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Towards Handheld Mobile Devices in the Hospital

Suggestions for Usability Guidelines

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Preface

This thesis is part of a research initiative aiming to explore future possible arenas and use situations for mobile devices under the caption: "UMTS—Third Generation mobile networks: New services, New devices." The research focuses on designing tomorrow's mobile interfaces, services, and devices. The research initiative came from joint efforts of Dag Svanæs, Department of Computer and Information Science (IDI); Trond Are Øritsland, Department of Product Design (IPD), Telenor R&D, and Sintef.

The project behind this thesis empirically explored the possibility of mobile handheld devices and use situations of the hospital arena by building prototypes and have them evaluated by real users in realistic settings. The main aspects of discussion are: what characterizes work that is suitable in this context; how well does the technology support the user's work —input of data, output of data, navigation, ease of handling, and general usability of device; and what the ideal mobile device in a hospital would be.

I would like to thank:

My primary councellor, Dag Svanæs, Associate Professor at IDI, for input during the project period and throughout the writing process. Trond Are Øritsland, Associate Professor at IPD, for design input during different stages of the project, and for office facilities. Arild Faxvaag, Chief Doctor and Associate Professor of the Rheumatology Division at St. Olav's Hospital, for being a valuable doctor-contact and channel into the hospital. All the test participants who willingly played along during evaluations and shared their knowledge. Telenor R&D for sponsoring hardware and hosting an inspiring tour of their research facilities in Oslo. Sintef Digimed/ MOBel group for letting us set up a patient room usability lab in their facilities. The Interaction Design Institute of Ivrea, Italy, for hosting a visit to Dag during his year with them. Øyvind Lillerødvann for being a good project partner and schoolmate, and Tod for all the support, editing, and feedback on my perception of the English language.

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TABLE of Contents

CHAPTER 1

Introduction

The Department of Computer and Information Science (IDI) and the Department of Production Design (IPD) at the Norwegian University of Technology and Science (NTNU) joined forces with Telenor R&D on research for third generation (3G) mobile networks in a project aiming to investigate upon new services and new devices. Systems of interest were several small, relatively unintelligent, mobile interactive devices that communicate continuously through 3G. The research initiative aimed at building prototypes for evaluation in realistic settings to test possible uses.

1.1 Introducing the Project

This project evaluates handheld mobile devices in the hospital context: PDAs in the Rheumatism ward at the St Olav's Hospital in Trondheim (then RiT). The evaluation focuses on usability and usefulness of both the prototyped graphic interfaces and the physical interface of the device in this context. Suggestions to how an ideal system could be are added at the close of this paper. The project work was carried out during late Spring and Fall of 2001 together with Øyvind Lillerødvann, the other student assigned to this project. The empiric results will be used in separate thesis work.

1.1.1 Health Informatics

Dahlbom defines *Informatics* to be "the design-oriented study of information technology use," how human activities and the use of IT are studied with the ambition to come up with new ideas and possible uses [1]. The British Medical Informatics Society [2] defines the term *health informatics* to be: "the understanding, skills and tools that enable the sharing and use of information to deliver healthcare and promote health." They say health informatics is also an academic discipline that has developed over the past decades, engaged in advancing and teaching knowledge about the application of information and communication technologies to healthcare—where health, information, computer science, psychology, epidemiology and engineering intersect. The Journal of Mobile Informatics sees that "mobile computing is the next technology frontier for healthcare providers. Data capture and retrieval using a PDA by physicians, nurses and allied healthcare professionals, are enhancing patient care and improving efficiency"[3].

Work in the field of health informatics is focused on a broad range of topics such as computerized patient records, medical concept representation, nursing informatics, biomedical pattern recognition, data protection [4]; medical imaging systems, mobile computing, natural language processing and clinical information systems [5]. Local initiatives are several: Norwegian Health Informatics is a health-oriented company which has evolved from NTNU and Sintef[1], and their main project is the development of an electronic medical handbook [6]. Kvalis and MOBel are interdiciplinary research initiatives focusing on developing electronic patient records [7] and mobile electronic patient records [8], respectively. Fieldcare is a Sintef project where they have developed a field information system for pre-hospital collaboration, taking advantage of technologies such as electronic tags and PDAs [9].

I chose to do a project within health informatics because the field offers many interesting problems and a chance to do exploratory research. The idea of equipping nurses and doctors with handheld mobile devices, and possibly finding new, efficient, and elegant ways of assisting them in getting their

[1] Sintef: The Foundation for Scientific and Industrial Research at NTNU.

job done has value and is likely in the near future. I knew from previous studies that St. Olav's is, to a great extent, a paper-based hospital awaiting good digital solutions. Those studies also left impressions of what is specific to health informatics as a field: hospitals, doctors and nurses represent a work hierarchy not found elsewhere [10], the value of the informal communication is often neglected [11,12,13], and the vast amount of data the hospital staff document in their own ingenious ways has so far represented a serious challenge to the IT developers when it comes to modelling good systems.

1.1.2 Research Questions

A hospital is an arena where handheld mobile devices could bring value. What situations and tasks of the healthcare professionals' job might be considered useful and efficient to do with a mobile handheld device? It is natural to assume that: the hospital as a context would influence technology choices; that handheld devices are likely to have possibilities and limitations that are specific to the hospital context; and that the different user groups in a hospital would probably have different perspectives on handheld devices and their relative usefulness. All these assumptions relate to functional and practical usability for the professionals. This thesis will investigate upon the usability of graphical and physical interfaces of handhelds like the Compaq iPaq within the hospital context by the following research questions:

1. What characterizes work that is useful to support with a mobile handheld device?
2. How well does the technology support the user's work?
3. What would the ideal mobile device in a hospital be?

Work is seen in a two-way system-oriented perspective, where users do tasks and receive services. A task should be understood to be something the user does (e.g. order a test), while a service is something the users receives from the system (e.g. see a test result).

1.1.3 Research Approach

The purpose of this qualitative project is to explore ideas and perform basic scientific research, with less focus on details and statistics. Qualitative research is sometimes accused of being opinionated and subject to personal bias, thus inferior to quantitative research [40:26]. However, opinions and personal impressions are the point of this project. Designing and testing prototypes on real users will offer insights into what is liked and understood; hence be one step closer to finding good digital tools for hospitals.

The research project started with a field study that allowed to chose situations and tasks well-suited for a handheld mobile device. After building the first prototype came a focus group evaluation that gave feedback on the prototype. The feedback was the basis for revising and building a new and improved prototype, which was subjected to a usability test. This second test again gave feedback for further enhancements and revisions. This was the extent of the project work. The data collected in the project will contribute to a discussion of usability and usefulness of mobile handheld devices in the hospital context, which again will lead to suggestions for usability guidelines.

1.1.4 Delimitation of Scope

It is important to narrow down the scope of projects, to ensure that the focus is kept in the right direction and the data collected are relevant. There are many areas where other research groups are working to find solutions regarding patients, hospitals and electronic patient records, such as speech interface, patient information security, and so on. The solving of those problems will be left to others with bigger budgets and more development time. Some practical limitations encountered were:

Short time: There was not enough time for a paper prototype test, the compromise was a focus group discussion which discussed scenarios and looked at screen designs. There was not enough time to do as deep a field research as desired, and not enough time to develop prototypes extensively. All of these factors possibly limits the generalizability and validity of the project. Although respected figures of the field such as Gillian Crampton Smith stresses her acclaimed term “just enough prototyping,” meaning embellished prototypes is a waste of time and resources, just prototype enough to get the point across.

Resources: There were not recruited as many users as desired for the focus group and the usability testing. Good data was harvested, but there are probably areas in the system that did not get any attention. Feedback on the results of the field study from the doctor contact was never received despite two attempts, likely due to the public mail service. That means that the next step of the project was outlined from a field study report that was not evaluated.

Professions and settings: The study and evaluations were carried out with doctors and nurses of the Rheumatology ward only, because that is where access was granted. The Rheumatology ward is a very calm and quiet ward where nobody rushes around. If the ward had been very busy and crowded, such as an emergency room just after a bus crash, the results would surely be different as the requirements would be very different. Other professions that could be interesting, but were left out, are ambulance personell, management and orderlies. The conclusions would likely have been more precise with a larger variation of test subjects and specifications for relevant contents. This limits how the results can be generalized.

The test methods for usability tests are designed for stationary computers and their software, often in a generic lab facility. Working with handheld mobile devices means taking the usability test out of the lab, and walking closer to real life. That also entailed abandoning esteemed test methods in favor of improvisation. A discussion of test methodology for mobile devices is downplayed here, as Øyvind Lillerødvann chose that topic for his thesis.

It is important to underline that the project never had the intention to develop a running system, hence moving into applied science. The prototypes were designed to have limited functionality. Hospitals are arenas with large amounts of information, and the objectives were centered around identifying a few functions that could be helpful to have on a handheld mobile device for people on-the-go. If the project was taken further, then later iterations would be the appropriate time to enter more functionality.

There are restrictions regarding the use of mobile phones at the St. Olav's Hospital. This is based on the hospital having many appliances that experience interference in the presence of radio wave technologies such as mobile phones. This project is designing for the future, and assumes that radio wave interference problems will be solved and therefore are outside the scope of this project.

1.2 Human-Computer Interaction

Preece says that during the technology explosion of the 1970s the notion of the *user interface*, also know as the *Man-Machine Interface* (MMI), became a general concern to both system designers and researchers [15:7]. Academic researchers were interested how the use of computers might enrich the work and personal lives of people, especially focusing on the capabilities and limitations of human users. The term human-computer interaction (HCI) was adopted in the mid-1980s, acknowledging that the focus of interest of the field was broader than just the design of the interface—it was also concerned with all aspects that relate to the interaction between users and computers [15:7]. See figure 1.1 for disciplines that contribute to HCI. Winograd says that human-computer interaction is the kind of discipline which is neither the study of humans, nor the study of technology, but rather the bridging between those two [15:54]. ACM SIGCHI 1992 offered a general definition in their conference proceedings:

> "*Human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them*"[15:7].

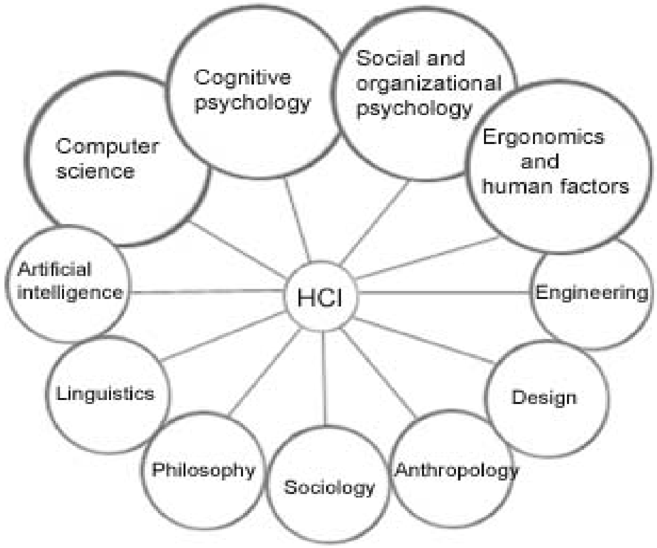

Fig. 1.1: The disciplines that contribute to HCI [15:38].

1.2.1 Ubiquitous Computing and Pervasive Computing

Several interaction paradigms have grown within HCI, such as *ubiquitous computing* and the later *pervasive computing* [16:60-62]. Ubiquitous computing is the paradigm that first moved "beyond the desktop," seeing the possibilities offered by wireless, mobile and handheld technologies. Weiser envisioned computers disappearing into the environment so that the user would no longer be aware of them; this beyond making computers merely portable [16:62]. The focus is to have computers integrated seamlessly into the physical world, "invisibly" augmenting human capabilities.

Pervasive computing follows the ideas of ubiquitous computing, but with the focus on seamless integration of technologies [16:62]. The idea is that people should be able to access and interact with information any place and any time. The technologies are also known as smart devices or information appliances, such as mobile phones, handheld devices like palm pilots, intelligent refrigerators and interactive microwave ovens.

1.2.2 Context Awareness

Context awareness is a concept within ubiquitous and pervasive computing that plays on how wireless technical devices can take advantage of information from the surroundings, i.e. the device is "aware" of and casually interacts with the context around. This is a two-way street: the devices must be able to pick up information, and the context must offer information. CHI2000 [57] had a workshop on context awareness. They defined *context* to be understood as *implicit situational information,* and recognized that "…often [the developers] don't know what contextual information is relevant, useful, or even how to use it. However, by improving the computer's access to its context, the richness of communication can be increased in human-computer interaction making it possible to produce more useful computational services" [57]. The CHI2000 workshop outlined three context-awareness behaviours that an application might exhibit:

- the presentation of information and services to a user
- the automatic execution of a service
- the tagging of context to information for later retrieval

This makes context awareness an augmentation of the mobile device to achieve higher usefulness through better services, thereby augmenting the usability of the device. What contextual information is useful and how to use it is an integral part of this project, where user preferences will be explored.

1.3 Human-Centered Design

Psychology is the basis of human-centered design, where the foremost advocate is Donald Norman. Dr. Norman is a trained psychologist who has applied theories of cognitive psychology to the study of everyday things, and to the psychology of how humans approach them, interpret them and use them [17:248]. Norman argues for a human-centered view of technology where the user-experience and usability is essential. The next sections will briefly introduce the change from technology-driven products to customer-driven products, and some key concepts within the psychology of interface design.

1.3.1 Mature Technology

Norman points at how the word *technology* is used in everyday speech to refer to things that are new, where technology dominates over usefulness and usability [14:24-36]. When the item is commonplace —reliable, robust, convenient and experienced as useful—it is spoken of as a *consumer appliance*. Early in the lifecycle the technology exists for technology's own sake (technology-driven products). Sales are low, the early adopters are usually techno-enthusiasts who tolerate low performance, low usefulness and a lot of grief so they can explore new technology. The product matures by enhancing performance and thus filling more user needs and expectations, and this is closely related to adoption in the market (see figure 1.2). However, increased product performance is important for market adoption only until basic needs are met. For a mature product it is not the technology inside, but rather the good user experience that convinces the market. A product will not be widespread adopted if it is not perceived as *useful*. The larger parts of the market are not techno-enthusiasts, they are conservative pragmatists who are concerned with practical results. The product must provide utility to real people. Within this theory is embedded how a product will take time to find its form, functionality and application area(s) as a consumer appliance. Early version releases should often be seen as advanced prototypes rather than products.

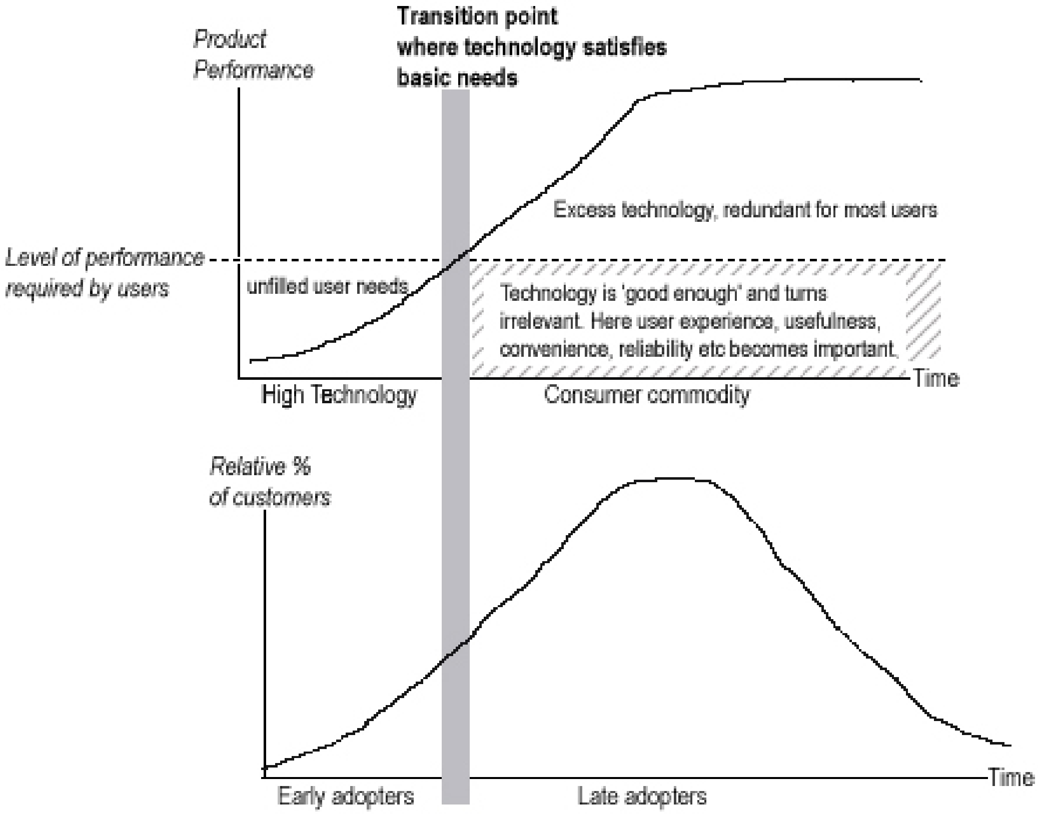

Fig.1.2: The change from technology-driven products to costumer-driven, human-centered products (adapted from Norman [14:35]).

1.3.2 Definitions of Concepts

Mental models are models users have of themselves, others, the environment and the things with which they interact [18:17]. These models are formed through experience, training and instruction. A *conceptual model* is the overall idea of how to design something to best match the user's mental model. Any good conceptual model will allow the user to predict the outcome of his actions as it corresponds to the user's mental model. In short, users have mental models, software designers have conceptual models.

Interface metaphors take something assumed familiar to the user, and uses that concept in the interface. The purpose behind the idea is to draw on knowledge the user already has, and make the user ideally understand without explanation. The first and very famous interface metaphor was the Star desktop interface made at Xerox PARC in 1973. The metaphor made the interface into an office desktop on the screen, where familiar concepts from office work was embodied, e.g. there was filing cabinets and trash can symbols for storage and deleting, respectively.

Norman says *affordances* provide strong clues to the operation of things [18:9]. Knobs are for turning and slots are for inserting of things. When affordances are applied, the user knows what to do just by looking. *Constraints* are cues that limit the alternatives for how to operate things. For example, a door should communicate how to use it, by giving clear alternatives and limitations.

1.4 USABILITY

Usability is a key concept of HCI, and is concerned with making systems easy to learn and easy to use. The next sections explore different definitions, and then compare them.

1.4.1 Nielsen

Jakob Nielsen, the most prominent figure in the field of usability, states that usability is not a single one-dimensional property of the user interface, but has multiple components and is traditionally associated with five usability attributes [19:26]:

- *Learnability*: The system should be easy to learn so that the user can rapidly start getting some work done with the system.
- *Efficiency*: The system should be efficient to use, so that once the user has learned the system, a high level of productivity is possible.
- *Memorability*: The system should be easy to remember, so that the casual user is able to return to the system after some period of not having used it, without having to learn everything all over again.
- *Errors*: The system should have a low error rate, so that users make few errors during the use of the system, and so that if they do make errors they can easily recover from them. Further, catastrophic errors must not occur.
- *Satisfaction*: The system should be pleasant to use, so that users are subjectively satisfied when using it; they like it.

In addition, the primary concern is the overall system acceptability of whether the system is good enough to satisfy all the needs and requirements of the users and others, like users' clients and managers. Where usability belongs in the overall acceptability of systems, is modelled in figure 1.3.

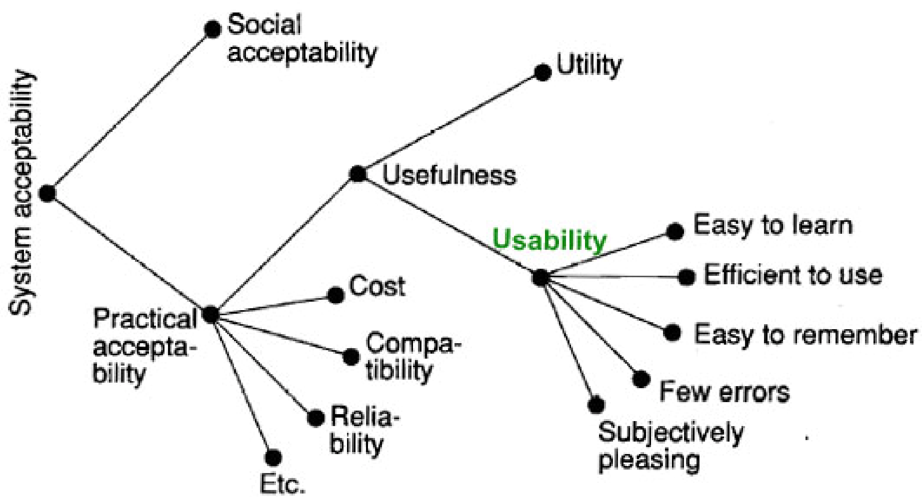

Fig.1.3: Nielsens model of the attributes of system acceptability [19:25].

1.4.2 ISO 9241-11

ISO is an international standardization organization. In International Standard ISO 9241 "Ergonomic requirements for office work with visual display terminals (VDTs) – Part 11: Guidance on Usability" a framework and a definition of usability is offered:

> "*The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" [20:2].

The key attributes are further defined as:

- *Effectiveness*: the accuracy and completeness with which users achieve specified goals
- *Efficiency*: resources expended in relation to the accuracy and completeness with which users achieve goals
- *Satisfaction*: freedom from discomfort, and positive attitudes towards the use of the product.

1.4.3 SUMI

SUMI (Software Usability Measurement Inventory) is a method of measuring software quality from the end-user's point of view [21]. It is a consistent method for assessing the quality of use of a software product or prototype, and can assist with the detection of usability problems.

Work on SUMI started in 1990 when a unit within the MUSiC project developed questionnaire methods for assessing usability. The work entailed examining and expanding an existing method called CUSI (Computer User Satisfaction Inventory), and to commercialize the new questionnaire set as an international standard. The result of this project was a commercial project called SUMI, launched first in 1993 and is today available in many languages worldwide.

The method consists of 50 statements where the user will reply either *Agree*, *Don't Know* or *Disagree*. The different questions are based on research findings, the developers tested different sets of questions and ended up with the combination that gave the best internal correlation.

Example statements [21, section 3.1] :

Item no:	Item wording:
1.	This software responds too slowly to inputs.
3.	The instructions and prompts are helpful.
13.	The way that the system information is presented is clear and understandable.
22.	I would not like to use this software every day.

The SUMI method diverts along five usability dimensions:

- *Efficiency* measures the degree to which users feel that the software assists them in their work and is related to the concept of transparency.
- *Affect* measures the user's general emotional reaction to the software – how they like it.
- *Helpfulness* measures the degree to which the software is self-explanatory, as well as more specific things like the adequacy of help facilities and documentation.
- *Control* measures the extent to which the user feels in control of the software, as opposed to being controlled by the software, when carrying out the task.
- *Learnability* measures the speed and facility with which the user feels that they have been able to master the system, or to learn how to use new features when necessary.

1.4.4 Summing up Usability

The three definitions of usability have similar focus and most of the attributes or dimensions have a corresponding attribute in the other definitions. This suggests that the groups behind them probably inspired each other. The choice of definitions vary to some extent, but the reasoning behind is based on the same principles. There is a complete match between efficiency, satisfaction/ affect in all three, and Nielsen and SUMI also have learnability in common. Memorability and helpfulness with Nielsen and SUMI are quite similar as they focus on the system being self-explanatory on one, and how rarely used systems should not force the user to learn everything over again every time on the other. There is agreement on the following dimensions to define usability:

- *Efficiency*: ability to achieve goals and produce, and that the software assists the user in the work and is transparent.
- *Satisfaction*: how the users like to use the system, is it pleasant.
- *Learnability*: how easy the system is to master and the user can focus on getting work done.

1.5 HANDHELD MOBILE DEVICES

Handheld Mobile Devices can be seen as advanced prototypes giving glances of what the near future will offer. Defining what they are requires splitting up the term and looking closer at what each of *Handheld* and *Mobile* entails.

1.5.1 Handheld

Weiss describes handheld devices as "extremely portable, self-contained information management and communication devices," and introduces three tests that a candidate must pass to be considered a handheld device [22:2]:

- it must operate without cables, except temporarily (recharging or synchronizing with a desktop).
- it must be easily used while in one's hands, not resting on a table.
- it must allow the addition of applications *or* support internet connectivity.

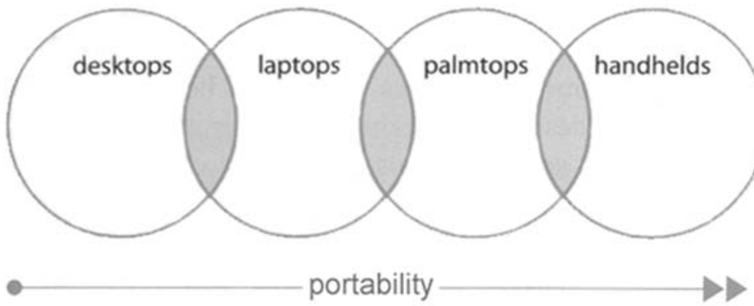

Figure 1.4: Weiss' personal computing continuum [adapted from 30:3].

In figure 1.4 Weiss shows how most devices fit into one of the categories. The figure models the relationship between size and portability: the smaller the more portable. Weiss further divides *handhelds* into the categories *mobile phones*, *pagers* and *PDAs*.

1.5.2 Mobile

Dahlbom and Ljungberg introduces three modalities of mobility – wandering, visiting and travelling. They argue that all work and activities involve mobility [1]. A user making trips to offices in the near environment, e.g. a mobile IT support worker who makes a new entry in her to-do list on a PDA while servicing PC users in their offices, is a *wanderer*. A second modality of mobility is *travelling* between sites, utilizing IT while in a vehicle. The last modality is *visiting*. They give an example of a consultant using a computer at the clients' premises.

Weiss says that handheld devices define mobility [22:8]. They are small, lightweight and very portable. He lists the following traits as what makes a device mobile:

- *Combined weight:* Typically a handheld device weighs less than 8 ounces, approximately 230 grams.
- *Number of required components:* Handheld devices frequently have a stylus input device stowed within the unit. All components for handheld devices must be portable or stowable, with the exception of cradles for synchronization and recharging.
- *Cables needed for operation*: Handheld devices typically require only a power cable when they are recharging.
- *Size:* Handheld devices fit in a shirt pocket.
- *Furniture*: Handheld devices require no furniture except when charging or synchronizing.

A truly mobile device should support all three mobile modalities (wandering, visiting and travelling) through its hardware traits. However, the context in our project is mobility within the limited local area of a hospital ward, thus attaining mobility for the wandering modality is sufficient.

1.6 GUIDELINES

Nielsen states that *guidelines* list well-known principles for user interface design which should be followed in development projects [24:91]. He further identifies different levels of guidelines: general guidelines applicable to all user interfaces, category-specific guidelines for the kind of system being developed, and product-specific guidelines for the individual product.

Brown says that guidelines may come from different sources; evidence from experience, predictions from theories on human performance, principles of cognitive psychology, principles of ergonomic design, evidence gathered through engineering experience, expert judgment, common sense and practical experience [23:2]. Brown further says that benefits of applying guidelines into the design of interfaces are reduced training, reduced errors, increased efficiency and increased user satisfaction, as well as others.

