Ole Andreas Alsos

Exploring interface metaphors for using handhelds and PCs together

Abstract

By distributing the user interface between devices like a PDA and a PC, one can utilize the best characteristic from each device. This thesis has investigated what conceptual models and interface metaphors one should use when designing systems using handheld computers and PCs together.

This has been done by exploring the design space of the devices, resulting in seven interface metaphors that have been adapted to a hospital case. Based on results from a focus group session and an interview, several prototypes based on the interface metaphors have been developed. These prototypes all enable a physician to display x-ray images on a patient terminal by using a PDA. In a usability test experiment the users' actions and think-aloud protocol when using the prototypes have been captured and analyzed to find their mental models.

The analysis has resulted in four general metaphors on which users internalize when using handhelds and PCs together. A design process using the user's mental models as a basis for the creation of the conceptual model is presented. The thesis concludes with that the general metaphors found can be a good basis for the design of a conceptual model and ends with general guidelines for systems using handhelds and PCs together.

Keywords: Handheld, PC, conceptual model, mental model, metaphor, design process, usability test, card sort.

Acknowledgements

This thesis would have been hard to accomplish without the help from several people. First of all I would like to thank *Dag Svanæs*, NTNU, for excellent guidance trough these five months. I would also like to thank *Ida Aglen* who has helped me with love, care and proofreading.

The following have made important contributions to this thesis: *Sigurd Juvik*, Cardiac AS, has given me support and inspiration to interesting field of work. *Helge Alsos* and *Eli Aglen Hollup* have helped me assuring the quality of the work. *Gry Seland* and *Yngve Dahl* have helped me with usability test issues. *Reidar Martin Svendsen* has helped me with equipment and usability lab setup, and has also been an excellent camera man during the usability tests. *Martha Rice Skogen* has been a good discussion partner and given me many good ideas. *Arild Faxvaag* has helped me recruit physicians to the usability tests. At last I would like to thank all who attended the focus group session and all usability test subjects.

During a short hospital admission in the beginning of June because of a serious hand injury, I really saw both the need and the potential of the x-ray image viewer I developed during the work with my master thesis.

Ole Andreas Alsos

Trondheim, July 2005

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1. Introduction

Handhelds, like mobile phones and Personal Digital Assistants (PDAs), are used by almost everyone in the western world today. A handheld is very mobile but has a small screen size, limited power capacity, and low performance compared to a PC. By distributing the user interface between devices like for example a PDA and a PC, one can utilize the best characteristic from each device.

Used *together* “the whole is greater than the sum of its parts”; the small PDA-display can be extended by the PC-monitor, the PDA can be an additional input device for the PC or the PDA session can be transferred to the PC when higher performance is required or the handheld battery capacity is running low. By using the devices together when they both are available, the handheld’s good mobility can be combined with the big display of the computer.

Many different interface metaphors can be used when designing systems using handhelds and PCs together. The handheld can for example be used as an input device or remote control and parts of the user interface on the PC can be moved or duplicated to the PDA. Selecting the right conceptual model and interface metaphor of how the system should work is important to map the designer’s intended model of the system onto the users’ mental model of the system. If the designer succeeds in this, there is a greater chance that the users are able to use the system with higher effectiveness, efficiency and satisfaction. An important question when designing such systems is what conceptual model and interface metaphor one should use when designing such systems.

1.1. Background

Recent years some research has been made on user interfaces consisting of handhelds and PCs, where input and output is distributed between the two. The most profiled research group is The PEBBLES project (Myers, 2001). This project has demonstrated that using handhelds and PCs together in a distributed user interface may augment the use and services offered by them separately. The focus of the PEBBLES project has mainly consisted of building example systems as “proof of concept” to demonstrate the value of combining the two devices. Brad Myers, chief investigator in PEBBLES Project, claims that “there is not enough research about the issues around carrying handheld devices in and out of spaces where other handheld and fixed devices are operating” (Myers et al., 2001, p. 3).

What seems to be missing in existing projects is focus on what conceptual models that should be used when designing them and the users' *mental models*, the users understanding of how these systems work.

One important issue when designing any interactive system is to develop a good *conceptual model* for it. The conceptual model is an idealized view of how the system should appear to the user and how the devices are going to be used together. To create this model the designer has to have a clear picture of how the users will understand the system. Users make their own internal models in their head of how the system works when using it, and a mismatch between the designer's conceptual model and the user's *mental model* may lead to serious usability problems.

A conceptual model includes an *interface metaphor,* which is used to describe how the user interface appears for a user. This can be based on *internal metaphors*, metaphors that the users utilize when using the system so that it can be related to things and experiences in the real world. This will let them use recognition rather than recall, thus making the system easier to operate. In addition a term called *general metaphor* is used in this thesis, which basically is one or more internal metaphors that is generalized.

1.2. Problem to be addressed

The main problem to be addressed is w*hat conceptual models and interface metaphors should be used when designing systems using handheld computers and PCs together?*

This problem is answered by investigating which conceptual models and interface metaphors *can* be used in such systems. This sub-problem is addressed by exploring the design space of handhelds and PCs used together. This means investigating the design space of all possible design solutions given by the design elements. Inspiration has been found in other systems and research projects (Myers, 2001; Graf, 2003; Svanaes and Verplank, 2000). This has resulted in several *interface metaphors,* and shows that handhelds and PCs can be used together in many different ways

The knowledge about possible interface metaphors is used to find out what mental models the users create and what internal metaphors they use to understand the system. This is based on the assumption that the users' mental models can be used as a basis for better conceptual models, as seen in Bjørkli (2000, p. 83). This second sub-problem is addressed by adapting the different interface metaphors to a particular case. The metaphors are used as a basis for prototypes appropriate to this case. The prototypes are tested on representative users and their actions and think aloud protocol are recorded and analyzed to understand the test subjects mental models and what internal metaphors they used to understand the system.

1.2.1. Relevance

System development for handhelds and PCs used together is a relatively new field and there exists little knowledge about which conceptual models that applies when designing such systems. There also exist little empiric data of what mental models users create for various interface metaphors and how the users perceive these systems. It is therefore necessary to investigate these models to give the designer a clear picture of it, making the task of creating the conceptual model easier.

Today, the handhelds' integration with fixed devices is limited and the visions of ubiquitous computing, where input and output is distributed among different devices, are still not completely reached. When designing systems for handhelds and PCs, most developers still focus on how handhelds can *replace* PCs when users are mobile, for example by making their scheduler available on the handheld when the PC is not present. It is rather necessary to make a different approach by focusing on how the two devices can *augment* each other when used together.

One of the larges IT-projects in Norway, developing the IT-infrastructure for the new St. Olav's Hospital in Trondheim, is currently in progress. The project consists of several different parts, among those the development and installation of *patient terminals* used as an advanced "hospital bed entertainment system" for the patient. Also, personal digital assistants (PDAs) are given to the medical staff as a tool to support their daily tasks. Both the patient terminal and the PDA are offering a range of services for their users. Today the devices are not used together, but there exist at the present time only vague prospective plans for them. These devices in combination serve as an excellent case for using handhelds and PCs together. By looking at what conceptual models and interface metaphors one should use when designing such systems, it may address a few of the challenges the designers face.

1.2.2. Scope

As a complete conceptual model can be very extensive, the focus in this thesis will therefore be restricted to high leveled conceptual models and the associated interface metaphors used between the handheld and the PC.

The particular case used in this thesis; a future scenario from the health care, where handheld PDAs are used by the medical personnel and patient terminals are available above each patient's beds is looked at.

> *Paula, a physician at St. Olav's Hospital, is seeing one of her patients. The patient has got lung cancer, probably because of smoking. Paula has to motivate her to stop smoking and does this by showing x-ray images of her sick lungs. She accesses the patient's electronic record through the PDA and scans through the latest x-ray images. As she selects the images on the PDA, they instantly appear on the patient terminal above the patient's bed. First, she shows a picture of a*

normal lung. Then she finds a picture of the patient's sick lung. Paula points at the image and explains the strong connection between smoking and cancer.

1.2.3. Method

A combination of different research methods is used in this thesis. To understand the users needs and what scenarios in health care in which the handhelds and PCs can be used together, a focus group session was arranged and an interview carried out. The focus group session was used to understand different ways the two devices can be used together by the medical personnel in a hospital ward, and to understand what conceptual models and interface metaphors they suggest and prefer for this interaction. The interview was used to understand and verify the findings from the focus group.

These methods gave inspiration to an x-ray image system where a physician can select images on the PDA and present them on the patient terminal. After designing prototypes based on the metaphors, they where formally tested in a usability test in realistic environments with real users. A combination of several usability testing methods have been used to identify the users' model, including *think aloud protocol*, *question protocol* and *cooperation* between the test subjects. Unstructured interviews were used after the usability test to supplement the observations made during it.

Card Sort was used after the usability test. The purpose was to encourage the users to discuss the interaction methods and prototypes they just tested and to let them rate the methods so that they could be analyzed statistically.

Figure 1 shows an overview over methods and outcomes of the thesis.

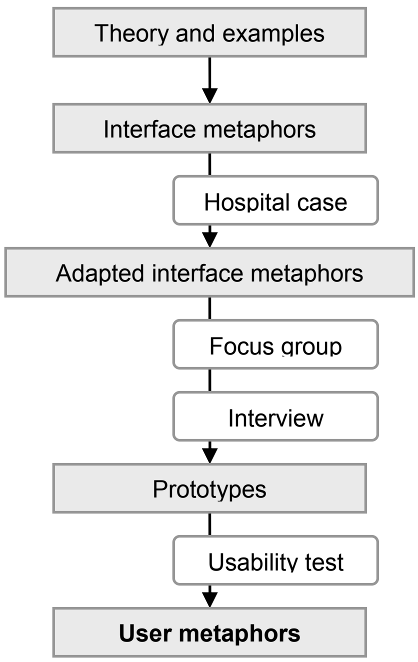

Figure 1: Overview over methods and outcomes.

1.2.4. Outcomes

The results show that only one of seven interface metaphors was better than operating directly on the patient terminal. This emphasizes the importance of developing a good conceptual model. The analysis has resulted in four general metaphors that users internalize when using handhelds and PCs together. A design process using the user's mental models as a basis for the creation of the conceptual model is presented.

The thesis concludes that the general metaphors found can be agood basis for the design of the conceptual model and interface metaphors and ends with general guidelines for systems using handhelds and PCs together.

1.3. Thesis outline

The current chapter is an introduction to the thesis which consists of four parts containing a varying number of chapters.

Part I, Theory and research methods, is in *chapter 2* presenting the theoretical framework and examples of systems where handhelds and PCs are used together. In *chapter 3* the research methods used in this thesis are presented.

Part II, Metaphors, shows in chapter 4 several different interface metaphors that can be used such systems. These metaphors are adapted to a case from the health service in chapter 5.

Part III, Research methods, shows the setup and main results from a focus group session and an interview in *chapter 6*. The purpose was to understand how the handheld and PC could be used together in the case environment. In *chapter 7* the usability test experiment setup is described where prototypes based on the metaphors from *part II* are used. A card sort method with the purpose of ranking the prototypes is also described.

Part IV, Results and reflections, presents the results from the usability test and card sort in *chapter 8*. In *chapter 9* the implications of introducing a handheld device is looked at. *Chapter 10* is analyzing the card sort while *chapter 11* is looking at what mental models the users created when using the system and what internal metaphors they were based on. *Chapter 12* looks at how the internal metaphors can be used in any system using handhelds and PCs together. In *chapter 13* the research methods used is evaluated and the results validity is discussed. *Chapter 14* draws together the topic discussed and presents the conclusions. *Chapter 15* displays references.

Part I – Theory and research methods

Chapter 2 presents the theoretical framework and examples of systems where handhelds and PCs are used together. In chapter 3 the research methods used in this thesis are presented.

2. Theory

In this chapter relevant theory is presented. It clarifies the inspiration for the interface metaphors used in later chapters and it establishes the necessary theoretical framework for discussion and analysis.

2.1. Ubiquitous computing

In 1991, Weiser introduced the concept of *ubiquitous computing*, a new paradigm within the field of human computer interaction. The main idea is that computing power will be embedded in a broad variety of different devices with different sizes and properties. The devices are spread through the physical space and are all communicating wirelessly with each other, giving distributed user interfaces and computing, and contribute to get the users away from the typical form of human computer interaction – sitting in front of an office desk (Weiser, 1991, 1993).

Today, computing appears in more and more devices around in homes and offices. Advanced mobile phones and handheld computers such as the Pocket PC and Palm Pilot, laptop computers, PCs, and wall-size displays are becoming a necessity for many people. Meeting and lecture rooms have control panels or remote controls enabling the user to adjust the room environment such as lights, blinds, volume etc. The recent revolution in wireless communication is letting all these devices talk easily together, laying a strong foundation for ubiquitous computing.

2.1.1. A short history of handhelds

A handheld device is a small portable computer that is able to operate without cables, easily used while in the user's hands. It supports additional applications or internet connectivity (Weiss, 2002). Typical handheld computers are the new generation of smart mobile telephones, Personal Digital Assistants (PDAs) and Tablet PCs.

The use of handhelds and PCs together has changed during the technological development. When handhelds (as for example PDAs) were first introduced, their purpose was mainly to replace the PC when the users were mobile (Myers et al., 2004). Point one to four below summarizes the development of handhelds.

1. The first PDA's introduced in the middle of the '80s was *autonomous handhelds* and was not designed for communication. It was an extra-cost option to be able to communicate with PC. Examples of the early handhelds are personal organizers.

2. Later, it was possible for *occasional synchronization* of information between PC and handheld by physically connecting the handheld to the PC. Examples are early PDAs that could be connected to a PC by wire to update and synchronize information.

3. *Automatic synchronization* of information between PC and handheld when they are within range of a wireless connection is common today. Examples are PCs and PDAs with WLAN and Bluetooth.

4. Now, a few systems are demonstrating *close and interactive communication*. The handheld is not only a replacement for the PC when users are mobile, but is also used *together* with the PC. Examples are a PDA that is used to control from a distance a PC running a PowerPoint slideshow (see *SlideShow Commander*, part 2.2.2).

2.2. Areas where handhelds and PCs work together

Looking at systems where handhelds and PCs work together, there are relatively few in the category where the handheld is not only a replacement for the PC when users are mobile, but is also used *together* with it (point four from section 2.1.1). In this part some systems in this category are presented.

2.2.1. Fluid computing

Fluid computing is a sub-area of ubiquitous computing. It represents the real-time replication of an application state on several devices. The application state is apparently *flowing* like a fluid between devices. Possible usage scenarios include the coupling of multiple devices for better usability and making best use of both full connectivity and intermittent connectivity (Graf, 2003). Figure 2 shows an application running simultaneously on two different devices.

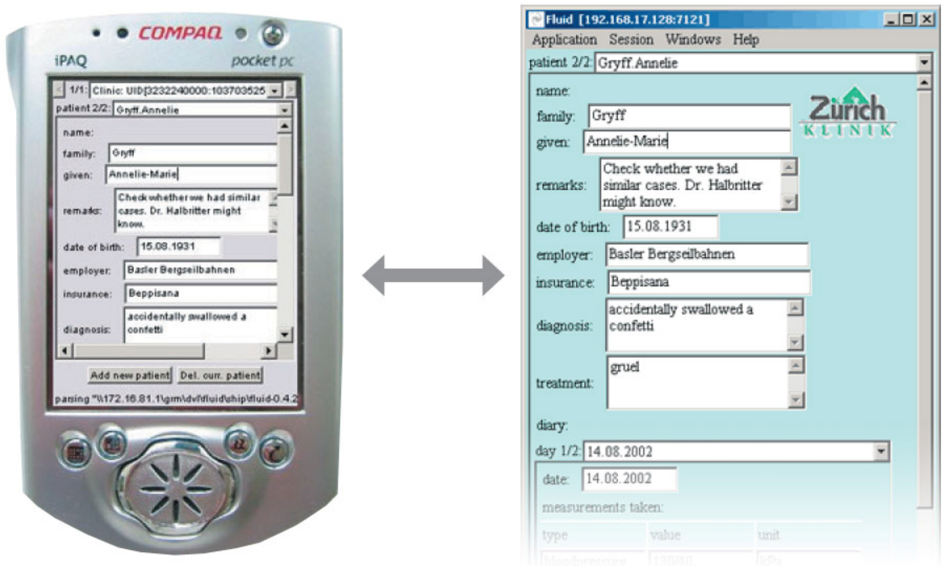

Figure 2: Fluid Computing transfer the system state from a handheld device to a PC when they are near (adapted from Graf, 2003).

There are three main application areas for fluid computing:

- *Multi-device applications where s*everal devices may be temporarily coupled to behave as one single device, for example, a mobile and a stationary device.
- *Mitigation of the effects of variable connectivity where* applications on ubiquitous devices uses full, sporadic or no connectivity in a seamless fasion.
- *Collaboration* where multi-person applications enable several users to collaborate on a shared document in synchronous mode (at the same time) or in asynchronous mode (at different times) without the user having to switch the application.

Below a scenario is presented to show a possible implication of fluid computing (adapted from Graf, 2003):

> *Paula is a physician at St. Olavs hospital. All doctors and nurses are equipped with handheld PDAs that give them access to their patients' data wherever they are. A wireless LAN provides connectivity to the PDAs throughout the clinic's premises.*
>
> Paula is visiting a patient and is browsing through information on her PDA. She is studying x-ray images. The PDA screen is small and Paula scrolls back and forward to view the details on them. She needs a larger screen, so she walks up to the patient terminal available above each patient bed and the image appears on the PC. She continues to navigate through the information on the patient terminal. Every keystroke is immediately reflected on her PDA. In an emergency she could

immediately leave the PC – it would not be necessary to press a “sync button” to synchronize the two devices.

2.2.2. The PEBBLES project

The Pebbles project is exploring how handheld devices, such as PDAs and mobile phones, can be used when they are communicating with different devices, as for example regular personal computers, other handhelds or computerized appliances such as telephones, radios, microwave ovens, automobiles, and factory equipment (Myers, 2001).

A key focus in the PEBBLES project is that the handhelds are used both as output devices and as input devices to control the other computers. Myers introduces a concept, unlike conventional user interface design, called *Multi Machine User Interfaces* (MMUIs), “where the user is dealing with multiple devices with displays and controls”. Another term used for MMUIs are *distributed user interfaces*.

Matters to consider when designing MMUIs are which parts of the user interface to be moved to the handheld device and which device to leave on the original device. For example, a lot of text input should be done on the PC, while viewing status information or operations requiring only simple tapping can be done on the handheld screen.

The project has resulted in several interesting applications developed as *proof of concept*. The goals for all these are to use a handheld device to augment and control a PC while the PC is functioning as normal. Some of the applications are presented below.

Remote Commander

RemoteCommander is an application which let several people control a PC from a remote location using their handheld (Myers et. al., 1998). A picture of the PC screen can appear on the handheld as the full screen downscaled, or as zoomed in on parts of the screen (see figure 3). All mouse and keyboard functions are available and several users can control the PC simultaneously. The creators point at the advantage that *RemoteCommander* enables the users to control the PC from a distance without mouse and keyboard.

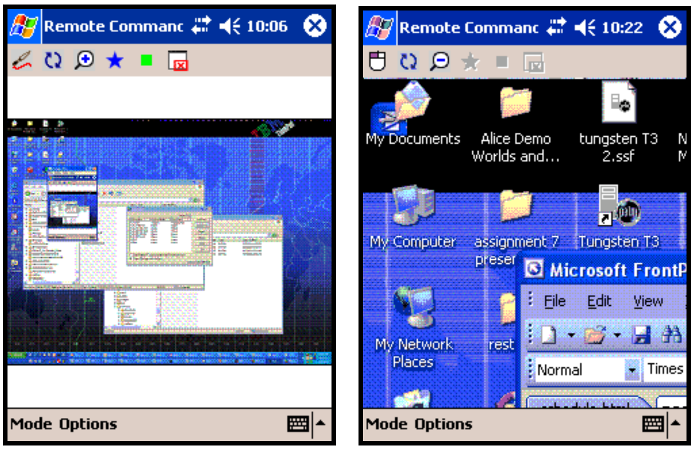

Figure 3: Screenshots from RemoteCommander displaying the full PCscreen on the PDA (to the left) and a segment of the screen (to the right).

SlideShow Commander

SlideShow Commander is an application that runs on a handheld and controls a PC that is running PowerPoint. The handheld displays a picture and notes of the current slide, slide titles and time (see figure 4). The user can change slides, preview other slides without changing the view for the audience and draw figures on current slide (Myers, 2001).

The advantage of SlideShow Commander is that the users can control the presentation running on the PC with the handheld device. They can also change slide content and look at slides without disturbing the audience.

Figure 4: Screenshots from SlideShow Commander showing a list of slide titles (to the left) and a slide thumbnail with comments (to the right)

Command Post of the Future

The Command Post of the Future (CPoF) is based around a large screen display with multi-modal input and laser pointing. The users carry a handheld device which enables them to operate with the large display. The handheld is used for *private drill-down of* *public information*, in this case an application letting the users specify a map-area of interest by using direct pointing or *semantic snarfing* (using a laser pointer), and the handheld displays details of the selected map. The details can be edited or further explored, and then be merged back with the information on the large display (Myers et al., 2001).

The advantage of CPoF is that the users can use the large display on a PC-screen to show overview information that will not fit on a handheld screen. The details of this information can be shown on a handheld without disturbing any other users with uninteresting information (see figure 5).

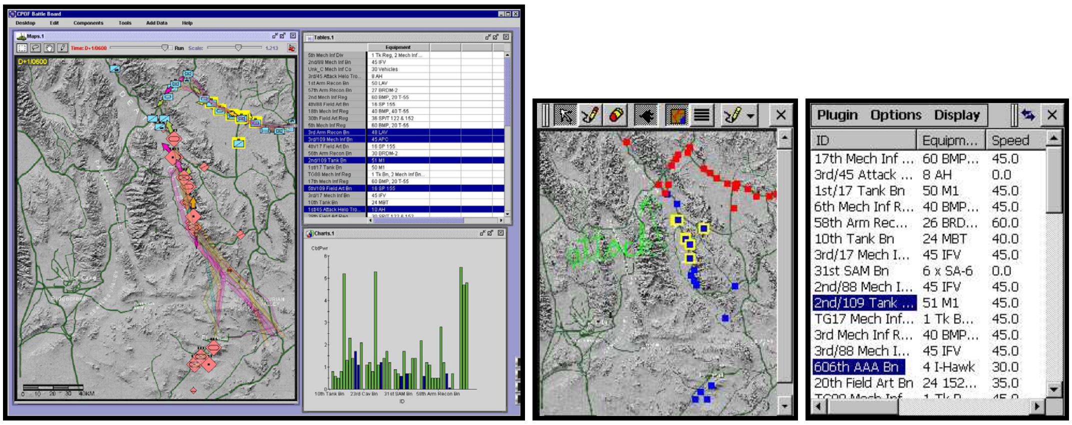

Figure 5: When the main display shows a large map (to the left) the handheld can be used to annotate and investigate various scenarios (middle) or to drill-down to investigate in detail in a table (to the left)

Shortcutter and Personal Universal Controller

The tool *Shortcutter* allows users to create shortcut widgets on the handheld to control any PC application. The handheld with the widgets can be placed besides the PC keyboard or mouse and allow two-hand input, for example pointing with the mouse and scrolling with the handheld. It can also be used as a remote to control media players or a favorite application (see figure 6).

