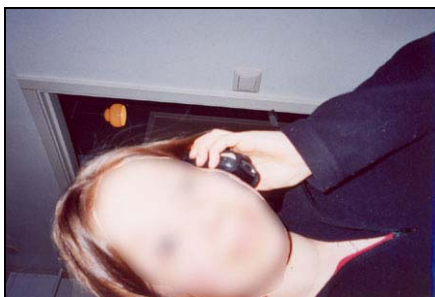
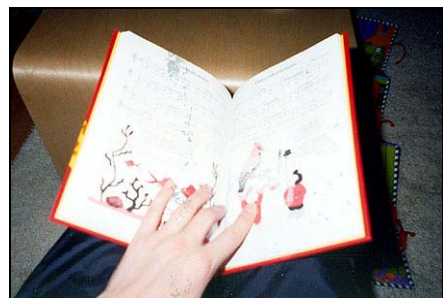
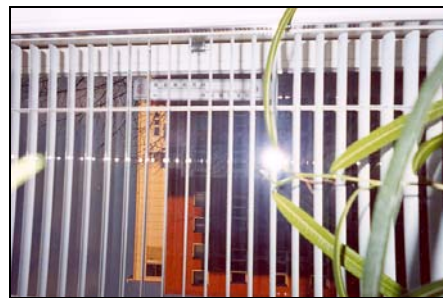
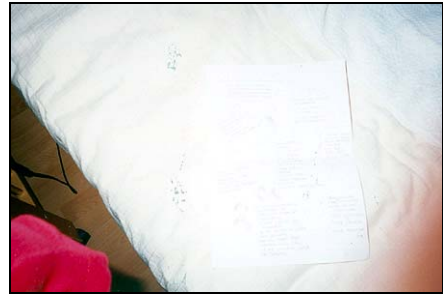
Ordinary 1



Appendix 1: Photo diary pictures



Ordinary 2

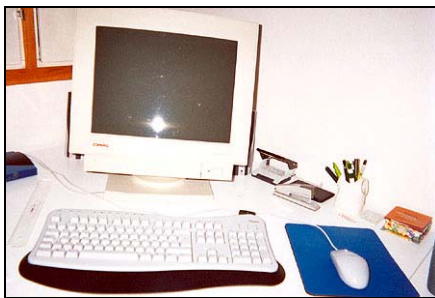
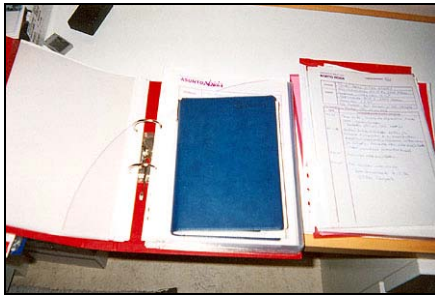




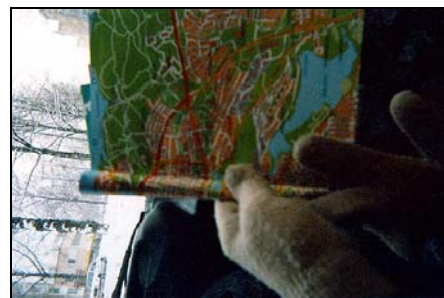
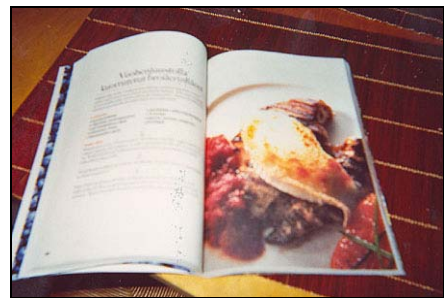
Ordinary 3



Appendix 1: Photo diary pictures



Ordinary (pilot)





Nokia 1100



Nokia 6100



Nokia 3510



Nokia 6230



Nokia 3660



Nokia 6310i



Nokia 6600



Nokia 6820



Nokia 9210i



8310

Nokia



Nokia 9300



Nokia 9110



SonyEricsson Z1010



Siemens ST60