1.6.1 General User Interface Design Guidelines

Nielsen has published his general interface design guidelines (he calls them the *Ten Usability Heuristics* or *usability principles*) in numerous books and papers with similar wording [19:24]:

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

- *Match between system and the real world*
  The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
- *User control and freedom*
  Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
- *Consistency and standards*
  Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
- *Error prevention*
  Even better than good error messages is a careful design which prevents a problem from occurring in the first place.
- *Recognition rather than recall*
  Make objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
- *Flexibility and efficiency of use/ Shortcuts*
  Accelerators — unseen by the novice user — may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users.
- *Aesthetic and minimalist design/ Simple and Natural Dialogue*
  Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
- *Help users recognize, diagnose, and recover from errors*
  Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
- *Help and documentation*
  Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

1.6.2 User Interface Design Guidelines for Handheld Devices

Weiss offers a collection of product-specific interface design guidelines for handheld devices in his book *Handheld Usability* [22: 66-70]:

- *Design for Users on the Go*
  Handheld users are likely to be conversing in a hurry, so designs must include context and forgiveness. Wireless devices are less about surfing, and more about instantaenous search and retrieval, and the users typically have immediate goals.
- *'Select' vs. 'Type'*
  Typing on a handheld device is extremely difficult unless a keyboard is attached. Even with a keyboard, the user may be in a situation where it is not feasible to attach one. Alternative input methods such as handwriting recognition software and on-screen keyboards are painfully slow for data entry, so when possible consider to offer a selection mechanism rather than require typing.
- *Be Consistent*
  Borrow from well-designed applications if standards or guidelines are not available. Don't invent new user interfaces when one of the existing ones will do nicely. Your users do not want to learn new techniques to access information unless the new technique will save them a great deal of time and effort. Use the same terminology and interaction schema within an application and between applications which will reduce the learning curve for new features.
- *Consistency Between Platforms*
  Consistency can be an effective tool to increase ease of use, but can hinder good design when migrating a user interface from platform to platform. Retain terminology and processes only when they are equally appropriate for the smaller screen. When either becomes an obvious hindrance in the wireless environment, you need to redesign for the wireless user.
- *Imply User Control*
  Provide the illusion that the user is in control. Menus can be designed to provide cross-linking between areas of applications and even between entire applications. The clipboard model is the ability to cut/ copy/ paste data anywhere on desktop computers, which gave the user a great deal of control. This can be compensated by enabling common actions on visible data, e.g. enable users to call when a number correlates to dialing system format, provide access to email when user selects text that includes the @ symbol. Anticipate how a user will act on data, and build her desired actions into your design.
- *Design Stability*
  Wireless data connections are prone to failure and will remain so for the foreseeable future. It is critical that your applications provide a stable user interface. When the network connection drops, the application should restore state and context without requiring re-entry once the network goes

back online. The interface should also display a message confirming that parameters are restored, possibly offering to restart a process with pre-populated entry fields.

- *Provide Feedback*
  Each page of an application should provide the user with enough information to understand what the application is and how to navigate from that page.
- *Forgiveness*
  If a user makes a mistake, the user interface must offer a means to correct it.
- *Use Metaphors*
  Use metaphors from the real world. The desktop metaphor is a poor choice for handhelds and phones, since the display is too small to make the conceptual leap. The "bookmark" is a very effective metaphor for the wireless web, especially since entering URLs into a handheld is so awkward.
- *Clickable Graphics Should Look Clickable*
  "Clickable-looking" means they should have defined borders and/or have high contrast with the background color. Conversely, images that are static and not linked should not appear clickable.
- *Use Icons to Clarify Concepts*
  This is for color bit-mapped displays, not tiny displays with no graphics support. Icons provide users with additional assistance, and should be carefully designed as representations of concepts (not as hieroglyphics). The best icons are very simple representations, usually nouns. Icons may not be immediately obvious to users, but they can be memorable.

CHAPTER 2

Related Research and Products

There are electronic patient record (EPR) systems in most hospitals in Norway, with varying degrees of success and satisfaction, but none have implemented large-scale mobile solutions [25]. One hospital is run paperless (Aust-Agder), but their electronic patient records are made from scanning paper records, thus with a static result [25]. St Olav's Hospital had in 2001 an estimate of *15,000* shelf meter of paper patient records [26]. The three most common EPR systems are DocuLive, Dips and Infomedix (Imx).

This chapter will review some aspects of selected research and systems that offer interesting input to a discussion of handheld mobile devices in the hospital. The presentations below are impressions from reading textual descriptions (what was available) and looking at demos (where available).

2.1 LIFELINES

Plaisant and Rose introduces LifeLines as a “visualization environment for personal histories,” where the visualization includes enhancing navigation and analysis of personal records [27]. They say LifeLines is a technique on how to summarize, filter and present large amounts of information without long lists to scroll, clumsy searches, endless menus, and lengthy dialogs: details which ultimately promote user rejection. LifeLines is selected to offer input on navigation and presentation of data.

Lifelines is planned for a 1024x768 screen resolution, requiring a rather large screen [27]. A device sporting that type of screen is larger than typical handheld devices, and thus not truly mobile according to Weiss (see p.13). The benefits of LifeLines is that it reduces the chances of missed information, it facilitates the spotting of anomalies and trends, it streamlines access to details, and it remains simple and tailorable to various applications [28].

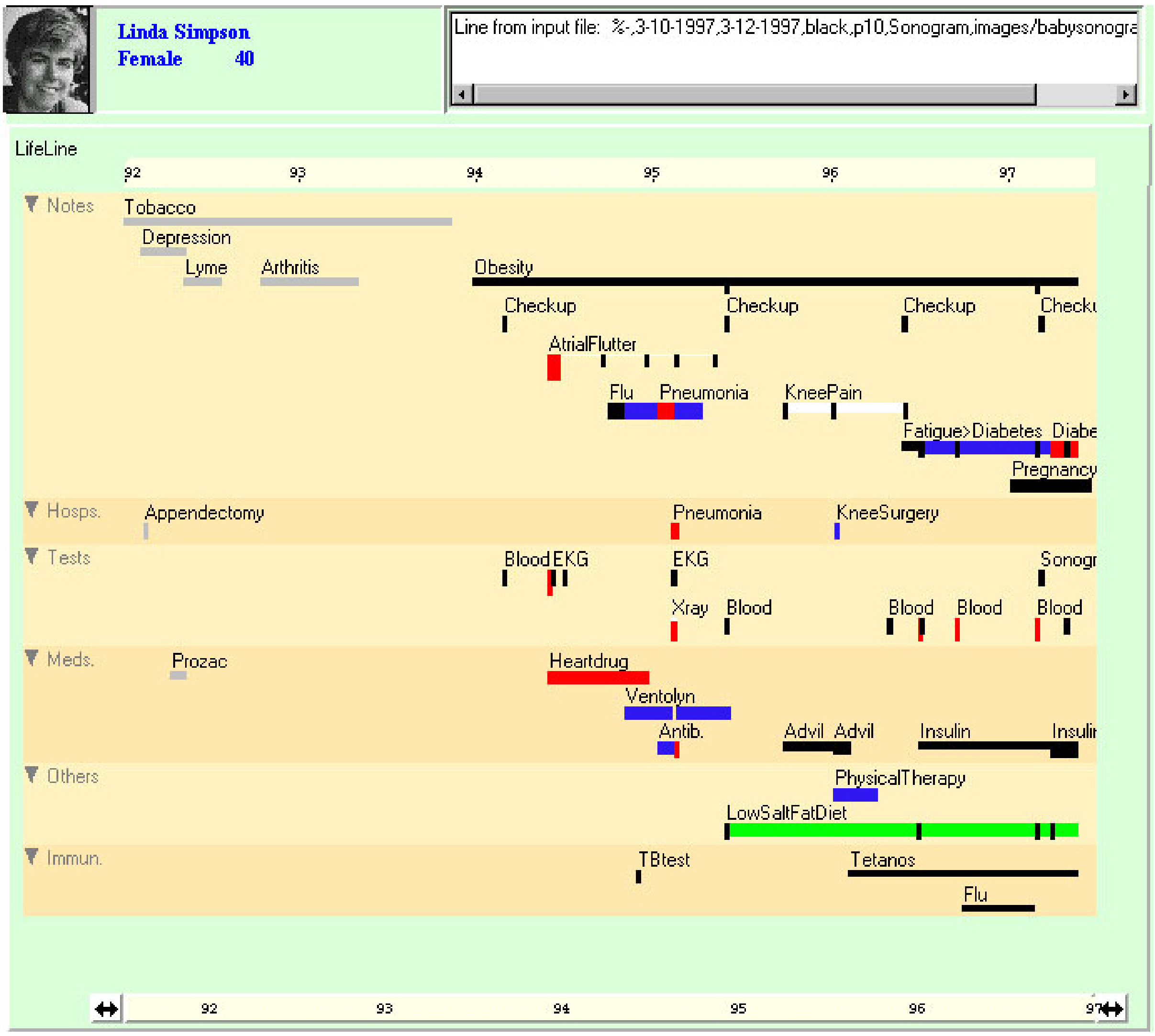

Fig. 2.1: Information visualization in the Lifelines screen interface [28].

The LifeLines patient record (see figure 2.1) has medical problems, hospitalization and medications represented as horizontal (life-) lines, while icons represent events such as physician consultations, tests, progress notes, etc. Line color and thickness can illustrate relationships or significance, and there are rescaling tools and filters that allow the user to focus on part of the information as it reveals more details [27]. Consequently, the interface acts as one giant menu where all icons have more information behind which is easily accessible by one click. This overview picture helps the user not to get lost along with having few depths in the design.

This visualization design helps the user gain a lot of knowledge and understanding in a short time. The conceptual model corresponds to the user's mental models, including natural mappings between cues and outcomes. Both retrieval and presentation of large amounts of information is efficient, and navigating through it all is intuitive with high usability.

2.2 WardInHand

WardInHand is an EU-funded project aiming to support the day-to-day activities of doctors and nurses within a hospital ward, by providing a tool for workgroup collaboration and wireless access to patient's clinical records through mobile computers [29]. The main purpose is to support doctors and nurses at the patient's bedside, complementing existing systems (such as EPRs). Ancona et al. says that information is first written on paper and then later typed into computers of existing systems, with all the possibilities for errors, omissions, duplication of information and added work to doctors and nurses one can imagine [30]. The system is piloted and used within three hospital wards in Italy, Spain and Germany [29]. The WardInHand system is selected because it is research on handheld mobile computers in hospitals.

Fig. 2.2: Top level of WIH [31].

The application for WardInHand runs on the handheld device Compaq iPaq 3630 (32 Mb RAM), which is a PDA that is connected to a ward server through IEEE 802.11 wireless LAN [31]. The number of access points in one ward depends on the topology and structure of the ward (typically 2 or 3), and the application can also be accessed on other terminals like desktop computers [31]. Virtuoso and Dodero have experiences with the physical constraints: devices must be small and light in order to be carried along and used while standing at bedside, while the small size limits the screen display severely [29]. Low weight requirements gives severe constraints on the battery lifespan, which in turn limits available power for transmissions. The consequence is that client-server interactions have to be minimized to save power.

WIH has three components, the Patient Record Manager (PRM), the Workflow Manager (WM) and the Personal Organizer (PO), and three user profiles with authorization levels: doctor, nurse and system administrator [29]. The relevant work processes in the PRM are [31,32]:

- new patient creation, select existing patient
- create and modify admission and discharge reports
- patient record updates: introduce personal information of patient, browse and retrieve stored information, complete and modify information
- physiological signs: read and update all the relevant physiological signs (body temperature, pulse rate, glycemia, blood pressure, breath rate, etc.)
- dynamic creation and visualization of graphs (e.g. to visualize the body temperature values)
- treatments (drugs, diets): user can browse, modify and create
- administer prescriptions and drugs
- prescribe clinical tests and show results when ready.

Examples of how work processes have been implemented as interfaces can be seen in figures 2.3-2.6.

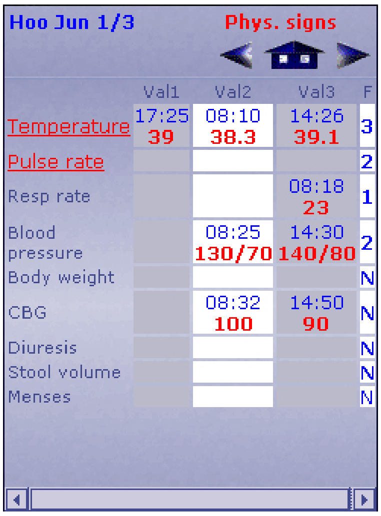

Fig. 2.3: Physical signs menu in WIH [33].

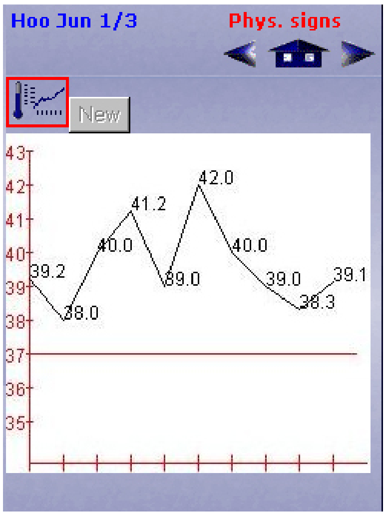

Fig. 2.4: Temperature graph in WIH [33].

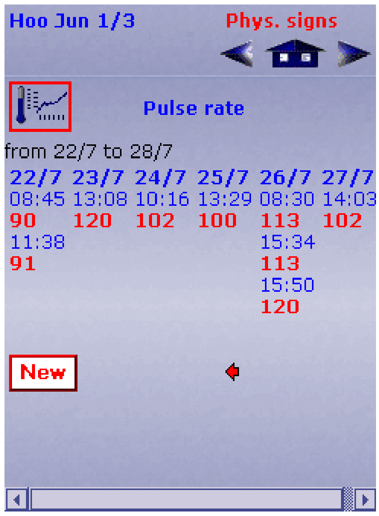

Fig. 2.5: Pulse rate in WIH [33].

The Personal Organizer gives real-time lists of tasks to be executed to the personell (see figure 2.7). Completion of a task can elicit a new task to be scheduled in the workflow. For example: when a doctor registers a drug prescription it will trigger a new task (or a repeated series of tasks) for the nurse, instructing him to give the patient that particular drug. WIH also has a messaging system which can coordinate activities with colleagues of other shifts, and make appointments to other wards and labs instead of by phone [31].

WIH uses two modes of data entry. One is input by stylus on the touch screen with a predictive virtual keyboard (WTx) [34]. The second is voice input into a microphone with a speech recognition engine that “supports command and control capabilities, navigation and intelligent form filling in the major European languages” [29]. The latter is advanced and does not exist as an off-the-shelf product. Ancona et al. states that the problem of data entry is a crucial one: users are normally standing, a fact that discourages the use of a keyboard [30]. Further, he claims that handwriting recognition software requires the users to be trained on writing styles and write words letter by letter, which makes it a tedious task.

Ancona et al. concludes that mobile devices do not have good concepts widely applied to collect input data [34]. They say the WTx used when standing up is proven to be superior in speed to all other methods, including virtual keyboards and hand-writing technologies. However, they also say the speech recognition tools on mobile devices in hostile environments such as a hospital ward “is not yet comparable with similar tools working on desktops, thus it is necessary to wait for improvements for a really significant use.” Ancona et al. do not consider a virtual keyboard an asset to usability, since it puts further limitations on an already small display, is frustrating to use and hardly productive when standing up [34]. They say that physical keyboards have not been considered for WIH since the users are normally standing up.

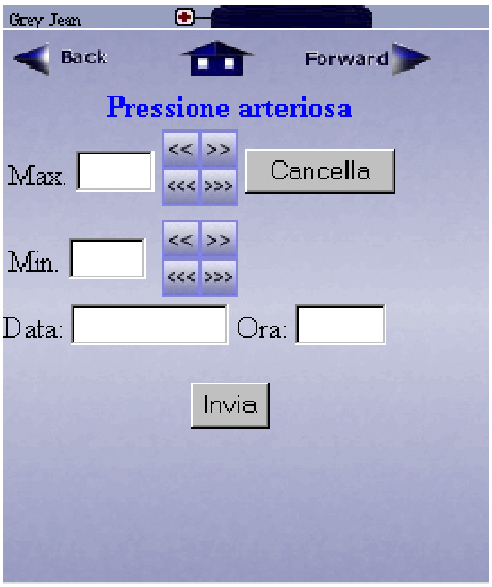

Fig. 2.6: Entry of blood pressure in WIH [36].

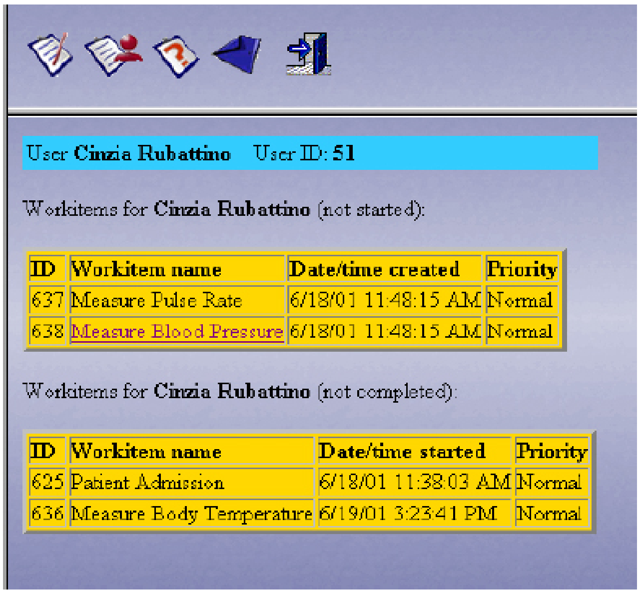

Fig. 2.7: Personal Organizer in WIH [36].

In WIH the output is voice reminders or display information. The GUIs appear to be designed larger than the screen at first sight, thus considerable scrolling seems accepted even if it gives bad flow. For example, in figure 2.7 the wideness of the interface is evident. The screen seems cluttered with less useful items, like User *and* UserID (last name possibly with first name initial should suffice). In the

Workitems column, there are also ID numbers. If they are room numbers they justify being there, if not, then they occupy valuable screen space for no apparent reason. *Priority* has the value "*Normal*," where the limited screen could benefit from something shorter. Last, the *Date/time created* field seems unnecessarily large, even if based on working practice. "*6/19/01 3:23:41 PM*" is a long string, where "*6/19/01 15.23*" should suffice. Seconds are hardly important for this logging.

Navigation with a speech interface allows hands-free operation and should be efficient. The reports neither say how personell actually feel about talking or giving commands to a machine, nor if learning these commands is easy or a strain. The pen may not be ideal for navigation due to high demands on finger motorics, as mentioned by Ancona et al., "the elevator in a scrollbar can be very difficult to manipulate" [34]. As in figure 2.7, the interface is sometimes wider than the screen and demands a lot of scrolling. The amounts of information accessible versus burying navigation does not appear to be a problem here. In figures 2.3-2.6 the interfaces seem more appropriate and limited to presenting useful and recent information, allowing natural navigation.

The design of WIH has three priorities: first, to have flexibility and device independence to ensure the longevity of application and to allow the end-user to adopt device by preference (e.g. screen dimensions and form factor). Second, extensive use of icons and selection menus for predefined choices. Third, minimal use of numeric data entry, which is replaced, for example, by sliders (see figure 2.6) [29]. The overall design and interaction modes included in WIH makes it seem like a useful and well-suited mobile device for integrating, synchronizing and making work processes more efficient.

2.3 ACTIPIDOS

Actipidos is real-time patient record management software made by the French company Stylus [35]. Actipidos has been used at hospitals in France since 1998, and is now in use also in Spain, Belgium and the United Kingdom. Actipidos can run on stationary PCs, but is most known for its solution on mobile pen-based wireless tablet computers, which is why Actipidos is selected here.

The introduction to the system claims "St. Joseph's Hospital in Marseilles reported reduced nurse workloads by as much as 40% with the system in place. French hospitals have also found that the amount of medicines prescribed unnecessarily, or lost in the system, dropped by up to 40% when the computer system was introduced" [35]. Other benefits come from saving doctor's time, and improvements in the hospital process caused by streamlining the ordering of tests and procedures [35].

The documentation do not offer much information on suitable mobile devices to match the software, but the Actipidos interface is approximately A4 size. Tablet PCs (also called *pen tablets* and *slates*) come without an integrated keyboard and is operated mostly by pen, usually sporting a display around 10 inches. They usually include connectivity to high-speed networks, one of the keys to their mobility.

The website uses the St. Joseph's Hospital in Marseilles as an example, saying it is a large hospital with 760 beds treating 30,000 patients annually. It has 400 desktops in use, 37 wireless points and 115 pen tablets, with about 800 staff at the hospital using the pen tablets everyday [35]. The number of staff relative to the number of pen tablets suggests that the users do not carry them around at all times, which is further supported by the statement "The wireless pen-pads are light, and easily carried by doctors or nurses *on a ward round*" [35] (italics added). The tablet PCs are purposefully picked up to be used specifically on rounds at point of care (see figure 2.8). This use model is a consequence of the form factor, pen tablets cannot be carried comfortably over time both due to size and weight, and do not fit in any shirt pockets. While on the rounds, the user carries the device and operates it while holding it, much like one would do with a regular pen and notepad.

Fig. 2.8: The Actipidos Use Model [33].

Actipidos has several views and functions. It carries the patient records sorted under wards [35]. The records can be customized and combines all information about the patient, such as family history, medical history, needs and diets. The system allows the clinical staff users to:

- introduce new patients into the system by drag-and-drop a "person" into the chosen available "room number," and then patient information can be entered.
- get an overview of tasks to be done by them, as well as execute tasks.
- care-planning.
- order and receive laboratory and radiology investigations.
- integrated care pathways.
- drug prescribing.
- do administrative work and make referrals to other staff or organizations.

Care pathways and protocols are automated in the displays; for example the automation of the pharmacy process from prescription to administration. Doctors can order all types of prescriptions and investigations with one click at the patient's bedside. The system also uses a drug database, which allows clinical decision support in real-time; and doctors can likewise get results of blood tests and x-rays in real-time at the patient's bedside. Pre-admission boards, planned exits and beds occupation makes it possible to predict and manage a patient's stay. Figures 2.9, 2.10 and 2.11 show examples of interface views in the Actipidos system (for more and larger images, see appendix G).

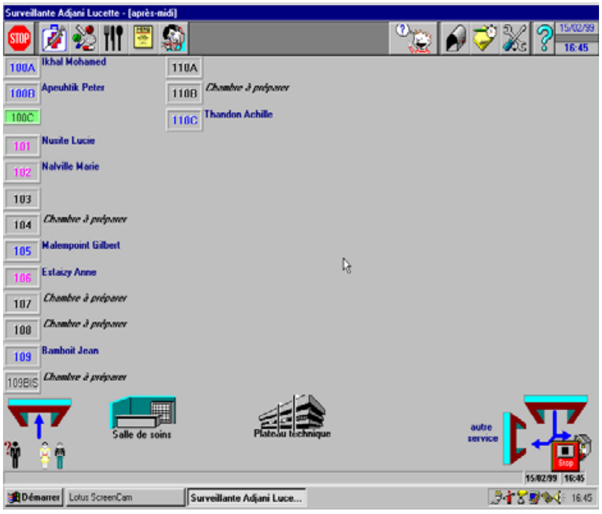

Fig: 2.9: Users Worktop in Actipidos [35].

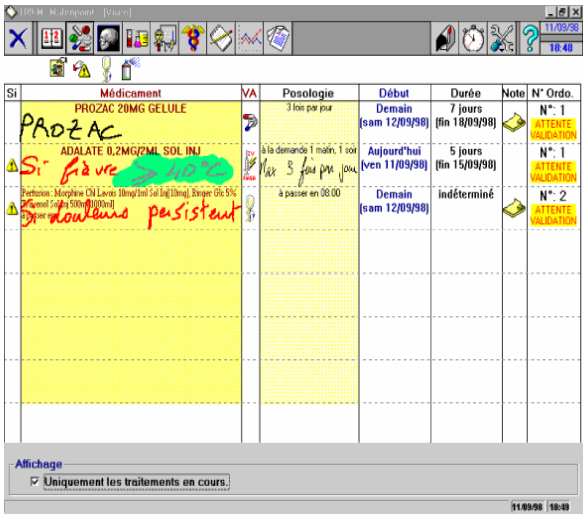

Fig: 2.10: View of a patients prescriptions [35].

The constants diagram (see figure 2.11) displays physiological measurements such as pulse, temperature and blood pressure of a patient. The diagram has simultaneous along-side views of interventions and treatments, such as drugs administered and pathology results. The doctor can use the pen to zoom in on a precise time or detail of the measurements. The constants graph displays several constants at the same time.

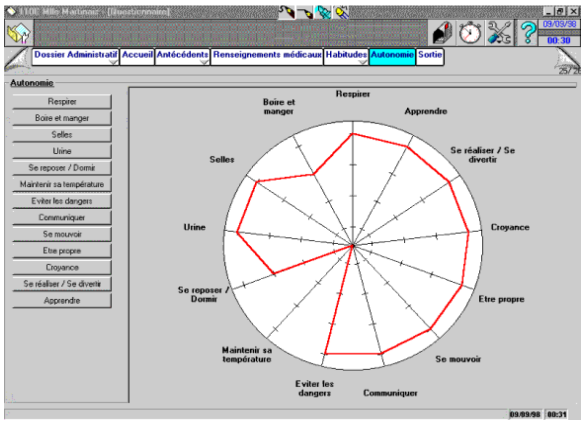

Fig. 2.11: Constants graph curve [35].

The input can be done either with the pen on the mobile pen-tablet, or with a physical keyboard on a stationary PC. Speech input is not available. Actipidos allows the user to both jot notes down in natural cursive handwriting (achieving digital text input through handwriting recognition) and pen gesture commands (achieving navigation through gesture recognition). Data capture devices such as color, eraser, underlining, etc. is available with the handwriting option [35]. This flexible use of the stylus allows Actipidos to carry quick informal human habits into the conceptual model. Healthcare personell often have a well-established habit of noting small bits of information on any available paper for later use. This habit has become a clever pen-on-paper metaphor in the interaction design of the system.

The extensive use of gestural commands for input and navigation (see figure 2.12) is also very intuitive, efficient, and saves space on the screen (also see p. 79). To make a selection the user circles the target (1), and undoing the last event is done simply by crossing it out (2). To request help, the user writes a question mark (3). Scrolling is done by drawing a line in the desired direction: up, down, left or right (5). Shortcuts are also used, e.g. when filling a prescription the user can chose medication and then handwrite “3x” (4), and the handwriting recognition technology changes it to digital input such as “Aspirin to be administered 3 times a day.” Likewise, when the system helps by suggesting a size—from amounts of medication to dates—it can easily be adjusted by drawing diagonal lines, increasing and decreasing respectively (6). The navigation further seems to carry few depths, making it easy not to get lost. Input and navigation seems to have high usability in Actipidos.

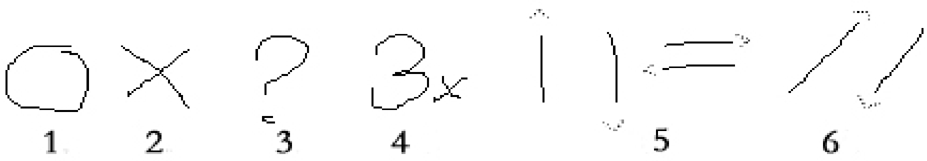

Fig. 2.12 Intuitive gesture commands in Actipidos.

Actipidos carries extensive use of metaphors: resting the pen over text offers help text in a bubble. Corners are “folded” to give the illusion of one “page” among other pages in a paper patient record, thus users will understand there is more information available. There is also extensive use of icons on the buttons as cues rather than text. Warnings come as yellow flashing stars with text rather than the ordinary message box, which communicates to the user: “this one you need to read and not just push OK out of habit.” The pen tablet with Actipidos has an overall notepad metaphor, and reinforces this with notepad binding down the middle of the design. The pen-on-paper metaphor is carried into the interface taking advantage of established knowledge and work routines of the user. The concept models the user’s mental models to a great extent, and makes it intuitive and highly usable. The mobile device seems very well-suited in integrating and making work processes more efficient.

2.4 JetRek

JetRek is software for mobile handheld PC’s, and was implemented in two wards (the medical and surgical wards) at Aker Hospital, Norway [36]. Benjaminsen and Tjora say that JetRek is developed for filling requisition forms for lab tests, x-rays, physical therapy treatment, and such. The software runs on Hewlett Packard Journada 680, which has a small screen, small keyboard and fits in a shirt pocket. The use model entails doctors bringing the Journada on rounds, and fill requisitions at bedside—one (required) field at a time. The Pocket PC is put in a dockingstation after rounds, and the requisitions are printed, signed and sent to recipients [36]. JetRek is included because it offers experience.