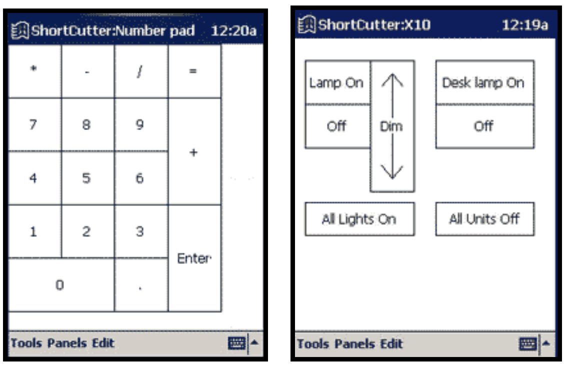

Figure 6: Screenshots from ShortCutter using the handheld as a num-pad (to the left) and as a device to control lights (to the right)

The Personal Universal Controller (PUC) has a similar function, except that the user avoids drawing and laying out the control first. The PUC on the handheld automatically downloads a specification from the device or appliance that needs to be controlled. The specification contains enough for the PUC to automatically create a graphical user interface for the appliance based on the user's preferences (see figure 7).

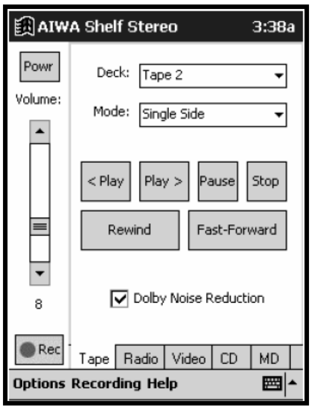

Figure 7: Screenshot from Personal Univeral Controller showing an automatically generated user interface for a shelf stereo

The advantage of these applications is that the user can control PCs or appliances from a distance with the handheld as a remote control. For the PUC, the user interfaces can be consistent across different appliances. The PUC can also automatically adapt to user preferences, for example an interface with larger buttons.

2.3. Conceptual models

When using an interactive system, users construct a model of the system and how it works in their minds. By doing this, they can predict the system's behavior and transfer what they have learned to new situations. If the designers of the system develop a good conceptual model of it before they design a user interface, the chances are great that the users will more quickly understand how they can use the system.

A conceptual model is a high level description of how an interactive system is organized and how it should work (Johnson and Henderson, 2002). It represents what the user is likely to think, and how the user is likely to respond, and is also described as "(…) the model that the designers want the users to internalize as a mental model." (David E. Liddle in Winograd, 1996).

The conceptual model is specified by main *metaphors* and *analogies*, the *concept* the system exposes to the users, the *relationships* between these concepts and the *mapping* between the concepts and the task-domain the system is designed to support.

It is important that conceptual model introduce as few new concepts as possible. Every new concept that is introduced and not recognized by the user has to be learned. Also, a new concept potentially interacts with every other concept, and one that is added to the system may increase the complexity exponentially.

Conceptual models should according to Johnson and Henderson (2002) be:

- *Simple.* The designer should not burden the users with complex conceptual models when a simple covers the users' needs. It should be as simple as possible while providing required functionality.

- *Task focused.* A more direct mapping between the system and the real-world domain will improve the chances for the designer's conceptual model to be correctly reproduced and adopted by the users.

Johnson an Henderson also claim that designing a conceptual model as a first step will provide several benefits in later steps, such as designing graphical user interfaces (GUI), implementation, documentation and other steps.

In the late 70'is David E. Liddle headed the development of the Star operating system, which was a forerunner of today's graphical user interfaces, such as Microsoft Windows and Macintosh. The development method differed from usual methods at the time. Rather than deciding what the system would do and then producing user interfaces, they focused on the user's conceptual model of what the system was and what it could do. The innovations made during this work, was the model for many of the concepts of windows, icons, menus, and other widgets in today's GUIs (Winograd, 1996). Liddle's team also used techniques where they developed several different conceptual models or designs and let users rank these models. The design preferred by most users was used in the final design (Bewley et al., 1983).

2.3.1. Metaphor and analogy

Another way of describing a conceptual model is through an interface metaphor. A metaphor in language is a comparison made between two seemingly unrelated objects or situations where an object usually is described as being a second object. In this way, the first object can be economically described because implicit and explicit attributes from the second object can be used to fill in the description of the first (*Metaphor*, Wikipedia).

The same principle apply to interface metaphor, where it is a powerful tool to let the users use them as abstractions that could relate to the real world. They let the users use their knowledge about known artifacts and events to give structure to less understandable concepts.

"The purpose of computer metaphor, (…) is to let people use recognition rather than recall" (David E. Liddle in Winograd, 1996). The metaphor can help the user recognize system status and possible actions in the system. Users are good at recognition, but they have more trouble with recall. When users see objects and operations on the computer screen, they recognize the objects and the operations that can be done with them. When they are asked to remember a command string, they usually face greater difficulties.

Examples of common and powerful metaphors are the spreadsheet metaphor used in applications like MS Excel, as well as the desktop metaphor used for managing objects in operating systems like the Star and Windows. Here the users can relate the objects visible on the screen to their real world experience making the usage of the system is easy to learn. An example is a windows desktop showing a paper bin icon.

The advantages of spending valuable development time on the metaphors are several. First of all the users will be able to more quickly use a system if the conceptual model and metaphor is done properly. The users will also do fewer mistakes if the system is acting according to their mental model.

A metaphor cannot map to all the functionalities a system designer want. Every metaphor has a limit, and the designer often has to combine metaphors or create new composite metaphors. By combining metaphors the flexibility is increased in the virtual world. A normal user can usually without any problems make the mental leaps required to understand these combined metaphors. For example, on today's personal computers "windows" on our "desktop" are used without any questions (Øritsland, 2003).

When a user uses a system, the metaphor is the reality. The result is that the user learns to use the metaphor, not the product. The user creates functional mental models of the metaphor rather than structural models of the system.

2.3.2. One system – three models

There is a relationship between the design of a conceptual model and the user's understanding of it (Norman, 1988). Norman describes three different components; the designer, the user and the system image (see figure 8). Behind these components there are three connected conceptual models;

- *The design model* – the model the designer has of how the system should work
- *The system image* – how the system actually works
- *The user's model* – the user's understanding of how the system works

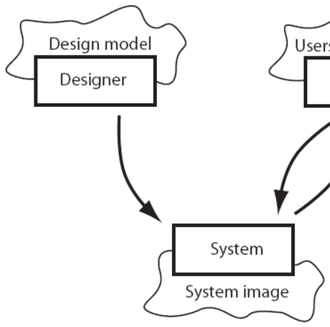

Figure 8: The users create a mental model based on the system image, which is based on the designer's conceptual model (adapted from Norman, 1988)

Ideally, all these models should map completely onto each other. Users should be able to use the system as they want in the way the designer intended. This is done through interacting with the system image, which makes it obvious to do so. However, if the mapping between the system image and the design model is not clear to the users, they are likely to end up with an incorrect understanding of the system. This will probably make them use the system ineffectively and make mistakes.

2.4. "Metaphors we live by"

Lakoff and Johnson (1980) claim that the human thought process is largely metaphorical. "(...) the way we think, what we experience, and what we do every day is very much a matter of metaphor". One example is how humans conceptualize time as something valuable that can be borrowed or wasted, something one get or loose, something that go or come.

One way to explore these metaphors is to examine our language. Since communication is based on the same conceptual system as used when humans think and act, the language is an important information source about how this system works. By analyzing linguistic data, one can get insight in the metaphors that structure the way humans understand, think and act. In other words it is possible to get insight in the users mental models by listening to what they say.

To understand the users' mental models or metaphors, Svanæs (1997), inspired by Lakoff and Johnson, preformed an experiment to reveal the "metaphors we interact by". By taking the users *literally* when they usied an interactive system he could understand the metaphors they used to explain an interactive behavior. He created simple examples with one, two and three interactive squares that changed between black and white after various rules when one of them were clicked on by the user (Svanæs, 1997, pp 128-132). By analyzing the users actions and think-aloud description of the interactive examples, he could find the implicit metaphors they used to understand them. For example; when a user described the squares to have a toggle behavior by saying "it's on" when the square is white or "it's off" when it is black, he assumed that the user had used a *switch metaphor* to explain the squares' behavior (see figure 9)(Svanæs, 1997, pp 133-161).

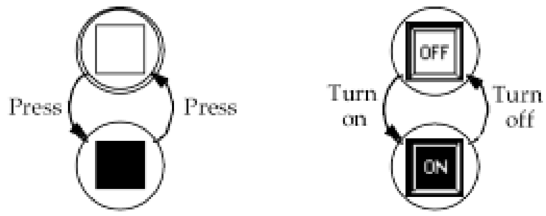

Figure 9: State Transition Diagram over one of the first examples of the interactive squares and one of the test subject's description of it (Svanæs, 1997)

2.5. Design strategy

One method to explore and learn about the potentials of a new technology is to build test applications and prototypes. According to Svanaes and Verplank (2000) this method leads to the danger of focusing too much on what is technologically possible and therefore not seeing the new design space opened by the technology. To overcome this problem they suggest a *design strategy for a new technology*. This exploration of the design space involves three steps;

1. Find the dimensions and elements of the technology. It should be based on empirical studies of how users structure their experience with the technology

2. Build simple demonstrators illustrating the dimensions and elements

3. Find metaphors that fit the applications. The search for metaphors can be formal, inspired by usability tests, other media or cultural phenomena.

As an example of this design strategy, one of Svanæs' experiments to identify the dimensions and elements for GUIs (Svanæs, 1997) is included. He developed several simple abstract examples to systematically explore the design space.

The example is the *interactive bits*. The device is a tile that can be pushed and with that changing the state of it. The tile has two states; white and black. These tiles are then used as building blocks to create different "products" as for example a font editor or an Othello game. By adding communication between the tiles, a new dimension in the design space is opened. Two tiles can be connected, creating an impression that one tile is working as a *remote control* for the other if the pushed tile does not change state, while the neighbor does (see figure 10, to the left). If both tiles change state when one is pushed, this will give the impression of *synchronized behavior* (see figure 10, to the right). If a white tile is moved close to a black tile, the tiles switch states and simulate a *token behavior* or *fire* with a small modification (see figure 11). Svanæs is (1) finding the dimensions of the technology (interactive bits), (2) building demonstrators (for example figure 10), (3) then finding the metaphors that fit the applications (for example remote control).

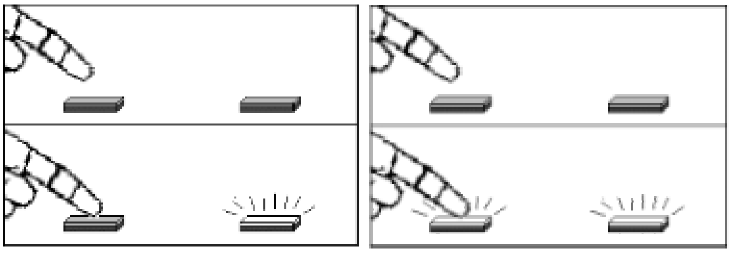

Figure 10: Svanæs' interactive bits used to give impression of *remote control* (to the left) and *synchronized behavior* (to the right), (Svanaes and Verplank, 2000).

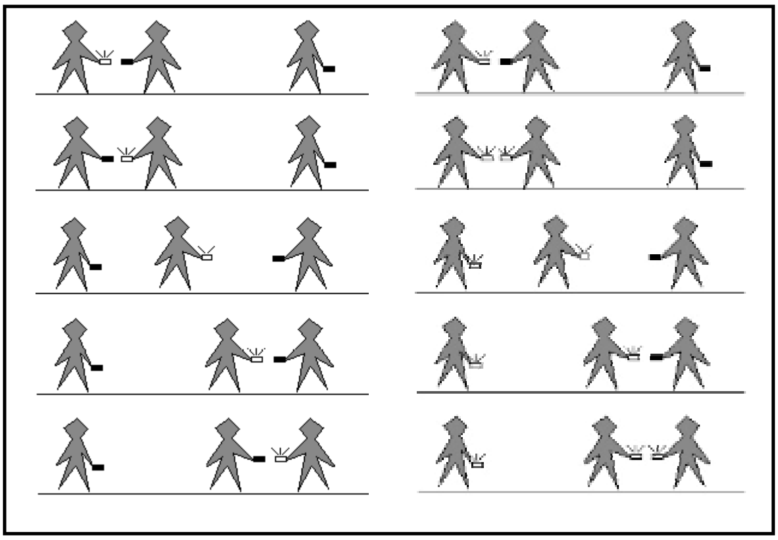

Figure 11: The interactive bits simulating token behavior (left figure, from Svanaes and Verplank, 2000) and fire behaviour (right figure, adapted from Svanaes and Verplank, 2000).

2.6. Usability engineering lifecycle and parallel design

Nielsen's usability engineering lifecycle includes three main stages (Nielsen, 1993). The *pre-design phase* includes among other things a field study of the problem and how it is solved with an old solution. The *design phase* starts with a *parallel design* session, where the design space is explored "by making up diverging designs that solve the problem in many different ways" (Nielsen, 2001). These designs are tested on users and the best design or the best elements from several of the parallel designs are used in an *iterative design* process. This process has the purpose of evolving simple prototypes to a finished product through several iterations with help from usability tests and user feedback. The usability engineering lifecycle and its parallel design versions are shown in figure 12. The lifecycle also includes a *post-design phase* which uses feedback from users to improve or redesign the finished product.

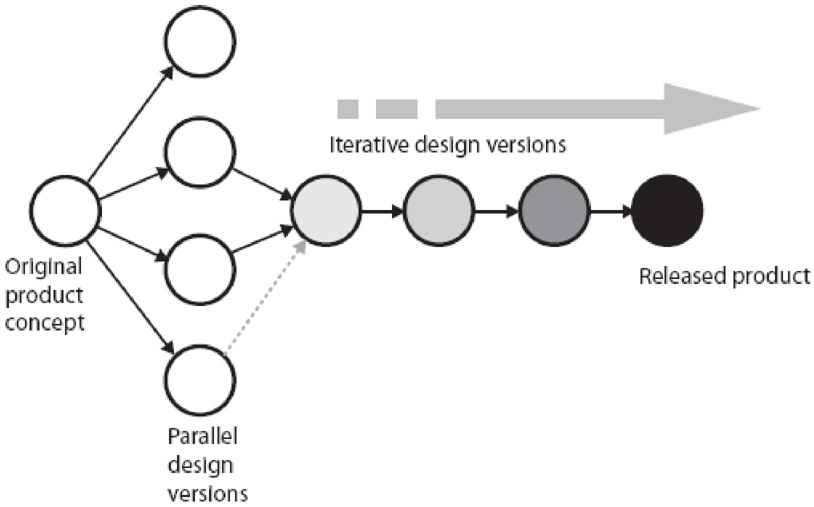

Figure 12: The usability engineering lifecycle (Nielsen, 1993)

3. Research methods

Descriptions of the research methods used in this thesis are presented in this chapter. In addition to this an evaluation of the methods used and how they are applied will be briefly discussed.

3.1. Background

There exist two extremities within research methods, the *qualitative method* and the *quantitative method* (Robson, 2002). Qualitative method is used when a deeper understanding is needed and one wants to know more about the characteristics of a phenomenon. The aim could be to understand human behavior, thoughts, actions, experience or expectations. To achieve this, the researchers have to use themselves as instruments by interviewing and observing users. Quantitative method is used when one seek a broader understanding of a phenomena. This could be testing hypothesizes statistically and testing causal connections. This is usually achieved through statistic methods to verify or falsify a hypothesis.

The difference between these methods is elegantly summed up by this quotation: “Qualitative method is used to understand the difference between apples and pears, while Quantitative method is about counting how many there are of each” (Repstad, 1993).

All the methods used in this thesis fall under the category of qualitative research methods, but quantitative data can be generated from all of them. The primary research method is *usability test*, while *focus group*, *interview* and *card sort* have been used to triangulate the results.

3.2. Usability test

To be able to model the user’s mental model which is not directly observable (see part 2.2), it is necessary to know what the users think. There exist several methods to capture the user’s mental models and gain knowledge about their thoughts. The two main methods are *usability testing* and *inquiries*, where only the first is used here.

Usability testing is a method where representative users perform selected tasks on the real system or a prototype. There are several strategies for usability testing (Bjørkli, 2000):

- *Performance measurement*
  Time, error frequency, types of errors and efficiency can be measured and the results

are compared for example between users that are given different training. Breakdowns are particularly informative.

- *Think-aloud protocol*
  The facilitator in the experiment invites the test users to think aloud while they are performing the test. The facilitator encourage to this by asking the users to explain their behavior, what they think about the system behavior and why things are not working as expected, and to solve a task verbally before it is performed on the system.

- *Question protocol*
  In addition for the users to think-aloud, the facilitator will ask them direct questions about the system or prototype.

- *Cooperation*
  The facilitator groups the test users and asks them to solve the tasks together. They are encouraged to explain for each other what the do and think. This will feel more natural for the test-users than the think aloud protocol.

Norman (1983) is pointing at challenges of using logs from usability tests. Even if protocols may be informative, they will always be incomplete. It is impossible for users to give a complete picture of their thoughts, as mental models are subconsciously generated and hard to verbalize.

Another issue is that the think aloud protocol is artificial for the user. The users think different and more rational when they have to explain their behavior. There is also the danger for them to tell the facilitator what they think she wants to hear. Still, these methods may give valuable insight in the user's mental models (Bjørkli, 2000).

The experimental scenarios should be as realistic and complete as possible. As the laboratory is not the real world, it must be as realistic as possible. The users should have control over the interaction and they should be representative for the real users. The test should be videotaped and analyzed (Bjørkli, 2000, p35).

In most cases it is enough to test a prototype on five persons (Nielsen, 2000). With this number of test users Nielsen claims that at least 85 percent of all usability problems can be found. The remaining 15 percent of usability problems can be found by testing ten additional users (see figure 13). Due to time and cost issues this is not recommended. The new test users will mostly repeat errors already made by the previous users, so this will not result in any significant results.

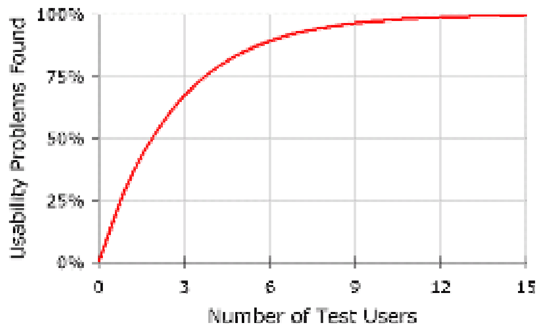

Figure 13: Testing a prototype on five test users will reveal 85 percent of all usability problems (Nielsen, 2000)

3.3. Interview

Interview is about asking questions to informants in order to obtain information. The interviews can be structured, semi-structured or unstructured (Robson, 2002).

- Structured interviews use predetermined questions in a fixed order. All the informants get the same questions, for instance a questionnaire.

- Semi-structured interviews also used predetermined questions, but the interviewer can modify the order and can change, remove or add questions if the setting or context changes.

- Unstructured interviews are used when the interviewer has a general objective, but let the informants control the conversation. The interviewer's role is to screen the important information and guide the informant through the conversation.

Interviews are flexible and easy to change prior to and during an interview session. The interviewer gets immediate answers from the informant, and it is easy to change strategy if the interview does not work as planned.

Unfortunately interviews have some drawbacks. Both the interview itself and transcribing the results afterwards take a long time. The informants may answer what they believe is right or omit information of different reasons. Therefore, interviews should be together with other methods.

3.4. Focus group

Focus group is an informal technique that can be used in interactive systems development to help the developer discover user needs and feelings prior to interface design and after implementation (Nielsen, 1997). Focus group is also known as group interview.

Focus groups require several representative users. Nielsen suggests that the focus group should have six to nine users to maintain a flowing discussion and various perspectives.

The developer should run more than one focus group, because the outcome of only one session may not be representative and discussions can get sidetracked. It should not be used as the only source of usability data. The interview typically lasts about two hours and is run by a moderator who maintains the group's focus. The interviews are usually semi-structured or unstructured.

Nielsen points at two different pitfalls with the focus group. Firstly, because focus groups are groups, individuals do not get the chance to test the system themselves. Usually the facilitator provides a product demo as the basis for discussion. Watching a demo is different from actually using the product. There is never a question as to what to do next and the user do not have to ponder the meaning of numerous screen options.

Secondly, as with any method based on asking users what they want, focus groups can produce inaccurate data because the users may think they want one thing when they really need another. This problem can be minimized by exposing users to concrete examples of the technology being discussed.

3.5. Card sort

Card sorting is a user-centered design method. A representative selection of users sort a series of cards into groups that make sense for them, each card labeled with a piece of content or functionality. From this card sorting can provide insight into users' mental models, particularly if combined with the think aloud protocol (Deaton, 2003).

The sort session can be done individually or in groups. Group sorts typically provide richer data than individual sorts, mostly because individuals need to be prompted to "think aloud," whereas groups tend to discuss their decisions. The researcher has few limitations in how to design the cards. The design space is the number of cards, size of the cards and the objects that are put on them.

To conduct a card sorting study, objects to sort is needed and a criterion for how objects are to be sorted. Different sorting techniques are appropriate to different research goals. It is also necessary with a strategy for how to analyze the results. Prior to a card sort should the cards be randomly scattered around on the table.

The card sorting as a research method or as an input in a user-centered design process has several advantages and disadvantages (Maurer and Warfel, 2004). Card sorting is fast and easy to perform, both for the facilitator and the participants. It is also a cheap method, costing not more than the facilitator's and participants' time and some index cards and labels. It is a well tested method that has been used for a long time. The sorting takes little time, but the analysis of the data can be time consuming and difficult, particularly if there is little consistency between participants. Card sorting is only one input in a user-centered design process and should be complemented by other activities

Part II – Metaphors

Chapter 4 explores the design space of handhelds and PCs used together and presents several different interface metaphors that can be used in such systems. These metaphors are adapted to a hospital setting in *chapter 5*.

4. Metaphors when using handhelds together with PCs

This chapter describes several different interface metaphors that can be applied to systems where handhelds are used together with PCs. It also show a design strategy based on Nielsen' usability lifecycle explore the design space of handhelds and PCs. It describes three possible *basic metaphors* and seven possible *interface metaphors* that can be handhelds and PCs are used together.

4.1. Parallel design

Part 2.6 presents Nielsen's Usability Engineering Lifecycle (1997). The approach chosen in this thesis is differ Nielsen's approach. Rather than uniting the best designs or design elements parallel in one design, the approach is to focus on several parallel designs where each design idea is evolved through several iterations. Parts of the modified Usability Engineering Lifecycle with several parallel design sessions are shown in figure 14.

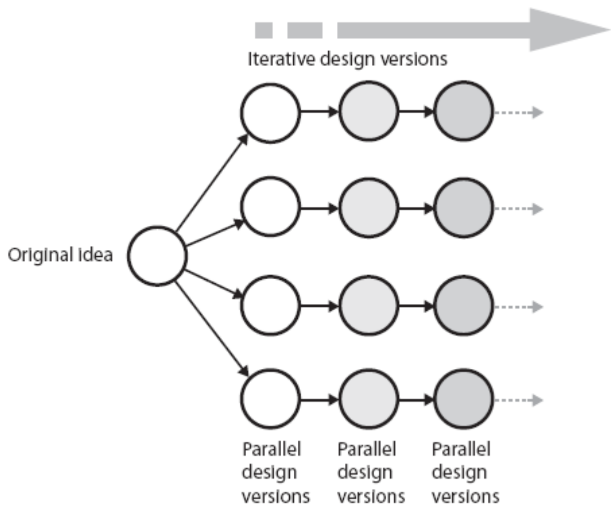

Figure 14: The modified Usability Engineering lifecycle with several parallel design sessions (adapted from Nielsen, 1993). A darker circle represents a more developed prototype.

The original idea is to use handhelds together with PCs. The first iteration of parallel design is the possible interface metaphors for using the devices together. This iteration is presented below in part 4.4. The second iteration, described in part 5.2, is the same metaphors adapted to a health care setting. The third iteration is prototypes that are based on these metaphors. They are presented in part 8.1.

4.2. Designs space and elements

In section 2.5 Svanæs' work with interactivity and interactive bits is presented. It shows how a particular design space can lead to different behavior and metaphors. In this case, the following design elements and space exists; a handheld, a PC, and a network infrastructure that enables them to be used together from a distance.

If the handheld and PC are compared with the interactive bits, a number of metaphors can be applied to the connection between them. An example of the *causality* concept is letting the handheld control the PC like a remote control. An example of the *identity* concept is that all actions on the handheld are reflected on the PC and vice versa, as the two being synchronized. The *token* or *fire* concept is for example used if information objects are transferred or copied from the handheld to the PC when they are close.

4.3. Basic metaphors

Alsos (2004) introduced several different ways for handhelds to interact with large scale displays on a conceptual level. These ways to interact are adapted to the case of using a handheld together with a PC. They are named *basic metaphors,* as they are high leveled metaphors that describe how information is viewed or transferred between the devices. Below three of these basic metaphors are described.

Private drill down of public information

Private drill down of public information look at a scenario where the computer display, which is larger than the handheld display and shared by people, contains public and high leveled information. A user may drill down the high leveled information from this computer onto her handheld computer. The user can then view the details of the information on her private screen without bothering other users, while the high-leveled information still is available on the computer display (Myers, 2001).

This basic metaphor is inspired by the Command Post of the Future from part 2.2.2 where the users can get detailed information onto their handheld from overview information on a large scale display.

Bulletin board

The basic metaphor *bulletin board* can be explained by the following scenario: The handheld computer displays information objects available for the user. To share this information with other users, the user somehow *places* the information objects on the larger computer display.

This basic metaphor is inspired by bulletin boards where people can place their private messages onto a surface in a public space, visible for anyone present.

Navigation

The following scenario explains the navigation basic metaphor: The computer display shows information objects. The handheld is used to navigate through the information on the display by using it as an input device or remote control.

This basic metaphor is inspired by the RemoteCommander, Shortcutter and Personal Universal Controller from the PEBBLES project (presented in part 2.2.2). They let the user navigate on and control PCs and appliances from a distance with their handheld device.

4.3.1. Analyzing the basic metaphors

The basic metaphor *bulletin board* and *private drill down* metaphors is quite different from the basic metaphor *navigation*. While the two first basic metaphors are used to transfer or copy objects between the handheld and the PC, the otheris used only to navigate through information objects on the PC.

The basic metaphors can be used together with interface metaphors. An example is the *RemoteCommander* from section 2.2.2 where the handheld is used to navigate on the PC by controlling its mouse pointer. This system is using an *input* interface metaphor and the basic metaphor *navigation*.

There are some combinations of basic metaphors and interface metaphors that are less suitable. For example is the input interface metaphor probably unsuitable for the basic metaphor bulletin board. How can the user use the input metaphor to present information from the handheld to the PC? There probably can be designed solutions but they will probably be unnecessarily awkward.

4.4. Possible interface metaphors for using handhelds and PCs together

As the design space were explored, a number of interface metaphors became obvious. The metaphors below are inspired by the simple prototypes described by Svanaes and Verplank (2000), by various systems from the PEBBLES project and from metaphor elements that exists in common computer systems today.

Seven metaphors were found. They are presented and described below. Its inspiration is revealed and it’s most suitable basic metaphor is presented. Based on the metaphors conceptual basis they are given names. It is important to note that anyone using these interface metaphors may want to call them by other names than the given because the users may have a different understanding of the metaphors than the designers.

4.4.1. The URL metaphor

The URL metaphor is described like this: The handheld offers links to information objects. When the user taps on a link, the object it refers to will open on the PC, not the handheld. The metaphor is conceptualized in figure 15.

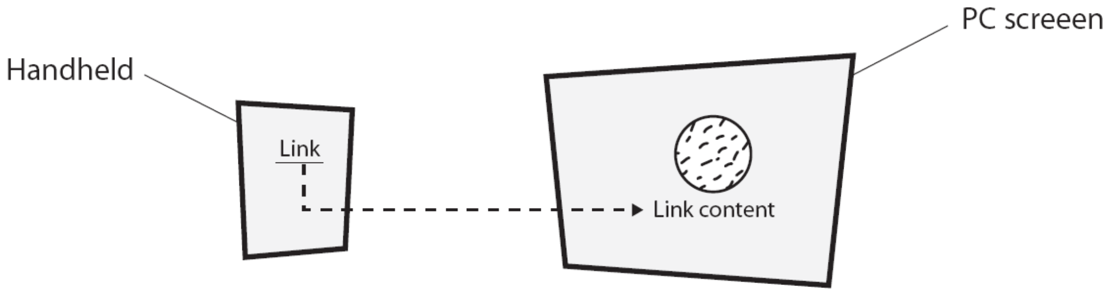

Figure 15: The link content is opened on the PC screen

This metaphor is inspired by web browsers. In most web-browsers today the user can right-click on a link and choose to open its reference in a new window. It has also similarities to the *remote control* from part by Svanaes and Verplank (2000), where something is done on the handheld and an effect is observed at the PC.

The URL-metaphor can for example be used for *private drilldown of public information*. The handheld can display the same overview information as the PC. Tapping on a link will display the detailed information on the PDA but leaving the PC unchanged. It can also be used for *bulletin board.* Tapping on a link on the PDA will display the link target on the PC.

4.4.2. The Screen extension metaphor

The handheld and the PC are somehow interconnected so that objects can be dragged between the devices. When the user drags an object on the handheld towards the screen edge it will appear on the PC-screen. The user can continue manipulating the object from the PC. The metaphor is conceptualized in figure 16.

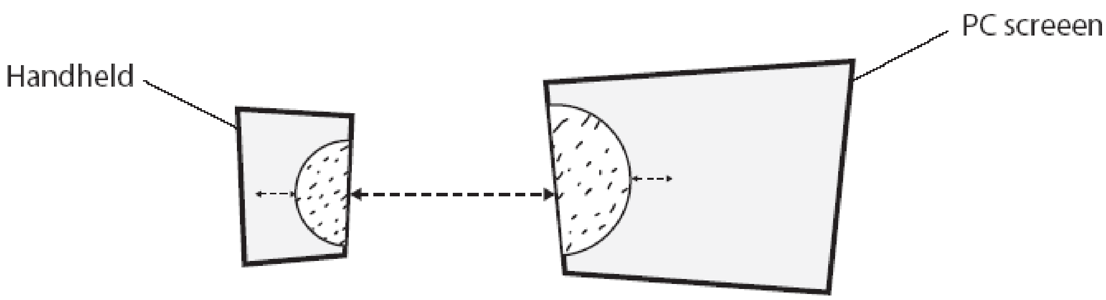

Figure 16: The PC screen is extended to the handheld and objects can be dragged between the devices

This metaphor is inspired by the possibility to extend the Windows desktop over two screens if both are connected to the same computer. Windows and icons can be moved from one screen to another

The screen-extension metaphor is appropriate for the basic metaphor *bulletin board*. A user can drag objects from his private PDA to a public PC-display.

4.4.3. The Mirroring metaphor

The handheld is showing a copy of the PC-screen where all the changes on one are reflected on the other. Usually the handheld has a much smaller screen with a lower resolution so the handheld displays a downscaled copy of the entire screen or a section of it. The metaphor is conceptualized in figure 17.

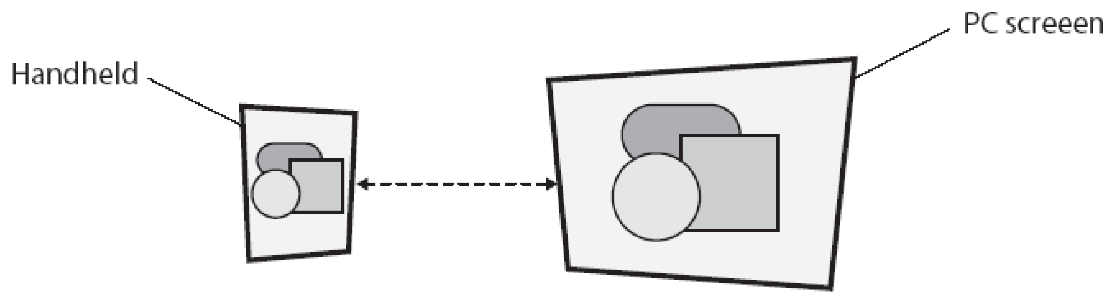

Figure 17: The handheld and PC displays the same things.

This metaphor is enthused by the *synchronized behavior* from Svanaes and Verplank (2000) where the changes on one interactive are reflected on the other. It is also inspired by the *RemoteCommander*, where the user can control the PC via a handheld device which is showing a copy of the PC-screen.

In RemoteCommander the basic metaphor *navigation* was used. The same apply to the mirroring metaphor. Because the two screens displays the exact same tings, it is like using the PC directly and no information objects are transferred between the handheld and PC.

4.4.4. The Remote control metaphor

The remote control metaphor lets the user control the PC by pressing virtual buttons (or widgets) on the handheld's touch screen. The metaphor is conceptualized in figure 18.

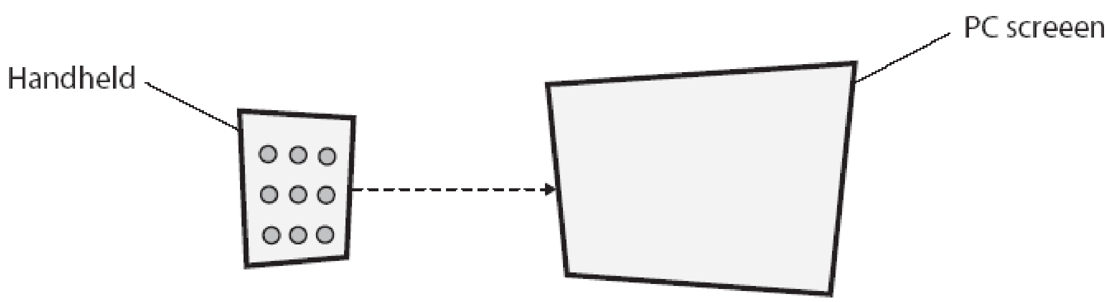

Figure 18: The handheld is a remote control for the PC .

The remote control metaphor is motivated by the interactive bits used as *remote control* by Svanaes and Verplank (2000). One interactive bit never changes state, but is pushed to change state on another bit. Transferred to this setting, the handheld is used to change system state on the PC, but does not change state itself.

It is inspired by the *ShortCutter* and *Personal Universal Controller* described in part 2.2.2 where buttons pressed on the handheld is connected to actions on the PC. It is also inspired by a typical remote control used with TVs and DVD-players.

This metaphor fits under *navigation*. The PDA is used to navigate through menu choices on the PC and no information objects are transferred between the devices.

4.4.5. The Input device metaphor

The PDA offers key input and a way to control a mouse cursor on the PC so that the user can replace a regular mouse and keyboard. The multifunctional input device can control the PC from a distance and is very mobile. The metaphor is conceptualized in figure 19.

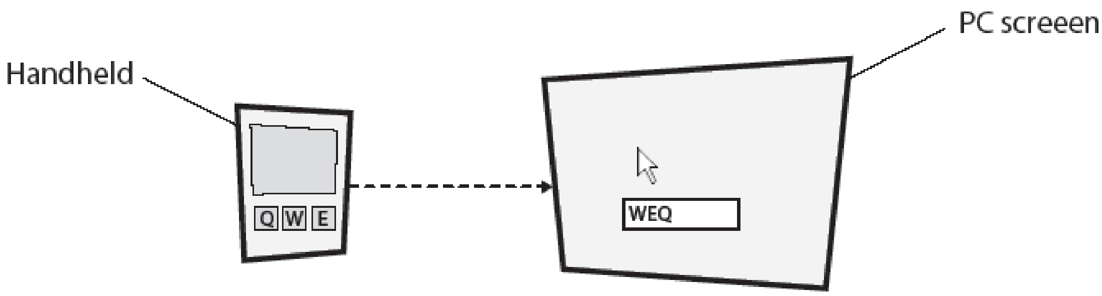

Figure 19: The Handheld offers key and mouse input to the PC

The input device metaphor is inspired by the mouse and keyboard connected to a PC. The handheld can offer mouse input through a touch screen or key input through a virtual keyboard on the handheld screen when the devices are close. The metaphor has also similarities to the *remote control* from Svanaes and Verplank (2000), where one interactive bit that never changes state is used to change state on another bit. Transferred to this setting, the handheld is the device that never change state and at the same time is used to change state on the PC.

This metaphor fits under the basic metaphor *navigation*. The PDA is used to navigate through menu choices on the PC by controlling its mouse cursor.

4.4.6. The Drag and drop metaphor

Icons on the handheld representing information objects can be dragged and released over an icon representing the PC. The objects will then appear on the PC.

The *Drag and drop* metaphor is inspired by operating systems and applications using drag and drop and direct manipulation. For example, when Windows and Mac users want to delete objects they drag and release icons representing the objects over the paper bin. This interface metaphor is most appropriate with the metaphor *bulletin board* because objects are taken from the handheld and presented on the PC. The metaphor is conceptualized in figure 20.

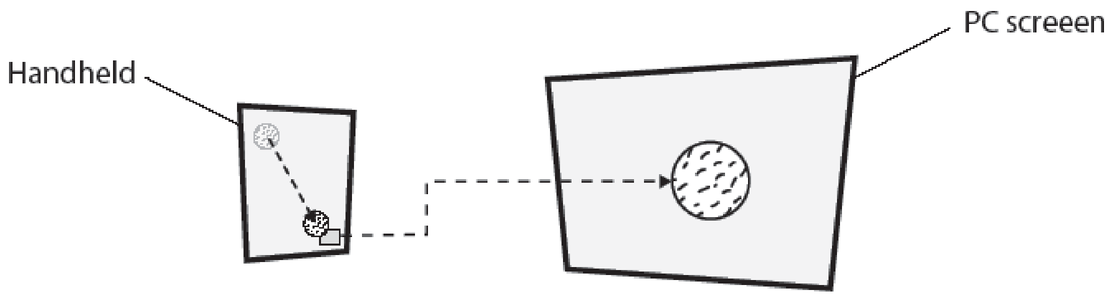

Figure 20: The user drags object-icons to a PC-icon and the object is displayed on the PC

4.4.7. The Torch metaphor

Using this metaphor for a handheld, PC and wireless network as design space is giving the following scenario: The handhelds displays information objects. A user selects an information object and stretches the handheld towards the PC-screen. When the devices are close enough, the content on the handheld can be transferred to the PC, like a burning torch lighting another. The metaphor is conceptualized in figure 21.

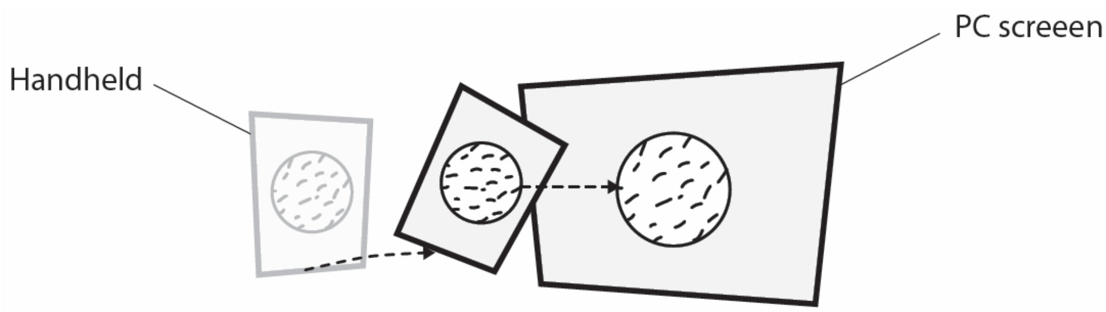

Figure 21: The object is displayed on the PC when the handheld is moved close.

The *Torch* metaphor is inspired by the modified *token and fire behavior* by Svanaes and Verplank (2000) where the interactive bits are transferring its state when they are close to each other. This interface metaphor fits best under the *bulletin board* metaphor because objects are transferred from the handheld to a PC.

4.4.8. The metaphors and their corresponding basic metaphor

The metaphors presented above were classified as one or more of the basic metaphors. In table 1 the metaphors and their most appropriate basic metaphors are summarized.

Table 1: The metaphors and their appropriate basic metaphor

Metaphor	Appropriate basic metaphor
URL	Private drill down of public information or bulletin board
Screen extension	Bulletin board
Mirroring	Navigation
Remote control	Navigation
Input device	Navigation
Drag and drop	Private drill down of public information or bulletin board
Torch	Bulletin board

From the interface metaphors presented one see that they are divided into two main groups; one where the handheld is used to send information or objects between the devices, and one where the handheld is used to navigate through information.

4.5. Factors affecting metaphor choice

There are several factors that affect what conceptual model and interface metaphor a designer should apply to a system using handheld and PCs together. Three of the factors considered most important are presented below.

The *characteristic* of the devices are an important factor. The handhelds and PCs have different sizes, screen sizes, computing power, battery capacity and uses different forms of input. Most mobile phones are operated with physical buttons, while PDAs use a combination of stylus input and buttons.

The *users* also influence what interface metaphor to use. They have different background knowledge and various experiences with other electrical appliances. A boy from the so called *play station generation* would probably prefer another interface metaphor than a university lecturer for controlling lights in a room through a smart phone.

Another important factor is the *use context*. A system where the handheld are used to control a game on the PC will require an other interface metaphor than a system where the handheld is used to control a PowerPoint presentation running on another PC.

There exists several other factors, among those *security*, but they are not discussed here.

4.6. Summary

In this chapter the design space has been explored. It has resulted in three basic metaphors and seven interface metaphors that *can* be used when using handhelds and PCs together.

These metaphors are used as a basis for the next chapter, where they are adapted to a hospital setting.

5. Using PDA and patient terminal together

One of the larges IT-projects in Norway, developing the IT-infrastructure for the new St. Olav's Hospital in Trondheim, is currently in progress. The project consist of several different parts, among those a *patient terminal* used as an advanced "hospital bed entertainment system" for the patient, and a PDA as a tool for the medical staff. Both the patient terminal and the PDA are offering a range of services for their users.

These devices in combination serve as an excellent case for using handhelds and PCs together. In this chapter the dimensions of the technology is investigated and the metaphors presented in chapter 4.4 are adapted to the hospital case.

5.1. Design strategy

In section 2.5 a design strategy for new technologies were presented (Svanaes and Verplank, 2000). As the dimensions of the technology are predetermined by the hospital case, there is no need to build demonstrators before finding metaphors that fits the technology. The demonstrators should rather be working prototypes demonstrating the metaphors. A slightly different approach is therefore made, switching the two last steps in Svanaes' and Verplank's design strategy, giving the following modified design strategy:

1. Investigate the dimensions of the patient terminal, PDA and network infrastructure.

2. Find metaphors that fit this technology.

3. Build demonstrators.

5.1.1. Dimensions of the technology

In 2002 the building of the new St. Olavs Hospital started. It is scheduled to be finished in 2014, and includes one of the largest IT contracts in the Norwegian history (Asphjell, 2005). The vision is a futuristic hospital with the patient in focus. To meet the vision, the hospital builder has decided to install a patient terminal over each bed, offering patient centered services for the guests. Medical staff in key positions will be equipped with PDAs that will offer a range of services that will give them the right information at the right time.

Patient terminal

The terminal will mainly be operated by the patient, but also by the medical staff so that they can have bed-side access to the patient record. The main goal with the patient terminal is to provide entertainment and information that will make the hospital visit better for each patient. The patient terminal is basically a PC where all input and output is done through a touch screen. The patient terminal is mounted on a movable arm (see figure 22), so that it can be moved according to the patient's or staff's preferences (Vinje, 2004).

Figure 22: The patient terminal offers patient-centered services and is mounted on a movable arm (Illustrations from Cardiac AS)

The patient terminal offers a range of services, mostly entertainment for the patient;

- IP-based radio, TV, and video "on demand",
- Hospital signaling,
- Controlling lights, blinds, heath and other functions,
- Internet, email and games,
- Telephone.

Medical Digital Assistant

The PDA (see figure 23) is in St. Olav's Hospital called Medical Digital Assistant (MDA), because it is not personal but follows a specific role, for example being a physician or nurse. The services include a calling system and telephone, and also cover services like

- Telephone directory,
- Contact information,
- E-mail,

- Messages,
- Access to several medical reference books (like NEL, Felleskatalogen).

In the future the PDA will offer additional services as medication control and order lab tests. According to Sigurd Juvik, Cardiac AS there are also prospective plans for integrating the PDA with the patient terminal to offer additional services.

Figure 23: The Medical Digital Assistant is a handheld used to offer various services for medical personnel. In St. Olav's Hospital it will be a regular PDA.

Network infrastructure

Every device in the hospital with networking capabilities can be interconnected through an IP-based messaging system. Devices with wireless networking capabilities can be connected to the network from about anywhere on the hospital area.

PDA and patient terminal used together

The network infrastructure makes it possible for every PDA to be used together with any patient terminal and any other PDA in different ways, opening an enormous design space. The two devices used together must obviously provide a valuable service for the users, restricting the design space considerably. There are a large number of complicated security issues to manage – both technical and social – but it is here assumed that all these issues can be solved.

5.2. Metaphors for using PDA and Patient Terminal together

As step 2 in the modified design strategy presented in part 5.1, the interface metaphors from part 4.4 are adapted to the case of using PDA and patient terminal together. Compared to the modified usability lifecycle inspired by Nielsen (1997) (section 2.6), this is a second iteration of parallel design with the metaphors. Step 3 in the modified design strategy is demonstrated in later sections.

5.2.1. Using the URL metaphor

With the *URL* metaphor the user selects shortcuts/links on the PDA, and the target shows up on the patient terminal for viewing and manipulation (see figure 24). The interaction is one way. The purpose is to display detailed information or information objects on the patient terminal.

Figure 24: The user selects a shortcut or link on the PDA (top) and the content of the shortcut opens in the patient terminal (bottom).

5.2.2. Using the Screen extension metaphor

With the *screen extension* metaphor the patient terminal and PDA is acting as one display. The user can drag objects from the PDA screen to the patient terminal screen (see figure 25). The purpose is to move information objects from the PDA to the patient terminal. Because both devices use touch screen, one cannot use the same techniques when two screens are connected to a PC. In the latter case a mouse pointer can be dragged between the screens, but with touch screens one has to drag the object partly from one screen into another and continue from there.

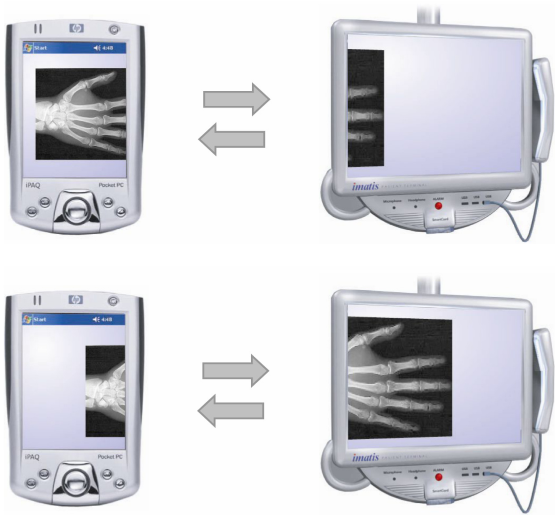

Figure 25: The PDA and patient terminal act as one screen and objects can be moved between them.