Melby did some work evaluating JetRek [37]. She says the project is not very ambitious and works to the side of today’s routines. Melby uses both doctors and nurses as examples. A doctor in the medical ward stated that the device is not useful to type on due to the small keyboard, and that requisitions were still entered at pre-visitation similar to old routines.The difference was that the requisitions with JetRek was carried in the pocket during visitation, before finally printed. A medical ward nurse stated that her ward uses JetRek often to write requisitions and nurse reports, saying the keyboard works well. The report becomes more structured and easily understood with the new system. A nurse in the surgical ward reported that nobody uses JetRek (anymore), as surgeons prefer yellow post-its and having the nurses fill the requisition forms for them.

Melby concluded that there were different use patterns in the medical and surgical wards. When JetRek was implemented, there was less erred requisitions due to lack of significant information on them, and the notes were more structured without poor handwriting. However, the system is cumbersome since the requisitions still must be printed and signed. Thus, JetRek complements rather than replaces paper in the requisition routines [37].

When a system is not being used by the majority it can be a good indicator that usefulness and usability is not good enough. Another reason behind the user rejection might be the hospital hierarchy: it is quicker and easier to jot a couple of words on a post-it note and have someone else take over, than actually using JetRek.

2.5 User Interface Design Principles for the Hospital Context

Health Infodesign is a website by M. Moore, a published professional in nursing informatics (see also [39]) [38]. Moore lists some health information design principles, and problems of the context on his website:

- *Summarize information*
  The volume of information for a patient makes it impossible to show everything at once. Showing everything at once would also overwhelm the user; most clinicians want to see information that is either *new, abnormal* or *significant*. The goal of a good medical UI is then to show those things first, and use the principle of progressive disclosure to let the user see more when they need it.
- *There is no typical user*
  One piece of software can not be expected to work for all users in the clinical setting. Job classifications have variations in clinical expertise, computer skill, training, job responsibilities and tasks.
- *Avoid interruptions*
  Clinical users, especially physicians, are more bothered by interruptions like message boxes than typical users. Perhaps because the task of forming a picture of the patient demands so much concentration that a “chatty” system is especially bothersome. Clinical users really only want to

know if something may be about to harm the patient, and the rest can wait. Another issue is that users stop reading messages if they are frequent, and blindly click OK.

- *Wrong patient*
  Designers might be tempted to save some pixels by making the patient information small; but at best this will occasionally waste time while the user tries to fix having done work on the wrong patient, and at worst result in a patient getting the wrong treatment.
- *The burden of work*
  When implementing a computerized system, the burden of work shifts more directly to caregivers, and away from clerical staff. This has probably killed more medical systems than everything else combined. If users perceive that they are simply replacing clerical work without getting any real benefit, that is the kiss of death for a system. This means that there should be clear and direct benefits for users interacting with the system themselves. Providing drug-drug and drug-allergy checking at the point of medication ordering is a good example of a tangible benefit that is lost if another person were to do the work.

2.6 Pervasive Healthcare

This section looks at some work concerning role-play and pervasive healthcare done in parallel or after the project, as it is interesting to see how finds correlate. First, some reports that bring insights to the relative success of EPR systems, then some visions for pervasive healthcare systems and experiences with PDAs in hospitals, including context awareness. Lastly, some new methodology for using role-play as a source of creative input for systems development.

There has been some studies which offer insights to the status of EPRs in hospitals. Melby [66] has investigated how health workers use information- and communication media during the first 24 hours of a patient's hospital stay by tagging information sources. In one example she describes how health workers rely on memory and personal notes to communicate information to others in morning meetings as digital information does not exist in the EPR system yet—the information gathered during arrival is on a dictation tape waiting to be transcribed. Melby concludes that work practices have not changed despite efforts to introduce electronic alternatives: health workers continue to lean on paper-based media in their daily work. Melby points to several reasons for the problems of EPRs in hospitals: Health workers in wards are mobile workers while EPR systems do not support mobile work, EPRs are on stationary PCs. Further, EPRs have poor functionality compared to paper: paper need little or no training (to read and enter information), paper is very flexible and informal while computers often enforce formats, paper is mobile and can be brought anywhere, and paper-based information systems is an established practice that they make work.

Bardram agrees that contemporary desktop EPR solutions are unsuitable to support fast-paced mobile medical work [67, 68]. He says they are designed for sit-down office work, while medical work is by nature nomadic. Bardram offers an example how the introduction of an EPR system actually made the work of the nurses even more nomadic: Before, handing out medicine involved walking to the medicine room—then to the patient room. Now the route has become: office (to review patient's medicine plan) — medicine room (get medicine)—patient room (deliver medicine)—office (document medication event). Bardram adds that nurses have established a work-around: They start every morning by printing out relevant data sheets from the EPR, especially medicine plans. The print-outs are used during the day as a mobile tool for the medication hand-out, including reading the prescriptions on the paper and documenting directly, writing notes on the paper. Before leaving the ward in the afternoon, they type in all the notes taken during the day. The nurses created their own mobile system where paper is the vital information media.

Bardram sees two options to create good systems for mobile and nomadic users: One is to equip the hospital staff with mobile computers, like PDAs and Tablet PCs; the other is to equip the hospital with computers located in relevant places and create a computing infrastructure that enables the user to move around while preserving their user session (to avoid constant tiresome login-logout). Bardram envisions that health professionals can approach interactive surfaces anywhere and carry on their work: conference tables, beds, wall-sized displays, ceilings, floors, pill containers, medicine cabinets, surgical tools; with roaming application and user sessions between various public computers available (e.g. transfer ongoing work from a PDA to a desktop PC by using the PDAs barcode scanner and scan a barcode on the PC, a radiologist arriving at a conference room is be able to transfer his entire conference from his PDA to a wall-sized display).

Turner et al. offers experience from a project where doctors of a ward and their secretaries used PDAs [69]. They found that the PDAs were useful not only in providing access to essential patient details and documents at any time, but also for providing instant consultation in a drug formulary (data on all hospital-approved drugs) and access to a reference guide for junior doctors (gastro-intestinal guidelines). The most used functions regarded entry of consultation notes at point of care; problems, diagnoses, requirations of tests and procedures, drug details, and follow-up problems. Being able to request tests via PDA was highlighted as a vast improvement over previous paper form filling. Turner et al. also found that the virtual keyboard was satisfactory, but slower than a conventional PC keyboard. Most users preferred handwriting with stylus (with handwriting recognition) to enter text for notes, as it was quick and intuitive. Input of test requisitions, diagnoses, and drug treatment was done by drop-down boxes, which doctors found to be very fast, easy to use and inherently accurate—handwriting recognition is not necessarily as accurate—although not so effective when list of options was long and perhaps required scrolling. Bardram envisions various kinds of multi-modal interaction, where surgeons can access medical records and images by using voice and gestures while operating. Turner et al. enabled doctors to dictate text for letters (referrals, to patients primary doctor, etc.) via the PDA, which uploaded it to a server where it was transcribed via voice recognition into database. Complete automated letters were immediately available for printing or other medical staff. The dictation did require a formal style with clear pronounciation, but overall worked very well.

Bardram [67, 68] sees context awareness to be where applications have knowledge about the users' work context and are able to adapt to it, and says that support for context awareness is central to the success of clinical systems. He created passive verification of user by way of context awareness; the user's location was matched to a digital token the user had (a personal pen). Tracking the location of users helped decide what machines they could access. Kjeldskov and Skov [71] designed a handheld context aware solution using PDAs to support nurses in their highly mobile work activities. The mobile EPR system MobileWARD recognizes the location of the nurse and presents information and functionality adapted to context automatically, i.e. presenting information about patients close by. The goal was to achieve reduced information complexity of interfaces. They found that nurses would sometimes miss reminders presented on the screen because their focus was engaged elsewhere, and some got confused or annoyed when on-screen content automatically adapted to their physical location. Kjeldskov and Skov concluded that context-awareness was not always supportive of the nurses work activities, as it was sometimes seen as an obstacle to interacting with the system. Dahl and Svanæs [70] agree that location-based interaction techniques can give a potential loss of user control due to inaccurate physical positioning and/ or because certain elements of interaction are hidden from user.

Turner et al. [69] concludes that the usability of the PDA does not pose major problems, neither with data entry nor presentation, i.e. reading text from screens and inspect images. They believe that access to blood results is a potential killer application that can guarantee uptake and wide acceptance of the technology. Bardram [67] sees PDAs as capable of alleviating some of the problems of EPRs by providing specific support for isolated tasks, but has hesitations whether the display size and computing power is sufficient; he does not think PDAs are able to solve the problems of EPRs as a stand-alone solution. Bardram found Tablet PCs to be considered too bulky, as they do not fit into the pocket of a white coat.

Last, Svanæs and Seland have proposed a design method for role-play workshops, where end-user participants use their own experience to create and stage imagined situations from their own life. Key is that participants simultaneously explore future use and future technology. The design method is seen as suitable for early stages of a project, and entails users assuming their work-role and improvising, while stating desired functionality into very simple prototypes (lo-fi). Scenarios and prototypes develop on stage while facilitators learn by observation. Svanæs and Seland claim this method is especially valuable in projects involving mobile technology and multiple users. They have drama exercises as a warm-up in their method, where some time is spent on teaching basic drama skills to enable users to improvise (scenes from the hospital). A lesson they learned was that users should have direct experience from the kind of work (or leisure) that is being dealt with in the workshop.

2.7 CONCLUSION

Chapter 1 offered some general design guidelines and guidelines specific for mobile IT. This chapter described some research and systems that offer interesting input to the topic "handheld mobile devices in the hospital," among the array of software systems for hospitals. Lifelines shows intriguing ways of presenting large amounts of information sporting elegant, intuitive navigation without drowning the user. WardInHand is research on using a handheld mobile device in the hospital context. Actipidos is an existing mobile system for the hospital context, with very sleek interaction metaphors, input techniques and navigation. Actipidos also presents and makes sense of large amounts of information for the user, like Lifeline. JetRek offers some experience in using a mobile handheld device, although this system had limited impact on existing work routines. Moore offers his experience as interface design principles for the hospital context. Last, a look at some work concerning pervasive healthcare and role-play done in parallel or after this project, to see how finds correlate.

These designs are all examples of products or research for the hospital context. Common for all of these is how little documentation were available of user experiences, usability and usefulness. There were few notes in reports with analysis of what the users experience to be most useful, or tests with real users of what they use most frequently among the functions that are included; and how this product or system impacted on their everyday worklife and routines. This chapter shows how there is a lack of empirical investigations upon usability and usefulness among the selected systems. Bearing the research questions in mind, this suggests that an independent study where we follow the lead of the users to harvest empirical insight into the usefulness and usability of mobile handheld devices in the hospital is interesting and relevant. The project results can later be compared with the findings in this chapter, and from that guidelines for handheld mobile devices in the healthcare context can be sketched.

CHAPTER 3

Research Methodology

Chapter 2 concluded there is a lack of empirical evidence concerning the usability and usefulness of mobile healthcare systems. This chapter will consider and choose methodology for a case study where mobile technology is explored with real users of this specific setting. The empirical evidence collected throughout the case study will offer insights upon the usability and usefulness of handheld mobile devices in hospitals.

3.1 DEFINITIONS OF CONCEPTS

There are two distinguishable methodologies for studying behaviour and phenomena, which can be seen as paradigms or schools of research:

Qualitative research concentrates on understanding phenomena of the social sciences, especially human behaviour in social contexts where qualitative methods often are required to capture complexity and meaning. Methods and theories are adapted to the item of investigation, and the researchers' reflection over the research process is part of the knowledge. The people's words and actions of the subjects are examined by description, and the outcome of the research is text. Typically there are few subjects and usually much time is spent on each subject. Qualitative methods usually cannot offer the same tightness of control and rigour as quantitative methods.

Quantitative research is interested in observation of phenomena and translating the observations to statistics. The purpose of investigation is explaining and predicting observable events, searching for causal relationships and laws of nature, thus investigations require tight control of the conditions of the experiments.[40:20]. Typically there are many subjects, and little time is spent on each subject. Quantitative research is founded on the positivist tradition where predictions are made, and then tested. Popper, a philosopher well known for his theories on what constitutes scientific research, demands that predictions must undertake an empiric test to reach knowledge, and that any scientific prediction must in principle be empirically falsifiable.

There are some key concepts of research:

Validity is a consideration of how relevant the measurements are, referring to whether a method is measuring what it is supposed to be, given the purpose of the investigation.

Reliability is a consideration of the consistency of the measurement process. A reliable research method is one that consistently produces the same results on separate occasions under the same circumstances.

Generalizability is a consideration to which extent the findings are relevant and applicable outside the specifics of the studied situation.

Triangulation is often an attempt to harvest more extensive data, thus increase the validity of the research. Supportive results make the findings stand stronger, or can light more nuances on the same topic [40:174]. Data triangulation is applying more than one method of data collection; observer triangulation uses more than one observer in the study; and so forth. For example, conducting a qualitative observation along with a qualitative interview of the same phenomenon is data triangulation, and can first shed light on what the observed *are* doing, secondly their thoughts about what they did.

3.2 Approach to Selecting Research Design

This research aims to investigate the phenomenon of mobile handheld devices in hospitals, more specifically to learn about the usability and usefulness of mobile devices in this setting by collecting empirical feedback from real users. The St. Olav's Hospital does not use any mobile handheld devices today[2]. The research design approach will then be to create the phenomenon in order to learn about a technological possibility. Moran describes this as:

> "There is what the British call 'bespoke design' and the Americans call a 'custom system,' which is aimed at a particular customer or user community for use in a particular way in a particular situation. [...] Then there's design of a generic product, in which there is no particular targeted user. There is also 'technology exploration,' in which we try to understand the properties of the technology and we invent imaginary scenarios to apply it to" [15:349].

Robson says that the exploratory purpose of research "seeks to find out what is happening, seek new insights, ask questions, assess phenomena in a new light and generate ideas and hypotheses for future research [40:59-61] ". Svanæs adds, "a qualitative study should start out with an openness towards the phenomenon, and allow for a theory to emerge from the data [41:116] ". Thus this research approach can be described as a qualitative case study where mobile technology is explored with real users in a specific setting. The overall strategy will be to start wide to allow knowledge to emerge from empirical evidence.

Creating the phenomenon of study— handheld mobile devices in hospitals—requires one to design system proposals and have them evaluated by the users. User-centered design (UCD) is the natural choice of systems development model to support the case study, as it involves an iterative cycle of user evaluations that guides and refines prototype designs. The sections below introduces user-centered design (UCD), the ISO standard 13407, user participation, and prototyping. It will be argued how the use of UCD helps validate the qualitative research approach of this case study, and what adaptations should be considered when the technology up for evaluation is mobile.

3.2.1 User-Centered Design (UCD)

User-centered design is a key element of HCI, and has as an objective to produce systems with a high degree of usability. Essential in this model is that design suggestions are made early, the designs are evaluated by users, the feedback from users is used to guide design alterations, and this process is iterated until design goals are met. Rubin says "UCD is an evolutionary process whereby the final

[2] Some reports have been published lately of health care workers using handheld mobile technology, but not at St. Olav's Hospital, and there were no reports available at the time of the project. The focus here is to learn about usability by following users without prejudice or assumptions. Thus, recent contributions are largely not included in this thesis.

product is ‘shaped’ over time [42:17]. ” He adds that designers need to take the attitude that optimum designs are acquired through a process of trial and error, discovery and refinement.

Data collection methods used in UCD evaluate whether design proposals fit the needs of the users, along with identifying problems of the design. The evaluation methodology itself can be standard scientific methodology applied on a different context and purpose. The methods collect empirical evidence of the system by using prototypes to elicit information and facilitate communication. UCD is founded on the international standard ISO 13407.

3.2.2 ISO 13407: Human-centered design processes for interactive systems

The ISO 13407 standard proposes four design activities that should take place in the process of developing a system. Key in this is that the human-centred design process should start early, and be repeated iteratively until the system meets the requirements [43].

The model in figure 3.1 shows the interdependence between these design activities, and visualizes how each step is visited each time the cycle is iterated. Also notable here is that both design methods and research methods play their part in the model. Design methods are the principles behind creating the prototype that will elicit feedback from the users, while research and evaluation methods are decisions on how to collect feedback on the prototype from the users. The four design activities are:

Understand and specify the context of use: acknowledges that the characteristics of the users, the tasks and the organizational and physical environment defines the context where the system will be used. Different types of users can also be required to be identified, for example where users have different levels of experience or perform different roles. The physical work environment includes the hardware, software and materials used. The result of this design activity should be a description that identifies which of these aspects have an important impact on the system design. Observations and field studies are natural research methods to gain this understanding of context.

Specify the user and organizational requirements: considers the aspects of cooperation and communication between users and other relevant parties, the user’s jobs, work design and organization, and the human-computer interface and workstation design. Other aspects that might be important are, for example, legislative requirements, task performance, performance of system against financial objectives, and management of change. Observations and field studies are still relevant here, along with more in-depth field studies including interviews.

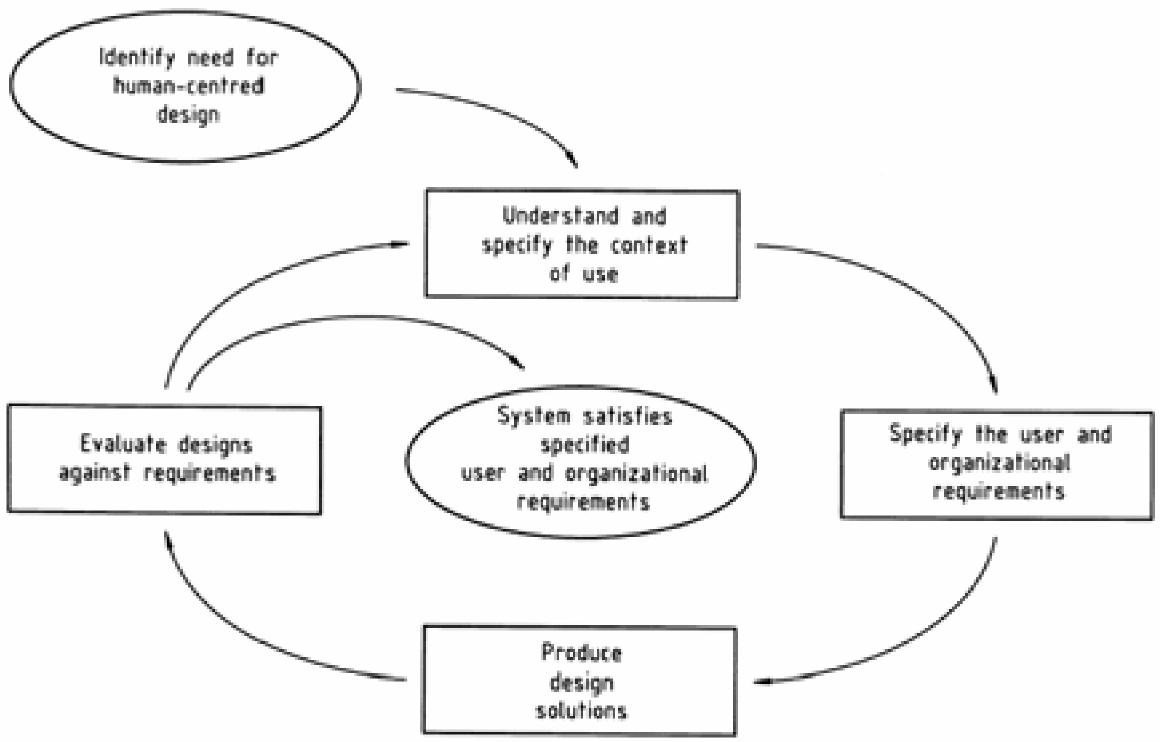

Fig. 3.1: The interdependence of human-centered design activities [43:5].

Produce design solutions: states that design solutions should be made early, and with growing detail. The potential design solutions should be made by using established technology, the experience and knowledge that the users contribute, and the results of the use-context analysis. The growing detail of this activity involves making the design solutions more concrete with simulations, models, mock-ups, etc., and present those to users and allow users to perform tasks (or at least simulated tasks). The design is altered in response to the user feedback, and the process is iterated until design goals are met. This activity uses design methods such as prototyping rather than research methods.

Evaluate designs against requirements: is essential in human-centered design and should take place at all stages. Evaluations are used to provide feedback which guides redesign. It can also be used to assess whether user and organizational objectives have been achieved, and to monitor long-term use of the product or system. The first is most relevant in the early stages of development, while the latter is more relevant in later stages, when a more complete prototype is available. Changes are relatively inexpensive early in the design process—the longer the process has progressed the more fully the system is defined. There are several options to conduct design evaluations with users, such as paper mock-up tests and usability tests. Design proposals can also be evaluated by others, such as usability experts writing design reviews or developers conducting heuristic walk-throughs.

3.2.3 User Participation and Expert Users

The motivation behind having users participate in systems development is dual. First there is the political or ideological perspective, that participation fronts democracy in the workplace [44]. The second perspective is economy and relates to receiving value for investments—user participation is a tool to map all user needs in the requirements specification. Experience shows this gives a better system, and by that a better investment. The method of involving users in systems development is commonly called *participatory design* (also known as *the Scandinavian approach* [15:376]).

Rubin [42:20] describes participatory design as more of an embodiment of UCD than a technique. He specifies that with participatory design, one or more representative users are brought on to the design team. This allows end-users to influence design while regarding the users' knowledge, skill set, and sometimes emotional reactions to the design.

Grønbæk et al. [45] insists that without user participation it is very difficult to make a good requirements specification. He says that traditional systems development focuses on the product; there is an assumption that future user's needs in the new system can be understood and mapped accurately, and then production can start. Grønbæk et al. argues that it is impossible to have all needs known to the users themselves, customers, and designers at project start. He argues the development's focus should be on the *process* rather than the product. Each step should focus on identifying user needs in cooperation with the users, and the requirements specification should be dynamic and adjustable; while the design proposals should focus on finding ways to meet requirements that surface.
Only then will the specification mirror all the requirements of the users with certainty, and the total outcome is the best possible quality of a system.

An *expert user* in this circumstance is when an end-user is a special source of information for the design team, either because the expert user is deeply involved, or because the expert user has knowledge of the field that benefits the design.

3.2.4 Prototyping Concepts

Prototypes are visualizations of ideas towards users, and work as tools that allow designers to communicate more efficiently by offering something concrete to relate to and play with. The prototypes are often used to collect user feedback in evaluations, which drives the design process. Prototyping also allows designers to explore several design concepts before they settle on one.

A *horizontal prototype* shows the surface layer of the user interface, but has little or no functionality behind the buttons. A *vertical prototype* has all of the high level and low level functionality for a chosen part of the system. A *full prototype* has full functionality both horizontally and vertically, although with lower performance than a complete system [15:540].

Rapid prototyping [15:540] is used to collect information on requirements and on the suitability of possible designs. The prototype is not developed into a final product, but it is made quick and dirty (and cheap) with the intention of throwing it away. Rapid prototyping recognizes that requirements are likely to be inaccurate when they are specified.

3.2.5 Validity and Reliability of Research Approach when Technology is Mobile

Lindroth and Nilsson [46] did a study where they evaluated usability testing methods and theories from the mobile perspective. They found that testing mobile devices without taking the context of use into consideration might make the test results entirely irrelevant. Lindroth and Nilsson questions the validity of applying standard usability methods to mobile devices, as the methods might not measure how usable the product really is. Lindroth et al.'s results shows that users use the device in different ways depending on the situation. Even if the device works fine in the office setting without stress or other contextual challenges, this does not say much about situations where the user is mobile. Lindroth and Nilsson cites Järvinen, 1999:

> "The larger the number of factors that is under control in an experiment, the more scientific rigour is emphasized. The more natural-like the experimental setting is, the more relevant and applicable the results will be."

As a consequence of this, Lindroth and Nilsson proposes methods such as role-play, diaries and direct observation to be more appropriate for testing mobile devices than the existing methodologies for testing stationary computers, because these methods include awareness of the context of use. Lindroth acknowledges that with the proposed solutions for testing in context there is a loss of rigour over the test situation. There is an increase in the number of factors that can possibly affect the test and might affect the result in unpredictable ways, but Lindroth and Nilsson does not see this as a major drawback. Lindroth and Nilsson emphasizes that they see control and rigour as a very important factor, but not at the price you have to pay when you lose relevance. Lindroth and Nilsson cites Fagrell (2000) on how to achieve validity of experiments (italics added):

> "I believe that it is more important to establish techniques to capture and evaluate IT use concepts. This is in contrast to the typical CHI community usability study that quantitatively compares the speed of use between two systems. The types of usability study (in a wider sense) that I like is *validation in practice*."

Rubin says that "in an exploratory research design based on the UCD process, the experiment does not require as much control and validity as classical experimental methodology. Validity in learning about user interfaces is satisfied at an early stage through involving real users in an iterative cycle harvesting feedback through testing" [42:29].

This case study will explore technology in a specific setting by means of the UCD development process. As the technology is mobile, relevance should be prioritized over rigour by choosing evaluation methods that can include role-play and direct observation that take context into consideration. That will offer higher generalizability of the results. According to Rubin, collecting feedback from real users with the UCD process will ensure sufficient validity of our case study. The users will validate our prototyped use concepts in practice. As a total, the UCD systems development process offer sufficient validity as a research approach to learn about the usability and usefulness of handheld mobile devices in hospitals.

Traditional means to increase validity and reliability of qualitative research relates to demonstrating within the results that the research has been conducted thoroughly, carefully and honestly [40:171,176]. Such a demonstration can be attained by showing trails of empiric evidence in descriptions and interpretations, thus increasing their scientific validity. Audio and videotapes can be used whenever possible, and notes of observations can be triangulated with interviews to establish their validity.

Lastly, a common threat to validity is bias of researchers and participants, and should be taken into consideration [40:171-172]. Researchers can bring assumptions and misconceptions to the table, thus inadvertently include these in the results, along with reporting results founded on opinions rather than empiric evidence. Participants can have alternative agendas working that makes them withhold information or obstruct evaluations, along with the "good bunny" bias, where participants try to read what answers are desired (also known as *good bunny* or *social desirability response bias*).

3.3 Available Relevant Methods to investigate upon Usability

User-centered design makes use of various methods for data collection and evaluation. The methods included here are both traditional research methods of the social sciences, and methods more typical for evaluating computer systems on users. Lindroth and Nilsson compiled a complete list of methods used to investigate upon usability, see appendix A. The following sections briefly introduces some methods and techniques for data collection that are relevant for the proposed case study, where the aim is to explore usability issues of mobile technology in a specific setting.

It is appropriate to start by defining what a *case study* is. A case study is a strategy for conducting research which involves empirical investigations of a specific phenomenon within its context [40: 178-180, 545]. Case studies typically use multiple methods of data collection. The case in focus can be a person, a group of persons, an institution, a situation, an innovation, a decision, a service, etc. Robson says that the central defining characteristic is *concentration on a specific case studied in its own right* [40:179].

3.3.1 Interviews

Interviews are good for exploring issues. The advantages are that the interviewer can guide the participant, if necessary, to explore each issue thoroughly. Interviews can have a conversational setting where the participant can volunteer relevant issues, and the interviewer can follow up on interesting responses at will. Interviews encourage contact between developers and users in general.
Disadvantages to interviews is that they are time-consuming, and an artificial environment may intimidate the participant, and thereby negatively influence the responses [16:214]. Biases can be difficult to rule out, such as helpful participants wanting to give "right" answers (*good bunny*), and alternative participant agendas.

Interviews are commonly divided into three categories [40:270]:

- *Fully structured interview*: Pre-determined questions with fixed wording, usually in a pre-set order.
- *Semi-structured interview*: Pre-determined questions, but the order can be modified based upon the interviewer's perception of what seems most appropriate. Question wording can be changed and explanations given; particular questions can be omitted, or additional ones included.
- *Unstructured interview*: The interviewer has a general area of interest and concern, but lets the conversation develop within this area. It can be completely informal.