5.2.3. Using the Mirroring metaphor

With the *mirroring* metaphor, the PDA displays a copy of the patient terminal. All actions done on the patient terminal is reflected on the PDA and vice versa. The main purpose is to steer the patient terminal with the PDA from a distance. The mirroring can use different solutions. One way is to provide a reduced reflected patient terminal image on the PDA, as shown in figure 26. If the patient terminal contains small text, it can be hard to read on the PDA. Therefore the PDA should offer mechanisms to zoom the reflected screen. This can be done by letting the PDA show parts of a zoomed copy of the patient terminal. The user can move to other zoomed parts with different navigation means. An example is shown in figure 27.

Figure 26: The PDA is reflecting the content of the patient terminal and vice versa

Figure 27: The PDA shows segments of a zoomed copy of the patient terminal. The mirrored segment can be moved around to control different part of the screen

5.2.4. Using the Remote control metaphor

With the *remote control* metaphor the PDA act as a remote control or a control panel to control the information displayed on the patient terminal from a distance (see figure 28). The arrows are used to change menu selection, similar to a DVD-remote control. This metaphor is well known from TVs, stereos and videogames.

Figure 28: The PDA is a remote control that can be used to navigate through choices and menus. A click on the left arrow will cause the highlighted button to change

5.2.5. Using the Input metaphor

With the *input* metaphor the PDA is used as an input device for the patient terminal. The PDA can for example offer key input through a virtual keyboard or character recognizing and the user can also control the patient terminal cursor by using the PDA screen as a touch pad (see figure 29). The metaphor will let a user operate the terminal from a distance.

Figure 29: The PDA offers a touch pad and a virtual keyboard to control the patient terminal

5.2.6. Using the Drag and drop metaphor

The PDA uses a *drag and drop* metaphor, similar to the desktop or direct manipulation metaphor found in many operating systems and applications today (such as Windows). The user can drag objects from the PDA to an icon representing the patient terminal and a representation of the object will be displayed on the patient terminal (see figure 30).

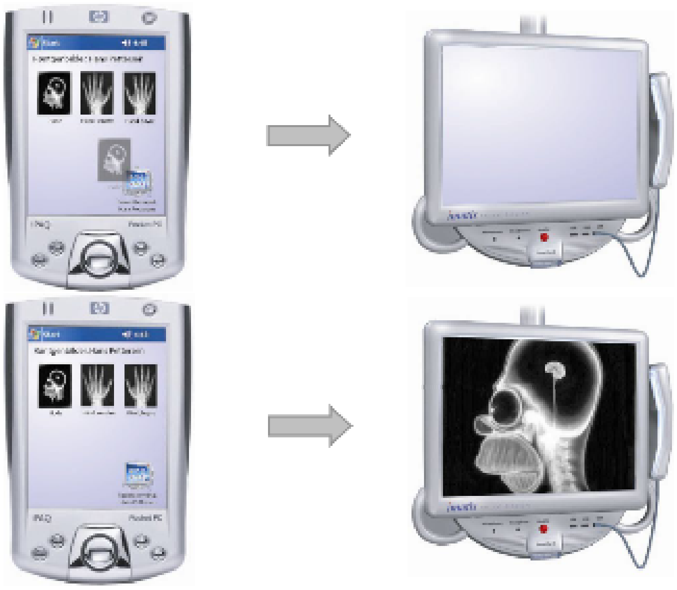

Figure 30: The PDA displays information objects, here as x-ray images. Objects can be dragged and released over an icon representing the patient terminal. The information object is then transferred from the PDA to the patient terminal

5.2.7. Using the Torch metaphor

The *torch* metaphor uses the user's gestures. After the user has selected an information element on her handheld device, she transfers it to the patient terminal by stretching the PDA towards the terminal. When the devices are sufficiently close, the content on the handheld is transferred to the patient terminal like a burning torch lighting another (see figure 31).

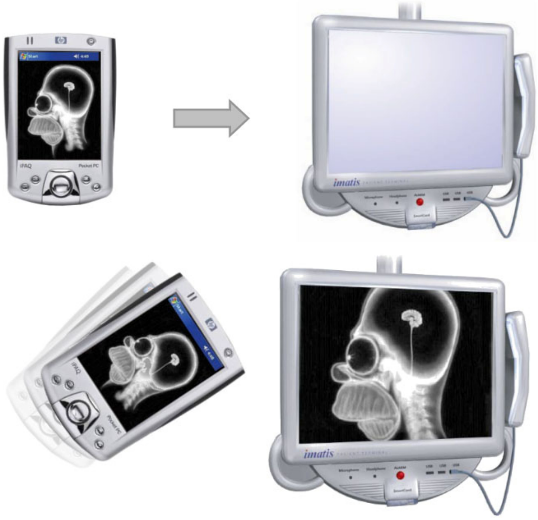

Figure 31: By moving the PDA close to the PC, the information is transferred to the PC like a burning torch is lighting another

5.3. Summary

This chapter has investigated the design space of a PDA and a patient terminal in a hospital setting. Seven interface metaphors that fit the technology have been found with basis in the metaphors from the previous chapter. The interface metaphors are used in the next chapter where they are presented to focus group participants and used as a basis for prototypes.

Part III – Research methods

The setup and main results from a focus group session and an interview is presented in *chapter 6*. The purpose was to understand how the handheld and PC could be used together in a hospital setting. In *chapter 7* the usability test experiment setup is described where prototypes based on the interface metaphors from *part II* were used. A card sort method with the purpose of ranking the prototypes is also described.

6. Focus group and interview

Focus group and interview were used as supporting research methods in this thesis. The results from a focus group session and interview gave inspiration to an *x-ray image viewer* which let a physician select an image on a PDA and display it on a patient terminal. This is an example of a system using handhelds and PCs together.

6.1. Focus group

The purpose of the focus group is to find possible scenarios in the hospital setting where PDA and patient terminal could be used together. Another goal is to get comments on the metaphors presented in part 4.4 and 5.2, and to reveal new metaphors. Focus group as a research method is presented in part 3.4.

6.1.1. Participants

At the focus group meeting, four representatives from St. Olav's Hospital attended. Seven participants were invited, but three of them could not attend because of various reasons. One of the participants was a male physician, the rest were female nurses. Their ages ranged between around thirty to fifty years. None of them had used a PDA before, but all of them had used a mobile phone and they had all some background knowledge about the patient terminal. The participants formed a representative selection of users, except that no patients were present.

6.1.2. Location and equipment

The meeting was held in the usability lab at the Norwegian Center for Electronic Patient Records (NSEP). The layout and furniture in the lab was simulating a hospital ward.

A PDA and a Tablet PC, simulating respectively the Medical Digital Assistant and patient terminal, were available for the participants (see figure 32). The devices were turned off, because only their physical shape and possible user scenarios was focus for the session. The participants were able to use them whenever they wanted. The purpose of the devices was to give each participant the opportunity to show the facilitator and the other participants how they would use these devices as they explained possible user scenarios.

Because a Tablet PC is smaller than a patient terminal, and therefore not a perfect substitute, a LCD touch screen monitor with the same size as the terminal was available in the usability lab to let the participants see the correct size of it. This display was not used by the participants directly but was used to show a presentation of the ideas and very simple prototypes that demonstrated each interface metaphor.

The moderator was careful not to influence the participants during the session and terms like "ways these devices can speak together" was used rather than the word "metaphor". The entire session was videotaped and transcribed.

Figure 32: A PDA simulating a PDA (to the left) and a Tablet PC simulating a patient terminal (to the right)

6.1.3. Focus group plan

Several ideas of how these devices could be used together and possible metaphors were already conceived by the moderator, but these were not unveiled to the participants until they had discussed scenarios and metaphors together.

The coarse plan for the focus group session is explained below.

1. Present the external conditions (PDA, patient terminal and connection between them) and the main idea – that the devices can be used together.

2. Invite the participants to find possible user scenarios for the idea.

3. Present interface metaphors of how the devices can be used together.

4. Invite the participants to find the most suitable interface metaphors to the scenarios and new metaphors.

6.2. Results

The focus group resulted in many interesting opinions and ideas, but not as structured as the moderator had hoped. The findings were grouped together and discussed under suitable subheadings.

6.2.1. Finding scenarios

During part 2 and 4 of the focus group plan several user scenarios emerged. When the participants came up with a new scenario, they often used the devices available to physically show how they could be used together. Occasionally they played out the scenario in front of the patient bed. The main results are presented below.

Using the PDA to identify patients

One of the participants suggested that the PDA had a bar code scanner that could scan a bar code around the patient's arm. This could automatically display the right patient data on the PDA or the patient terminal. She also suggested that the PDA could feel that it was near the patient terminal or a chip operated under the patient's skin. She used the term "key" as a metaphor for the PDA; the PDA was the key to show patient information on the patient terminal.

Using the PDA as an input device when documenting the patient

When the medical personnel is visiting the patient, they occasionally carry with them a laptop computer to document the patient's state and given medication, and to access the patient record. This laptop is uncomfortable to carry around and is often not available.

According to the focus group participants, the plan for the future hospital is that the patient terminal or the PDA is used for documenting and to access information from the patient record instead of the laptop. The participants were very skeptical about documenting directly on the PDA because of the small screen size. They are also skeptical about using the patient terminal because of privacy issues. They suggested that the devices could be used together for this purpose by using the PDA as an input device for the patient terminal.

The participants were concerned over ergonomics. They were concerned that they had to bend over the patient's bed to control the patient terminal, especially in situations where the content on the patient terminal should be viewed simultaneously by the patient and the medical personnel. When they are writing documentation, should they be standing or sitting? They saw a potential use in the PDA as an input device for the patient terminal so that they could sit anywhere to type or move a mouse pointer on the patient terminal.

Using the PDA to log onto patient terminals

The focus group participants believed that an on-logging procedure on each patient terminal or room is a very unpractical solution. They thought that it is better to use a laptop that requires one logon and let them easily switch between many different patients. Then they suggested that the logon could be done once on the PDA and that it could be the *key* to logon if the patient terminal somehow could sense that the handheld was near.

PDA showing list of patients

The participants thought that the PDA could hide the list of patients in the hospital ward. If this list should be displayed on the patient terminal, the physician would have to move it away from the patient because of personal information protection laws. The participants saw a potential problem in that the patient would feel ownership to the patient terminal and dislike that the medical personnel took it away from them.

PDA hiding log-on, browsing and searching

The focus group participants were concerned that the patients could be confused when they watched the medical personnel logging on to various systems, browsing and searching through the patient's medical record, so they suggested that PDA could be used for this purpose. The PDA would be the medical personnel's private screen and not visible for the patient. They would use the PDA to select what information from the patient record they would show on the patient terminal. They also suggested that the PDA could display personal sensitive information that should be hidden for the patients.

PDA and patient terminal used for preoperational briefing

The focus group participants wanted to show x-ray and CT-scan images on the patient terminal screen with the purpose of explaining medical issues to the patient, especially prior to operations.

One participant was very skeptical about using too many gadgets when explaining different issues with the patient because it would draw the medical personnel's attention away from the patient. Instead of talking and looking at the patient, the focus would be on for example the PDA or the patient terminal. Also, the patient could be distracted from the devices and miss important information from the medical personnel. Another issue is that it undermines the physician's trust when she only reads from a screen.

The information that could be showed to the patient on the terminal should of pedagogical reasons be simple. They believed that pages with text would be too confusing and that only images and illustrations only should be displayed on the terminal.

Using the PDA to control the patient's environment

One scenario that was thought of early in the research, was that the PDA could be used as a remote to control functions on the patient terminal, such as lights, heat and blinds. This scenario did the participants not mention during part three of the focus group. When the moderator suggested it afterward, they considered this scenario as uninteresting. The patients could handle that from their own patient terminal.

6.2.2. Evaluating interface metaphors

Part four of the focus group took a different direction than first planned. The participants discussed the metaphors loosely rather that trying to fit them to different scenarios. One of the participants said that "you can't use only one [metaphor] for a particular scenario, but may have to use a combination of several, depending of what you want to achieve". Their main conclusion was that various situations and different individuals required different interaction methods and that one should be able to change between different methods.

The most interesting results are summed up below:

- The participants thought the remote control metaphor was pointless. They thought it would be easier to just press the patient terminal screen directly.

- When using handheld to display sensitive information on the patient terminal it is extremely important that the information pop up on the correct patient terminal. The participants felt that this would feel more secure when they operated directly on the patient's terminal.

- They thought the URL and Drag and drop metaphors seemed simple and useful.

- The participants felt that mirroring showing only a segment of the patient terminal on the PDA was risky because it could hide important parts of the screen.

6.3. Interview of a physician

The response from the focus group indicated that they needed a tool where they could show x-ray images to a patient from the PDA onto the patient terminal. To further investigate this need, a physician/specialist at the rheumatology ward at St. Olav's Hospital was interviewed. The results from this interview confirmed and explained the need for a tool that could display x-ray image on the patient terminal. The purpose of the interview was to investigate the results from the focus group in more detail.

6.3.1. Results

According to the physician there are several situations where x-ray images are advantageous to show to patients. He defined the patient as the owner of the medical problem and the one who is exposed to risk. Also, the patient is the one who can describe pain and worries, and has often an assumption about the diagnosis. The physician has to *convince* the patients and *prove* for them what the medical problem is, *encourage* them to agree on the treatment plan and convince them that they are treated.

Diagnostics is about finding an explanation of the medical problem and making this clear to the patient. *Treatment* consists of four steps. First a treatment plan has to be made. Next, the patient has to approve this plan. The plan is then carried into effect. After finishing the treatment, it is then evaluated.

The physician had good experiences in explaining the patient's diagnosis by using x-ray images as supporting "proofs". According to him, it is important to prove for the patient that the diagnosis is correct, as the patient may have incorrect assumptions about the diagnosis and the risks that follow. In situations where the physician has to convince the patient to approve the treatment, he also uses x-ray images as "proofs".

The physician claims that x-ray images are tangible and objective proofs and are often more convincing than the physician's explanation. When the treatment is evaluated by the medical personnel and the patient, x-ray images is also used by the physician to convince the patient that the treatment is successful.

When the physician displays x-ray images to a patient, not all of the available images are used. This is mainly because not all of them are interesting, but also because showing all of them may confuse the patient.

6.4. Design decision

The results from the focus group session indicated that using PDA together with the patient terminal can offer something extra than operating on the devices separately. The idea that seemed to be most useful and realistic for the medical personnel was a system which let the users find and select images on the PDA and present them for the patient on the terminal. It is here called *x-ray-image viewer.* This serves as an excellent case for the special case of using PDA and patient terminal together, and is at the same time a good generic case for using handhelds and PCs together.

6.5. Summary

This chapter has presented the design elements (PDA and patient terminal) and possible interface metaphors to a focus group consisting of health personnel. It has resulted in several user scenarios where using the PDA to show x-ray images to a patient was most interesting. This scenario has been further detailed in an interview, and has resulted in an idea of an x-ray image viewer. The idea is used in the next chapter as a basis for several prototypes using the interface metaphors from the previous chapter.

7. Usability test and card sort

The results of the focus group and the interview implied that the health personnel needed a tool to show x-ray images to the patients during visits. The methods proposed a system where a PDA can be used to find and select images and display them on a patient terminal so that they can be viewed by the patient. Prototypes of an x-ray image viewer system were implemented to test the different interface metaphors from part 5.2 in a usability test experiment. A ranking was conducted directly after the usability test using card sort. The aim of the experiment and sort session was to provide data for later analysis.

7.1. Designing prototypes

As part of the step 3 in the modified design strategy presented in section 5.1, eight different prototypes of a system capable of presenting x-ray images on a patient terminal were developed. Each prototype represented one of the interface metaphors described in part 5.2, except for one extra case; direct interaction with patient terminal. The prototypes are a third iteration of parallel design (see figure 14 on page 29). A prototype can be defined as "an experimental, incomplete design or program developed to test design ideas" (Preece et al., 1994, p. 718).

The purpose of the prototypes was to let the user test realistic implementations of the different interface metaphors. All prototypes let the test subjects performing the same task; selecting images using the PDA and displaying them on the patient terminal. There was one exception; one of the prototypes used the patient terminal only to solve the task. The purpose of this prototype was to have a null-case to find out if there was an advantage to use the PDA and patient terminal together compared to use the patient terminal alone.

7.1.1. The prototypes' basic metaphor

In part 4.3 three different basic metaphors were identified, where two of them are used in the prototypes. These basic metaphors are *bulletin board* and *navigation*. The prototypes using the bulletin board metaphor let the user choose one image from a selection of images on the PDA, and present it on the patient terminal. The prototypes using the basic metaphor navigation let the user select one image from a list on the patient terminal by using the PDA as a navigation tool. The selected image is then displayed on the terminal.

Each of the implemented prototypes represents one interface metaphor (except one prototype). Each metaphor is either used to represent the *bulletin board* or *navigation* metaphors. Table 2 displays which basic metaphor each interface metaphor has used. The special case of direct interaction with patient terminal is using a navigation basic metaphor.

Table 2: Basic metaphors used for each metaphor

Interface metaphor	Basic metaphor used
URL	Bulletin board
Screen extension	Bulletin board
Mirroring	Navigation
Remote control	Navigation
Input	Navigation
Drag and drop	Bulletin board
Torch	Bulletin board
Direct interaction with patient terminal	Navigation

7.1.2. How it works

The prototypes in the different groups are simulating different situations. The prototypes using the basic metaphor bulletin board are simulating access to the x-ray image database through the PDA, see figure 33. The images are sent from the PDA to the patient terminal for display. The prototypes in the second group are simulating access to the x-ray image database through the patient terminal, using the PDA as a navigation tool, see figure 34.

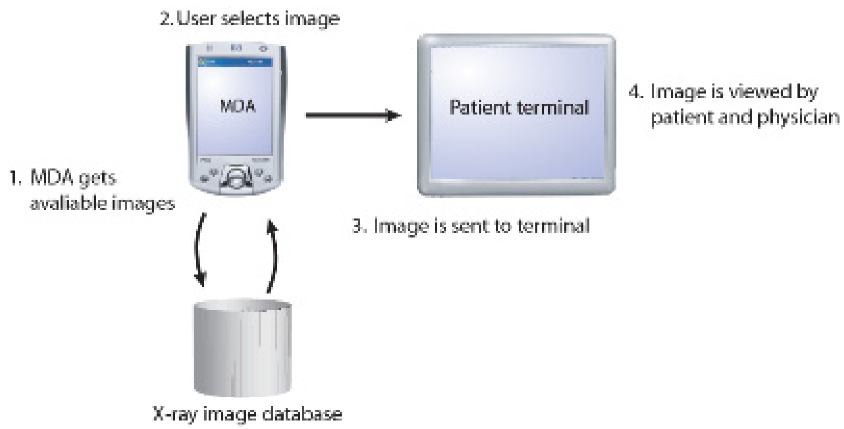

Figure 33: The designers model, conceptual model for the bulletin board basic metaphor

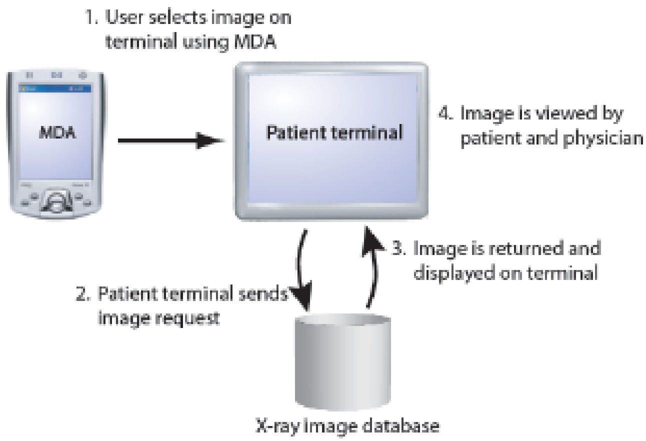

Figure 34: The designers model for the navigation metaphor

The prototypes are implemented in Macromedia Flash MX Professional. An evaluation version of Macromedia Flash Communication Server is used to let the Flash-movies on the PDA and the Patient Terminal communicate with each other.

The Flash-movies connect to the Flash Communication Server and shares an object holding variables and values on the server. For a typical interaction technique, the prototype work like this (see also figure 35):

- The Flash-movie on the PDA and the patient terminal connects to the server.
- The user selects an image on the PDA and the Flash-movie sends the picture number to the server and changes a variable on a shared server object.
- The Flash-movie on the patient terminal listens to the shared server object. As soon as it is changed, a synchronization method is forcing the movie to jump to a predefined frame number.
- The frame is holding the same image as selected on the PDA, so all that is sent is a number referring to the correct image. All the logic and images is placed in the flash movies.

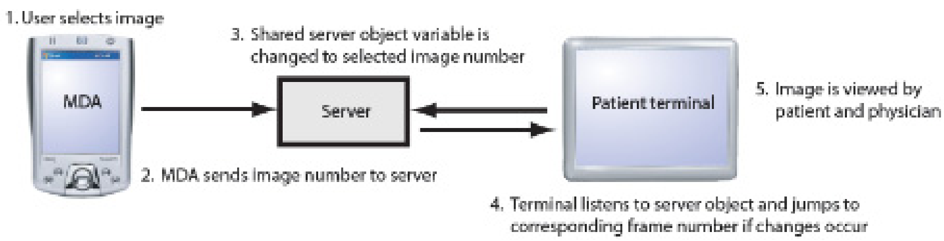

Figure 35: Model of the system image

There are two special cases; the prototypes *Input* and *Torch*. For input, the synchronized object is holding variables like mouse position and if the mouse is pressed or not and is continuously updated. For *Torch* a Wizard of Oz technique is used, involving a third

Flash-movie and a human simulating the computers behavior. This is further explained in section 8.1.7.

Each prototype is described in detail together with the results in part 8.1. For more information about how the system works and source code, see appendix A.

The testing of the prototypes was done in an artificial environment with representative users. Below the experiment setup and procedure is further explained.

7.1.3. Equipment and setup

To represent the medical digital assistant, a Pocket PC with a wireless network connection and flash player installed was used. The patient terminal was imitated using a 15’’ touch screen LCD monitor. For complete hardware details, see table 3.

Table 3: Hardware used in the usability test experiment

Simulated device	Hardware details
MDA/PDA	Fujitsu Siemens Pocket LOOX, Microsoft Pocket PC, 520 MHz
Patient terminal (PC)	DELL Inspiron 500m 512 MB RAM 1,5 GHz Pentium Mobile
Patient terminal (Display)	LG LCD Touch Screen Monitor L1510SF

The monitor was connected to a laptop computer. All the cables and the laptop were hidden under and in front of the bed so that the users could not see them while playing out the scenario. The monitor was placed on a table besides the patient bed in a position so that both the patient and physician easily could see and touch it, resembling the movable arm that the patient terminal is mounted on. The experiment setup is shown on figure 36.

Figure 36: Experiment setup showing the patient's bed and the patient terminal

The test was conducted in the usability lab of Norwegian Center for Electronic Patient Record (NSEP), simulating a real hospital ward. The test monitor, physician and patient were equipped with a wireless microphone transmitting speech to a separate control room.

The tests were recorded by two cameras. One of the cameras was remotely controlled by the cameraman and was mounted in the ceiling. This camera recorded the participants' interaction with the patient terminal. The second camera was placed in front of the test participants and recorded their facial expressions and interaction. In addition, the PDA screen was automatically captured with mirroring software and added to the recorded video. Figure 37 displays a typical video frame from the test.