3.3.2 Field Studies

Preece et al. says that field studies seek to understand the context of user activity, by observing activity in its natural context [16:214]. Preece et al. further says that field studies are most often used early in design to check that users' needs are being met, or to assess problems or design opportunities in the exploratory phase. The location is in the users natural environment, where the observer studies natural behaviour. The data that comes out of a field study are qualitative descriptions often accompanied with sketches, quotes, anecdotes, and other artifacts [16:344].
The advantages of conducting field studies are that observing actual work gives insights that other techniques cannot offer. The disadvantage is that it is time consuming, and potentially accumulates huge amounts of data [16:214]. Possible threats to validity are participant (social desirability response bias) and researcher bias (observer may affect situation knowingly or otherwise).

3.3.3 Focus Groups

Rubin [42:20] says that focus groups are typically used at the very early stages of projects to evaluate preliminary concepts with representative users. He further says that design concepts can be presented in the most preliminary form, such as paper-and-pencil drawings, storyboards, and/ or more elaborate screen-based prototypes or plastic models. Focus groups collect users' opinions and feelings through group discussion, and do not include testing (i.e. co-discovery test). A focus group will highlight areas of concensus and conflict, identify whether concepts are acceptable or not, and suggest how to make them more acceptable [42:20, 16:214]. Lindroth and Nilsson says focus groups are often held to extract user requirements prior to initial design [46].

Robson adds that the method is relatively inexpensive and flexible, and can be set up quickly. Also, group dynamics help focus on the most important topics and participants tend to provide checks and balances for each other, where extreme views are eliminated [40:284]. Disadvantages to focus groups is the possibility of dominant characters in the group [16:214].

3.3.4 Expert Evaluations

Expert evaluations (also known as predictive evaluations) involves making a review of a system or product, which is usually done by a usability or human factors specialist who has little or no involvement in the project [42:22]. The data outcome is a list of problems and quantitative figures, such as how long it takes to perform a task using two different designs. The expert often suggest a solution to the problems. Expert reviews are founded on practical heuristics and practitioner expertise [16:344].

3.3.5 Design Walk-Throughs

Design walk-throughs are techniques for predicting user problems without running user tests. A designer may guide a colleague through actual user tasks, attempting to explore how a user might handle the product or interface by imagining the user's route through an early prototype, while other team members record problems and concerns [42:21,16:420].

Some advantages are that it is a cheap and fast evaluation compared to full-scale usability test, and flaws in design can be eliminated before more extensive tests. Possible biases to this technique can be hidden agendas by designer or evaluators, and others.

3.3.6 Paper-and-Pencil Evaluations

A paper-and-pencil evaluation is a technique typically used very early, where users are shown a concept or aspect of a product on paper and asked questions about it, or asked for other responses. It is a quick and inexpensive way to collect information, usually carried out before any programming has started [42:21]. An example is a *paper mock-up test*, where screen design ideas are put on paper and then played through (wizard-of-oz) before they become anything more than sketches. Such a paper mock-up test is sometimes called a *paper prototype usability test*.

3.3.7 Usability Testing

Usability testing is collecting empirical data while observing representative users attempt to use a product for pre-defined tasks [42:22, 22:188]. Rubin divides testing into two approaches: the first one involving formal tests conducted as true experiments (quantitative), the second approach is a less formal one, which employs an iterative cycle of tests intended to expose usability deficiencies and gradually shape or mold a product (qualitative) [42:22].

The traditional qualitative usability test is conducted in a lab where users are observed through video and interaction logs, one user at a time. These logs are later analyzed to find problems in design. Sometimes the developers study what routes were chosen through the software. The usability test is generally recommended to test 5 $^{+}$/-2 users to expose the majority of problems. Throughout the test the users are asked to say out loud everything they are thinking and attempting to do. This *Think Aloud* technique enables developers to understand how the users view the system, and how they interpret each item they see.

Threats to validity and reliability may lie in the selection of users (not representative of target population), the selection of tasks, and users being put off by the artificial environment and behave differently than normal, among others. User opinions are usually collected by interview or questionnaire after the test, exploring issues of user satisfaction or what the user regards as problems.

3.3.8 Quick and Dirty

"Quick and dirty" is a highly practical technique to get feedback on designs and ideas quickly and when desired through informal evaluations. Several of the data collecting techniques above can be carried out "quick and dirty," meaning the focus is on collecting qualitative feedback with little time and effort, not on carefully documenting findings. The feedback can come from users (observations, asking questions to individuals, focus group discussions), or consultants reviewing software quickly to suggest improvements (quick and dirty expert review). The data that comes out are usually qualitative, informal descriptions [16:344].

3.4 Choice of Research Design

Chapter 2 concluded there is not much empirical evidence available with real users that say something about the usability of mobile healthcare systems. This section will present the choice of research strategy for how to collect empirical data of the usability of handheld mobile devices in the hospital setting. The research design is tailored to the context of study, the research questions, and the available resources. End-users will be participants of the process as much as resources permits.

The context of focus is the Rheumatology Division of the St. Olav's Hospital, and its staff of experienced healthcare professionals. However, the St. Olav's Hospital does not use any mobile handheld devices in their wards, like most hospitals in this country. The research approach of this case study is to create the phenomenon in order to learn about a technological possibility. Providing end-users with hands-on experiences of mobile handheld technology in their work situation will enable them to offer valid and hopefully valuable feedback.

The first research question, "*What characterizes work that is useful to support with a mobile handheld device*?" requires gaining knowledge of what tasks are useful to offer on a handheld mobile device. This will make it possible to later identify common characteristics of the approved tasks.
The second question, "*How well does the technology support the user's work*?" requires to first choose a specific handheld mobile device to represent the type of technology, and then investigate upon how well-suited the chosen technology is for the hospital context. The focus of this investigation will be both on the physical and the graphical interfaces users meet. Main test objectives for investigating the suitability of the mobile device will be specified in chapter six. After this investigation it will be possible to reflect on what the ideal mobile device in a hospital would be, as the third question addresses.

The strategy to shed light on the research questions will be a variant of the UCD model (see figure 3.2). First, seek to understand and specify the use context by looking at the users' work situation and map what users do in their everyday job, which will establish a foundation for targeting work processes for prototyping. This calls for a field study. The next steps are iterations of design, evaluation and analysis.

The first prototype will be built based on the results of the field study, and then evaluated. There are several evaluation methods that could work here. The method will be a focus group, as availability of participants is limited. An evaluation such as a paper mock-up test would require recruiting at least 5 participants, while a focus group can do with less. The focus group will be a session with both nurses and doctors, where they get their first impression of the handheld mobile device and a GUI prototype built for their work situation. The prototype will be a quick visualization on paper of initial ideas, both regarding GUI designs and the selection of tasks. Together the group can digest and discuss the proposals, lead each other on to visit different topics, and make suggestions where they draw on their professional experience.

The focus group results will be analyzed to establish recommendations, which will guide the design of a new and improved prototype. This second prototype will be evaluated with a usability test, which will be followed by an interview. The usability test entails building a more complex prototype, as it will be a test in a lab approaching reality through role-play. There is a lack of literature for testing mobile devices. Lindroth and Nilsson [46] proposes use of role-play, as it includes awareness of the use context; relevance is gained by forsaking some control and rigour.

The interview will be semi-structured with prepared questions on what to explore, while the nature of the interview will seem more like a conversation to the participant, where interesting statements can be followed up. This informal style allows participants to express information the interviewers do not think to ask about. The results of this evaluation will be analyzed to create recommendations for further enhancements of design.

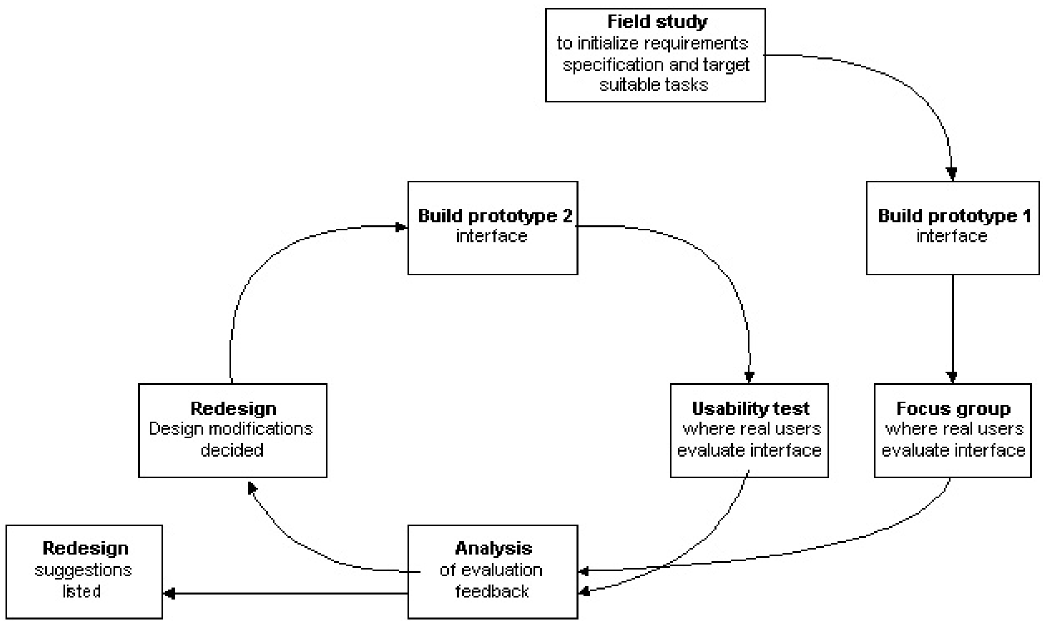

Fig. 3.2: The final choice of research design for the case study.

Using two different data collection techniques in the same evaluation session is method triangulation, and will increase the scientific validity of the results. The test will allow observation of the participants while attempting to complete pre-defined tasks, and the interview will allow exploration of the participants opinions of the prototype and the use situation. Concepts and designs which created problems may be discussed, and the participants can offer what they see as problems and make suggestions.

The research design involves one specific hospital division, which will limit the immediate validity of the case study to entail that ward specifically. Generalizations should be made only when apparent similarities are present.

CHAPTER 4

Field Study

This field study was done at the Rheumatology ward at St.Olav's Hospital, Trondheim, 13-15 June 2001. The purpose was to form an impression of the flows of information and work, and from that draw what functionality would be desirable in the system, as an initial requirements specification and a starting point for developing a prototype. Work processes found interesting for handheld mobile technology is presented as UML Use Cases in the conclusion of this chapter.

4.1 Research Method

The field study was conducted as an initial mapping of the work that is done—an attempt to gain a top-layer understanding of processes and information flow. It is important to acknowledge that the information flow at a hospital department is very complex and can be an impenetrable matter for someone who does not work in healthcare. As outsiders the aim was to gain surface knowledge of the ward in this study. Field studies are generally valuable early in projects when looking for informal information to form a starting point.

The field study was a non-intrusive observation. There was opportunity to follow both doctors and nurses around in their work, but there were instructions not to ask too many questions as repeated interruptions might hinder them in their duties. Access to meetings (pre-visitation), rounds (visitation) and one-on-one sessions with patients (arrival exam) was also given.

The results were logged as paper notes, and written out a few hours later. The field study was conducted over three days, where each day started with a morning meeting discussing individual patients (pre-visitation). Some information was gathered through direct observations, some from explanations and statements of the staff, both doctors and nurses.

The qualitative observational nature of the study does not offer enough control to bring the classic high validity or reliability present in various quantitative methods. The strengths of this empirical study lies within close contact and study of real staff. The users were selected randomly within the Division of Rheumatology, but they all worked with related or same tasks; offering different views of the same issues. This gives sufficient validity, and as the results sought were general and top-layer, one can expect to produce the same results on separate occasions under the same circumstances. However, it is important to note that the validity and reliability of this study is true for a specific ward. Any generalizations must consider this limitation in any comparisons or conclusions. The short time-period and the limited access to people during the study set a further limitation. In the analysis the findings are considered to be suggestive rather than factual. However, the study provided enough informal information to enable making decisions.

4.2 Results

The Division of Rheumatology of The Department of Ortopaedy and Rheumatology is located on the sixth floor in one of the high-rises of the St. Olav's Hospital at Øya in Trondheim. The division is made up by a ward (sengepost) and a clinic (poliklinikk), and has a reception and administrative staff servicing both. The clinic is for outside appointments with rheumatology specialists, while the ward is for hospitalizing patients while they undergo treatment. The ward has two single-rooms, six double-rooms and one quadruple room, allowing a total capacity of 18 admitted patients. The division has 7 doctor and 22.5 nurse positions, along with 4.5 administrative positions, mainly health secretaries. The hospital is a university hospital, which means there is also academic staff such as professors and nursing instructors. This study focuses on the rheumatology *ward* only.

The primary goal of the staff is to give the patients sufficient treatment and care, which goes hand-in-hand with another and equally important job: documenting the patient care. Paper is important for this task—large amounts of paper—which together with administrative routines and electronic systems keep the information flowing in a controlled fashion. These results are an initial description of the information system at play, the basis for the medical patient record. The description is based on activities, so the functionality and characteristics of the patient record can be visualized through the activities that creates and makes use of it.

Most of the patients were diagnosed before coming to the Rheumatology Ward. They may have a new incident that requires an exploration (utredning), or the illness may have developed in a direction that necessitates hospitalization.

4.2.1 The Patient Record

The patient record is a formal legal document, thus rules are strict regarding documentation of all information and events concerning the patients' treatment and care. The doctors, as responsible parties for patients, ultimately are the ones responsible for documentation. A patient record stays in the hospital, and follows the patient throughout her life. Each record has 20-200 paper pages of forms: test requisitions, test results, nurse records, referrals, graph sheets, previous medical history, priorities on hospitalizations, status reports, and other data. Doctors at the Rheumatology Ward estimate that they spend a couple of hours every day updating records by handwriting, and admit this method causes now and then.

The g*raph book* (kurvebok) is selected from the patient record. This short version contains chosen parts of the main record that are relevant for the present hospitalization. The assigned doctor relates to the graph book rather than the patient record, as the graph book offers all the recent data and test results. The g*raph sheet* (kurveark) is a part of the graph book, and is a graphical presentation of essential information about the patient: numerical data describing current condition such as temperature, pulse and blood pressure; and a list of medications, dosages, frequency, etc. The graph book is prepared by secretaries or nurses. Sometimes two prints are made of new information, and both the record and the graph book receives one copy. The contents of the graph book is always put into the main record (except doubles) when the patient leaves. The graph book is also sometimes referred to as "the record" in this paper, where the difference is not significant.

4.2.2 The Nurse Record

Different divisions in hospitals often have slightly different methods of conducting business which is specific to them. The most common nurse work model in hospitals is to have each patient assigned a *responsible nurse*, while a *head nurse* is responsible for all the other nurses and patients in the ward. The head nurse usually reports on all the patients to the doctor during pre-visitation. However, at the Rheumatology Ward, the patients are distributed among nurses at the beginning of each shift with a greater responsibility to their patients than a responsible nurse, and is called a *primary nurse*. Each primary nurse reports directly to the doctor of her patient's during pre-visitation.

In the Rheumatology Ward, each nurse also documents in their own *nurse record*, which becomes part of the main patient record when the patient leaves. The nurse record is kept in a binder. There are *care plans* (which contains less sensitive information) which are available at the direct vicinity of the patients in a holder in the lobby of the ward. The care plan works as a planning tool. This system takes the rheumatology division further than the general right all Norwegian patients have to see their record. The system is called "Open Careplans." The patient does not only get to look at the documentation, but can also make notes himself, e.g. urination and sleep, and then sign. The *nurse report* is a legal document that the nurse writes either alone or in cooperation with the patient. This report also works as a memory helper to the nurses, and is entered into the main record when the patient leaves. Just as the patient record is sometimes referred to as "the record," the nurse record is sometimes referred to as "the patient binder."

The open careplans have its background from the time when the rheumatology division was the only hospital division in Norway affiliated with Plain Tree (the type of tree that Hippocrates, the founder of modern rational-empirical medicine, is said to have lectured his students under). The Plain Tree model is based on care of the whole patient, not just the sick organ. Even though the membership in Plain Tree now is terminated, the division has carried the ideas with them further. The gap between patient and healer is minimized, to avoid estranging the ones in need of care and treatment. One of the methods to reduce this gap is the open careplan. The system focuses on reciprocal trust and respect between patient and healthcare personell, and the patient's right to be part of decision making regarding the treatment of his own illness. Plain Tree has, on the other hand, been criticized for not giving enough regard to patient privacy.

4.2.3 Patient-Focused Care

The Rheumatology Division is an exemplary department under RiT 2000, where patient-focused care is seen as very important. The patients normally stay for an extended period, so the ward is made to appear like a home by choices in color and furniture. If a patient does not like the picture on her wall, she can have it changed. They have a modern and friendly kitchen where patients can cook if they desire.

Fig. 3.1: Patient kitchen.

Fig. 3.2: Living room.

Patients who feel up for it eat their meals as a group at a dining room table. The living room has bookshelves full of relevant medical literature and a computer with a locally stored webpage. The purpose is to give the patients access to information about their own illness, such as how treatments are carried out, and potential side effects of different medications. Regardless of how busy the staff may be, priority is given to creating an environment of peace and quiet, which contributes to the overall enjoyment of the patients. That includes staff keeping strictly to a stroll pace in the hallways, as fast walk signalizes stress toward the patients.

4.2.4 Routines for Patient Admission

The admission process starts with a request or application for admittance from an outside doctor, depending on the acuteness of the illness. The request or application must be signed by a doctor. When the application arrives at the rheumatology division, it is assessed by a person of proper authority and competence, usually a chief doctor. The chief doctor decides whether the application is relevant, and will grade it using a priority scale from 1-4, where each level has several criteria. (Sometimes such requests are sent to the wrong division, then it is rejected and forwarded to the correct address.) After the priority degree has been decided, the application is entered electronically into PAS (*Pa*tient electronic *S*ystem) which holds the waiting list. Data entered are the identity number of the patient, the name of the doctor who made the request, the doctor who decided priority grade, the priority grade, and date of application assessment.

The hospital stay is planned when a patient has been chosen for admittance. If the patient is coming for surgery, time is scheduled with the operating room (OR). If the patient is not coming for surgery, vacation cycles and shift schedules are considered before the arrival date is set. When this date is close, the patient's record is ordered from the record archives at St.Olav's Hospital. The record is prepared by the health secretaries by assembling a Graph book, including sheets of stickers (with patient information: identity number, name, address, department, etc., used instead of writing headers on forms to save time) and some empty forms, along with the original request letter that has been stored at the department. All new patients have an arrival exam the following morning in the Artoteque.

4.2.5 Arrival Exam at the Artoteque

During this first consultation, the doctor fills a “sandwich list” of information about the patient. This includes personal information, present medications and dosages, and numeric data, like pulse and blood pressure. The doctor listens to the heart with a stethoscope, and performs a general assessment of health. After this first consultation, the doctor will produce an *arrival report* (innkomstjournal) in the form of a dictation. The patient record with dictation tape is put in the shelf marked “new records” in the health secretary’s office. The health secretary will later retrieve the patient’s data in the program DocuLive, enter the dictation by typing, and make a print for the paper patient record. Another print is put into the graph book. The secretaries also produce a brief statement of why the patient is in the hospital. The doctor notes data about the patient on the *graph sheet*, and fills formal requisitions (for blood tests and x-rays) as she sees necessary.

Observation of Arrival Exam:
A middle-aged woman has been admitted for surgery due to arthritis in her hand. She introduces herself to the doctor with a handshake, and sits on the chair next to the desk. Her patient record has been retrieved from the archives, and the doctor flips through these to form an impression of the patient’s medical history. The doctor asks questions to assess the general health condition: How does the patient feel?, does she have pain?, how her joints functions?, what medication she uses and any side-effects these might have? The most important information is noted temporarily on a blank sheet of paper. On the graph sheet the doctor notes blood pressure, medication she uses, and pulse. Then the doctor makes and gives the patient a test requisition so she can walk over herself to the department of clinical chemistry to have a blood sample taken later that day. As soon as the patient has left, the doctor uses the temporary note to make a dictation. The cassette tape is given to the health secretaries, who enter the information into the electronic patient record. The doctor makes a short version record for the surgeons, which is done before all surgeries. The surgeons also get a paper copy of the dictated arrival report. The treatment plan (utredningsark) is completed twice by hand, one version for the graph book and one for the nurse record. The doctor flips through the graph book during this exam.

The doctor observed in the artoteque stated that a normal workday usually includes 1-2 hours of paperwork. The doctor thinks that important papers like the Graph sheet should still exist in paper form, because that is safer. The Graph sheet is often moved around, so having a backup in a computer is wise.

4.2.6 Pre-visitation

The workday starts at 07.30 with the dayshift. The nightshift gives a report to brief the dayshift, and the day nurses are also handed over the report from the afternoon shift the previous day. These reports are first used during the pre-visitation meeting to make a quick medical assessment of the patients, and later put into the appropriate records by the health secretaries. While the previous shift of nurses brief the new shift, doctors begin their day by having a meeting with the doctor who has been on duty (ansvarlig lege) as their preparation before pre-visitation.

Pre-visitation is a meeting where nurses, doctors, and other health care personell discuss the work of the day. The agenda is mostly concerned with discussions of cases, and making decisions on the further treatment of each patient. The doctor on duty manages and leads the meeting, and is present during the extent of it. Primary nurses, however, come and go to be present when their patients are discussed. Sometimes physical therapists/ occupational therapists and other specialists are also present. One to three nurses are in the room at all times, one discussing her patients and the others waiting their turn. After a nurse is finished discussing her patients she leaves, and a new nurse will come in and wait to report. The group also discusses incoming patients of the day, who already have a nurse assigned. Everybody has a printed list of the wards' patients in front of them, which they use to keep the overview of admitted patients, agenda for discussions, and jot notes of things to do.

Fig. 4.3: Pre-visitation meeting.

The nurses bring the patient binders (the nurse record) for each of their patients with all their recent and relevant information. On the table are piles of papers: patient records, nurse binders, to-do lists and random notes handwritten by doctors and nurses. They rumble through piles, look for various papers, discuss and note on several ends of the table. The situation looks complex and chaotic from the outside, and it is the experience and routines of the employees that make it work. However, some of the papers that are supposed to be in the nurse binder or the record are often missing. The group then has to stop and look for the missing part, causing delays. A doctor comments half-serious that they have talked about putting a “queue-free tag” [48] on the record so they can track it, and find it easily at all times.

The group discusses test results, adjust and change medications, estimate the various conditions of the patients, and evaluate cause and effect. They write requisitions for tests and x-rays to other departments.

They check if the patient has received the information pamphlet before starting new medication, if requested tests have been taken, and whether the results have come back or need to be reported missing. Going over the previous days' test results sometimes elicit diagnosis and needs for treatment, and sometimes the need for further tests to get more information about the patient. They must wait for results before deciding if they need other tests, so missing results slow down the whole treatment process. There often is a delay due to late or missing test results, and misplaced records. They also discuss who is scheduled for surgery, and all the information about the day ahead is comprised in a *treatment plan* of the ward.

The individual nurse uses several means when communicating information about the patients to the doctor. The nurse record is eagerly flipped through, but the information is also brought as notes on temporary sheets of paper and yellow post-its. The chief doctor explains to us that information from the nurses is vital to the doctor who is doing the treatment. Often a patient is most open to the person they see the most, and this person is the primary nurse. The patient sees and talks to the nurse several times daily, and they often form a close relationship. The doctor uses information from the nurses and from the record when creating her own written task list. The doctor uses the task list later as a starting point for morning visitation. Such lists are not part of the patient record, but are entered into a computer program, which sums up the information on paper from doctors and nurses.

4.2.7 Morning Visitation

The doctors bring their task list on morning visitations along with the graph book. During the visitations the doctors talk to the patient, and note relevant important medical information in the graph book. The doctor also make assessments regarding requisitioning tests or other forms of treatment while talking to the patient. New information from the patient can shed new light on some test results they where discussing at pre-visitation. The requisition is not filled on the spot—the doctor makes a temporary note which he will use later when filling the formal requisitions. Only requisitions signed by doctors are legally valid, and only these are put into the patient record by the health secretaries. The nurse that assists the doctor on the round brings a *visitation book* where he makes temporary in-house notes of what the doctor orders. These notes do not make it to the patient record either; they work as a task list of work that must be done and referrals that need to be followed up. Equally important is to make notes of what *not* to do. For example, if a patient does not want to have bandages changed on a wound, that is also noted.

Observation of morning visitation:

Two doctors and a primary nurse come into a patient room of the department to talk to a female patient suffering from arthritis. The doctors decided during pre-visitation that they need to consult the patient to plan further treatment, and have noted this in their task list. One of the doctors start by asking if the *patient uses or have used a specific type of medication, and if so, how long the patient used it. The patient has not used the medication, and this is noted in the graph book by the doctor holding it. Then the patient is asked if she uses any estrogen supplement. The patient explains that she used this while she was menstruating, but had a reaction to it. The doctor then recommends the medication they first discussed, because it will protect her skeleton. The patient agrees to start medication with half a tablet daily for the next 14 days. The doctor explains to the patient that she will start the medication the next morning, and information about type and amount of medication is noted in the graph book and the visitation book. The patient is handed an information pamphlet of that medication. The doctor then asks if she has any questions. The patient asks if the medication has any side effects, and is informed of possible side effects. The patient also says that her ankles hurt, and the doctor performs a physical exam. One of the doctors ask the nurse to note the problem in the visitation book.*

In the same room is another female patient which the doctors want to consult. Before they entered the room, they looked at the task list and made themselves familiar with the problems the patient experiences. One of the doctors flips through the graph book of the patient and informs that the blood test has good results. Also the liver and kidney values are good, while the results for metabolism have not yet come back. The doctor's opinion, assessing the patients problems, is that the patient should have a breast- and gynecology exam. The patient is positive to this, but also wishes to have a cell specimen taken at the same time. The patient says she has an intestinal disease, and therefore it is unsure whether the discomfort is due to that illness. She asks to be referred to a gynecologist at the hospital. (The doctor is hesitant as the gyn. exam will then stretch further the hospitals tight budgets, while it is not really relevant to the problem she is there for. A gyn. exam at her primary doctor would be outside this hospital's expenses). The doctor and the patient discuss the options. The doctor says that the CT-scan the patient has gone through would have shown any irregularities, but finally agrees to refer her to a specialist (gyn.) at the hospital.

4.2.8 Requisitions and Test Results

Doctors give test requisitions to the nurses, who are responsible for bringing the papers to the proper department, for example the Department of Clinical Chemistry every afternoon. The staff at clinical chemistry then visit the rheumatology division to collect samples around 09.00 the following morning. The test result, the legally valid paper version that must be included in the main patient record, is physically collected at the Department of Clinical Chemistry around 17.00. Usually it is also available electronically around 12.00. The electronic results are entered by the staff at Clinical Chemistry. Just as the doctor must sign when he fills a requisition, he must also sign that he has seen the test results. This is done by signing on the paper containing the test results. St.Olav's Hospital will begin using electronic signatures, making paper-based requisitions disappear with time. Requisitions are completed in three separate samples:

- The front page is for lab/ x-ray unit as the actual order
- The back page is kept by the division to document that a test has been ordered and is kept until the result has come back
- The result page in the middle is completed by the test-taker, and comes back to division with the test result written on it.

Test results that presently exist in electronic format are assessments, numeral values (raw data) and images. A requisition can also be asking another specialist for input, an assessment of a problem related to their field. If a test result is raw data, the person doing the analysis always includes a comment or assessment on them. Common test results in electronic format are blood values and assessments.

Test result routines:
The doctors of the Rheumatology Division explained test result routines to us: The Rheumatology Surgeon and Orthopedist work in the OR every day, and use Main X-ray. Other doctors of the ward get their x-rays from Red Cross X-ray, where the x-ray doctors demonstrate (show and comment in a session) x-rays on Tuesdays and Thursdays. If a picture is taken Wednesday, the doctor will have the result demonstrated the following Tuesday. The doctors report that the pictures are often "messy": wrong pictures are sent back; pictures are misplaced; and organized searches seems to be happening often. Electronic x-ray will be standard equipment "soon." Until then, patients stay hospitalized for days waiting for test results. Sometimes it takes over two weeks to get test results, and sometimes they do not get them at all. The hospital's internal mail system is slow, and test results are sometimes lost.

4.2.9 Epicrises

The epicrisis (end report) is created when a patient is released from the hospital. The epicrisis sums up what treatment has been given and what treatment the patient needs in the future. Three copies are made. One goes to the patient's primary doctor (local), the second copy goes into the main patient record (kept in the hospital archive), and the third copy goes to the department the patient might be referred to for further treatment. If the patient is transferred to a different hospital, e.g. Radiumhospitalet, only the epicrisis is sent to Oslo. The patient record stays in Trondheim, and a new record is made for the patient at Radiumhospitalet.

4.2.10 Administrative Positions at the Department

The Division of Rheumatology has 4.5 administrative positions who are health secretaries. The nurses, however, do many administrative chores in addition. For instance, to check when a patient can be admitted at the division, put the patient on the waiting list and send a letter to the patient with this information. The nurses are also responsible for asking the health secretaries to order records from archives for incoming patients, and to make sure requisitions from the doctors are delivered to labs.

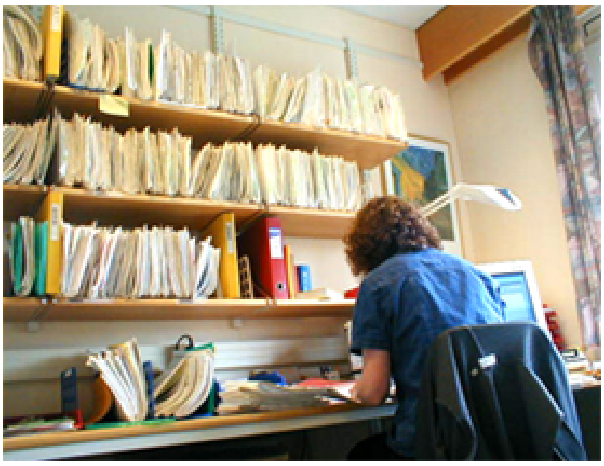

Fig. 3.4: Patient records waiting their turn to be updated..

The health secretaries spend a lot of their time transferring handwritten data and dictations to electronic form. The shelves for storing records with work waiting are big and full. The health secretaries are also responsible for "getting" the test results. Every day a list of arrived test results, written on paper, is checked against a list of expected test results. If any test results are missing, the health secretary first checks if the Department of Clinical Chemistry has entered the results on data. If that proves futile, a phone call is made to request the result. That may lead to test results being entered electronically over at the lab, and printed on the receiving end before it is given to the doctor. It is not uncommon to experience missing test results, and sometimes a nurse is sent over to fetch it as it is quicker.

One of the secretaries stated that she is often two-three weeks behind in transferring the contents of the dictation tapes over to data, print it and add it to the patient record. According to her it is a slow job, especially since she often finds herself using up to 70% of her work time tracking down and requesting missing test results.

4.2.11 Existing Computer Programs at the Department

The electronic patient record at St. Olav's Hospital is called DocuLive. It contains the last patient record note entered, and the last epicrises. With DocuLive, they do not need to retrieve the physical paper record from archives to get access to elementary information about a patient. It is possible to write an epicrisis of a patient using this program. DocuLive is text-based and stores data as free text, a "chunk" in the database, thus not available for search. The system exists at several hospitals, but so far information is not shared or exchanged electronically either between different programs at one hospital, or between hospitals. All information is entered by the health secretaries, who electronically sign upon entering data. DocuLive is fitted with access levels to respect patient privacy, making information available on a need-to-know basis. DocuLive is intended to go nationwide.

The nurses use PAS, a patient administrative system with a text-based interface. PAS handles visitation lists and waiting lists, appointments, and schedules for doctors, among other things. It was introduced in 1993, and the nurses complain about a "painful interface." PAS relies to a great extent on the user remembering arbitrary mappings of menus and choices—it is not intuitive.
KSWeb is a program that offers an overview of procedures to use in various treatment situations. These procedures are also available in binders in the nurse's workroom/ computer room.

PRS is the personnell- and resource system, where all work hours are entered. The department nurse must check here and approve what is entered every day for each of the nurses.

4.3 ANALYSIS

As mentioned initially, this field study services as a help to get an initial overview of work processes, and to allow for analysis and choice of where an introduction of handheld devices could be valuable and efficient. The analysis and conclusion can be viewed as a requirements specification for the first prototype. As discussed in chapter 3, the requirements specification will be increasingly refined throughout the design process.

4.3.1 Application Area

A handheld mobile solution will be useful mainly when there is a need to quickly find or add notes about a patient in the electronic form, where it is impractical or impossible to have a stationary PC available. This is most relevant when visiting patients in patient rooms, when doctors and nurses wander while working. The second parameter which makes a work process interesting is when double work is being done; where information is written twice or more and/or carried around in pockets on temporary sheets of paper and post-it notes awaiting later, proper documentation. This also relates to circumventing problems of lost information, and making information available for colleagues sooner rather than later.

4.3.2 Users

The structure of the division is built up around a role system, and specific roles must be filled at specific shifts. For example, *department nurse* or *assistant doctor 2* are roles that are filled by different people on different shifts. The workgroups at the ward may be divided into:

- Nurses
- Doctors
- Administrative staff

Nurses and doctors divide the work between them based on professional orientation. Nurses are oriented around needs and care of the patient, while doctors are oriented around biology and diagnostics.
The nurses contribute care for the patients, and supply patient information for the doctors through patient records. The nurses were several times referred to as the “glue” of the ward by doctors. They are the ones who pick up all types of slack and make the system work for everybody. The nurses have a wide spread in job experience, from recent graduates to seniors with 20+ years of varied experience. Before the visit there was an assumption that the nurses would, in general, be people who try to avoid using computers if they can. This proved to be wrong, as the hospital gives extensive training when new

systems are launched. The nurses used computers often, and generally had an open and interested attitude towards them.

The doctors do not harvest raw data like the nurses. Rather, they use data to try to form an understanding of the patient's case. The doctors also order requisitions, make referrals and check test results. The observed doctors did a lot of handwriting when maintaining records. The doctor (Dr. Faxvaag) admitted that the hospital is a place of hierarchy, and many doctors feel they have a choice whether to use new systems or not. If it pleases them, they can refuse and have someone else do it for them (dictation). Many of the senior doctors had taken the time to learn a system when they were younger (e.g. MS-DOS), and think that ought to suffice. Some are very reluctant to learn something new outside of medicine. Therefore, a new system ought to be useful and effective to the most computer-savvy doctor, as well as to the novice computer user.

The Administrative staff spend their work day in their office by their stationary computers. A handheld mobile computer is here assumed to be less useful for them, as they do not wander. They would rather be on the beneficiary end, as computers could reduce their workload by, for example, avoid missing test results.

4.3.3 Work Processes

The field study showed that most of the information in the patient record is handwritten twice or more. One doctor stated that 1-2 hours daily is used for handwriting record updates. In addition there is a huge problem with missing record papers inside the ward, and test results getting lost while travelling between wards. This creates delays and occupies resources on all ends. Health secretaries, nurses, doctors, and lab staff have a daily task of looking for missing papers, and patient stays are extended for days while waiting for missing results, which again affects hospital economy and waiting lists.

The documentation of patient records is complex for several reasons. Firstly, there are many contributors to the records. This complicates the tracing of information flow. Secondly, the record does not always mirror an accurate turn of events. Often information is entered differently than what the formal record itself depicts [17], i.e. the record does not reveal the time span between event and documentation, nor temporary documentation routines. Thirdly, there is the informal information exchange between staff that should be considered when tracing information flow [11]. Any analysis and proposed system should take into account the reality of information gathering and documentation, not the depicted turn of events of records.

The following section looks closer at how information is gathered, moved and stored within the ward by using data flow diagrams (DFDs). The conclusion will sum up this analysis by suggesting UML use cases for further focus.

The context diagram in figure 4.1 shows which outside entities interact with the Rheumatology ward. The information flow is built up around patients arriving, receiving treatment, and leaving.

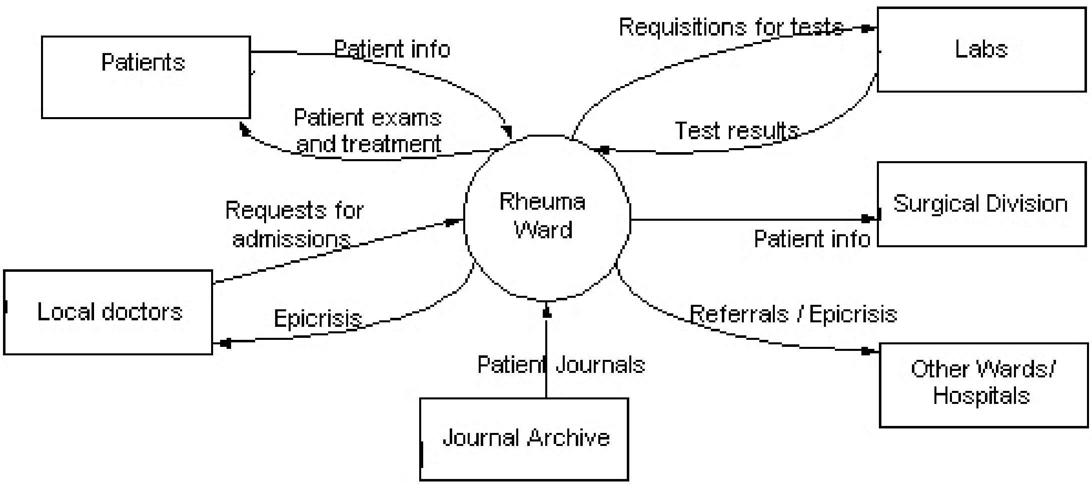

Fig. 4.1: Context Diagram.

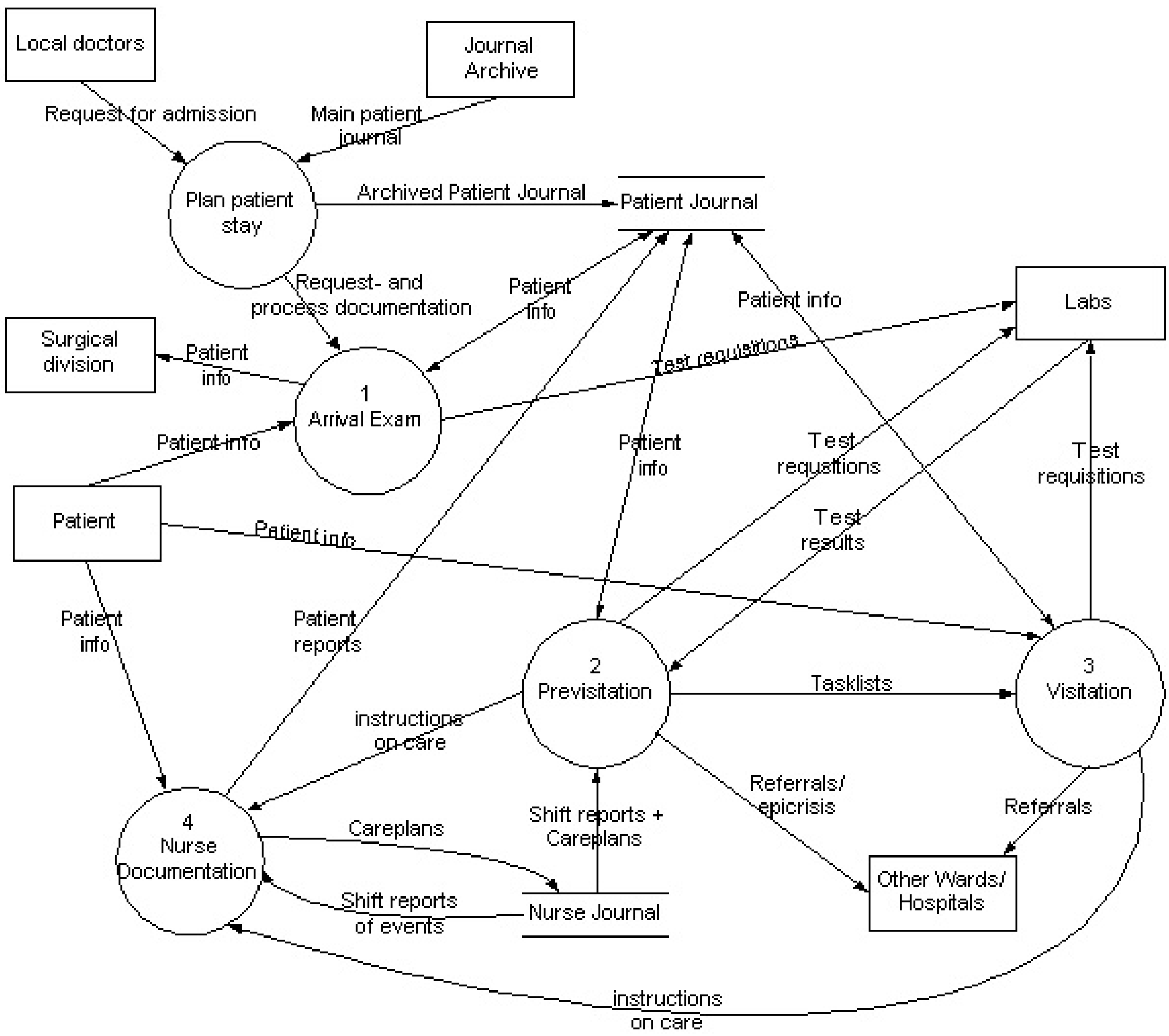

Fig. 4.2: DFD_0 Top Level Processes.

Figure 4.2 models a further breakdown of the process Rheuma Ward from the context diagram, into smaller and more detailed processes. This outlines how information is gathered and stored between the main activities of the ward. Information seems to criss-cross a lot at first glance. In the following DFDs there will be a closer look at the processes numbered 1- 4, paying special attention to where information is gathered, and how it is stored. See definition for concept *working while wandering* in chapter 1, p. 12.

The arrival exam (see figure 4.3) takes place in an office, and as such does not involve wandering while working. It appears to be a collection of standard questions and standard tests. If this is true, perhaps it could be automated. The doctor could choose “arrival tests” on a computer system, and the set of standard requisitions is either printed out ready to sign, or better, sent to the right department with digital signatures.

The process is however laden with information redundancy. The doctor scribbles down the essential information temporarily on a piece of paper as a base to expand further on later. The treatment plan is handwritten twice, the same information is repeated in handwriting in a surgeon's brief, and in a dictated arrival report that will later be passed around in paper form. From the dictated material also comes a statement of why the patient is admitted, a short brief of status and symptoms. The graph sheet is fitted with the vital statistics temperature, pulse rate and blood pressure, and current medications.

This process is also laden with storage redundancy. In a future system, there should be no need to separate between main patient record and graph book, and the nurse record should probably not be separate. A system where electronic patient records are available on handheld technology would be reliant on sharing databases with other programs. This suggests a main patient database that can service different systems working with patients, to allow for cooperation and communication across platforms and applications. Today's computer programs do not communicate or share information. More flexible database structures may be necessary to even consider a handheld system.

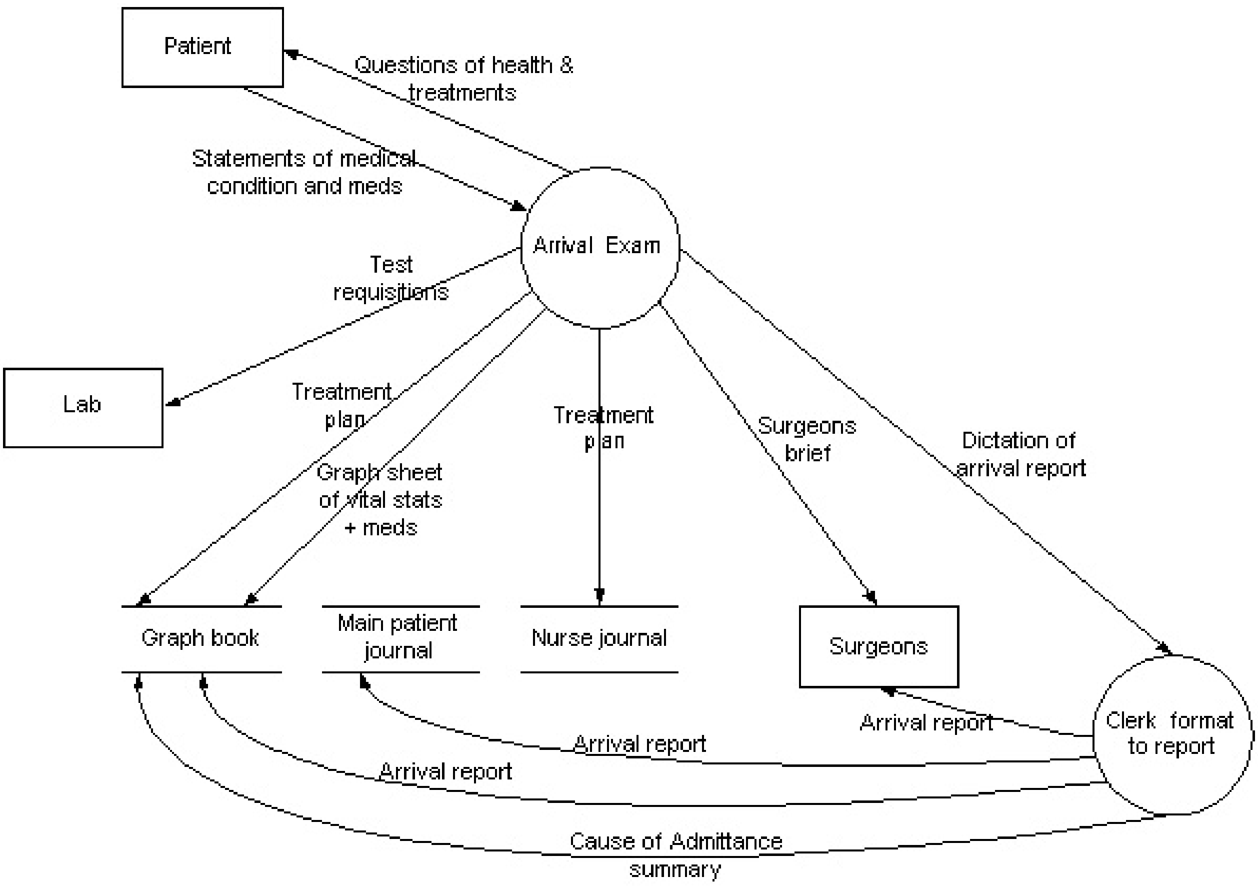

Fig. 4.3: DFD 1.1 Arrival Exam Process.

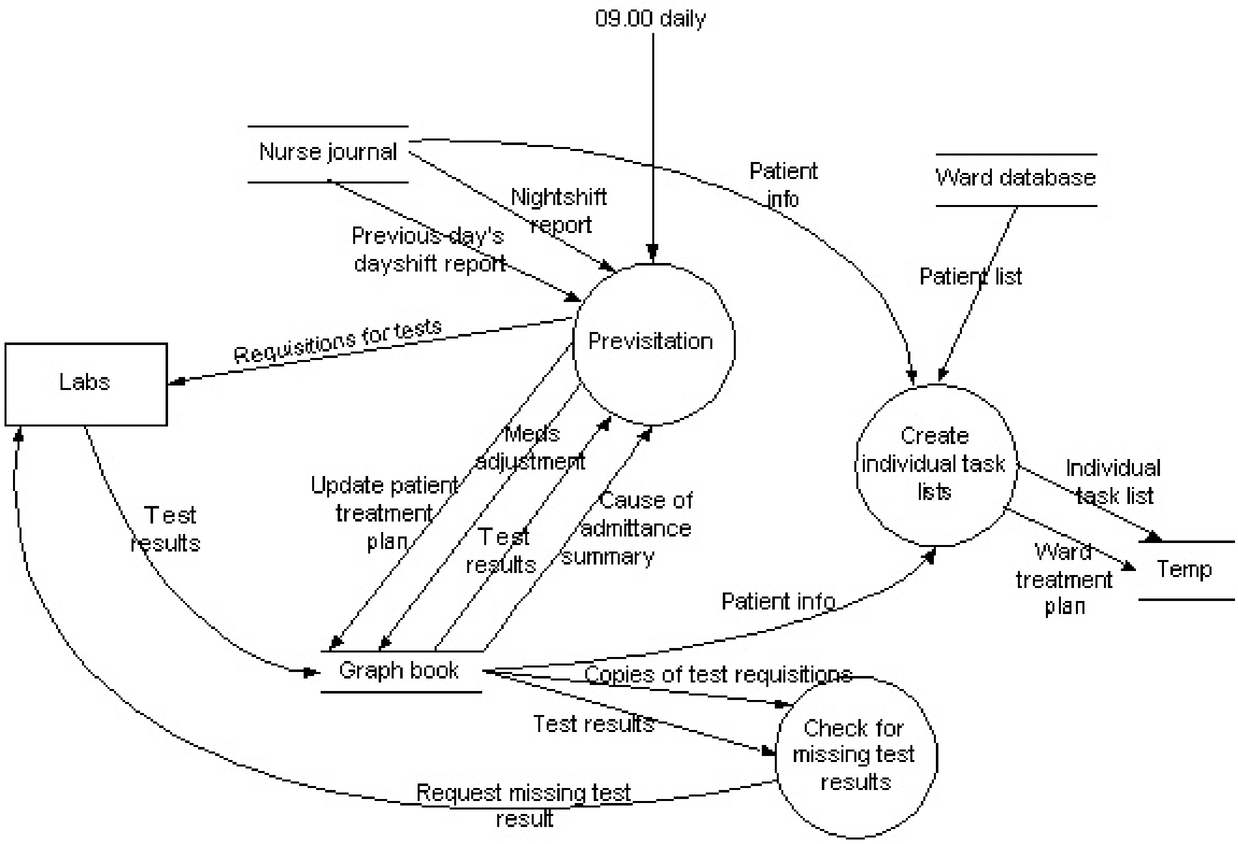

Fig. 4.4: DFD_1.2 Pre-visitation Process.

The pre-visitation process (see figure 4.4) is essentially a preparation for the days' work, a planning meeting between professions. Doctors, nurses and other specialists go over patient cases, and each individually make a task list of what to accomplish during the day by making notes on a printed list of the wards patients. They set up an overview over what each patient has scheduled this day, a ward treatment plan. Pre-visitation is the only place where test results are discussed, and they check if any should be considered missing.

Pre-visitation is not work done while wandering, but it is related as it prepares for the wandering work. If more information was available while wandering, maybe some of this planning would be redundant? This analysis will not suggest to remove pre-visitation completely, as it is efficient when experts with different knowledge convene to discuss a case, usually more efficient than if one person (doctor) would read page after page of reports to gain the same insight. In the future, one should expect pre-visitation to be supported by computers. There is no need for handheld computers here per se, as it only fulfills the least important requirement, double work, but there is a need to make task lists created here later available on the handheld. This goes back to more flexible database structures which allow platform independency.

Visitation (see figure 4.5.) is an interesting process in this study. Plans made in pre-visitation are tentative. Doctors have to consult the patient before anything is decided. As all the work during visitation is done while wandering, and all the documentations are done twice or more, it can be assumed that using an electronic device to accomplish the task immediately would be more efficient. The current use of temporary (mobile) documentation is a patch for the wandering nature of the work.

Task lists, the graph book, and the visitation book comes along on visitation. The doctor uses the graph book to both look up and adjust information while at bedside. The nurse makes notes in the visitation book, which is later used for task list updates and as a basis for reports. Requisitions and referrals are not completed in the patient room. The standard routine is for the doctor to write down key information for later, when he has time and opportunity to fill forms properly. In the example of morning visitation (see p. 51), the doctor discusses with the patient what referrals to make. The same is true for managing medications. For example, the doctor waits to make final medicinal decisions until having conferred with the patient; the patient may have allergies or may have tried the medication before with bad results. The patient also has the right to influence treatment.

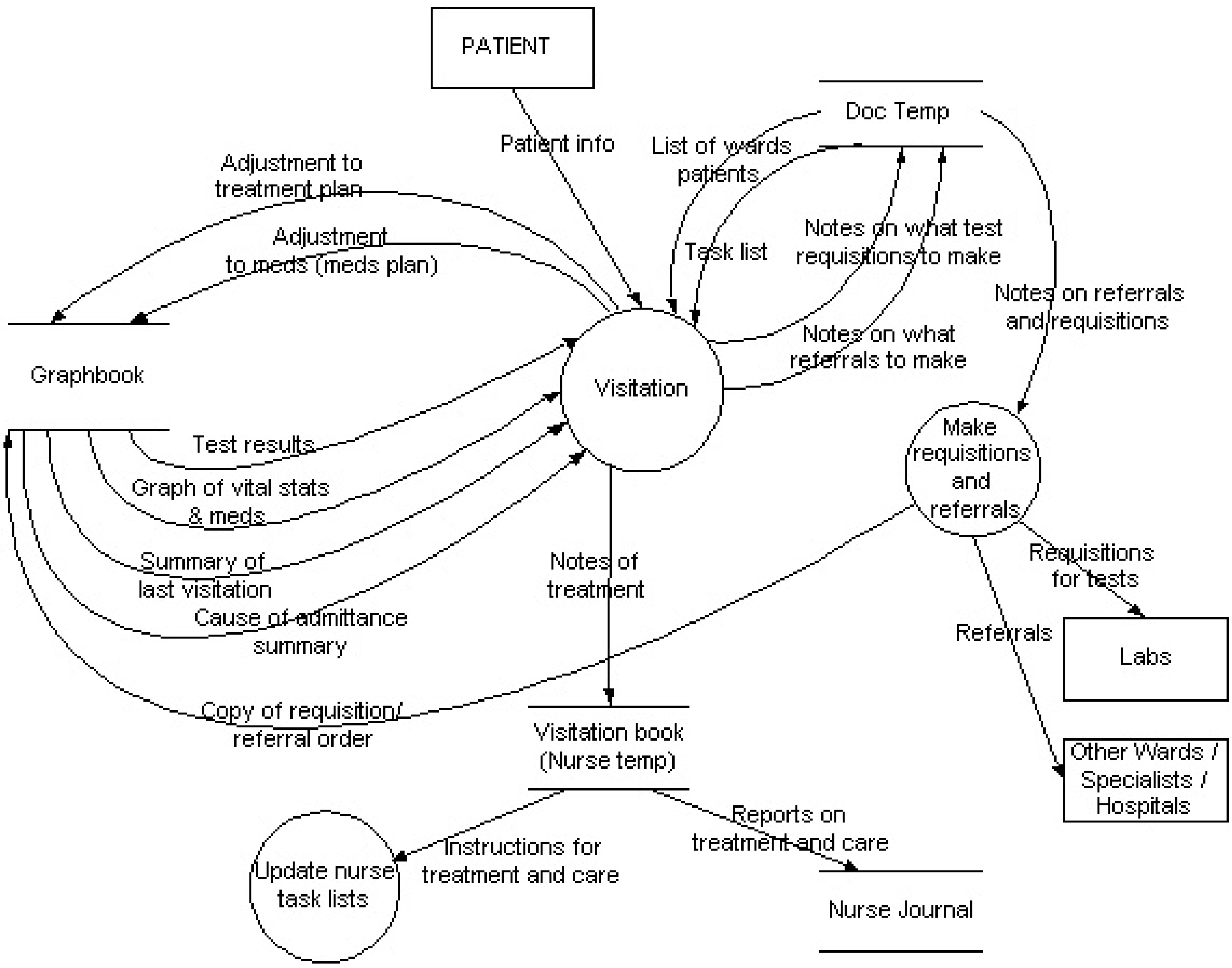

Fig. 4.5: DFD_1.3 Visitation process.

Dr. Faxvaag disapproves of the existing standard routines for test requisitions during visitation. He says that having the possibility to fill the forms in the room and not having to go back to it later, is a great benefit. The doctor added that the drawback of being able to do this electronically (assumes quickly and easily), is the not far-fetched scenario of over-requisitioning tests that are not really required or useful, because they *can* and it is *easy*. Tests are very expensive for the hospital, and such a service should include a method to influence doctor behavior, e.g. put the price tag of the test into the interface.