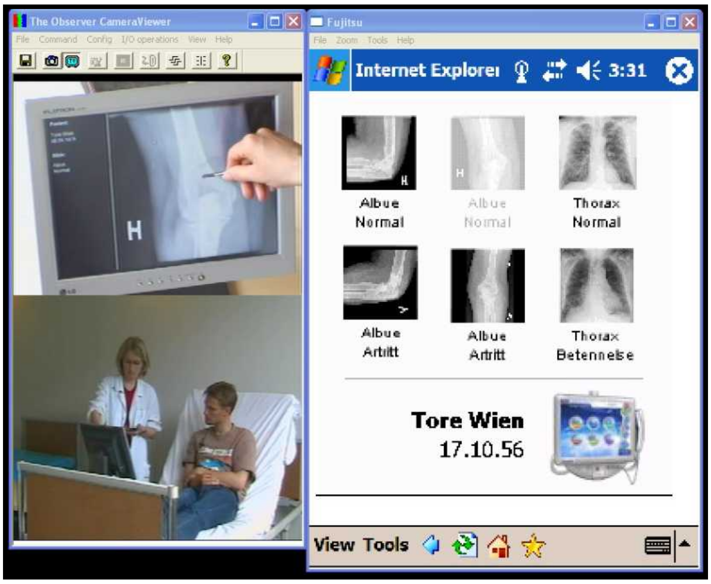

Figure 37: Frame from video captured during the usability tests

7.1.4. Test subjects

Each of a total of five tests was conducted with two test subjects, one playing the role of a physician and one playing the role of a patient. The test subjects playing the role of physicians was real physicians recruited partly from NSEP (three males) and partly from St. Olav's Hospital (one female and one male). The physicians from NSEP are working partly as researchers and partly as specialists at the hospital. The test subjects' age ranged from around 30 to around 50 years.

The test subjects playing the role of patients where all recruited from the NSEP area. Four of them were students and one was a researcher. Two of them were males and three were females. The patients' age ranged from around 25 to around 35 years.

7.1.5. User task and scenario

The scenario used under the test was inspired by the results from the focus group from part 6.2 and the interview from part 6.3.

> *The patient, Tore Wien, has arthritis*[1] *in his left elbow joint. You want to explain to the patient about his arthritis and how you are going to make him well again.*

[1] Arthritis is an inflammation in a joint

To support your explanation and make it as pedagogic as possible, you may show the patient any x-ray images you have available.

The physicians have seven x-ray images available. Two of the images are from the sick elbow joint and two images are from the normal elbow joint (side and front). There are also three images available that has nothing to do with the scenario. They show a CT-scan of the head, a normal chest x-ray and a chest with pneumonia. The purpose is to have information available that the patient does not have to see. The physicians is free to explain to the patient as they want or as the usually do. They can choose to use any of the available images when they explain to the patient. They can also show the images as many times they want.

The patients' task is to observe the information and give a subjective opinion of how they like this particular interaction method. They will of course not get a first hand impression of using the PDA, but they will see two main differences in the information presented to them; one where they see a list over pictures on the patient terminal, and one where this list is hidden from them. In addition, the input metaphor will display a mouse pointer. The patients will be asked how they perceived and liked the current interaction method.

7.1.6. Test procedure

A ten-point test procedure by Tognazinni (1991) was followed before each test. This included introducing the test monitor and cameraman, and explaining the purpose of the test. The participants got a quick introduction of the equipment in the room and were reminded that the test was recorded only because of the later analysis. The physician got a short training session in using a PDA if he or she never had used one before. Both was trained in the "think aloud"-protocol. Both participants were informed about the scenario and their tasks. They were also reminded that they could abort the test at any time.

The patient was invited to lie down in the bed and the physician was asked to stand besides it and play the scenario with the first interaction technique. Each time the experimenter introduced a new interaction technique, he referred to it as a "new way to use the PDA", and never by the names given to them by the designer.

Due to the relatively large number of interaction techniques to be tested, it was not possible to make a thorough interview of the users after each test because of time issues. When the physicians were recruited they were very clear on that they did not have much time, so the total test time was restricted to maximum one hour. Each of the five tests lasted between one and one and a half hour, and produced a total of five hours recorded material. The material was partly transcribed.

After trying an interaction method, each physician was interviewed about how he or she liked it. Each patient was also interviewed, and together with the physician they were encouraged to discuss the method together. The interview questions were restricted to *what did you think about this interaction device*, encouraging them to tell freely what ever they wanted. If anything interesting came up, follow-up questions were improvised to gain a greater understand of the users' mental models about an interaction method and how they would have improved it.

If the physicians demonstrated that they mastered the interaction technique or if their explanation was very long, the experimenter in some cases interrupted them and asked them to move on to the next interaction technique because of time issues.

These steps were repeated for each of the eight interaction techniques. In order to limit the number of dependent variables, the prototypes were tested in the same order for all the tests. This may of course have influenced the results for prototypes late in the test, particularly because of learning effects from the previously tested prototypes. The alternative would have been a random order for testing the prototypes, but this would have made it difficult to control the learning effect.

The test order is chosen based on feedback from two usability pre-tests. In these tests the test subjects wanted to test resembling methods together to be able to compare them more easily. The test subjects tried direct interaction with patient terminal before introducing the PDA to see how introducing the handheld would affect them. The rest of the order is presented in table 4.

Table 4: Test order of prototypes

Order	Protoype
1	Directly with the patient terminal
2	Drag and drop
3	Screen extension
4	Input
5	Remote control
6	URL
7	Torch
8	Mirroring

7.2. Ranking the methods with card sort

After trying all interaction techniques, the users were asked to rank all the methods with a card sort. The purpose of the cards was to make it easier for the test subjects to remember and compare the interaction methods. The physician was responsible for the sort with support from the patient. They should try to agree on the card order, but if any disagreements occurred, the physician should decide the final order. They were encouraged to discuss each interaction technique before ranging them in a card stack with the preferred method on top. The inspiration of using ranking is found in the design of the operating system Star, where a similar approach was used to let the users' opinions affect design decisions (see section 2.3).

7.2.1. The cards

The card stack contained eight cards, each card representing one interaction technique. They where labeled with a name, a description of the interaction and an illustration describing the interaction technique. In addition the card had a large letter code to make it easier to recognize when analyzing the videotapes. The size of the cards was approximately 18 cm wide and 13 cm tall. A typical card is shown in figure 38. All cards are found in the appendix.

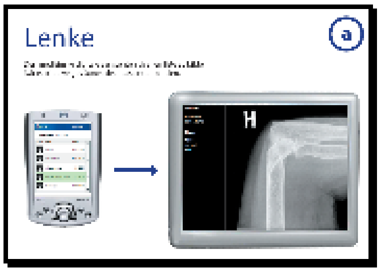

Figure 38: A typical card from the card sort

7.2.2. Card sort procedure

Both the physician and patient were invited to sort the eight cards representing each interaction technique after the usability test. The purpose of inviting both participants to do the card sort, even if only the physician had used the interaction techniques directly, was to support a discussion rather than forcing them to think aloud.

The cards were randomly scattered on a table before the test subjects were asked to sort the eight cards in a stack after their own preference. They were encouraged to discuss and explain their decisions. The purpose of doing an open sort was to let the test subjects to reveal what factors they found most important.

Each card's position in the stack was recorded and gave each interaction technique a score after the placing it had in the stack. For example, the interaction technique placed on top of the stack got eight points; the next got seven, et cetera. The card sort session was captured on video by a ceiling camera. Figure 39 displays a frame from the card sort session.

Figure 39: Frame from video captured during the card sort experiment

7.3. Final interview

After sorting the cards, the participants were asked if they had any additional comments or other ideas about the interaction techniques or combinations of them. After the microphones were switched of, the participants were invited to a lunch room for a cup of coffee and an informal chat to “keep the door open” for additional comments.

7.4. Summary

This chapter has explained the basis for the prototypes, the experiment setup and procedure for the usability test and card sort. The results from the experiment are presented in the next chapter.

Part IV – Results and reflections

The results from the usability test and card sort is presented in *chapter 8*. In *chapter 9* the implications of introducing a handheld device is investigated. *Chapter 10* is analyzing the card sort while *chapter 11* look into what mental models the users created when using the system and what internal metaphors these models are based on. *Chapter 12* examine how the metaphors can be used in any system using handhelds and PCs together. In *chapter 13* the research methods used is evaluated and the results validity is discussed. *Chapter 14* draws together the topic discussed and presents the conclusions. *Chapter 15* displays references.

8. Results

This chapter presents the results from the usability test and card sort session where the prototypes where ranked. With five test subjects and eight examples, a total of 40 cases were investigated. This produced over five hours with video material and resulted in an extensive transcript.

Not all of the recorded data from the usability test and card sort is presented here. When the user has a problem with an interaction method, this can have two reasons. First of all the problem can be caused by a usability problem. Another reason may be that the underlying metaphor did not match the mental model the user created. The results are presented and interpreted with the second explanation as a standard. The main focus is therefore on what the users say and do, not on the prototype's usability faults.

The results are structured after the various examples. A short description of each prototype is also given prior to the specific results. Words in [brackets] are additional information for the reader and are the experimenter's interpretation of the data.

For more information about the prototypes it is possible to download them from a webpage presented in appendix A.

8.1. Results from usability test

After presenting the images on the patient terminal, the physicians changed their focus towards the patient terminal and explained the medical problem to the patient. During this explanation, they gestured a lot and pointed much towards the screen to show the patient what to look for. In most of the cases, all four available x-ray images of the patients arm were displayed by the physicians. None of the images irrelevant for the scenario was shown, except for a couple of cases where the physicians accidentally showed the wrong picture or improvised a new scenario. The patient terminal was not used by the physicians only. Four out of five test patients touched the terminal screen at some point during the test to change picture.

The physicians often pointed directly on the screen and referred to the x-ray image. One of them said; ”To make it easier for you to see, we've got the images on this screen [referring to the patient terminal]”. Several times the physicians materialized the image and changed from referring to the *image* of the patient's arm to the *real* arm; “Let us see if we can get the normal arm [displaying a new image]”.

Some observations indicated that when the physicians used a method they thought was easy, they did not use the think aloud protocol as much as when they used an awkward method. When using a simple method, they played out the scenario with more empathy than when using a hard method. The test subjects revealed more of their thoughts when they used interaction methods they had problems using and generated a longer think aloud protocol than simple methods.

An x-ray-image viewer similar to the system proposed in part 7.1.2 had never been used by any of the physicians. They were not used to displaying x-ray images bedside. Both the physicians and the patients found it very useful and they were very enthusiastic and interested in it. The patients felt that it was a very pedagogic way to explain the medical problem.

A description of each prototype, observations done during the test and results from the following interview is presented below.

8.1.1. Testing direct interaction with patient terminal

Prototype description

This prototype let the user show x-ray images by touching the patient terminal directly. The user displays the wanted image by pressing the corresponding image from a list on the left side displaying all the available images of the patient. After selecting the image, it is displayed immediately. Important patient and picture data is also shown. Figure 40 shows screenshots from the prototype.

Figure 40: The user interface from the prototype using *direct interaction with patient terminal*

Observations

None of the users had any problems using the patient terminal directly, and all of them seemed to find it easy to use. They presented the pictures fast and naturally, and explained at the same time to the patient. The focus changed between the screen and the patient. The physician tended to materialize the image.

Interview after the test

The patients felt that this was a very pedagogic way to get information about their diagnosis. One of the patients wanted to press the screen herself, but the rest felt that the physician had control. They thought that it was "(…) very useful to get a visual and oral explanation of how it looks. When I can see before and after images, it is easier to understand the case."

One of the physicians had this opinion about the interaction method; "Very simple, very instructive. I'm not used to touch screens, but provided that everything is ready when you see the screen and that I can avoid plundering in front of it, this seems like a very good solution".

None of the users thought that it was cumbersome to bend over the terminal, but some of them were worried that it could bother the patients.

8.1.2. Testing the Drag and drop metaphor

Prototype description

The prototype representing the drag and drop metaphor displays several icons on the upper part of the PDA screen. Each icon displays an image thumbnail that represents an x-ray image. The icons can be pressed and dragged by the user. In the lower right part of the screen is an icon representing the patient terminal. When an x-ray-image icon is dragged and released over the patient terminal icon, it will apparently disappear into the patient terminal icon and the full sized image will instantly appear on the patient terminal screen. To indicate that the image is displayed on the terminal the image icon is grayed out and inactivated. The user can change picture by dragging a new image over the patient terminal icon. When this is done, the first image is activated again.

The physician has full control over the images on the PDA and the patient terminal is only displaying the selected image, not the list over available images. Figure 41 shows screenshots from the prototype.

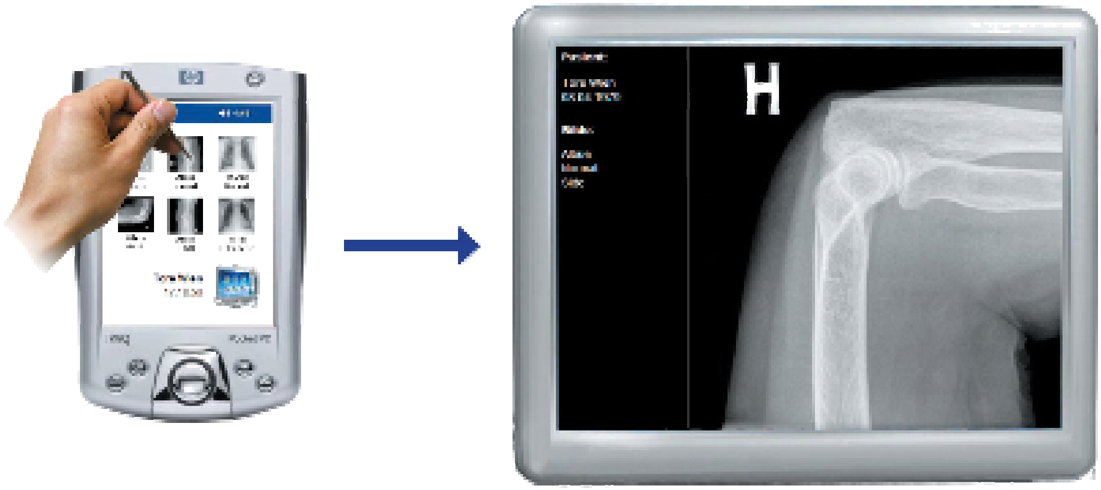

Figure 41: The user interface from the prototype using the *drag and drop* metaphor

Observations

Three of five users expected the image to appear on the patient terminal when they tapped the corresponding icon on the PDA, and needed a hint from the moderator that they had to drag the icons.

Two of the test subjects asked where the image icon should be dragged, before they tried the right alternative. The patient terminal icon had a different appearance than the real patient terminal, and some physicians pointed this out.

Two of the test subjects tried to drag the image *back* again from the patient terminal icon to its original place, showing that they thought the image was inside the patient terminal icon and had to be dragged back in place. One test subject said “oh, it has gone back again” when he saw that the first image was activated again after displaying a second image. As they had understood the interaction method, all test subjects found it fast and easy to use.

One physician explained to the patient how the system worked; “It’s so that this screen [patient terminal] has no direct connection, but it has a little box here [PDA]. So let’s see if I can show you from this box here so that you can see it in large format there [patient terminal]”

One physician felt she was *sending* the image from the PDA to the patient terminal. Another felt that he was physically taking the image; “First I *take* the image of the normal elbow [dragging it over the patient terminal], and then it *comes up* on the screen…”, and continues with; “If we then *take* a picture of an inflamed elbow…”

The physicians often changed between referring to the x-ray images as images and physical body parts: “Perhaps we should look at the x-ray image together? So let’s see if I can get it up on your screen [patient terminal]", "We can take your inflamed elbow and see how it looks"

Interview after the test

Almost all physicians felt that they got an extra device to focus on. One of them felt that he "get two places to see, and I experience that I speak less to the patient. I have to share my focus between there [patient terminal], there [PDA], and the patient. It's quite demanding, and I have to share my focus between three different levels"

One physician was positive to that he "don't have to bend over the patient and hide parts of the screen"

Some patients felt the screen was clearer when the list was gone, but others felt that the physician was hiding things on the PDA. One of the patients wonders "what secrets he [the physician] is hiding on the PDA".

One physician wanted to use the PDA to preview the images to decide which to display when she visited the patient.

8.1.3. Testing the Screen extension metaphor

Prototype description

The prototype representing the screen extension metaphor displays several icons on the left part of the PDA screen. Each icon displays an image thumbnail and is representing an x-ray image. The icons can be pressed and dragged by the user. On the right part of the screen is an illustration representing the patient terminal. When an x-ray image icon is dragged and released over this illustration, the image icon will apparently disappear into the patient terminal representation and the full sized image will instantly appear on the patient terminal screen. To indicate that the image is displayed on the terminal screen, the image icon is grayed out and inactivated. The user can change picture by dragging a new image over to the patient terminal. When this is done, the first image is activated again. The intension of this metaphor is to let the user get an impression that the two screens is one shared display, but the prototype became somewhat different from the description in section 5.2.2. Figure 42 shows screenshots from the prototype.

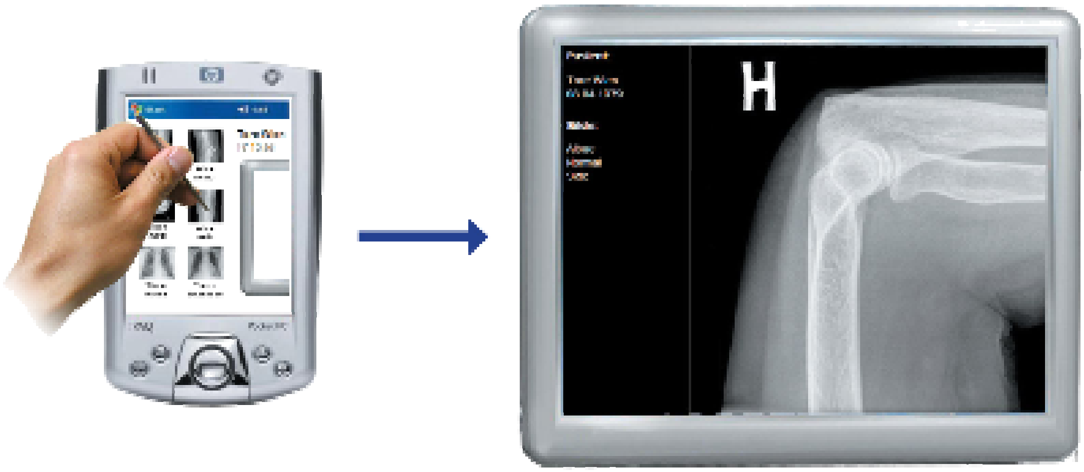

Figure 42: The user interface from the prototype using the *screen extension* metaphor

Results

Due to the similarities between this interaction method and *Drag and drop*, all test subjects mastered this easily. One user felt that the screen illustration on the PDA was small, and used some time to position the image in the middle of the screen. One physician told the patient that "I'm so lucky to have the pictures here on the screen [PDA], so let's see if I can move them [to the patient terminal] so that you also can see them."

Many users intuitively understood that the illustration on the right side of the patient terminal was the patient terminal, and used terms such as "*dragging* the image over [to the patient terminal]". The patients did not see any differences compared to the last metaphor. For example, physician 3 said "I have the possibility to see the images on the little thing here [PDA], but to make it clearer for you, we will *take* them over to this [Patient terminal] by *dragging* them over". Physician 5 said; "I press the image on my little computer, and you get it up here". For most users, it took less than one second to select a new picture and display them on the screen.

Interview after the test

Compared to *drag and drop*, most users found *screen extension* easier to use, mostly because the target was much larger and more obvious. In general the patients did not see any big differences between this method and the previous. Two of the test subjects got the impression of a screen extension or a shared desktop while one user considered them as completely identical.

8.1.4. Testing the Input metaphor

Prototype description

This prototype displays a grey rectangular box representing a touch pad simulating the touch pad found on most laptop computer today. The user moves a mouse pointer on the patient terminal by pressing and moving the PDA-stylus within the box. The input method is absolute – a stylus press in the upper left corner of the box causes the mouse pointer to move in the corresponding part of the patient terminal. To select an image, the user uses the stylus to move the mouse pointer over a list element. When the mouse pointer is over the correct list element, the user releases the stylus. This will select the list element and display the image. The mouse pointer had a small time lag compared to the stylus movement. Figure 43 shows screenshots from the prototype.

Figure 43: The user interface from the prototype using the *input* metaphor

Results

All the participants had startup problems, and it took between 10 and 60 seconds before they were able to control the pointer smoothly. One physician thought this was very unpractical and said "Oh, this was hard! Steering with this PDA and looking at another screen". One physician liked this way because he could operate the patient terminal without looking at the PDA, and with that focus on the patient and the terminal.

Most of the patients didn't notice the mouse arrow, even if it was oversized. Some patients got distracted by it. The physicians did not make use of the possibility of using the mouse arrow on the patient terminal to refer to image elements, instead they pointed directly on the screen. Compared to the previous techniques, the physicians tended to point less on the screen and talk less to the patients when using this interaction technique.

The prototype was implemented so that releasing the stylus simulated a mouse click. Many users misunderstood this, and tried to tap after positioning and releasing the stylus. This created many situations where the users displayed the wrong picture.

The prototype used absolute positioning, and most of the test subjects seemed to think relative – the same way a regular mouse works. After releasing the stylus, they very often started with it in the middle of the screen, not where they last released it. This created a lot of extra navigation.

Most users thought the PDA was an input device like a mouse. One test subjects said "Aha, with this [PDA] I can *lead the cursor* over there [menu on terminal]" and another explained "we can *navigate* us to your sick elbow, which looks like this".

Interview after the test

Most of the users felt that this interaction method was awkward and pointless, especially because the patient terminal was so close that it could be touched directly. One of them said; "I don't see the benefit compared to pressing directly on the screen. But if the screen is positioned on a remote wall, this could be an alternative".

One thought that the input field offered writing or drawing rather than moving a mouse pointer. The field offered absolute positioning, but the users did not think it would be easier with relative positioning. One user explained the poor performance with the time lag. Many of patients expressed that they got distracted by the physician's problems. They also got confused by the mouse pointer on the terminal screen. Most users thought the interaction technique was hard to use; "A bit harder to steer… Required a bit more training, need to grab and follow the arrow visually".

Some of the test subjects called this interaction method for a remote control or a way to steer the terminal. One described the method as "placing the arrow".

One user felt that the PDA took much focus; "I loose focus from the patient because it is a demanding task. I'm more concerned about the device than the patient". Another physician said; "Very hard to learn and easy to be annoyed". One felt that "…it was a bit hard to *control the cursor*, but I found it more satisfying that we both had focus on the same screen".

Two of the physicians suggested moving the menu on the terminal to the PDA instead of using the PDA to control the mouse cursor. Their suggestion is equal to the URL approach, and they suggested it before they tried that interaction method. One of the physicians actually says that he "would rather have the menu [on the terminal] on this [PDA]", even if he has not tried that option yet.

8.1.5. Testing the Remote control metaphor

Prototype description

This prototype displays five large buttons on the PDA screen. Four of the buttons are representing directions and are logically placed around the last button representing a choice. The prototype let the user navigate through pictures on the terminal in two ways. The up and down button on the PDA move the selected list element on the terminal, while a press on the middle button displays the corresponding image. The left and right button let the user change to previous or next image on the list without confirmation. It can be operated with the stylus or hand, and the intension is to give the impression of a remote control similar to those used for example with a DVD-player. Figure 44 shows screenshots from the prototype.

Figure 44: The user interface from the prototype using the *remote control* metaphor

Results

The users spent some time to find out what actions a button-press caused. A button click caused a jump to the next picture in the sequence, and one of the physicians' interpretation was; "Has to read on this screen [patient terminal] and turn the page with this one [PDA]. It's easier to press the patient terminal directly." The *turn page* analogy was used by two users.

Two of the users expected the arrows to control a cursor. It took a while for them to understand what the different buttons did. As for the input metaphor, many of the users pointed less towards the screen and forgot to explain to the patient because they focused a lot on the PDA.

One physician felt that the middle button's function was to "…activate the menu choice to make the picture pop up."

Interview after the test

One of the physicians pointed out that it takes a lot of time to select pictures that are far from each other on the list. One physician wondered why he couldn't use the physical buttons on the PDA. He tried this and preferred it compared to using the virtual buttons on the PDA screen.

Some users thought that this method was like turning the page, like turning to the next page in a book. Other users said that it reminded them of a remote control with buttons to change channel and another said one of the buttons it was like a "page down key" going to a new page.

One of the physicians thought the method was quite easy, but was still very critical; "This is some kind of remote control for that user interface [pointing at the terminal]… It doesn't make sense! It's not logical at all! Is it a game? It's easy to use, but you don't intuitively understand what to do"

One of the patients, that first were very negative to the hidden information on the PDA, was not bothered by it any more.

8.1.6. Testing the URL metaphor

Prototype description

The PDA displays a menu list with several elements, all displaying an x-ray image icon, image description and date. A press on one element will cause the corresponding image to show up on the patient terminal. The model that the prototype is communicating are links that are opened on a new display. Figure 45 shows screenshots from the prototype.

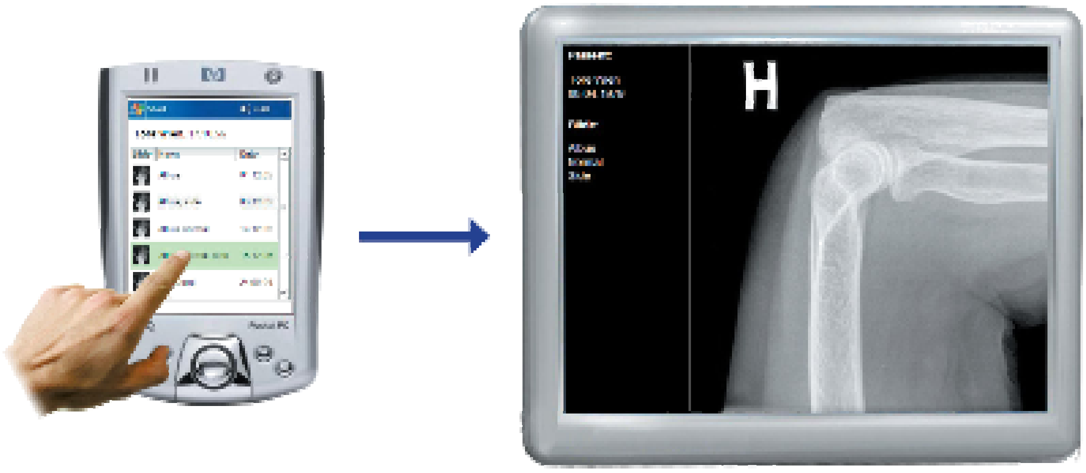

Figure 45: The user interface from the prototype using the *URL* metaphor

Results

All of the test subjects found this interaction technique very easy and fast to use. The time used to select one image was in every case less than a second and this caused the physicians to forget to "think aloud" during the test. They also materialized the body part on the image, with statements as "…take *a look at* your sick elbow."

Interview after the test

Some of the physicians thought that this method was like moving the menu from the terminal to the PDA; "This was one of the simplest. I can go directly on a menu choice. This is the same as touching the screen [patient terminal] directly."

The problem with demanding focus changes tended to be reduced; "I can, with one look and one tap, move the focus over there and have shared focus with the patient." Another user said; "I think that this approach is so simple that I believe it doesn't disturb the dialog with the patient more than using that [the patient terminal] directly." The patients felt that they got less disturbed with this method.

There were still physicians that felt that the problem was not completely gone; “When I’m in a dialog I have focus on some thing else than the patient and a common object. This [PDA] comes between us.”

One of the test subjects wanted to use the physical buttons to select the image. He tried this unprompted and felt that this was much better. He later described the benefits of the list on the PDA rather than on the patient terminal; “It’s better to lift up one and one [image] and place them on this notice board than showing a lot of information at the same time.“ At the same time he used gestures to show how he picked up “something” with the stylus and moved them to the terminal screen.

One test subject explained how introducing a computer tool can be a disturbing element; “Older people doesn’t handle that. Using a PDA, which is a disturbing element, to show pictures on a screen comes between the physician and the patient. I’m surprised I’m saying this, because I’m usually a big PDA-fan, but I see that this may be a potential disturbing gadget”.

8.1.7. Testing the Torch metaphor

Prototype description

The PDA displays a menu list with several elements, all displaying an x-ray image icon, image description and date. A press on one list element will cause the element to be highlighted. When the user then moves the PDA towards the screen in a controlled gesture, the image appears on the patient terminal. To achieve this effect a so called “Wizard of Oz” technique was used, where a human simulates the computer. In the control room, a technician pressed a button at the same moment he saw the user perform the gesture towards the patient terminal, causing the same image as the user selected to appear on the patient terminal. By doing this a “torch” effect was achieved, causing an image transfer when patient terminal was “ignited” by the PDA. Figure 46 shows screenshots from the prototype.

Figure 46: The user interface from the prototype using the *torch* metaphor

Results

One user thought that she had to press the list element and move the PDA towards the patient terminal simultaneously. In general, the users had no problems using this interaction technique. The interaction seemed smooth and natural.

To show what many of the physicians thought when using this technique, a quotation from test subject 1 is presented; Lets *take* the picture [on the PDA] we took of you and *send* it here [patient terminal]".

Interview after the test

Most users thought the gesture towards the patient terminal was awkward and unnecessary. Other users were more positive; "Just as simple as the last, but I feel that I am involving the patient more by doing this motion here [moving the PDA towards the patient terminal]."

One of the patients thought it was more awkward, but believed that older people would like this method; "It's almost like pressing the screen, he's doing something with the screen".

In one test the patient got a remote control feeling, while the physician assumed that the picture was sent by IR to the patient terminal.

Some physicians felt that it was easier to channel the pictures to the destination. They said it felt safer to send it to the screen instead of sending it on a network. "It feels safer, it's some kind of confirmation." Other felt that they were "illustrating what you do by dragging it over."

8.1.8. Testing the Mirroring metaphor

Prototype description

The PDA displays an exact but smaller copy of the patient terminal. The user can navigate through the images by selecting them on a list. The PDA is turned ninety degrees to make the PDA-copy as large as possible. By doing this a "mirror" effect is achieved. Figure 47 shows screenshots from the prototype.

Figure 47: The user interface from the prototype using the mirroring metaphor

Results

During the tests the focus switched to the patient terminal as soon as the image was selected. Many of the users didn't even notice that the pictures were displayed on the PDA because they switched focus to the patient terminal as soon as they had selected the right picture from the list. The mirrored copy on the PDA is quite small, and one test subject hesitated and said "Oh, here I have to get my glasses!" It was also hard for them to scroll down to see the rest of the pictures on the list.

During one test, the physician unconsciously put the PDA on the table and started using the touch screen instead, probably because the patient started touching the screen.

Interview after the test

One physician didn't like that the PDA was turned 90 degrees and had this opinion about the interaction method; "I have no value of seeing the same on the PDA and the screen [patient terminal], because it is on the screen things happen. Besides, the menu becomes smaller and harder to read."

Most users did not use the image on the PDA; "I used the PDA only to select, not to look at the image because I automatically moved my focus to the screen immediately after something appeared there because I knew the patient had his focus there." Another one explains; "The only value of seeing the image on the PDA is if I must decide if I want to show an image or not”. The focus seemed to be on the patient terminal; “It’s on the screen we have our focus, it’s there things happen”

One physician explains his visions about the method; “This possibility is good to have when I DON’T have the patient terminal in range and when I meet the patient in the hall. Then we could walk up to a computer and WOOOP [indicating that the image pops up on the terminal]. But it’s important that the image doesn’t pop up on the wrong screen. It should only be shown when I’m close to it.”

8.1.9. Other results

One of the largest issues during the interviews was if the image list should be on the patient terminal or the PDA. Most physicians thought at first that there was no point in hiding the list for the patient, while some of them meant that the list could distract the patient. There was also a chance that they would interpret information on the list without having the skills to do so. One physician was very positive to move the menu on the handheld because it means fewer distractions for the patient on the screen. He also felt that he lost the feedback on the patient terminal of what image in the sequence he was looking at.

Four of the patients wanted the list to be present on the screen. They wanted to see an overview over the images and felt that the physician was keeping secrets for them when the list was not present. Two of the patients changed their mind during the tests, and felt that the list took too much attention. They felt that it was easier to focus on the pictures and the physician when the list was not there. The last patient felt that he had so much confidence towards the physician that it didn’t matter if the list was there or not. He felt that the physician was controlling the show anyway. The patient did not miss the image list when it was gone. These observations were particularly done with interaction techniques that took much of the physicians’ focus.

“If this was information from the patient record, I would definitely *not* show this information on the screen to the patient even if they are allowed to see it. There are a lot of Latin and abbreviations that may confuse the patient”

Some physicians did not see any benefits of the secret screen, because there are few cases where the patients are not allowed to see the information. “Good that I can hide some information, for example descriptions“.

8.2. Results from card sort

The card sort was a very good tool to rank and get information about the interaction techniques. The short interview after testing each interaction technique gave valuable feedback, but the comments were understandably “marked” by the previous tests. The cards gave the test subjects a chance to compare all techniques at the same time.

The users often came with statements like “Oh! I liked this one!” or “I didn’t like this at all!” and then placed the card in the stack. Often they had to be encouraged to explain their decision. The discussion between the participants did not bring up any particular information that not already had been mentioned and it did not provide any good insight in how the users understood the interaction methods.

Each card sort session with the closing interview took between 5 and 19 minutes. The final card order reflected the methods’ performance and the user’s comments. The appearance of a typical stack after a sort can be found in figure 48.

Figure 48: The card stack after a card sort.

8.2.1. Card sort results

Table 5 shows results from the card sort. The number for each interaction technique and test shows how many points each technique got from the test subjects. For example, in test number three *Input* got place number 8 and hereby 1 point (the number in parenthesizes), indicating that the test subjects in this test preferred this interaction technique least of all. The number behind each column-description shows the minimum and maximum value for this column. A graph illustrating the average and variance is presented in figure 49.

Table 5: Results from the card sort session.

Metaphor	Test 1	Test 2	Test 3	Test 4	Test 5	Total	Place	Average	Variance
URL	2 (7p)	1 (8p)	1 (8p)	4 (5p)	1 (8p)	36p	1	7,2p	1,7p
Directly on the terminal	1 (8p)	5 (4p)	5 (4p)	2 (7p)	2 (7p)	30p	2	6,0p	3,5p
Screen extension	6 (3p)	3 (6p)	4 (5p)	1 (8p)	4 (5p)	27p	3	5,4p	3,3p
Torch	3 (6p)	7 (2p)	2 (7p)	6 (3p)	3 (6p)	24p	4	4,8p	4,7p
Drag and drop	7 (2p)	2 (7p)	3 (6p)	5 (4p)	5 (4p)	23p	5	4,6p	3,8p
Mirroring	5 (4p)	4 (5p)	7 (2p)	3 (6p)	6 (3p)	20p	6	4,0p	2,5p
Input	4 (5p)	8 (1p)	8 (1p)	8 (1p)	7 (2p)	10p	7	2,0p	3,0p
Remote control	8 (1p)	6 (3p)	6 (3p)	7 (2p)	8 (1p)	10p	7	2,0p	1,0p

- The *Test [number]* column shows the placing from each test [1, 8] and the points used to calculate total score, average and variance [(1p), (8p)].
- The *Total* column adds up the places giving a total score, where a lower number indicates that this was preferred by most users. [5, 40].
- The *Placing* column shows what place each interaction technique got, indicating which of them “won” the card sort. [1, 8].
- The *Average* column shows the average placing for each interaction technique. A high value is indicating that the technique is a preferred method by the test subjects, while a low value indicates a method that is not preferred. [1, 8]
- The *Variance* column shows the variance between the test subjects’ placing of the interaction techniques. A low variance is a sign of agreement between the test subjects, while a high variance is a sign of disagreement [0, 14.7]. The median for the observed values is 3,15. For variance-values larger than the median is defined as a sign of disagreement while smaller values are a sign of agreement.

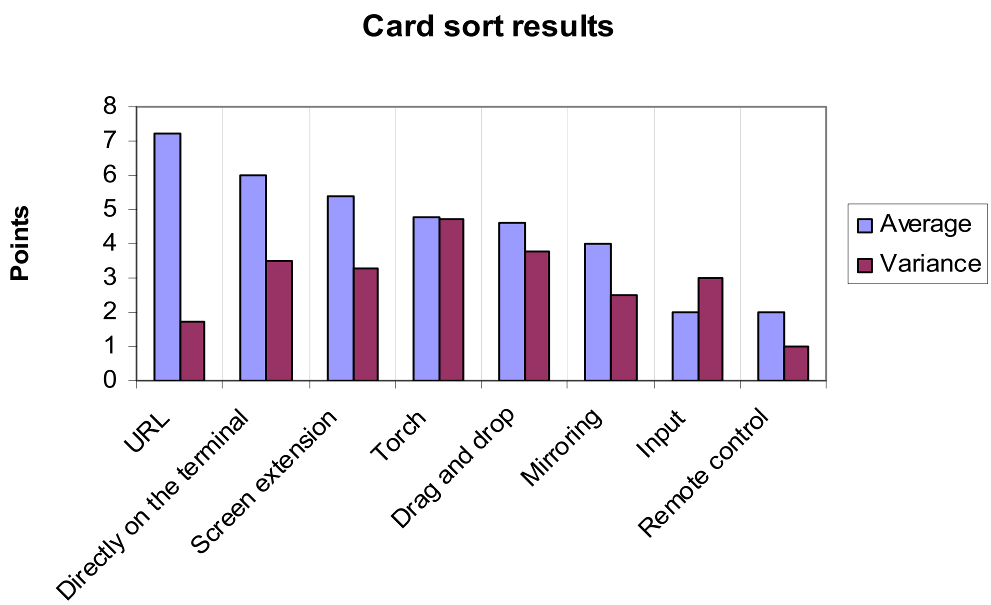

Figure 49: The card sort results in a diagram showing the average and variance for each interaction method.

8.3. Summary

This chapter has presented the results from the usability test and card sort. These results are further analyzed in the next chapters.

9. Introducing a handheld device

This chapter discusses some of the consequences of using handhelds and PCs together. The first task in the usability test was for the physicians to display images by using the patient terminal only. When the handheld device was introduced as a tool to solve the task, the user feedback and observations revealed several advantages and disadvantages. Below, the most important issues are presented and short conclusions are drawn from them. These conclusions can be used when designing systems using PDA and patient terminal together.

9.1. Private and public screen

By using the handheld as a private screen and the patient terminal as a public screen, the physicians were able to hide unnecessary information, such as the image list and the date they where taken. Some patients missed this information, but most of them felt that the terminal screen was clearer and easier to understand without it.

The patient needs one type of information – the physician another. Using the x-ray image viewer as an example, the patient should first of all be able to see the image and what body part it is from in common language. The physician must be able to see more information, such as the Latin term, the date it was taken, the radiologists interpretation, etc. From a patient perspective, this information is more confusing than necessary and may clutter the terminal screen. In figure 50 the user's information needs are represented through a Venn diagram.

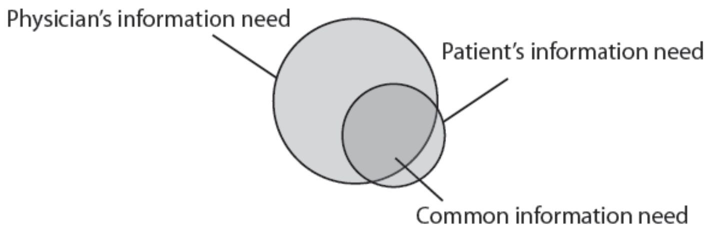

Figure 50: The users' information needs

The patient terminal should be used as a public screen displaying common information and the PDA as a private screen displaying detailed information that should be hidden from the patient due to privacy or usability reasons. Figure 51 is showing how the information is divided between different devices.

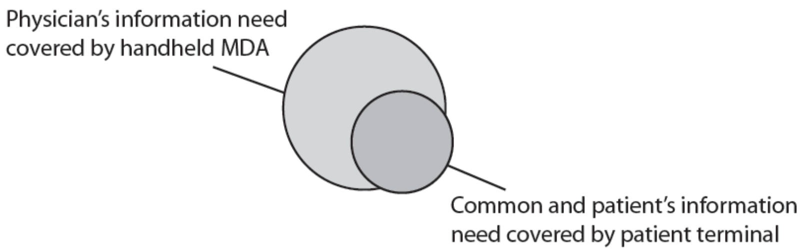

Figure 51: The information needs covered by different devices

9.1.1. The handheld to hide logons, browsing and searching

An important advantage by using a handheld device in the health care setting is that the physician is able to hide information from the patient by using the handheld as a private screen. Another thing that was suggested, both in the focus group and usability test, was to hide information or user interfaces that the patient *should not* see, such as logon screens or sensitive information. Browsing and searching are other tasks that the patients do not need to see.

There are very strict rules about displaying personal sensitive information to patients. The handheld should be used to hide such information and logon screens. It should also be used to hide browsing and searching to avoid confusion of the patient.

9.2. The change between PDA and patient terminal steals focus

The results from the usability test showed that the change of focus between the PDA and the patient terminal was quite demanding for most of the physicians, and it seemed to become a disturbing element in the communication with the patient. The observations indicate that demanding interaction methods requiring many focus changes between the PDA and the patient terminal, such as *input* and r*emote control*, took more attention from the physician than less demanding methods such as *URL*.

These observations may be explained by theories of how the mind is processing information (Proctor and Vu, 2003; Card et al., 1983). For example, relocating the head and retina takes time. According to Fitts' Law (Fitts, 1954), moving the hand from the patient terminal to the PDA are also operations that require additional cognitive processor capacity and time compared to operate one device only.

The focus change between the handheld and the patient terminal has a potential of stealing the physician's focus and become a disturbing element in the communication with the patient. The system should therefore be designed for as few focus changes as possible between the handheld and patient terminal.

9.3. The patient and physician is communicating on different levels

When the physicians and the patients looked at or used the same screen, they felt that they were communicating on the same "level". When the physicians started using the PDA, some of them felt that it became a disturbing element in the conversation and that they now were communicating on different "levels".

The patient has to compete with the PDA to get the physician's attention. It can be compared with having a conversation with a person writing an SMS. This person has to share her focus between the conversation partner and the cell phone and may, depending on her ability to accomplish concurrent tasks, give the impression of being in another "world".

The physician's focus should therefore mainly be on the patient or the patient terminal. The handheld should therefore be used only for short periods during the patient visits. An example is to use the PDA to prepare the images that should be displayed on the patient terminal so that the physician can change image on the latter without having to use the handheld.

9.4. The physician is keeping secrets on the PDA

The handheld screen will normally not be seen by the patient, keeping it private for the physicians. The tests showed that many of the patients did not like that the physicians kept "secrets" on the handheld. This negative feeling tended to be reduced or disappeared completely towards the end of the tests.

From the patient's point of view, the physician are doing "something" on the PDA that the patient does not have control over, and they are curious about what it is hiding. The observations indicated that this feeling was stronger for the first methods (*drag and drop, screen extension, input* and *remote control*) while they were weaker for the last methods (*URL, torch* and *mirroring*).

One explanation is that the first methods required more time and focus from the physician to accomplish the task than the last methods, and that the patients were more uncertain of what the physician was doing. Another explanation may be that the patients may have got used to the PDA in the end of the test.

9.5. Summary

This chapter has discussed some of the observations done under the usability test and shows some of consequences of using PDA and patient terminal together. It shows that there are both advantages and disadvantages of using handhelds and PCs together. The next chapter analyses the card sort results.

10. Analyzing the card sort

The interaction methods were ranked with a cards sort. The results from the sort were analyzed by primarily looking at the *placement* and the *variance*. A cluster analysis was carried out to find hidden trends.

10.1. Factors influencing the card order

The cards seemed important for the test subjects in order to remember and compare the interaction techniques. Humans are capable to remember about seven (plus or minus two) items in their short term memory (Miller, 1956). The number of tested prototypes is eight and is just on the limits of what the test subjects are able to distinguish and remember without any cognitive clues.

When the test subjects sorted the cards, especially three things seemed to have an impact on what position the card got in the stack (see figure 52). First of all, the *usability* of the prototypes was important. If the users did not understand how to use it, or if it was awkward to use, the corresponding card was placed towards the bottom of the stack. On the other hand, if a method was simple and fast to use, it was placed high in the stack. Another usability factor that influenced the card order was how much focus the PDA took from the physician.

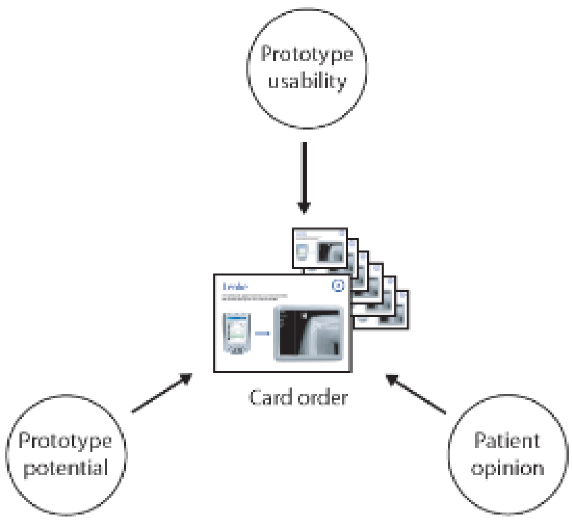

Figure 52: Factors influencing the card order.

Secondly, the prototype's *potential* seemed to have impact on the card position. If an interaction technique had poor usability, but probably would have been very good if these problems were solved, the technique was placed higher in the stack. For example, in one case the input technique was placed high in the stack because the physician realized that it would let him easily operate the patient terminal from a distance, even though he thought the usability of the technique was poor.

At last, the *patient's opinion* had an impact on the card position. They had in many cases strong opinions about an interaction technique's usability, even if they never had used it themselves, indicating that the patient's opinion often was influenced by the physician. Some patients felt that the physician was hiding things for them on the PDA and wanted to see the list showing available images on the screen. They also felt a higher degree of control when they had the opportunity to change image. These patients were usually negative to the interaction techniques where the patient terminal did not display the list of images. Other patients felt that the patient terminals legibility was negatively affected by the image list and was positive to it put it on the PDA.

10.2. Cluster analysis

To see if there were any trends that one interaction method often was placed near another, cluster analysis was applied to the card sort results. Cluster analysis is done only to discover structures in data, and it does not provide any explanations why the structures exist (StatSoft, 2005).

The purpose of applying the cluster analysis to the card sort results was not to get numbers and hard facts, but to discover hidden trends. The method was done by hand and no statistical tools were used. The results are therefore presented as a bi-directional graph not tables and numbers.

The method used is described below:

1. Rearrange the results with test number and placing as the main axis (as in figure 53). To make the tables more legible a code has been assigned to each metaphor as shown in table 6.

2. Measure the distance between the placing of interaction method N and M in one card sort. If N got third place and M got fifth place the distance is two (see figure 54)

3. Repeat step 2 for all card sorts and sum up the result (see figure 54)

4. Repeat step 3 for all combinations of methods. With eight methods this gives a total of 28 combinations.

Table 6: Code assigned to each metaphor.