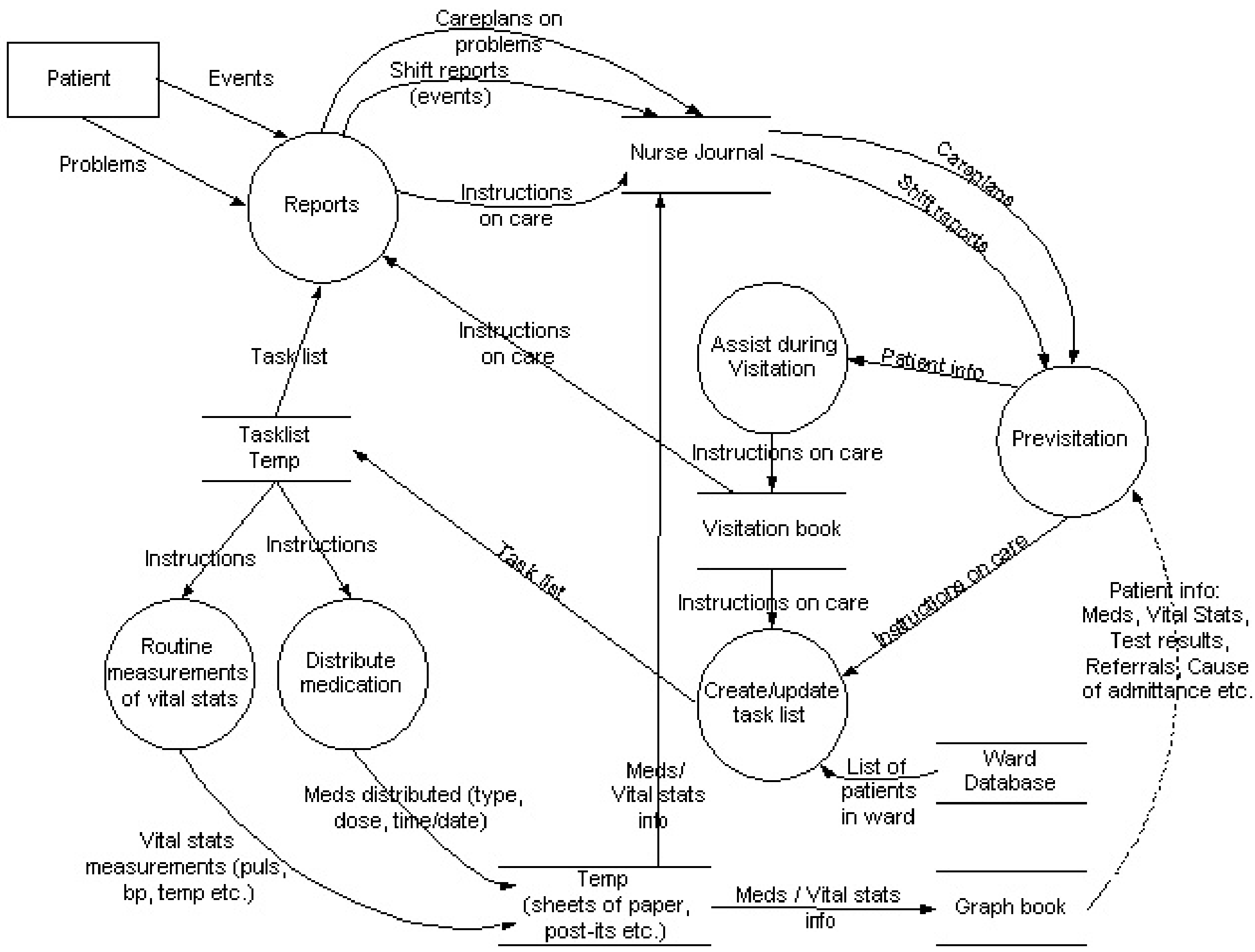

Fig. 4.6: DFD_1.4 Nurse documentation process.

Nurse documentation (see figure 4.6) is also an interesting process in this study. Nurses are constantly moving around, working while wandering. Nurses take small and quick measurements of vital statistics on patients: pulse, temperature and blood pressure. Nurses also distribute medication, and have to document this. These tasks are done several times a day, and are registered in the graph book. The usual way of doing this is to go to the patient, take the measurement, write it on a piece of paper, and later transfer the value to the record when one has a spare moment. Thus, the information gathered while wandering is always written twice or more, and the paper scraps probably disappear sometimes. Nurses handwrite reports of different types, but these are not necessarily done out in the ward. Patient *events* are, for example, eating, washing, change of bandage etc, while *problems* are fever, pains, loss of appetite, poor healing of wounds, and so forth.

Different lists were frequently used by the healthcare professionals as an aid in their job. During the pre-visitation meeting, a patient list (like a guest list at a hotel with room numbers) was available at a pre-filled format, where nurses could write comments and add what they had to remember to do with each patient that day. The task list supplied an overview and a reminder of the duties of the day. During morning rounds, the nurse wrote down instructions in the visitation book which would later be used to adjust task lists. Each doctor also wrote their own task list of what they needed to get done during the day in pre-visitation. Together they made a "today's treatment plan," which was an overview of what all the patients have scheduled. All these lists are temporary to-do lists, and they also help remind the list owner later during different record documentations and reports. Once the tasks and paperwork are done, these lists have no value.

Test results are important in the ward, but they consumed far more resources than intended (see structure diagram of how test results return in figure 4.7). Some test results were already available in electronic form, although as a "sneak peak" and not a legal version. X-ray images were expected to be digitally available next. Missing test results were a big problem. Health secretaries said they used up to 70% of their workday to track down missing results. Getting results back took fairly long anyhow. When a doctor decided to order a test from the Clinical Chemistry lab during visitation on Monday morning, he would get the result Tuesday afternoon, and it would be discussed in pre-visitation Wednesday morning. That is two days for a blood sample result. If the doctor ordered an x-ray from the Red Cross facility on Wednesday, he would get the result next Tuesday, six days later, at best. Sometimes it took up to two weeks to get the results. This study can not offer insight into why this is such a big problem, aside from stating that these facilities service many wards, and there is a lot of paper going around. Once the results arrive at the ward, they are put on a shelf. The doctors have to keep checking that shelf for test results.

The huge problem with missing test results could be solved by using computer systems in general, but that is not an issue for handheld technology specifically. Using electronic test results as a standard would, in addition, likely shave days off test result return times, and with that further increase efficiency. Overall, test results are very good candidates for any digital system.

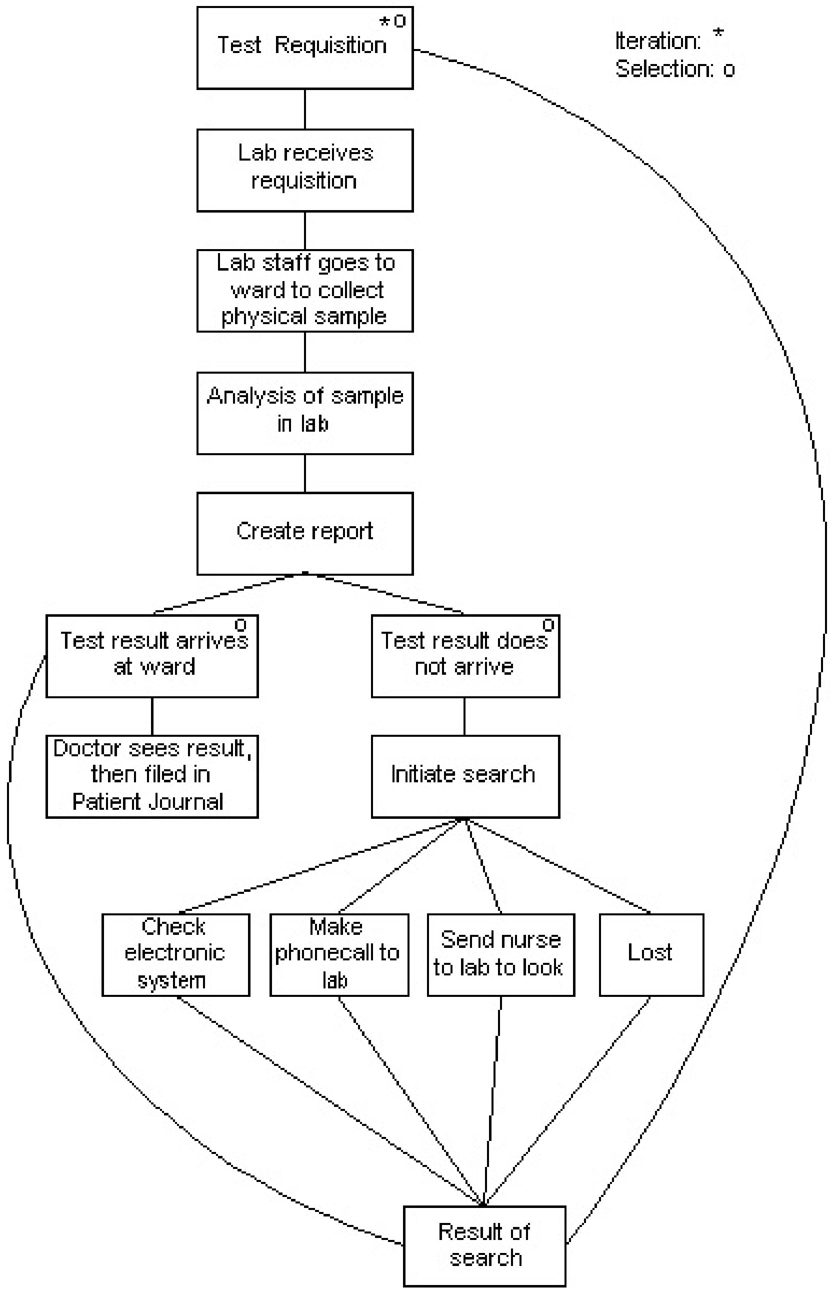

Fig. 4.7: Structure diagram of how test results return.

In a future system involving mobile technology, the doctor could get the results as soon as they are ready at the lab, then would not need to constantly check for their arrival. As doctors often wander in their job, it is interesting to think of them as the permanent entity which receive information, rather than a shelf. If test results are fitted with a "find the doctor" -behaviour by using a wireless handheld system, it would increase efficiency by freeing the doctors from hovering around the test results shelf, and having the test result sooner will allow them to make the next decision sooner. Having such a system in place would support the doctor in his work by keeping him highly current, even while wandering.

Many test results could be suitable for handheld devices, depending on data volume and the ability to visualize them sufficiently. X-rays may not be suitable as they are saturated in data (images), requiring high-resolution screens of a larger size. A handheld device may also pose limitations on what volumes can be transmitted due to battery capacity and network bandwidth. Test results of smaller volumes, such as blood values and other metric data, could have acceptable visibility on a small screen.

4.4 CONCLUSION

The main motivation behind an introduction of handheld digital patient records would be to increase efficiency. A key is to have information and tools available when needed, also when wandering. Many of the resources that are currently applied to administration and paperwork could be better used for patient care and treatment in the future. The improvements in efficiency may be reached through integrating today's paper-based and electronic systems with wireless mobile digital technology that partly or completely substitute paper records, requisitions, test results, and other paper-based forms of communication and management. Some tasks require entry of rather large amounts of information, so a physical keyboard may be required as a hardware attachment to a handheld device with an electronic patient record.

The work processes described in this chapter include various ad hoc solutions for keeping records of the patient's treatment and care within the law, while adjusting to a modern age of computer technology. The analysis left some primary candidates for prototype development. Figure 4.8 is a diagram of UML Use Cases which support work processes that most likely will benefit from handheld wireless technology. The work is done while wandering, and the volume is suitable for a smaller computer.

Digital availability while wandering seems highly useful, as data entries and retrievals could be done immediately. All the temporary notes and double work could be omitted, along with missing information. Nurses could be relieved of the responsibility of delivering test requisitions to labs, and test results could find the doctor. Decisions could be implemented without delay. The total gain lays in increased efficiency and a staff always updated on current information.

A Use Case diagram captures the functional aspects of a system by identifying primary actors and processes that interact, and hence define requirements. Primary actors are on the left, while the actors on the right side are indirectly involved in the use case. This use case selection does not reflect the existing computerized software, as the staff gave the impression that what they have is not that helpful anyway, being isolated programs requiring multiple bookkeeping.

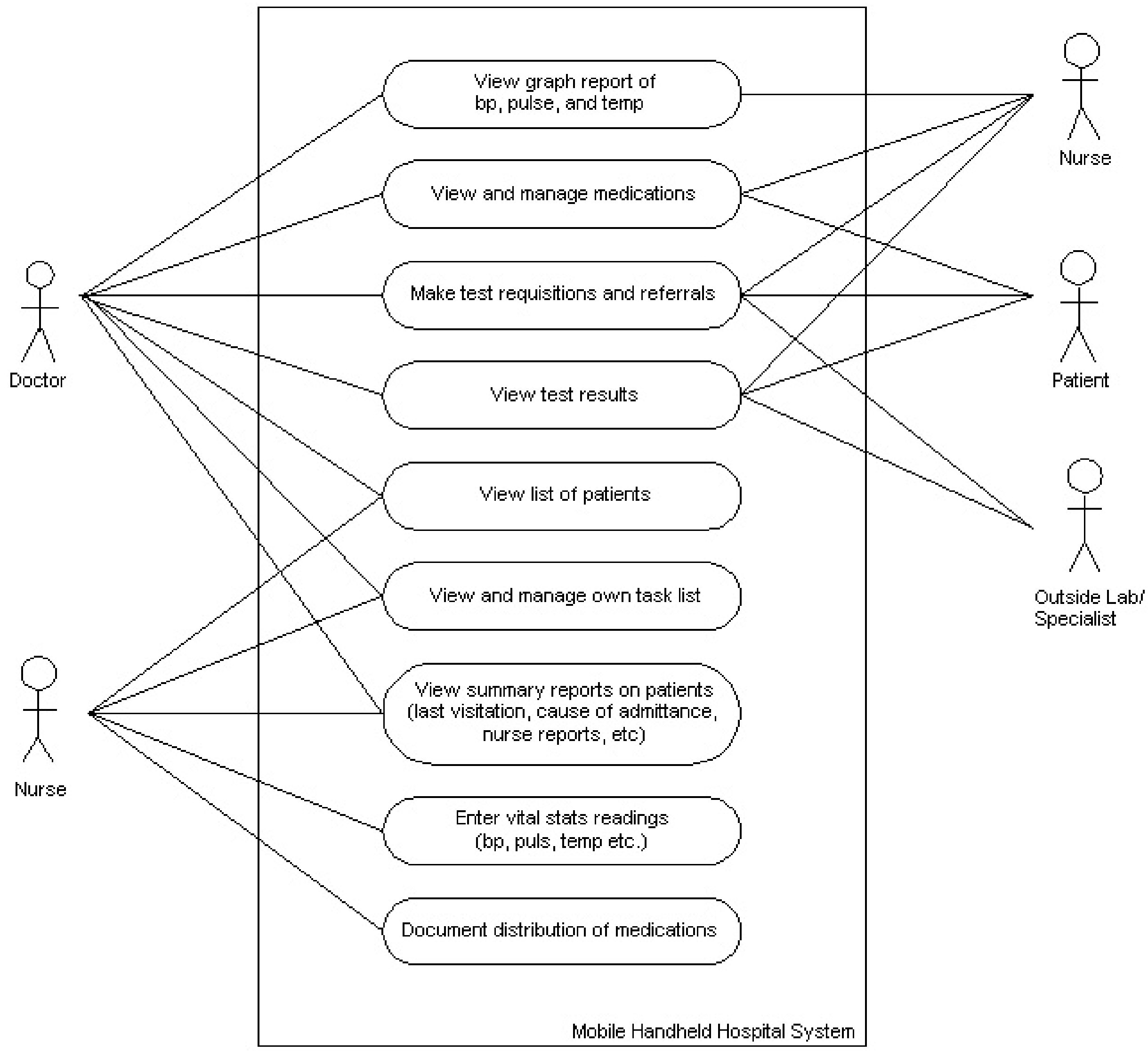

Fig. 4.8: Use Cases suitable for handheld technology in a hospital ward.

A system with handheld mobile technology assumes a main patient-database that can service different applications, contrary from today's situation where programs and databases do not cooperate. A flexible database structure would allow platform independency and tailored applications.

Other work processes that were considered, but eventually rated as secondary candidates, were the creation of treatment plans with later adjustments, arrival reports, and the nurse's documentation work. How useful and how possible those would be is still yet to be determined, and whether it is work actually done while wandering. Most of it seems to be done in office settings where other computers could suffice.

CHAPTER 5

Exploring the Technology Design Space

This section will explore the hardware technologies that are realistic to use for prototypes in this project. The conclusion has a brief overview of arguments behind each hardware choice. Chapter 6 details how these choices were later implemented.

It is important to initially define the two main models of connection: *circuit-switched connections* and *packet-switched connections*. Handheld devices such as mobile phones rely on circuit-switched connections today, much like regular house-phones. A dedicated connection must be set up before any data can be transferred, and the user pays for connected time. With packet-switched connections, however, the user is always connected, and pays by amount of data transferred. This gives the advantage of lower price. Weiss refers to NTT DoCoMo's *i-mode* in Japan as an example of an outstanding packet-switched system (9600bps). Due to the pay-per-data price model it costs ¥ 1 to send an e-mail message, less than 1 US cent [22:25]. Comparably, to send a 160 character message (SMS) in Norway on the GSM network it would not be unusual to be charged 1 NOK to send it, approximately 15 US cents.

5.1 WIRELESS CONNECTIVITY

Connectivity is the device's ability to connect to the internet or other devices. The two types of connectivity are called *internet connectivity* and *intra-device connectivity*. An internet is a network of interconnected web servers. A network can be set up locally as a *local area network* (LAN) or more widespread as a *wide area network* (WAN), essentially many LAN's connected. The world wide web is a WAN. For security purposes, many companies choose intranet inhouse, a LAN not connected to the outside world of WAN. A wireless local area network is frequently called a WLAN or Wi-Fi[3].

Stationary computers usually have cables that connect them to other devices and the internet, while for connectivity standards are not as established for wireless devices. The wireless devices either have built-in hardware for connectivity, or expansion options to add on. Sometimes there is a slot in the device, sometimes the device needs a jacket to carry the add-on. Cameras, bar code scanners, memory, modems and WLAN ethernet cards, etc. can sometimes be added if not included in hardware.

With wireless internet connectivity new issues surface. The frequency of base stations[4] relates to the *range* of the base stations. The range and frequency of base stations together make out the physical *coverage*, which again introduces synchronization issues. If the coverage is less than 100% of the area where the user is moving, there is a need for synchronization between the handheld device and the internet server to ensure that information is current once the wireless connection is re-established. The synchronization can be an upload or download of information towards the main system, wireless or through docking the handheld in a cabled cradle.

Areas where wireless internet connectivity is available is sometimes referred to as hotspots or IP-zones [49]. Figures 5.1, 5.2 and 5.3 show models of different possibilities for network WLAN connectivity: full coverage of WLAN, zones of WLAN and points of WLAN.

Fig. 5.1: Always-On

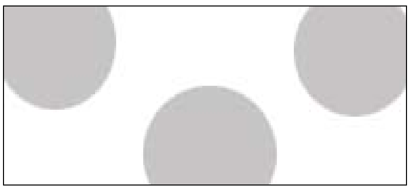

Fig. 5.2: Zones

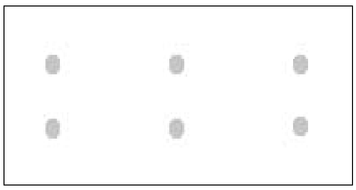

Fig.5.3: Points

Figure 5.1 models the Always-on approach, which does not require synchronization (besides recovery from network instability). Base stations are positioned to cover the entire physical area. The connection is roaming between base stations seamlessly. Figure 5.2 models Zones where major areas

[3] Wi-Fi (wireless fidelity) is guidelines for how the physical layer is implemented, and all equipment marked Wi-Fi is compliant with other Wi-Fi equipment [49].

[4] A base station is a repeater, basically a radio antenna.

of use have connectivity, but synchronization is necessary after moving outside the range of the hotspot. Figure 5.3 models Points, where coverage is scarce and the user must actively seek a hotspot for connectivity; he cannot move around much while being connected.

5.2 STANDARDS IN WIRELESS CONNECTIVITY

An established standard for WLAN connectivity is the IEEE 802.11. This standard offers fast and reliable connectivity [22:11]. However, if internet connectivity is not available through wire or WLAN, handheld devices can attain this through mobile networks[5] which deliver both voice and data transmission. Mobile connectivity is slower and in general less reliable[22:11], but availability is high.

Mobile- and WLAN networks are both based on radio waves. This basic similarity is becoming more important, as what used to be mobile networks for mostly voice communication is increasingly adding data services, and WLAN networks can add digital voice transmissions. The distinction between wireless telephony networks and wireless data networks is disappearing, making these emerging technologies competitors in the same arenas in third generation (3G) type wireless connectivity.

5.2.1 WLAN: IEEE 802.11

IEEE is the Institute of Electrical and Electronic Engineers. In 1997 they approved a mother standard for wireless local area networks using Direct-Sequence Spread Spectrum (DSSS). The standard IEEE 802.11 is modelled after the ethernet, thereby being compatible with existing wired networks of computers, printers and other peripherals [22:55]. This standard is what most people know as WLAN or Wi-Fi, and is increasingly being used in internet zones and hot spots in public places (see fig. 4.2). So far, the IEEE has approved the protocols 802.11a, b and g [49].

The IEEE 802.11 is a standard designed for high data-rate applications with medium range. The 802.11b protocol has a range of 40 meters and transfer speed of up to 11 Mbps. The upcoming expansion 802.11g will offer transmission speed of up to 54 Mbps, and they both operate in the unlicensed 2.4 GHz frequency band. With time 802.11g will replace and most likely be even more popular than 802.11b [49].

5.2.2 Mobile Networks

The world’s first mobile cellular network was established in 1981, the NMT 450. Since NMT (Nordic Mobile Telephone) was set up between the 5 Nordic countries (Norway, Sweden, Denmark, Finland and Iceland), it is also the worlds first international mobile network. Today GSM is the dominant standard in Europe, Asia (except Korea and Japan), Australia, Africa and the Middle East. In the USA they use the standards CDMA and TDMA along with GSM, necessitating triband phones.

It is common to speak of generations of mobile networks, where the first generation —1G— is analog mobile systems. 2G is digital voice technologies, and 3G is digital broadband for data and voice communication. 2.5G is a pit stop between generations, essentially being digital voice networks extended with data transmission.

1G: NMT 450

Nordic Mobile Telephone is an analog mobile network established in 1981. It has more or less full coverage of Norway, including mountainous areas and well into open sea [50]. The network standard was established in all the Nordic countries, and was also the first mobile telephone service that allowed roaming between networks. The standard NMT is today adopted in more than 40 countries around the world [51]. Telenor, the carrier that hosts NMT in Norway, has traffic agreements with 12 operators in 11 countries. Telenor has planned to phase out NMT ultimo 2004 to focus all efforts into 2G's GSM and later generations [50].

2G: GSM

The Scandinavian cooperation of NMT later evolved into a new standard: the worldwide digital GSM (Global System for Mobile communications) [50]. The 900 MHz band was established in 1994, while the 1800 MHz band standard opened for traffic in 1998. The transmission speed is 9,6 kbps and the GSM standard geographically covers 97 % of the population in Norway [50]. GSM hosts digital voice and SMS (Short Messaging Service). GSM is used all over Europe with seamless roaming access between operators. In 2003 Telenor Mobile had GSM cooperation with 188 foreign mobile operators in 101 countries [52].

2.5G: HSCSD, GPRS and EDGE

2.5G are initiatives to achieve higher data rates before the rollout of 3G. GSM is the foundation for 2.5G services in Norway, where base stations are upgraded to carry additional data services. Coverage is nearly as widespread as GSM.

HSCSD stands for *High Speed Circuit Switched Data*, a technology that is an upgrade of GSM while keeping the traditional circuit-switched connection. A dedicated line is made, and the user pays by minute. In Norway, Telenor Mobile offer transfer speeds up to 57,6 kbps, while Netcom offer 28,8 kbps in their net [49]. HSCSD is ideal for transferring large amounts of data, but is expensive for "small and often" -type use [49]. The system, however, is planned to be phased out over time, as packet-switched technology is the future.

[5] In Norway, wireless telephony networks are called *mobile networks* because they afford use of mobile devices. In some countries the term *cellular networks* is used for this technological infrastructure, where base stations create cells of mobile connectivity.

GPRS stands for General Packet Radio Service and also is an upgrade of the GSM net; but it is implemented as a packet-switched network. The upgrade occured in February 2001 [50]. The user can be always-on, which is relevant to internet-based services such as e-mail. The user pays for the amount of data transferred, not time, and the cost of use is in general low. GPRS is ideal for transferring small amounts of data with quick connections and fast maneuvering; speed depends on what the phones offer so far, around 40 Kbps [49]. Today GPRS is used for small sound files, MMS (Multimedia Messaging Service), digital photo services, internet surfing, as well as other applications.

EDGE is Enhanced Data rates for Global Evolution, a technology designed to be an interim data technology between GPRS and UMTS, regarding both technology build-out and speed, or as an alternative to UMTS for network operators who did not win licenses to operate in the UMTS spectrum [53]. EDGE allows data rates of 384 Kbps. The claim is to achieve higher speeds on existing networks by changing modulation [53], but the catch is that EDGE requires a higher radio signal quality than that found in average GSM networks before higher throughput can be reached. This requires more base stations and infrastructure build-out [54]. Telenor opened this network standard for general use in September 2004 [55]. Whether EDGE is a 2.5G or 3G standard seems to be debated, but most sources position it with HSCSD and GPRS.

3G: UMTS

UMTS (*Universal Mobile Telecommunications System*) is the future worldwide standard for mobile communication, initially planned to be opened for general use in 2001. The rollout has endured several delays; new estimates say that by fall 2007 the UMTS network will offer coverage to all communities with more than 200 inhabitants in Norway [50]. UMTS Digital Cellular [56] describes UMTS as a broadband mobile packet-switched network that offers transmissions of large quantities of data and a wide array of rich content services where the user is always-on. Options to be expected in devices involve pictures, graphics, video and sound, where music files and live video will likely be popular. UMTS Digital Cellular say that transfer speed is initially planned to be 256 Kbps, but with time will provide data speeds of up to 2 Mbps. Telenor opened their UMTS network late 2004, while Netcom came after in mid-2005.

5.2.3 Bluetooth

The idea behind Bluetooth was to design a wireless low-cost data transfer technology with low-power consumption, thereby ideal for mobile phones and PDA’s [22:55]. Bluetooth is primarily about intra-device connectivity with its short range of 10 meters. The standard operates in the 2,4 GHz frequency band (although incompatible with the WLAN standard 802.11). Typical use is modern office settings where Bluetooth can replace cables between computers and peripherals such as printers, along with headsets for stereos and earpieces for mobile phones. Bluetooth can also be an aid in gaining internet connectivity on a laptop or handheld computer by being the wireless link towards a mobile phone with access to LAN or WAN via mobile connectivity, see model in figure 5.4.

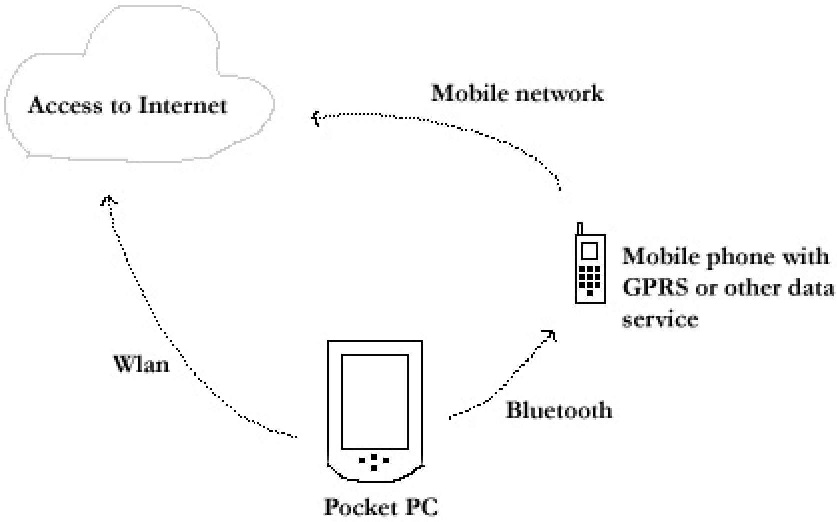

Fig. 5.4: Bluetooth can afford access to internet connectivity.