Code	Interface metaphor
A	Directly on patient terminal
B	Drag and drop
C	Screen extension
D	Input
E	Remote control
F	URL
G	Torch
H	Mirroring

Test number

Placing	Test 1	Test 2	Test 3	Test 4	Test 5
1	A	F	F	C	F
2	F	B	G	A	A
3	G	C	B	H	G
4	D	H	C	F	C
5	H	A	A	B	B
6	C	E	E	G	H
7	B	G	H	E	D
8	E	D	D	D	E

Figure 53: The results rearranged.

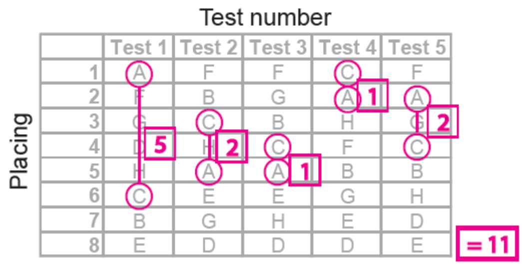

Figure 54: The distance between two interaction methods are measured for all tests, in this case A and C, and the total result is calculated. A low value indicate a trend that the users prefer these methods together.

The eleven lowest values are presented in figure 55 as a bidirectional graph while the full results are presented in appendix. The results are analyzed in the next sections.

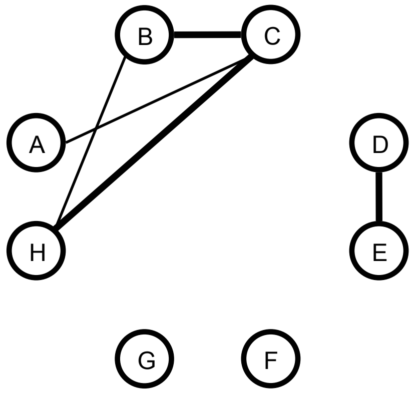

Figure 55: A bi-directional graph showing the most important trends of interaction methods placed together. A thick line shows a strong correlation between two methods. A thin line show a medium correlation.

10.3. General findings

In figure 49 in part 8.2.1, the average score of each interaction method and its variance is displayed in a diagram. It shows that only the interaction method based on the URL metaphor scored better than direct interaction with the patient terminal. This result suggest that the idea of using handhelds together with PCs is offering them something extra than operating the PC directly.

Seen from another point of view, direct interaction with patient terminal scored better than six of the seven interaction methods using handheld. This shows that it is very important to use the right interface metaphor for a particular task to make the use of handheld advantageous.

10.3.1. Agreement rate

In part 8.2.1 the terms *agreement* or *disagreement* were defined based on the variance of the ranking. A variance higher than the variance median is a sign of disagreement, while a variance lower is a sign of agreement. The results show that the users agreed on the interaction methods *URL, mirroring, input* and *remote control*. The users disagreed on the methods *direct interaction with the patient terminal, screen extension, torch,* and *drag and drop* (see figure 56). The highest ranking variances are discussed below.

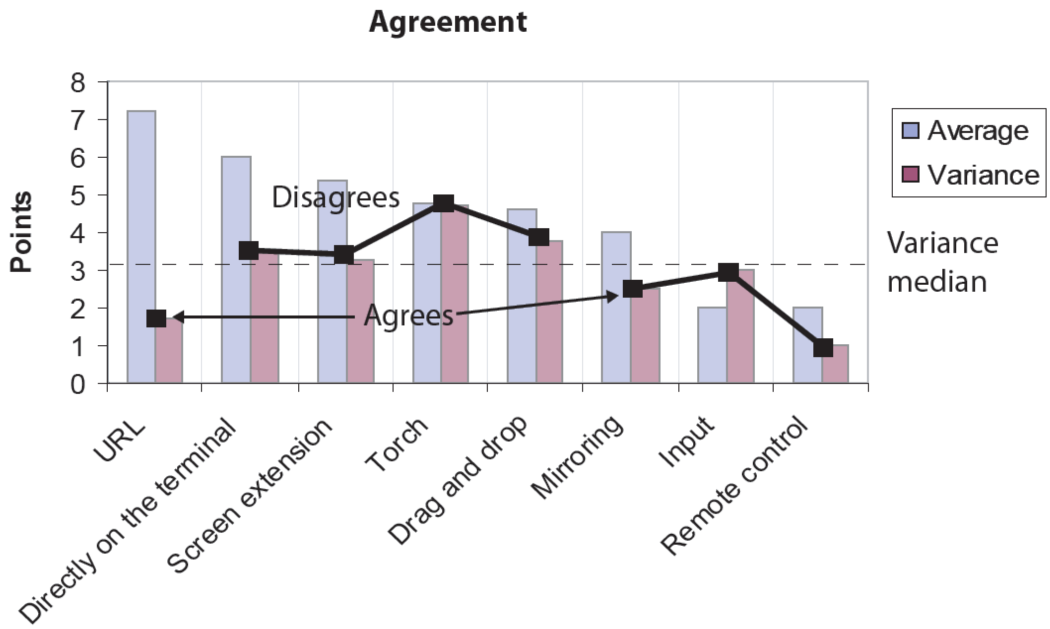

Figure 56: The interaction methods divided in two groups after agreement rate.

The URL method had the second highest agreement rate. This shows that this method with good certainty was the highest rated method by the users.

Input and remote control was the least preferred methods. They did not support the task of displaying images as good as the other methods and did not offer anything more than direct interaction with patient terminal as they were used as input devices for it. In addition, they were more awkward to use and slowed down the physicians and confused the patients. The variance shows that the test subjects were very consistent that remote control was least preferred. The users agreed also for input, but not in the same extent. This may be explained in that some users noticed the prototype's potential – that it could operate the patient terminal from a distance.

Torch had the highest disagreement rate. The method was very similar to the URL, except for the gesture towards the terminal to display the image. Some users liked it, partly because it was as simple as URL and partly because the gesture felt natural and prepared the patients that an image was on its way. Others felt that this gesture was completely unnecessary and time consuming and placed its card low in the stack.

The conclusions from this part are that URL should be used while mirroring, input and remote control should be avoided as interaction methods between the PDA and the patient terminal. For the other methods the disagreement rate is too high to draw conclusions.

10.3.2. Basic metaphors

In part 4.4.8 the interface metaphors' corresponding basic metaphor were investigated. With exception of direct interaction with the patient terminal, the interaction methods based on the basic metaphor bulletin board scored better than all the methods based on the navigation basic metaphor (see figure 57). Both the groups could solve the same task of displaying images on the patient terminal by using the handheld.

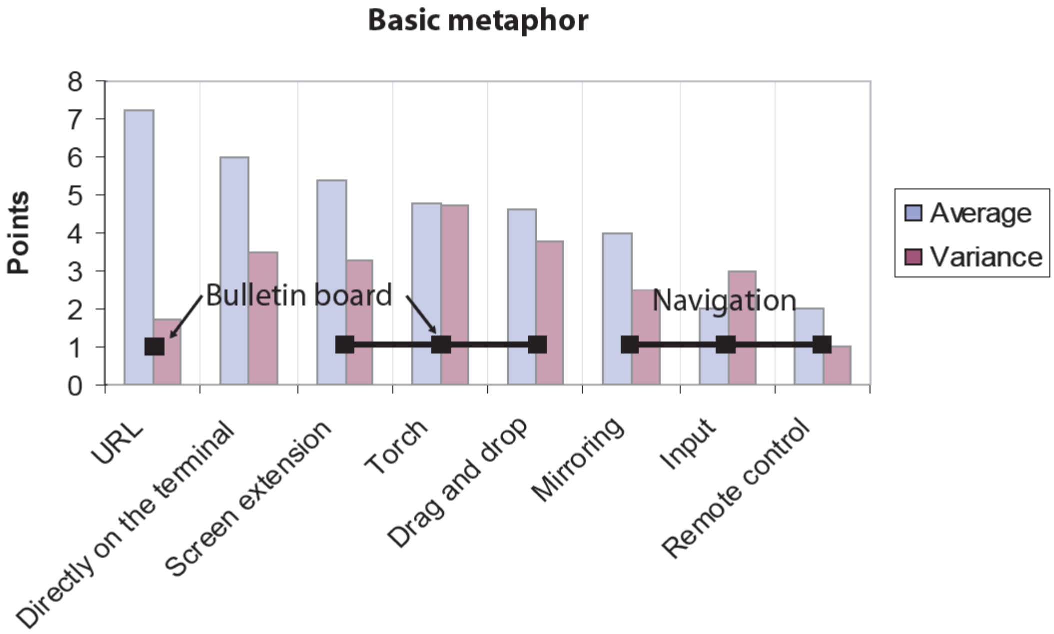

Figure 57: The interaction methods divided in two groups after their basic metaphor.

The results are clear on that using the handheld for navigating on the patient terminal is not preferred by the users. Many test subjects considered it pointless to use the PDA to select images from the list on the terminal when they stood within an arm's length from it and could easily press the screen directly. Besides, the image list had to be visible on the patient terminal when using navigation and could not be hidden for the patients. On the other hand, some of the physicians saw the potential of the methods based on the navigation when they had to operate the patient terminal from a distance.

With the methods based on the basic metaphor bulletin board, the physicians felt that *they* had control over the images and that they could choose to share them with the patient or not. It also made the patient terminal clearer for the patient because the list was removed.

These findings led to the following conclusions. When the physicians are standing within reach of the patient terminal, interaction methods based on the basic metaphor bulletin board or direct interaction with the patient terminal should be used. When the physicians want to *control* the patient terminal from a distance, interaction methods based on the basic metaphor navigation should be considered.

10.3.3. Clusters

The cluster analysis revealed that screen extension and drag and drop were placed near each other in most tests. This can be explained by the strong resemblance between the methods. They were also tested subsequent to each other, something that may have reinforced this impression.

Input and remote control was also ranked together in many tests. One explanation is that both these methods were ranked as the least preferred methods. This placed them together in the bottom of the card stack. Another explanation is that both methods were used to control the patient terminal from a distance using the basic metaphor navigation and that the users considered them similar.

Not all correlations between methods can be explained. Screen extension and Mirroring have a strong correlation in the cluster analysis, but are ranked in 3rd place and 6th place which is a quite large difference. This shows a limitation with this method. While Screen extension and Drag and drop are placed subsequently in all tests except one, the ranking of Screen extension and Mirroring are ranging between one and three places. Still the results are not more than one place in difference. If the cluster analysis was a more important method for the results, a more thorough analysis would have been required. One suggestion would have been to find the distance between two methods for all tests and use the median as a measure for correlation. This will reduce the impact of outliers.

The conclusions of the cluster analysis are that users tend to like or dislike Screen extension and drag and drop equally. The same tendency is clear for input and remote control, screen extension and mirroring.

10.4. Summary

This chapter has identified the main factors influencing the card sort. A cluster analysis was performed on the card sort results, but did not reveal any exciting results. The card sort average and variance was analyzed and revealed that the handheld used for navigation is not preferred for the x-ray image viewer. The variance was used to understand what methods the users agreed on. The next chapter analyzes the users' mental models.

11. The users' mental models

In this chapter the users' mental models are investigated based on Lakoff and Johnsons' (1980) claim that humans think in metaphors. A "light" version of Svanæs' (1997) approach is used to extract these mental models based on the test subjects' statements from the usability test. Several of the users' internal metaphors are identified and analyzed.

11.1. Analyzing the users mental models

Lakoff and Johnson (1980) claim that humans think in metaphors (see part 2.4). To find these metaphors the test subjects created when they used the system, a "light" version of Svanæs' (1997) approach was used. The test subjects were taken literally and the test subject's statement during the test was used as a basis for understanding what the users thought, what mental models they internalized, and what metaphors these models were based on.

The results from the usability test showed that there in many cases were quite large differences between the users' mental models and the designer's conceptual model. The metaphors are referred to with the names given to them in part 4.4, even if the test subjects may want to put other names on them. Where it has been possible, new names is found for the metaphors.

11.1.1. Direct interaction with patient terminal

Most users referred to the image as "the image of your arm" when they explained to the patient. Some of them referred to the image as "your arm", materializing the object on the image to something physical. The users seemed to see the object as a real image, not an electronic representation of an x-ray image.

The physicians obviously know that the screen does not contain the patient's arm. The reason for using this analogy can be explained in the interplay between physicians and patients. The physician could have referred to the image as *an electronic representation of an x-ray image of your left arm from the image database*, but the explanation is unnecessarily complex. A simpler explanation is to use *the image of your left arm*. But the patient will certainly understand that the simplification *your left arm* does not actually mean the real arm. Simplifications such as these were seen in most of the tests.

11.1.2. The metaphor known as Drag and drop

Some of the users tried to tap the images and expected them to pop up on the patient terminal. One interpretation is that they thought the icon was some kind of button on a remote control that opens the real image on the terminal, or a menu located on the terminal.

When the users dragged the image over the patient terminal icon, they saw that the images disappeared into the terminal icon and popped up to the patient terminal. When they later wanted to switch picture, they tried to drag the first picture out of the patient terminal because they already thought there was a picture. One interpretation is that they materialized the image icon and thought that the image itself was sent to the terminal and physically leaving the PDA.

When they later saw that it was sufficient to drag a new image over the terminal without doing anything else, some of them changed their mental model so that they sent a copy of the image to the terminal. Considering statements from some of the test subjects, they apparently thought that the images were automatically sent back from the terminal to the PDA when a new image was selected.

The users' actions and statements indicate that some of them *sent* the image from the PDA to the patient terminal. Other felt that they *took* the image over to the terminal screen; "First I *take* the image of the normal elbow [dragging it over the patient terminal], and then it *comes up* on the screen…", and continues with; "If we then *take* a picture of an inflamed elbow…". This is an example of a mental model where he physically takes the image from the PDA to the patient terminal.

The conclusion from the testing is that users apply a *direct manipulation* metaphor where they take pictures from one device to another. In some cases they use a *send* metaphor where the image is sent from the PDA to the patient terminal.

11.1.3. The metaphor known as Screen extension

All users mastered this method easily. Since the users had tried the resembling drag and drop prototype earlier, they could try the same mental model on this prototype with success. Some even concluded that they were identical.

Compared to drag and drop, many users used terms as "transfer the image over to the screen". This can be interpreted as they wanted to physically send the image through some medium from the PDA to the terminal.

Other users used terms as "dragging the picture over" or "take the picture over". On their PDA, they dragged images to a terminal representation. Immediately after, the image appeared on the screen. On interpretation is that they saw this screen-representation as the real screen and they could with the stylus "drag" or "take" the image to the terminal screen.

The users' actions and statements indicate that they are *sending* the image from the PDA to the patient terminal, just as drag and drop. As the users moved an x-ray image icon towards a representation of patient terminal screen, some physicians revealed a mental model indicating that they *dragged* or *moved* the image over to the patient terminal. One example statement is "I'm so lucky to have the pictures here on the screen [PDA], so let's see if I can move them [to the patient terminal] so that you also can see them."

11.1.4. The metaphor known as Input

Most of the users gave through their statements an impression that they *controlled* or *steered* the mouse pointer on the terminal screen. They also tried double taps (clicks) to select list elements and used the touch pad as for relative input. One interpretation is that they used the same mental model as when they use a mouse to control a cursor on a computer. As there was a mismatch between the designer's conceptual model and the users' initial mental model, most of the users had startup problems using the interaction method. After a short period of trial, they adapted to this.

11.1.5. The metaphor known as Remote control

Some users expected the buttons to control a cursor, not a big surprise considering the buttons mapping and the fact that there actually was a small cursor visible on the screen. They also probably tried to recycle the mental model from the previous test where they controlled a cursor. This early mental model was soon replaced.

One physician said she used the PDA to "turn the page" or as a "page down key". One interpretation is that she had a mental model that the screen was an album with pictures, and she could *turn to the next or previous page* with the handheld. One user obviously used a mental model or metaphor that can be described as *remote control* to steer the patient terminal, just as a DVD control.

11.1.6. The metaphor known as URL

Many users considered this to be the same as direct interaction with the patient terminal, except that the menu was *moved* to the handheld and therefore not visible for the patient.

One physician used a mental model based on a notice board metaphor where he *lifted up* images from the handheld and *placed them* on the patient terminal, which he viewed as a *notice board* visible for both him and the patient.

A new name suggestion for this metaphor should thus be *distributed menu* or *direct manipulation.*

11.1.7. The metaphor known as Torch

Two physicians used a mental model based on an infrared remote control metaphor. One of them pressed the stylus on a list element at the same time as she pointed it towards the terminal, perhaps so that it could "see" the signals from the PDA. The other assumed the image was sent via IR to the terminal.

Other thought it was the same as the previous, except that the gesture towards the patient terminal was a *confirmation* operation. Some used a mental model where the image somehow was *sent* to the terminal with the gesture. When the users gestured towards the patient terminal, they transferred the picture over.

11.1.8. The metaphor known as Mirroring

The PDA offered a list or menu, just as the two previous prototypes, except that it was smaller. The users may have used the same mental model as they had in the previous.

The user that unconsciously put the handheld away and started using the terminal may have thought that it did not matter where to push because they where equal. Another user said explicitly that he had no value of seeing the same on the two screens. There were no signs of users using a mental model based on a mirroring metaphor. They rather used a *distributed menu* metaphor with the possibility to preview the pictures.

11.2. Metaphors we use handhelds and PC together by

Analyzing the users' verbal protocol and their actions revealed several internal metaphors that the users created when they used the x-ray image viewer system. The most common metaphors and a conceptualizing of them are presented below. The conceptualization is in form of an illustration and is only an example of how it may be.

11.2.1. Sending the image to the patient terminal

Several users felt that they *sent* the image to the patient terminal. Most users did not reveal how they did it, but some thought they had to direct the PDA towards the patient terminal just as one does with a remote control towards a TV (see figure 58), or that the image was sent wirelessly to the terminal (see figure 59). They are believed to apply a internal metaphor where they send the image from the PDA to the patient terminal.

Figure 58: A mental model where the image is sent by IR to the patient terminal from the PDA.

Figure 59: A mental model where the image is sent wirelessly to the patient terminal from the PDA.

11.2.2. Steering the terminal

Several users felt for some interaction methods that they used the PDA to steer the patient terminal, either by using the PDA as a mouse or as a remote control. In figure 60 is one possible conceptualization displayed.

Figure 60: A mental model using a metaphor where the PDA is used to steer the patient terminal.

11.2.3. Distributed menu

Some users had a mental model where they felt that the menus or controls were moved or from the patient terminal to the PDA as displayed in figure 61.

Figure 61: A mental model revealing that the controls or menus are moved from the patient terminal to the PDA.

11.2.4. Direct manipulation

Some users felt that they dragged or took the image to the patient terminal from their PDA (see figure 62). One user called a notice board metaphor. This is direct manipulation of the image.

Figure 62: A mental model used direct manipulation metaphor where images are taken from the PDA and placed on the patient terminal.

11.2.5. Occurrences of users' metaphors

The internal metaphors that were revealed by analyzing the users think aloud protocol came from different interface metaphors. Their origins are presented in table 7. Unfortunately the results did not support a frequency table where the number of test users having a particular mental model could be registered.

Table 7: An overview showing for which interface metaphor the various users' internal metaphors were most common.

	Drag and drop	Screen extension	Input	Remote control	URL	Torch	Mirroring
Sending image	X	X				X	
Steering terminal			X	X			
Distributed menu					X	X	X
Direct manipulation	X	X			X		

11.3. Generalizing the internal metaphors

In the usability test of the x-ray image viewer and the following analysis mental models and the metaphors they were based on where revealed. Can these internal metaphors be generalized to be valid for systems using handhelds and PCs together? Lakoff and Johnson's theory claims that humans think in metaphors. They relate something unfamiliar to something already known and understandable. There is therefore a possibility that the same metaphors that appeared when testing the different versions of the x-ray image viewer will appear for most systems using handhelds and PCs together.

The four general metaphors found above show how the users think when a PDA are used together with a patient terminal. Assuming that the same metaphor will appear when handhelds are used together with PCs, they can be generalized as following:

- *Controlling* the PC by using the handheld as an input device. The controlling can take place from a distance.
- *Distributed interface* between the devices where the views and controllers are spread across the different devices.
- *Sending* objects between the devices. Examples are images, messages and web pages.
- *Direct manipulation* of objects on the devices where the user feel that she is literally taking objects from one device and placing it on another

11.4. Summary

This chapter has analyzed the users' mental models and has resulted in four internal metaphors they created to understand the prototypes. They are generalized to be appropriate for any system using handhelds and PCs together. The next chapter analyzes the generalized metaphors further.

12. Using the metaphors

This chapter shows how the system consisting of a handheld and PC can be viewed as on system or as two separate systems. It also explains how the interface metaphor for such systems can be clarified. A design process based on Nielsen's usability lifecycle is presented, where the user's mental models are used as a basis for the conceptual model.

12.1. One common system or separate systems

One interesting question that was not directly answered by the users during the usability tests was whether the PDA and the patient terminal was perceived as one system (see figure 63) or as two separate systems communicating with each other (see figure 64).

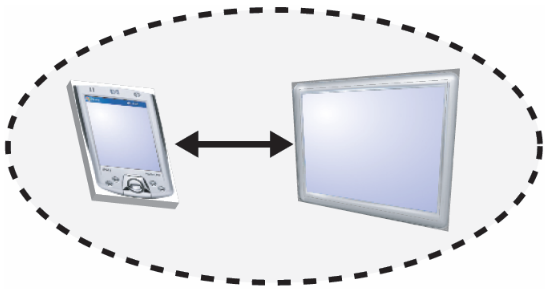

Figure 63: The handheld and PC perceived as one common system.

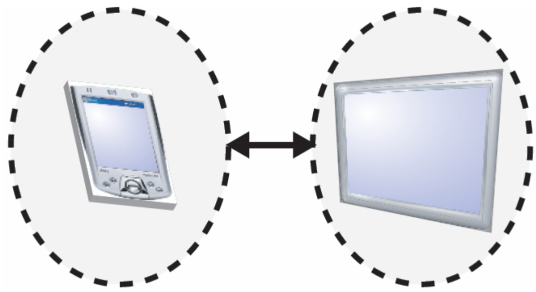

Figure 64: The handheld and PC perceived as two separate systems working together.

When the users tested the URL metaphor they felt that they were operating on one system. Several of them said it was the same as direct interaction with the patient terminal, except that the menu was placed on the PDA. The same thing is observed for PCs with multiple screens connected is viewed as one system even if it appears to have several user interfaces. This shows that for conceptual models where the user interface is distributed between the handheld and the PC, the users perceive the two devices as one system.

For the sending objects metaphor one of the physicians revealed that he saw it as two separate systems when using the drag and drop metaphor. This indicated that the system actually may be seen as two separate systems communicating with each other by sending objects between the devices.

The steering metaphor shows how the users think when the handheld is used to control a PC as a remote control or an input device. During the usability test the users used a mental model where the handheld was a mouse to control the patient terminal. None of the models two models above was applied by the users, they rather used a third model. The patient terminal is perceived as the system and the PDA is perceived as a steering device as shown in figure 65. In the same way a mouse connected to a PC is seen as a device to use the system, not a system itself, the handheld is expected to be a mean to control the PC.

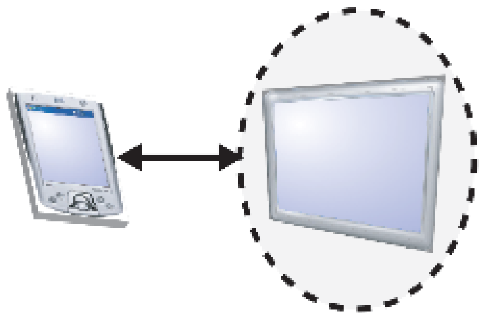

Figure 65: The PC is viewed as the system and the handheld is just a mean to control it.