5.2.4 Availability of wireless connectivity standards

Network coverage is largely related to population demographics. Establishing infrastructure for high speed broadband wireless networks may be a good investment in highly populated areas. In more rural communities the issue is range. Higher bandwidth is carried through higher frequencies. Higher frequencies have smaller and faster wavelengths that inherently have a shorter range than lower frequencies carrying lower bandwidth. Hence, high bandwidth demands more base stations, which makes the potential customer per base station low, thus making infrastructure investment turnover low for rural areas. Consequently, the less populated an area is, the less likely it is that advanced commercial wireless networks will be built.

Figure 5.5 models network coverage presented as population circles. The model shows how GSM covers nearly all of the population, even places with very scattered populations. Nature is a greater challenge than population, as mountains block signals and might make an additional antenna necessary to reach full coverage in some places. GPRS coverage nearly mirrors GSM coverage.
3G, however, represents a significant jump in “requirements” for population density: A UMTS network operator will likely desire much heavier population density to want to invest in infrastructure. Even more so WLAN, which requires more infrastructure per square kilometer than UMTS, but in return gives much higher data rates.

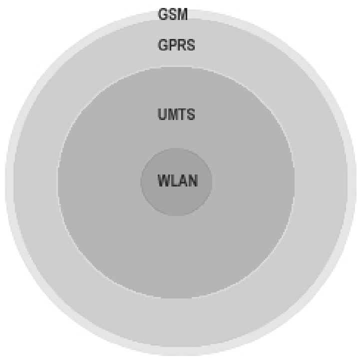

Fig. 5.5: Network coverage as population circles.

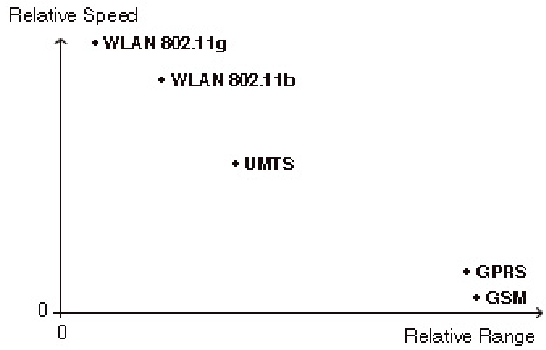

Fig 5.6: The axis of speed vs. range in network standards.

Figure 5.6 models the relation between range and speed inherent in wireless standards, also underlining the argument that population density is a factor for advanced network availability. Physics makes the ideal upper right corner of the graph empty, as high transmission speed and high range ismutually exclusive so far. PC World Norway suggests UMTS and WLAN to be complimenting technologies instead of rivaling— provided a seamless roaming between dissimilar networks— because population density says UMTS will have a much wider coverage than WLAN long into the future [49].

Other consequences of range and speed concern hardware solutions for multiple connectivity on computers and mobile phones. Since WLAN is not as widely available as mobile networks, handset producers of mobile phones have not integrated WLAN into their devices in a large scale yet. In the future WLAN is likely to be a required feature as hotspots expand, especially since WLAN is the fastest and most reliable connectivity offered. Likewise, it is reasonable to assume that computers such as laptops and PDA's will have integrated 2.5G (GPRS) and 3G (UMTS) data services, leaving out the mobile phone as link where WLAN is not available. Form factor, services and application areas that define device categories will evolve through convergence, innovation and sales, and will ultimately define what wireless standards are useful in each device category.

5.3 TAG TECHNOLOGIES ENABLING CONTEXT AWARENESS

Relevant technology for this project pertains to sensing techniques that can inform a mobile device about the location of the user, technology that gives cues about the user's physical context. The purpose behind this is to make nearby objects easier to select on the mobile device, and by that increase their digital availability for the user. The technology should be inherently simple, cheap and somewhat dumb. The technology need only provide a digital ID-string, hence act as pointers to online information.

Want et al. [58] refers to this as adding electronic identification *tags* to everyday objects to augment them, objects that already have a useful purpose independent of any electronic system. Want et al.. experimented with RFID tags, barcodes and IR beacons. Want et al. discuss how tags can set context: user ID can be established by adding tags to ID cards, signet rings, watches or jewelry; and location ID can be established by attaching tags to, for example, tables, chairs or doorways. These tags have unique ID's that can be read by a tag-reading sensor on the mobile device.

The relevant context to contemplate tagging in this project are objects in the hospital ward. The design space was limited to only consider tag technologies that can be affixed to patients and locations to provide patient ID and location ID. Context information will be created through coupling the tag-fed ID-strings in a database with patient-numbers and location sites such as room-numbers. Later the context information will be used in the screen interface as a portal to information about the tagged object, thus augmenting the interface with local information. Below are some essential tag technologies with informal consideration of their suitability as tags in a hospital ward. These parameters are seen as especially critical to usability:

- the read-situation should be unobtrusive to the patient, and tags should be easily read [58]
- the reader should have physical qualities that are suitable to the wandering use-situation
- the tag should be durable enough to handle the soiling that might occur in a hospital

5.3.1 RFID

Radio Frequency ID tags [59] consists of two or three computer chips integrated with tiny antennas in a capsule, and is used in areas from automatic individual feeding of animals to tracking goods in transit, identifying locations and access control. The RFID tags are generally inexpensive varying on sophistication and volume —a simple ID tag would cost around $0.25 [59]. RFID transceivers are also relatively inexpensive (about $80), small and can easily be added on to a mobile device[58]. The reader initiates communication by sending out a signal after which the tag responds back with a range of 5 cm - 30 m depending on radio frequency of the specific tag [59].

The RFID tags are physically robust and remain readable through dirt and smearing and also sustains cleaning for hygiene issues. The connection between tag and reader is wireless and offer the unobtrusive read situation where the patient should not feel invaded. Last, the reader is small and light. All of these features suggest good usability. Possible negatives are that the tag might be invisible, so it might not occur to the user that the local context offers a portal to information. Also the fact that there is a reader, however small, that needs to be carried around as extra equipment. This may be obtrusive to the user, even if not to the patient.

5.3.2 IRID

InfraRed ID is a tag that uses high frequency infrared light that is not visible to the human eye for communication. The IR beacon is a transmitter with a timer and an IR light diode that sends out pulses of light carrying data as a beam. Range can be from 20 cm to a few meters. Mobile computers with IrDA ports can be receivers of such beams. An infrared ID tag would transmit a simple ID-string. IR links can communicate only over a line-of-sight path, any object between sender and receiver will block the beam [60][22:54].

Want et al. [58] used the IrDA ports on their mobile computers to receive a room ID from strategically placed IR beacons. They say they augmented the patients with IR beacons to provide room ID information, but they do not describe *how* the patients where augmented. The weakest point of the IR technology in a hospital ward might be the necessity of a clear line of sight between the IR beacon and IR ports. Dirt and smearing might jeopardize readability, and ease of use will probably be challenged in the search for good angles. This might likewise jeopardize the unobtrusiveness of the read-off situation with the patient, depending on the placement of the tag. The great advantage lies in the IR reader hardware being integrated into several handheld computers. No extra equipment to lug around, or even expenses. IR is however widely regarded as a technology that will be replaced by Bluetooth and WLAN, due to the significant line-of-sight limitation [60][22:54].

5.3.3 Barcodes

Fig.5.7: A laser bar code scanner by Metrologic.

AIM [61] presents *bar codes* as a graphic representation of numbers and alphabetic characters. AIM says bar codes can be bought or designed with inexpensive software and printed on sheets of adhesive stickers with a standard laser printer, while the commercial option is to make barcodes integrated into packaging design. Bar codes are often used for inventory work and at payment points of shops today. AIM says a tag reader (see figure 5.7) is a scanner with decoder that illuminate the symbols and measure the reflected light, then convert the symbolic code to digital information.

A few issues arise when contemplating barcodes as tags for locations and patients in a hospital ward. The positive sides of this technology is good usability. The use model is straightforward with the swipe motion and the auditory beep feedback when a tag is read. It would be efficient and safe in the sense that it limits the sources of error of retrieving the wrong patient on the system. Also obviousness of use [58] is apparent with the visible tag. The possible negative sides concern the obtrusiveness of the scanning situation, and the extra reader equipment to carry around. The use model of swiping patients gave associations of assembly lines and tagging cattle. The conceptual model of the system should correspond to the philosophy of the company, in this case the hospital has a strong focus on treating patients as individuals. The users will then bring mental models of individualized care to the table. Bar codes was seen as not affirming this in their conceptual model, hence not making users nor patients satisfied.

Last, there is the issue of readability. The tag is made of paper, and can not be expected to withstand smearing such as water, blood, food, etc. With bar codes on every patient in a hospital it is likely that dirty bar codes both render the symbols unreadable and unsanitary, where both would cause problems and more work instead of less. The obtrusiveness of swiping patients, the dragging of a lumpy scanner around, along with the issue of readability, all suggest that hospital wards may not be the ideal application area for bar code tags.

5.3.4 iButton

The iButton [62] by Dallas Semiconductor is a computer chip enclosed in a 16 mm unique and durable stainless steel can, see figure 5.8. Each iButton has an unique and unalterable address that is laser-etched onto the chip inside the can, which may be used as an identifier or key.

IButtons [62] are in use for areas such as access control, data collection and authorization. Further, iButtons have two use models, both requiring physical contact. One is a momentary touch between the

Fig 5.8: The iButton.

Fig.5.9: Patient ID bracelet with iButton holder (Dallas Industrial Data Inc).

iButton and a receptor, the other is when the iButton is affixed to a receptor. The receptor is connected to a PC through cable. The technology is fairly inexpensive, a blue dot receptor costs $34 and the iButtons costs around $2 for unsophisticated versions.

Initially the iButton system was designed for a use model where the tag is carried and the reader is stationary. This technology is not so suitable when the ID tag is stationary on patients (example of this in figure 5.9) and locations, and the reader must accompany the wandering person. The read-off situation itself requires a physical touch or docking. The iButton system appears more appropriate for individual access control and logging. At the time of the project there were no readers ready as add-ons to handheld computers. iButton probe readers suitable for handheld computers within this design space have been made since, see example in figure 5.10.

Fig.5.10: iButton on patient bracelet (OneTouch Technologies Corporation).

5.3.5 Others

Bluetooth was not available as a tag nor in handheld computers at the time of the project. The qualities Bluetooth harbors as a technology would have made it a very strong candidate if available. It is wireless for unobtrusive patient read-off situations, the tags would be durable and reliable, and the readers would be integrated instead of extra equipment. It probably will be a natural choice for a similar project with time.

GPS (Global Positioning System through satellite) was not considered to be a relevant option as it involves paying high service charges to telecom operators. For the healthcare context, GPS is probably more useful in field situations where the core area is wider, and location need not be as accurate.

5.4 Hardware Input Technology

Handheld mobile devices come with various technology to afford data input: a touch screen, stylus (points, clicks and writes), virtual keyboard and often a sound recorder. The devices are designed to have the stylus replace both the keyboard and the mouse of stationary computers. The virtual keyboard usually pops up on demand like an application, covering between ⅓ and ½ of the screen real estate. Typing is done by selecting letters with a touch of the stylus. Screens are limited in size, thus each letter is quite small, and operating the stylus on the virtual keyboard requires fine-tuned motor skills of the hand. The input techniques of handheld devices rely on existing and emerging advanced technologies for handwriting recognition, speech recognition and gesture recognition.

5.4.1 Handwriting Recognition

Handwriting recognition is a computer's ability to translate handwritten text into typed ASCII text for data input. A stylus is used to write on a pressure-sensitive screen, and the screen displays the strokes as would a pen on paper. The two main forms of digital handwriting on handheld devices is the natural cursive handwriting and the constrained character handwriting. In cursive handwriting the machine initially guides the user through a training process to learn about the users' handwriting. For constrained character handwriting the user must learn predefined character strokes that are different from characters of the Roman alphabet. *Graffitti* used by Palm is an example of a system that uses constrained characters.

There are several challenges to handwriting recognition as a technology. The goal is natural handwriting, but some people sport such poor penmanship that they can hardly read their own writing. Some users still prefer a keyboard for text input as typing is faster than handwriting to them. This is especially true for larger amounts of data input. It might also be smart to consider the users when designing for a specific context such as healthcare. If most users cannot type well by choice, maybe handwriting and speech input options become even more valuable. At least it favors offering multimodal interfaces.

5.4.2 Speech Recognition

Speech recognition brings a whole new dimension to the user interface, where the ultimate and complex goal is to have the computer understand natural dialogue in the user's primary language. The near future involves speech commands (predefined commands the user must learn), dictation (converting speech to text) and synthetic speech (text to speech). Speaker independent systems are command systems of very limited vocabulary, while systems that allow natural language are speaker dependent. In the latter, the user is initially guided through a training process where speech patterns are sampled so the system can learn to recognize patterns and inflections in the individual speaker's voice. Words and sentences are then digitally represented as sequences and can be identified by finding matches in a wordbank.

Speech recognition in Norwegian is still in its infancy. Essential for progress is to complete a Norwegian wordbank. Gathering and analyzing such data is expensive, especially for Norwegian which has two versions of the written language [63]. Another challenge is the widespread use of strong dialects among the population; most people have a spoken language that is different from the written one. The Nordic Centre for Speech Technology (NST) in Voss was prioritized financially by the government for several years, but was unable to produce satisfying results. Thus a speech interface in Norwegian was not available for this study, but it is seen as very useful for hospitals both for speech commands and dictation. A speech interface in a foreign language was not considered as that was seen as bad usability.

5.4.3 Gesture Recognition

With most handheld computers, the stylus is used as a replacement for the keyboard and the mouse of stationary computers. Beyond these features is using the pen to draw gestures that the computer can recognize as commands, thus further increasing efficiency and usability.

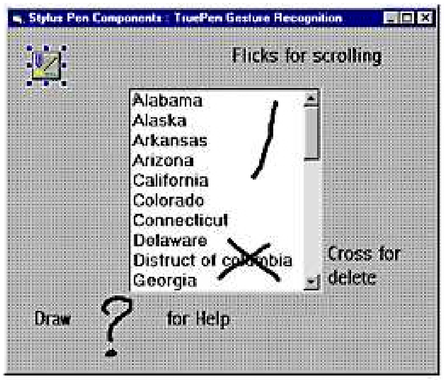

Fig.5.11: Gesture Recognition exampled by TruePen.

TruePen [64] (see fig. 5.11) uses a couple of common examples: to “erase” a word, use the stylus to draw a line through the word or make an “X” over it. To summon a “Help” box, simply draw a question mark on the screen and the box appears. To get to the next screen quickly, draw a small line from right to left anywhere on the screen, as if turning a page in a book. TruePen claims there are several advantages to gesture commands:

- they are intuitive and thus easier to remember than other types.
- they are efficient as they can replace two or more commands.
- they unclutter the screen as most buttons, menus and scroll bars fall out of use.

5.5 THE PHYSICAL INTERFACE OF THE MOBILE DEVICE

For this project the minds were set on a PDA. The desire was a small handheld that would fit in a pocket when not in use so it could always be carried along, and at the same time offer functionality that is considered valuable to the users. The key is usefulness and usability in every aspect, and not to expect users to lug it around for technology’s own sake. By exploring a PDA in a hospital ward, it would be possible to gage if these small handhelds can handle the type and amount of information that will make it useful there.

5.5.1 Personal Digital Assistants (PDAs)

PDAs are pocket-sized computers that are designed to be digital filofaxes, usually containing address books, calendars and options to make notes, along with internet surfing on some models. There are a number of types, but only two major operating systems: Windows CE is used, among others, by

Hewlett Packard, Casio, Compaq, Jornada, etc; Palm OS is used by Palm's own PDAs along with others such as Handspring Visor, TRG Pro and Sony's CLIE.

All PDAs can be seen as advanced prototypes that are put on the market without having found the mature form or application areas that lead to a widespread market adoption. It does not offer the functionality or usefulness to convince the conservative pragmatists (see p. 7). Dahlbom says:

> *Mobile computing is growing rapidly, but the technology has a long way to go yet. Mobile phones, PDAs(…) are developed and marketed, but their functionality is still rudimentary except for making telephone calls, playing games, and managing time* [1].

As many other technology innovations today, they are seemingly thrown into the market hoping users will find situations where they are especially suitable, or just grow dependent on the technology. PDAs are now mostly used as digital filofaxes by the business world, either for genuine technology interest or by trend. Thus finding new and useful application areas for this device is interesting.

Fig. 5.12: The COMPAQ iPAQ 3630 Pocket PC (in cradle in this picture).

Fig. 5.13: The Viewsonic Tablet PC V1100 featuring a 10.4'' screen. (Viewsonic.com)

The COMPAQ iPAQ 3630 (see figure 5.12) was chosen as a representative for handheld computers, it was the most advanced PDA on the market thus the natural choice. The COMPAQ iPAQ has 32MB memory, a 206 MHz Intel StrongARM processor, a 240x320 LCD color screen hosting over 4000 colors, a web browser and expansion-pack options for WLAN network connectivity readily available. In addition it is small, thin and light (ca. 13 cm x 8 cm x 1,6 cm and 170 grams), and also comes with an infrared port. With this hardware available, interactive prototypes could be made that would run on the iPaqs web browser, which was sufficient for this project. More technical data on the device is listed in appendix B.

5.5.2 Tablet PCs

Another interesting form factor to consider for hospitals, if PDAs should not suffice, are Tablet PCs. They have been issued by several companies, and are complete PCs which offer larger screens, more processor power and more memory, while at the same time upholding the mobility angle. Tablet computers come in a variety of form factors, from sleek slates to hybrids of laptops and screens. The Tablet PCs, however, entail trading off true mobility as the physical interface will exceed pocket size. They are very versatile. They function as a laptop in the office (parked in a docking station with keyboard and mouse), and can on the other hand be brought out as lightweight screen devices with WLAN network connectivity. Tablet PCs fill the metaphor of digital pen and paper with their solid handwriting recognition software. Typically the display is not a conventional touch screen, only movements of the magnetic field of the pen is understood as input. This allows the user to rest his hand on the display while writing as he would on a pad.

Tablet PCs are by Norman's theory (see p. 7) technology-driven, immature products. They rank low on market adoption so far, mostly due to lack of highly useful application areas. Like PDAs they can be seen as advanced prototypes testing the water. Viewsoniq's VT1100 (see figure 5.13) is an example of a wireless Tablet PC that could be suitable for larger amounts of information flow in a hospital (see also [65]).

5.6 Choice of Technology Solution to Explore in the Hospital Context

This chapter has reviewed several hardware technologies that are interesting for the hospital context. The most significant choice was the mobile device. Following that choice, an important aspect of all hardware was the possibility of combining it with a Personal Digital Assistant (PDA). Along with that the focus was on usefulness and the usability of the final choice. The goal was a system with a handheld, truly mobile device that would always accompany and support the user while wandering, ready for action.

For hardware the choice was the most advanced PDA available at the time of project. The Compaq iPaq 3630 has a 206 MHz Intel StrongARM processor, 32 MB RAM, 16 MB ROM and a 240x320 LCD color screen. The device runs the operating system Windows CE for Pocket PC with software such as Internet Explorer CE version installed, and also features an infrared port. Important for this choice was the available expansion pack for WLAN network connectivity using an expansion jacket and Orinoco 11 Mbps Ethernet card from Lucent Technologies. An airport base station from Apple with internal 10base-T Ethernet as access point has a range of 45 meters and capacity of 11 Mbps using the standard IEEE 802.11b (DSSS).

Of the wireless connectivity standards presented in section 5.2, WLAN technologies are believed to be best suited for hospitals. WLAN's strength is to provide high data rates over medium range distances (ideal for database access), while mobile cellular networks have their strength in wide area communication that require less data rates. Also important is that WLAN excludes commercial operators charging fees for use.

The network range and speed offered by Compaq iPaq 3630 with IEEE 802.11b WLAN expansion allows scenarios where users can experience all three coverage models (see figure 5.12) by distributing access points accordingly. The geographical area is limited, so making the entire hospital a hot-spot where users are always-on is possible. Another option that also might be sufficient is creating large zones covering all areas where patients, doctors and nurses meet and interact. It is believed that always-on is the future, and full coverage of patient rooms and hallways will be the model used in this project. This assumption will hopefully receive feedback during evaluations.

As discussed on p. 73, there will likely be a need for multiple wireless connectivity standards integrated into the hardware of mobile devices in WAN scenarios. This does not seem to apply for the device categories for hospital scenarios. WLAN and similar inexpensive, high data-rate, medium-range networks are likely to render inferior network standards redundant. WLAN also holds an upper hand to UMTS in this 3G scenario, underlining that WLAN is a realistic competitor to mobile cellular technologies in certain contexts.

The definition of context awareness (see p. 6) contains the phrase "often we don't know what contextual information is relevant, useful or even how to use it" [57]. This may be enlightened by testing users preferences in a specific context. Context will be tagged to information, then presented to users along with services. These tags enable context awareness, and focus is on creating an unobtrusive tag-reading situation, and also limit extra equipment necessary.

The tag technologies have a few things in common when considered for a hospital ward. They are designed with conceptual models where the tagged object or person is on the move while the readers are stationary. This situation is opposite, thus laying higher requirements on the form factor of the readers than what might be customary. Of the technologies presented in 5.2, Bluetooth was the best solution but not available in any PDAs when the decision was made. Then the choice was between RFID, IRID, iButton and barcodes. RFID and IRID are wireless solutions offering the important unobtrusive read-off situations, even though IRID tags might give brief problems at times with the line-of-sight limitation. Of these only IRID offered a reader integrated into a mobile device rather than extra equipment. RFID was seen as being a better technology than IRID, but having an integrated reader was very important to avoid strapping the users full of equipment. Testing other technologies would definitely be interesting.

Inspired by the iButtons patient bracelet (figure 4.9) and Want et al.[58], the decision was to prototype a system where patients are identified through a tag on the patient bracelet, and rooms are identified through tags on doorways. With this the usefulness of context awareness could be explored both through patient ID and location ID, while using them as portals to information. It is important to note that this not a test of tag technology, but rather whether users *lik*e or find context information *useful*, in addition to effective.

The choice of the handheld device also decided what input methods were available. The Compaq iPaq 3630 did not offer high level interaction such as gesture control. Handwriting recognition was offered, but only in limited applications. The Internet Explorer CE was desired as application holder, which was not one of them. Trying to expand handwriting recognition into a prototype would make a very advanced prototype early on. A speech interface was not available, besides short recordings without speech processing. It is believed, however, that both handwriting and speech interfaces are especially essential for future interaction styles for this context, and that gestural commands are likewise very useful on such keyboard-less devices with limited screens. Three main input methods were chosen for exploration: the stylus for navigation and selection (point and click on the touch sensitive screen), and for text input the virtual keyboard and an add-on portable keyboard would be compared.

CHAPTER 6

Experiments and Results

This chapter takes the conclusions from chapters 3, 4, and 5, and combines them to carry out the experiments of the case study. Chapter 3 concluded on research methodology and approach, the field study in chapter 4 recommended tasks to include in prototyping, and chapter 5 concluded on choice of hardware to explore. The first evaluation would preferably have been a paper mock-up test along with a workshop to design scenarios, but a compromise was made by having a focus group. This work enabled the design of a more advanced prototype, fitted for evaluation with a usability test. Each evaluation lays out how the research method was adopted to the situation, analyzes the test results, and concludes with recommendations for redesign. These recommendations are summaries of what was learned from the evaluations, thus based on empirical evidence. The first prototype only concerns software (screen designs), while the second prototype is a solution of both hardware and software.

6.1 PROTOTYPE 1

A rapid prototype was built using HTML, creating a series of web pages fitted to the screen of the iPaq to avoid scrolling as far as possible. The information included to constitute tasks is modelled from actual paper forms that were in use at the hospital ward to accomplish the tasks. The purpose of the prototype was to communicate ideas and help collect feedback regarding tasks, work processes, and screen designs. The prototype was horizontal with little interactivity behind buttons—intended to be just enough to explore initial concepts.

6.1.1 Choice of Tasks and Services

The tasks and services modelled in prototype 1 were:

View current patient info

- basic patient information
- summary of last visitation
- summary of symptoms
- graph (blood pressure, pulse, temp.)
- patients test results

Tests

- make requisitions
- view test results

Medications

- view current medical treatments (type/ dosage/ frequency)
- adjust medical treatments (type/ dosage/ frequency)(add and discontinue treatments)

Biometrical readings

- enter blood pressure, pulse, and temperature readings

User Views

- view own task list (ToDo)
- view list of patients in the ward
- view all new test results of the ward
- current patient (context information)

6.1.2 Screen Designs (GUIs)

The system was intended to run as a local area website, so the prototype was designed with the internet browser metaphor, i.e. links are underlined. Navigation is attained by clicking links. A navigational shortcut with the "K" button was included, which illustrated what it would be like to receive information from the context (context awareness). Choosing the K would bring the user to the patient pages of the nearby patient(s).

The prototype had two menus—one main menu that would always stay available, and one patient-menu which would be available while working on one specific patient. The main menu was designed to lay on top, while the patient menu was a navigation box at the bottom, to keep them apart. The main menu is related to the user as a healthcare professional. The two menus are intended to help navigation and make sure the user does not get lost when backtracking. The patient menu is also a physical statement telling the user he is "on" a patient (inside a patient's file). Figure 6.1 sketches the menus and the corresponding information:

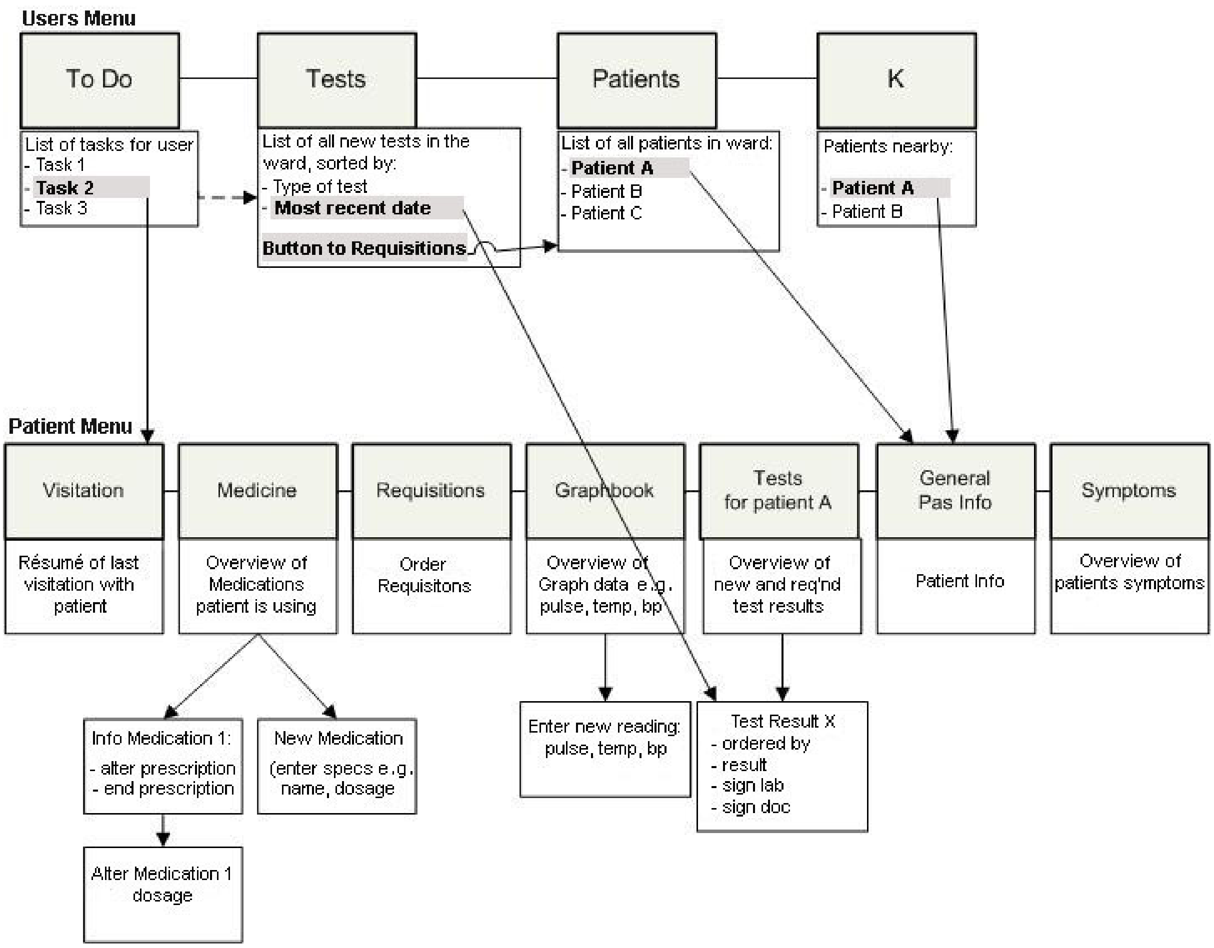

Fig. 6.1: Navigation sketch of Prototype 1.