For the direct manipulation metaphor, no direct observations were made during the usability test if the users thought they operated on one common system or two separate systems. The screen extension interaction method could have shown this if the prototype had been more successful. Still, the interpretation of the results give indications that the users apply a *one system model* to this internal metaphor.

12.2. Using the metaphors in systems with handhelds and PCs

The internal and general metaphors found in part 11 can be used as an inspiration for the conceptual model to a system using handhelds and PCs together. How should the conceptual model be designed?

12.2.1. Clarifying the conceptual models

Depending on which of the conceptual models to be used in a system using handhelds and PCs together, several things can be done to strengthen and clarify this model. For *distributed interface*, *direct manipulation* and other models where the devices should appear as one system, one should make it clear for the user that the devices are parts of the same system. This can be done by providing the same *look and feel* on both devices and provide immediate feedback on both devices when actions are done on one of them.

For conceptual models where the handheld and PC are seen as separate systems, such as the *sending objects* metaphor, there is no point in making the user believe that it is the same system by providing the same look and feel. Feedback is the clue here. When objects are sent, the handheld must provide feedback that the object is leaving it, and the PC must provide feedback that the object has arrived. The prototype based on the drag and drop metaphor succeeded in this.

The *steering PC* model should demonstrate that it is an input device for the PC. Immediate feedback is necessary for this. When the user does an action on the handheld it should immediately give feedback on the PC, for example in form of a moving mouse pointer or a typed character.

If the user has more than one system to deal with, there is a chance that the problems with demanding focus changes will arise, as seen during the usability test. Therefore, when designing conceptual models for systems using handheld and PCs together, the devices should appear to be one system, not several systems working together. This should be further tested to be proved or disproved

12.2.2. A modified usability lifecycle

In many cases there was a great variance between the designer's conceptual model and the users' mental models. For example, the *URL* interface metaphor was not internalized as a mental model by any of the users. Instead they used a *distributed menu* metaphor. This can lead to usability problems for the users since they are expecting a particular system behavior but are experiencing another.

The designer of the system in the example above should therefore have used the *distributed menu* metaphor in the first place, but the only way for her to find this model is to create a temporary conceptual model and test it on users. The users will provide feedback that will reveal their mental model and the underlying metaphor. These metaphors should be the basis for a new iteration of designing conceptual models. These models are likely to fit better to the users' model and the chance that Norman's three models (1988) will map onto each other is greater.

The idea of using the users' mental models and internal metaphors to create better conceptual models (Bjørkli, 2000) can be used as an additional step in Nielsen's usability lifecycle (1997). The modified usability lifecycle is presented in figure 66, and its steps are described below.

1. The original idea that the system is based on.

2. Create parallel designs of conceptual models using the designer’s interface metaphors.

3. Test the conceptual models and discover the users’ mental models and their internal metaphors.

4. Use the mental models in a new parallel design were the users’ internal metaphors are used as a basis for the interface metaphors.

5. Test these designs on users and use the best design or the best design elements in an iterative design process towards a released product.

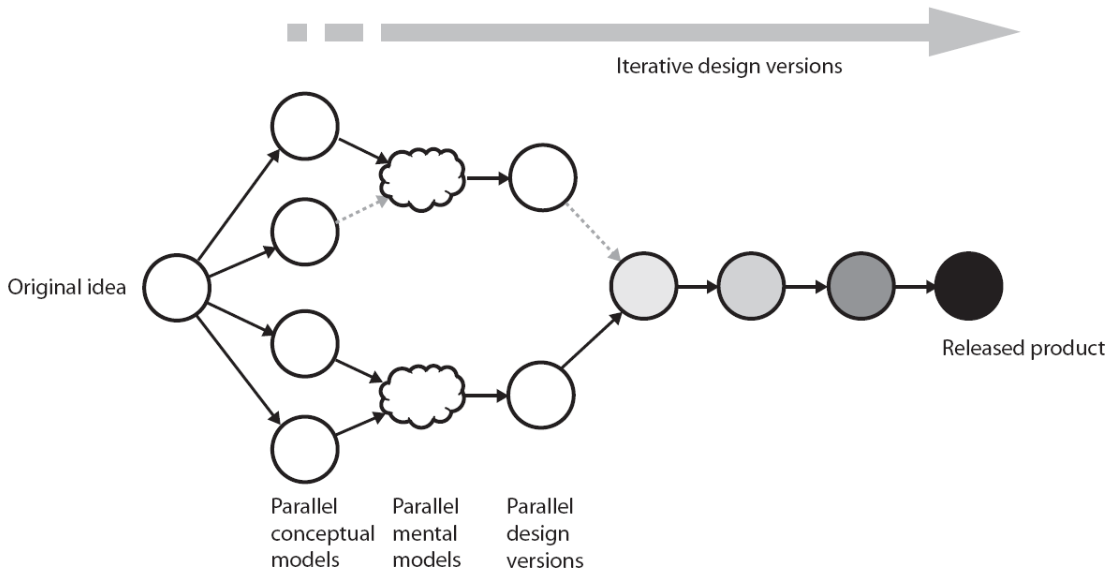

Figure 66: A modified version of Nielsen's usability lifecycle using the users' mental models as a basis for parallel design.

The main advantage by using this approach is that there is a greater chance that the conceptual model is corresponding to the users’ mental models. The main disadvantage is that it requires several iterations which cost time and money.

12.3. Using the metaphors with the x-ray image viewer

The x-ray image viewer is an example of a system using handheld and PC together. The usability test and card sort gathered enough data to make a specific decision about which conceptual model to use.

The results suggested that the users preferred and agreed on the interaction technique based on the URL metaphor. This metaphor caused the metaphors *direct manipulation* or *distributed menu* to arise in the users’ minds. These metaphors should therefore be basis for a new conceptual model.

The *direct manipulation* metaphor is excellent for placing images from the PDA to the patient terminal, but it has limitations and is not offering much more than that. If the x-ray image system is going to offer additional functions such as rotating and zooming, it may be necessary to make a composite metaphor, for example with the distributed menu metaphor.

The handheld and PC can be used together with a direct manipulation metaphor and distributed interface elements at the same time. The users will be able to make the mental leaps required to understand these combined metaphors (Øritsland, 2004). This metaphor is both simple and task focused as required Johnson and Henderson (2002). It does not require a complex mental model and the users can relate familiar objects from the real world. It is about placing images from the PDA onto the patient terminal and enables the physician to focus on the patient.

The direct manipulation metaphor also support many of the findings made in chapter 9 where the consequences of introducing a handheld were looked at. It gives the physician a private screen to hide things that the patent does not need to see. The URL metaphor, which the direct manipulation and distributed menu metaphors are based on, was the one that stole least focus from the physician. Since the image is moved to the patient terminal before the physician and patient discuss it, they will communicate on the same level and the patient and the image will get the physicians full attention.

The patient is negative to that the physician is keeping secrets on the PDA. If the physician is just using it for short periods when placing another image on the patient terminal, and it is believed to minimize the patient's feeling.

12.4. Summary

This chapter has looked at how users perceive systems with handhelds and PCs. It also suggest how the conceptual model can be strengthened. A modified usability lifecycle is presented, where the users' mental models' are used as a basis for a revised conceptual model. The next chapter analyses the research methods and discusses the thesis' validity.

13. Analyzing the research methods

In this chapter the research methods and their validity are discussed. The thesis' validity is evaluated and possible sources of error are discussed.

13.1. Comparing results from research methods

In an attempt to triangulate the results, three research methods were used. Triangulation in research is when one searches the same information from different research methods. The results from the usability test were in some extent in accordance with the results from the focus group. The interview covered a narrow field but was triangulating and supplementing the focus group and interview. Some examples are presented below where the methods showed accordance and not.

Cases where accordance was found

- The usability test and focus group gave results showing that the users wanted to use the PDA hiding log-on, browsing and searching.

- All methods supported the idea of the x-ray image viewer system developed for the usability test. The participants from the focus group session suggested an educational tool to explain medical issues to the patient. The interview supported this and detailed it to be an x-ray image viewer. The positive feedback from the usability test subjects indicated that it covered a need.

Cases where the results gave opposing answers

- The participants from the focus group session wanted to use the PDA as an input device for the patient terminal for documenting. The input device metaphor performed poorly on the usability test and was not preferred by any users.

- The focus group was worried about ergonomics when they had to bend over the bed to reach the terminal. This did not seem to be a problem for the test subjects during the usability test.

13.1.1. Evaluating qualitative data

Klein and Myers (1999) introduce seven principles for conducting and evaluating interpretive field studies in information systems. The third principle is about interaction between the researchers and the subjects. It requires critical reflection on how the research materials (or "data") are socially constructed through the interaction between the researchers and participants.

The research conducted is not field study and cannot uncritically be applied here. Still, Klein and Myers' third principle about interaction between the researcher and the subject is particularly important. During the focus group, interview and usability test the moderator/interviewer/experimenter affected the participants by his questions and body language. For example, at overtime of the focus group session the moderator asked the participants about using the PDA to control lights, blinds, etc. on the patient terminal. The moderator's body language and tone of voice undoubtedly disclosed stress and tiredness, and the participants responded that the scenario was unimportant, partly to satisfy the moderator and partly to be able to go home.

The focus group participants and test subjects also influenced each other. For example, during the usability tests and card sort, the patient had very strong feelings about the various interaction methods even if they had not used them themselves. The patients could say "I liked this one much better than the last one" even if it was designed to be completely identical from their point of view. The only way they could have got this strong opinion was through the physicians' statements and body language.

13.2. Reflections on research methods

The research methods used was as far as possible "done by the book" but when the methods were reviewed after being carried out, many potential improvements were discovered. Some of these are presented below.

13.2.1. Focus group and interview

In part 3.2 focus group as a method is presented. Unfortunately only one session was held and only four of the seven invited users were able to attend to the session, and lowering credibility of the focus group. Also the length of the focus group (75 minutes) was shorter than the two hours Nielsen (1997) suggests.

Another mistake may have been to reveal the idea that the PDA and patent terminal could be used together. This may have influenced the participants and made them come up with ideas that the moderator wanted to hear. Considering the limited time scope and that the aim was to find out *how* the devices can be used together, not that they *can* be used together, the results from the session was satisfying.

The main weakness with the interview was that it just based on information from one informant.

13.2.2. Usability test

The main disadvantage with the usability test was that it did not provide the context of real life. By testing the system in a lab that resembled a hospital ward and using "real patients in the bed, the effect was reduced. The results indicated that the test subjects slid into the role of being real physicians. This particularly supported by statements such as "I forgot to explain what I did while I used it [the system], I became doctor at once". This increases the research’s validity beyond the experiment setting. On the other hand, this led to a poorer quality of the think aloud protocol, as when the test subjects went into the role of being physicians, they forgot to explain their actions.

The usability test was performed with only five test subjects. The results were not particularly uniform, and several test subjects should have been used to increase the reliability of the data. A majority of the test subjects, both physicians and patients, were from NSEP, the same place the test was conducted. This is not an advisable situation, but real physicians are hard to recruit and the only other option was to run the experiment with non-representative users of the x-ray image viewer.

The design of the prototypes may have affected the reliability of the data. Other programmers may have created different system images of the same conceptual models thus giving different responses from the test subjects.

13.2.3. Card Sort

Both the physician and patient ranked the interaction methods together even if only the physician had used them. The participants were not given any specific ranking criteria to encourage discussion. This resulted in richer data, but the participants influenced each other. If the card sort was to be repeated, the participants could have discussed the ranking after the physician had finished it alone.

The fact that one interaction method was ranked above another method can be explained by the former actually being better than the latter for this particular task. But there can be many other explanations, all which may be equivalent to the first statement:

- Interaction technique A is better implemented than interaction technique B, so that technique A gave a better impression than technique B.
- Because of technology challenges technique B has an annoying lag, making the users prefer technique A. Without the lag B would have been preffered.
- The designer model and the system image is not mapping onto the user model for technique B, making the users prefer technique A.
- The user has previous experience with interaction technique A and no experience whatsoever with technique B, making him or her more confident in the former.

In a new ranking, specific ranking criteria should be given. The test subjects should also become aware of the possible other interpretations so that they avoid them.

13.3. Summary

This chapter has analyzed the research methods and discussed the thesis’ validity. In further investigations of the research questions, the experiment design should be reviewed to increase the validity of the experiments and conclusions. The next chapter presents the conclusions.

14. Conclusions

This chapter sums up the topics discussed and presents the conclusions of the thesis. It also suggests further work on the topic. Finally, the conclusions are grounded in several guidelines describing how to design systems using handhelds and PCs together.

14.1. Topics discussed and conclusions

This thesis has tried to answer the following research question:

> *What conceptual models and interface metaphors should be used when designing systems using handheld computers and PCs together?*

The approach in this thesis was to explore what conceptual models *could* be used when handhelds and PCs are used together. This question has been answered by exploring the design space of the devices and has resulted in several interface metaphors.

The metaphors found are basis for several simple prototypes of a system using ahandheld and PC together. The system is an x-ray image viewer used in a hospital setting where physicians can get x-ray images from their PDA and present them on a patient terminal with the purpose of explaining the images to the patient. The idea of developingan x-ray image viewer is based on the results from a focus group session and an interview, both with health personnel as participants.

The prototypes of the x-ray image viewer have been tested in a usability test experiment with physicians. The results from the usability test this, thesis has demonstrated that using handhelds and PCs together can offer something that the devices used cannot do separately. It shows that the statement "the whole is greater than the sum of its parts" in this context is true.

The results have also revealed that the conceptual model and interface metaphor is very important for the system's usability. Not every interface metaphor can be applied to a system using handheld and PC. The conceptual model has to be carefully adapted to the particular devices, the users and the usage context. This was shown in the hospital case with the x-ray image viewer as only one of seven interface metaphors with PDA and patient terminal was rated better than direct interaction with the terminal.

The x-ray image viewer using the PDA and patient terminal together has, according to the test subjects, several properties that are valuable in the case of displaying images to the patient. Among the most important is the physician's ability to hide logon screens, searching and the browsing process for the patient. This demonstrates that a synergic effect can arise when handhelds and PCs are used together.

Handhelds and PCs used together have the potential of improving the work situation of the users. In the health care case most of the users were not used to displaying x-ray images bedside, but all of them, both the physicians and the patients found it very useful.

The PDA together with a patient terminal has also the potential of making the system much more usable for both the patient and the physician. First of all, the user interface on the terminal can be perfectly adapted to the patient role because all interface elements concerning the physician can be moved to the PDA. As the interface elements the physicians are working with does not have to be adapted to both user roles, the physician will have an easier task when operating the system.

In cases where more than one user is involved, a new dimension to the usage of handhelds and PCs together is added. One example is how the patients influenced the physicians to dislike a method. Another example is how the patient did not like that the physician used the PDA because he felt that she kept secrets on it. The unanticipated behavior of humans makes the design of these systems difficult. This dimension is particularly complex, something experienced during the usability test.

Another part of the approach was to find out what mental models users make for themselves when using a system where handheld and PCs together. The purpose was to use the metaphors that the mental models were based on as a basis for further design. The analysis of the results from the usability tests revealed that most test subjects used four different general metaphors to understand the prototypes. These metaphors *are direct manipulation, distributed interface, sending objects* and *controlling the PC*. The thesis has argued that these metaphors are general and will be utilized by the users in most situations where handhelds are used together with PCs.

Further analysis of the results showed that the users either understand the handheld and PC as *one common system* or as *two separate systems*. The designer can influence the understanding of a common system by clarifying the metaphor with the same *look and feel* on both devices and by providing *feedback* on both devices when actions are done on one of them. If the designer wants to give an impression of two systems, extensive use of feedback should be enough.

The approach used in this thesis has led to a design process based on Nielsen's usability engineering lifecycle (1997). The modified design process presented makes use of the users' mental models to create better conceptual models. It is believed to be particularly useful when one task can be solved in many different ways.

There are not only advantages related to combining handhelds and PCs. Issues discovered during the usability test was that the handheld may require too much focus from the user and that the focus change between the PC and handheld might be quite demanding. These problems are particularly clear in situations where several people are involved. With other devices and in other contexts, the users are likely to experience different benefits and drawbacks.

The x-ray image viewer system is a good case exemplifying the use of handhelds together with PCs. With a small adaptation the system can be used in completely different contexts. The following scenario is one example:

> *Alexander, 14 years old, is visiting some friends. He has taken some cool pictures with his new high resolution camera-mobile-phone and wants to show them to his friends. Unfortunately the phone display is too small to see the cool details on the image by everyone, so he sends them wirelessly to a nearby 21 inch computer-screen. With his phone, he flips through the images on the computer screen and receives acknowledgments from his friends.*

The question is still the same; what conceptual models and interface metaphors should be used when designing this system? The conceptual model is important, not only for Alexander, but also for all his friends.

Looking back on the research question, the main conclusion is that there are no exact answers to this problem because several factors decide what conceptual model and interface metaphor to apply in a system where handhelds and PCs are used together. The metaphors found in this thesis can still be a good basis for design of the interface metaphor.

14.2. Future work and recommendations

The results are based on data from a small set of test subjects and from a specific case. The scope and size of this research project is too limited to have validity outside the hospital setting. Similar studies should therefore be conducted again in this setting and in other settings or with other systems to see if the user metaphors are universal or only specific for the particular case. If the metaphors found in this thesis are confirmed by other experiments, they can be used as a basis for the conceptual model and interface metaphor in systems where handhelds and PCs are used together.

The modified usability lifecycle was never used for an entire cycle but only to outline conceptual models from the users' mental models. It would have been interesting to see if using the mental models as a basis for the conceptual model will lead to improved usability in computer systems.

14.3. Guidelines for systems using handhelds and PCs together

To make the results and experiences done in this thesis more available for designers of systems where handhelds and PCs are used together, they are used in a number of guidelines. These guidelines are rooted in, but not based entirely on the results. These guidelines describe issues that are especially important to remember when designing systems where handhelds and PCs are used together.

System analysis

- Find the purpose of using the handheld and PC together. What is the task and what are the advantages and disadvantages of using the devices together?

- The handheld is an extra device to focus on. Don't use handheld and PC together when it is unnecessary.

Process

- Explore the design space. This means investigating the space of possible design solutions given by the design elements. Ask yourself in what different ways the task can be carried out.

- The modified usability lifecycle presented in section 12.2.2 is a good design strategy when you want to find out the most suitable interface metaphors for a system using handhelds and PCs together.

- There is no single conceptual model that is superior in all cases. It has to be adjusted according to the task an how the designers want the user to understand the system.

Interface design

- The user thinks in metaphors and is likely to utilize one of the metaphors presented in section 11.3. One of these metaphors should be a basis for the conceptual model in your project.

- Avoid metaphors where the handheld is used to control the PC if the user is within reach of the PC. Let them rather operate directly on it instead.

- Provide the same look and feel on both devices to strengthen the impression of them being the same system.

- Provide extensive feedback on both devices to increase the impression of the devices being used together.

- The focus change between the handheld and PC are demanding for the user. Don't use a conceptual model that requires too many focus changes between the devices.

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Appendix A. Prototypes

The prototypes and source code can be downloaded from this web page:

http://www.idi.ntnu.no/~oleanda/masterthesis/

The web page contains:

- Flash Communication Server (must be installed to run the flash prototypes).
- Flash Communication Server application folders (must be copied to the server *applications* folder)
- PowerPoint prototypes presented to the focus group.
- Flash prototypes tested in the usability test (it may be necessary to change IP-addresses in the source code to run them on different devices)

Questions can be directed to this e-mail address: Ole.Andreas.Alsos@idi.ntnu.no

Appendix B. Blocking results

The results rearranged

Code	Metaphor
A	Directly on patient terminal
B	Drag and drop
C	Screen extension
D	Input
E	Remote control
F	URL
G	Torch
H	Mirroring

Points	Test 1	Test 2	Test 3	Test 4	Test 5
1	A	F	F	C	F
2	F	B	G	A	A
3	G	C	B	H	G
4	D	H	C	F	C
5	H	A	A	B	B
6	C	E	E	G	H
7	B	G	H	E	D
8	E	D	D	D	E

The results from blocking

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
A	-	-	-	-	-	-	-	-
B	17	-	-	-	-	-	-	-
C	11	8	-	-	-	-	-	-
D	20	19	21	-	-	-	-	-
E	20	13	16	10	-	-	-	-
F	12	13	15	26	26	-	-	-
G	12	13	15	14	16	12	-	-
H	12	11	9	12	12	18	16	-

See chapter 10.2 Cluster analysis for details.

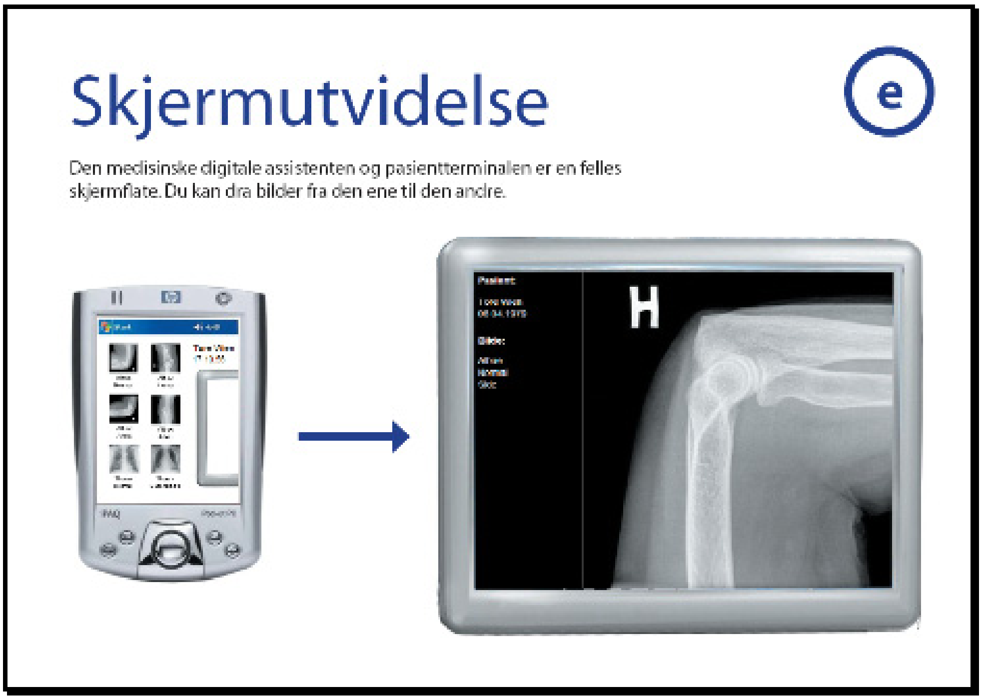
Appendix C. Cards

Link: The medical digital assistant displays a list of images. When an image is selected it is opened in the patient terminal

Mirroring: The medical digital assistant is mirroring the patient terminal. All actions done are reflected on the other.

Drag and drop: The medical digital assistant displays icons of x-ray images and of the patient terminal. When an image icon is released over the patient terminal icon, the image is displayed on the patient terminal.

Input device: The medical digital assistant can steer a mouse pointer and make selections on the patient terminal.



Screen extension: The medical digital assistant and the patient terminal is a common screen. You can drag images from one to another.

Torch: Image can be transferred by selecting image on the medical digital assistant and move it towards the patient terminal.

Only patient terminal: All x-ray images are selected and displayed directly on the screen not using the medical digital assistant.

Remote control: The medical digital assistant has buttons as on a remote control. These buttons let you make selections on the patient terminal.