This horizontal prototype only has two interactive features, Medicine and Graph book. Here the user can alter medicinal treatments and enter readings of pulse, temperature and blood pressure. The top menu (user menu) offers two portals to patient records: *Patients* and *K*. The *ToDo* service can entail different types of tasks, but if a task regarding a patient is chosen, this will take the user to that specific patient's record to see the summary of last visitation. Viewing test results of patients has two entrances then—also test results for the ward where the user may choose one and with that be taken to this patient's record to see Test results. The actual *Test results* page is a very basic model of what can be. Test requisitions were not modelled, as there was not enough background information available to make a decent proposal beyond horizontal level. Also entering visitation notes, changing patient

Fig. 6.2: ToDo – Lists tasks for the user.

Fig. 6.3: Patients – Lists patients in the ward.

Fig: 6.4: Tests – Lists all new tests.

Fig. 6.5: Tests – Lists blood tests sorted by date.

information and symptoms was skipped below horizontal level, as it was made a point to verify the concept itself before extending the prototype vertically. The prototype assumes digital signatures to be legal, for example when a doctor signs for having seen test results.

Figures 6.2-6.5 show the contents of the main menu. This information is related to the ward, thus the patient menu is not available. The next screen designs are from the patient-side of the system, see complete collection of screen designs in appendix C. The box of links at the bottom is the patient menu. “Puls m/k” (see fig. 6.6) refers to morning and evening readings, dates have different colors to easier see that each date owns two readings. The screen design only fits three days, while the three previous and three next days can be seen through the menu under. This is a compromise between designing for a small screen while needing to visualize larger amounts of information.

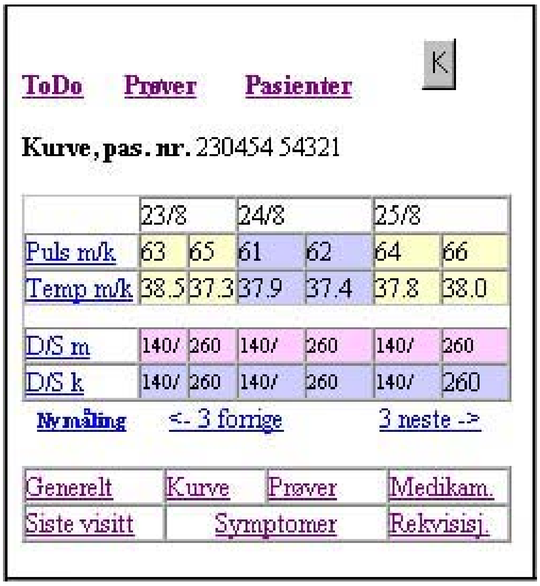

Fig. 6.6: Graph book.

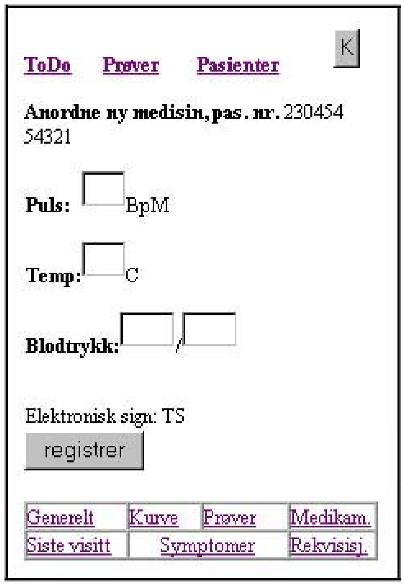

Fig. 6.7: New reading entry.

6.1.3 Main Test Objectives

Aside from designing screens for a prototype, the main test objectives of the evaluation were also decided. The second research question pertains to the hardware of the device, and its ability to support the user in his work. Chapter 3 stated that test objectives would be specified further into the project when more knowledge of the setting and the device was established. The following five test objectives were chosen to represent essential criteria for the overall usability of PDAs in hospitals:

- **Data entry:** Does entering text with a stylus on virtual keyboard work here? How about a physical keyboard? Is speech input the only alternative? Are there better alternatives?
- **Data presentation:** How does retrieving and presenting data work out? What volumes can efficiently be presented? How does the patient record work on the small screen?
- **Navigation:** Is it possible to navigate without losing the overview in such a small graphical interface, considering the possible amounts of information?
- **Handling the device:** How practical is it to drag the hardware around in their work situation? From room to room? Should the users keep it in their coats? The keyboard also? Will bringing the mobile device be an obstruction in their work? Is the PDA really *mobile* in this situation?
- **General Suitability:** How well-suited is the mobile device at making work processes more efficient, integrated and synchronized regarding test results, requisitions, and others?

6.2 EVALUATION: FOCUS GROUP

The focus group was adjusted to fit the situation where the aim was to discuss scenarios, evaluate paper screen designs, and have a group brainstorming session to elicit suggestions.

6.2.1 Methodology

The goal of the focus group was to harvest feedback on initial design concepts and the choice of tasks, basically a quick-and-dirty evaluation of ideas. The evaluation was held at a meeting room in the Rheumatology Ward, St. Olav's Hospital.

Participants

The focus group consisted of one doctor and two nurses from the Rheumatology Ward, of which the doctor was the expert user. They all had 5+ years of experience at this ward.

Conducting the Evaluation

The focus group brought users with common experiences together to discuss proposals between them, and through that valuable feedback and new ideas surfaced. A rigid time schedule was created to assure the four hours with the participants would be used as efficiently as possible, see appendix D-1. Three separate sections were prepared: one to introduce and discuss scenarios (1 hour), the next to evaluate screen designs (1 hour 15 min), and the last an unbounded brainstorming session where the participants could outline any functionality their heart desired (30 min). 30 minutes were left at the end for topics not finished in sections, and the rest of the time would be introduction, break, and wrapup. A scenario was created to begin scenario-discussions (see appendix D-3), this was part of preparations before a later usability test.

The prototype was presented as big prints of an iPaq on A3 paper, with screen images glued into the iPaq screens. These screen images were meant to elicit discussions. The participants were encouraged to write and draw on the paper screen designs, and to ensure that one person would not dominate the group (to catch every comment and idea), a post-it system was created. Green post-its to comment on good things, yellow post-its to comment on what was not so good, and pink post-its to comment on things that were incorrect. Before discussions started, the iPaq which was intended to host the screen designs was shown. Data was collected as comments on post-its, writings on screen designs, along with evaluators taking notes during the session. Audio was taped in the background for back-up. After the session the comments where written up into a more complete evaluation.

Some sketches of possible use situations were also prepared to help the participants form a working mental model of the system, thus better understand the topic of discussion:

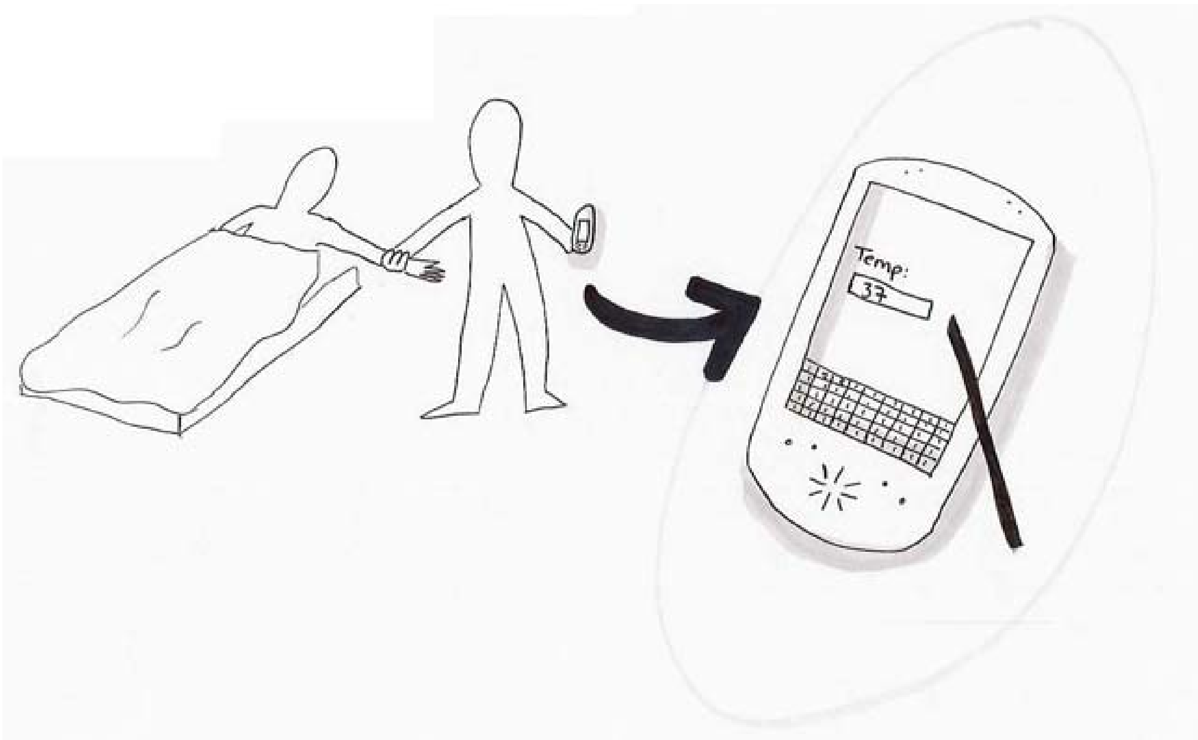

Fig. 6.8: Nurse takes temperature of a patient, enters the result directly into his PDA.

Fig. 6.9: Patient room equipped with docking station and keyboard for entering larger amounts of information.

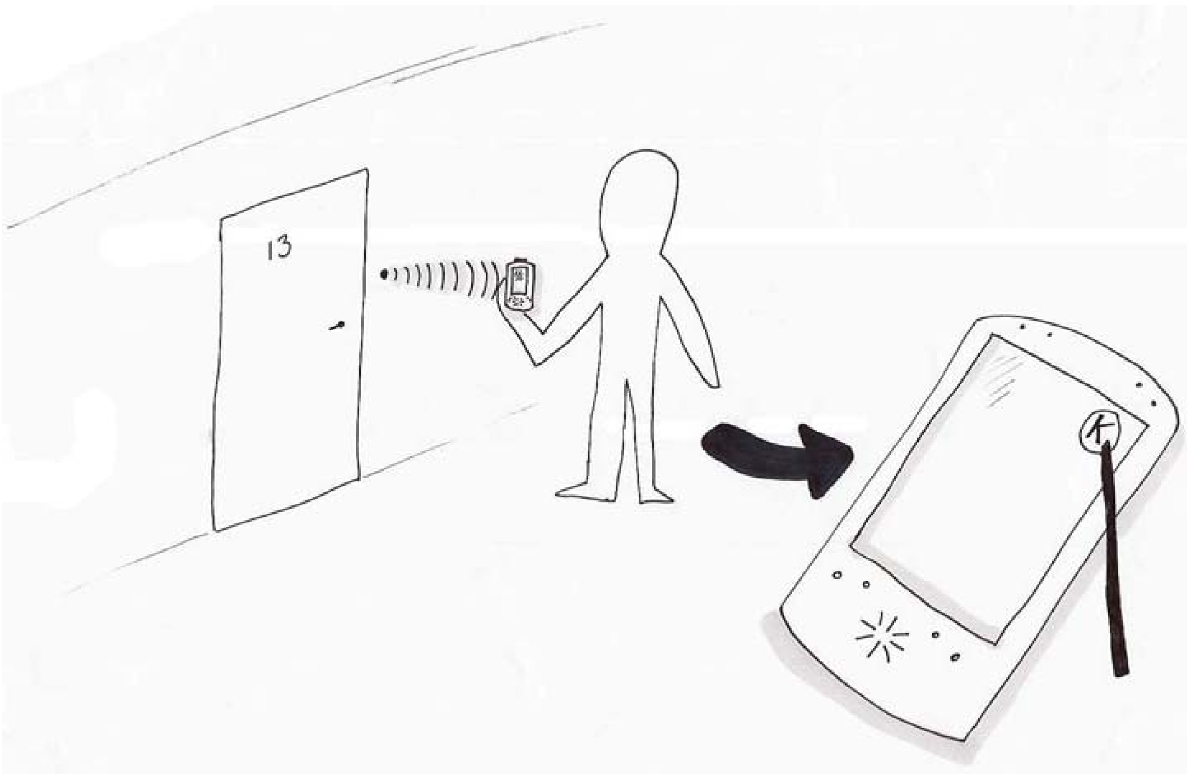

Fig. 6.10: Context Awareness: User is receiving location information.

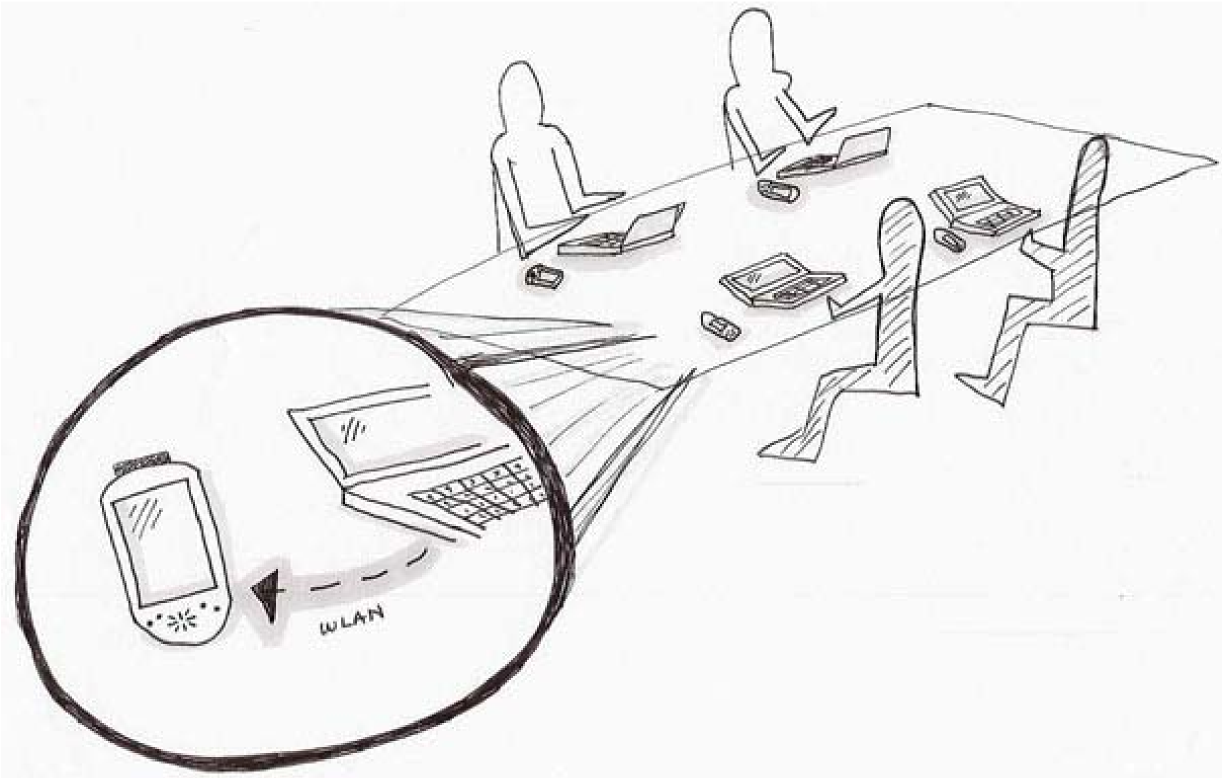

Fig. 6.11: Pre-visitation meeting: Each user has a laptop while stationary, their PDA is updated with any relevant information automatically and ready to go.

6.2.2 Analysis

The participants of the focus group proved to be enthusiastic and creative, and the group had a good size for discussions. Everybody got to speak, and there were no awkward pauses. The structured agenda was abandoned as discussions flourished, the participants were allowed to comment and discuss freely towards the end, just making sure there was time to focus on each of the screen images

Fig. 6.12: A3-sized iPaq screen designs.

Fig. 6.13: Focus Group.

and popping in questions now and then. After the session the comments and notes were written up into a more complete form. Occasionally the participants had to be stalled and asked to write things down, and not just discuss. The post-its color scheme was somewhat confusing, it probably would have been enough with one type as most comments can be made out as positives or negatives when reading them.

Overall Impressions

The tasks and services that created the most enthusiasm was entering biometric readings for the nurses and creating requisitions for the doctors, along with the ToDo work list. The nurses claimed that even if the device had as a sole function to enter biometric readings, that would be justifiable to develop the prototype into a system, as this chore takes so much of their time.

Menu

- The design concept of the menus is understood, although the concept can still be clarified with better visual cues. The information is mainly top-level, which gives the user a good overview. The focus group suggested to use archive tabs as metaphor on the patient menu, and move it to the right side as a sidebar.
- The group discussed the top menu (User's menu) headers *ToDo*, *Tests*, and *Patients*, and finally suggested the more clarifying *My ToDo*, *My Patients* and *Wards Patients*. Having a list of all the wards' patients easily accessible is seen to also function as a check against missing out on someone when creating one's ToDo.
- The design gives no cues where the user is in the menu system/ hierarchy, besides getting "visited"—colored links after using them. Visible cues would make it harder to get lost or confused.
- Summary of Symptoms is not valuable to have in the design—that function should be left out.
- The "K" button and the value of context awareness were not communicated well with this prototype. It seems necessary with more visibility in the design, and possibly a new concept.

Roles

- Prototype 1 experimented by using the roles Nurse – Assistant Doctor – Chief Doctor as the impression was that they had different agendas. The focus group strongly suggested using *Nurse* and *Doctor* as roles in the design.
- The work list function (ToDo) must be dependent on title, not person. It was made so that when Debra Doctor logged on, she would get Debra's work list, not Assistant doctor 1's work list. If Debra is having a day off, who will read her patients test results? A patient's care is not dependent on individual health professionals.

View patient information

- The identification of the patient is not good (p-number string). Using room number and name is better since that is what they work by, thus the identification would correspond to their mental model.
- The group came up with the idea to combine the text-based list of patients with symbols, in other words to *iconize* the patients medical history in one screen to visualize cues for instant knowledge without effort. They mentioned iconizing the pre-visit list under ToDo as desired. The group was very creative and enthusiastic on how to improve the ToDo function. The icons would communicate knowledge like: gender; patient has a problem and need to be seen; progress of total stay; etc. They made up the string **618II Per Jensen –62 INFO O P** meaning "patient is in room 618 bed II(2) 62 years old, wants a conversation with a doctor, has undergone surgery, and has a new abnormal test result" as an example.

Tests

- Being able to make requisitions while standing next to the patient's bed is regarded as very useful. However, there should be two entries for making requisitions: main menu –> requisition, and test result –> requisition. Sometimes reading a result initiates ordering another, for example seeing an x-ray may require another x-ray to be taken in 5 days.
- The middle layer of navigation should be cut for test results. Fresh test results are most interesting, and should be available "right there."
- Tests should get rated before they are shown as a test result, either manually by the test analyzer in lab, or as a hard-coded feature in the system. The group suggested H and L as options for rating– High and Low. This rating can be flagged next to the test result. Even "today's abnormal tests" would suffice. Tests are either *normal* or *not normal*. A H-rating can be flagged next to the test result on the correct recipient's ToDo list for viewing. Normal tests are not really interesting for doctors.

Medications

- Prototype 1 had functionality for administering medications. The doctor recommended dropping that feature, as the need for overview and information is just much too big for that screen. He explained that in the Rheumatology Ward, two nurses sign for the medications put into a dosage box for each patient. Patients are then given the dosage box, and are responsible for taking the medications. If the patient is unfit to make sure medications are taken, the nurses will distribute medications at appropriate times. The patient documents the intake of medications himself in his available careplan, and takes responsibility for own health. The nurse then has a position of teaching and encouraging healing. In other wards the nurses distribute medications in cups to each patient four times per twenty-four hour period.

Biometrical readings:

- The nurses said it is very positive to be able to enter raw data like pulse, temperature and blood pressure in an easy fashion right next to the patient. That would save them time and double work.
- There were some instances of wrong terminology. *Biometrics* is a word they use for biological values that are not interpreted, like pulse and temperature. In prototype 1 those measurements were put under Graph, and that was not entirely correct. They are established actions, and should stay that way in the conceptual model, too.

Suggestions:

- The focus group suggested to include parts of the nurse documentation, namely the care plan. There is one care plan per problem, and each patient usually have several care plans. The nurse documentation is the legally binding part of the patient record pertaining to nurse work, and is the nurse process to document their work. They give care, and evaluate problems constantly. The nurse documentation is updated three times a day, at every new shift.
- The care plan lists problems and resources, deals with symptoms and involves receiving and following up on information from doctor and patient. The evaluations of the care plans helps in diagnostic explorations, and when the doctors write epicrises they usually use the nurse documentation as a foundation due to its thoroughness. Benefits to having short versions of care plans implemented on a mobile device is to possibly save time for nurses, and also save time on shift reports – the information will be right there for the next nurse regarding her patients' pending problems and the fixes suggested and/ or applied for each problem.
- The focus group suggested a messaging system for the doctors and nurses to enhance collaboration. Example: a doctor can send a message to a nurse that is not there right then – send to her *ToDo* that something is ready for her (a note), or send to own ToDo list to appear 3 days later.

Other

- The focus group was curious how the PDA would get attention, as pagers and beepers are generally seen as disturbances. Does it rely on the doctor/ nurse to check it often (leave control to the user), or does it call out for attention with sounds or buzzes? In real life, if it is a hassle it may be left behind to get peace and quiet. A PDA can add to stress levels if the ward is contaminated with beeps and buzzes that insists on instant attention.

6.2.3 Recommendations for Redesign

Some of the issues pointed out in the analysis required simple adjustments, such as making the biometric names more accurate. Others should go through the thinkbox and be redesigned completely.

Roles

- The user roles "Doctor" and "Nurse" should suffice, although with identifiers such as "Nurse 1" so that users can choose to log on to that specific nurse role. The other option is a complete separation of interfaces/ systems between nurses and doctors. One system with two roles should be explored further in the next prototype before making any radical separation decision.
- The message system is a very complex project, although useful. However, the next prototype should not advance too rapidly, so this feature should be held off until later.
- The administration of medications was seen as too big for a PDA's screen. Digitalizing administration of medications is likely useful and necessary, but should not be prioritized in the next version prototype for the reason above.
- All the medications to be distributed are prepared as dosages and documented in the medications room, hence a stationary computer there should be able to service that function sufficiently.
- The service "Summary of Symptoms" should be abandoned completely in the redesign.
- Care plans should be included in the next prototype as a trial. Examples of the paper forms they work with were provided to model contents from.
- Iconizing the patient list is a very good idea, and very friendly to the small screen of an iPaq. That may work well for PDAs which have such limited screen real estate. A picture is known to say a thousand words, and that means more information per pixel when using icons rather than text.

Menu

- The context-awareness function "K" did not work out at all. In the redesign, the graphics should be changed to a better visual representation, and the concept explained better. As this is unfamiliar ground, the latter is likely the biggest problem. Consequently there should not be invested a lot of time designing a super-icon that single-handedly has the job of unveiling the mystery.
- The focus group suggested a change of the menu concept, and this should be done with attention to designing a good metaphor. Using "archive tabs" as a metaphor on the patient menu is worth a try, also the recommendation from the group to position this as a sidebar to the right. One great advantage with this is that the screen would not be limited downwards. Most important here is to keep the "Users menu" and "Patients menu" in a working conceptual model that leaves no room for confusion.
- The design of the menu hierarchy should have visual cues to clarify where the user is at all times.
- The focus group, mainly the doctor, recommended these items in the patient menu:

- Main patient page
- Lab results
- Other results (x-ray, physical therapy etc.)
- Blood pressure/ Pulse/ Temperature
- Liquid balance

Tests

- The test requiration page was empty in the first prototype (just included horizontally), and should be developed for the redesign as the task was encouraged. Examples of requisition forms were provided to model from. There is one form for each lab, virtually an 'ocean' of forms. Each form has a lot of vital information that must be included, ranging from:

  Pathology lab: is the object in formaldehyde or saltwater?
  Angiographics: is the patient on blood-thinning medication?
  Abdominal x-ray: is the patient pregnant?

  These type of questions have their own cross-off field in the paper form which cannot be omitted. In addition there are major text-input fields stating numerous details, for example, *reason for doing the test* and *urgency*. The doctor in the focus group said, "at least you should make ordering blood tests on the PDA, that would be a very useful feature and we do it all the time." Ergo, blood test requisition should be a task in the redesign of prototype.
- Rating the test results is a very good idea, and fits nicely into the family of desired functionalities where the system assists the doctor. This should not be very advanced in the next prototype, rather give a taste of what it could be like to first try it out. However, it can be risky to opt for only getting "*not normal*" test results back from the lab, considering the problems they have with disappearing test results. At least until that problem is solved, 36 ordered tests should yield 36 test results for control.

6.3 PROTOTYPE 2

The handheld device chosen for this prototype was the Compaq iPaq 3630, as it was the most advanced model available on the market (see chapter 5 p. 81).

6.3.1 Choice of Tasks and Services

The tasks and services modelled in prototype 2 were:

View current patient information

- basic patient information
- summary of last visitation
- lab results
- other results (physical therapy, etc.)
- liquid balance
- graph of biometrics (blood pressure, pulse, temperature)
- medications (horizontal presence, no functionality)

Nurse documentation

- create and view nurse documentation on patient
- create, view, and evaluate nurse care plans

Tests

- test requirations
- view test results (flag abnormal test results that need attention on user's task list)

Biometrical readings

- enter biometric readings (blood pressure, pulse, temperature)

User Views

- my patients
- my tasks (ToDo)
- wards patients
- current patient (context information)

6.3.2 Hardware: Platform and Solution

The Compaq iPaq 3630 had a 206 MHz Intel StrongARM processor, 32 MB RAM, 16 MB ROM, 240x320 LCD color screen, expansion jacket and Orinoco 11 Mbps Ethernet card from Lucent Technologies (see appendix B for further specification). The access point was an AirPort base station from Apple with internal 10base-T Ethernet. The base station offered a range of 45 meters and capacity of 11 Mbps with the standards IEEE 802.11 HR DSSS and IEEE 802.11 DSSS. A Targus

Stowaway portable keyboard was used for data entry, in addition to the stylus selecting characters on the touch-sensitive screen, displaying a virtual keyboard. The PDA ran the operating system Windows CE for Pocket PC with software such as Internet Explorer CE-version installed.

The IE browser was chosen for a client/ server-system between the electronic patient record on the iPaq and a serverside-script in PHP on the university's web server, which ran SQL queries towards a MySQL database. This script then sent dynamic information back to iPaq based on the information in the database. The point of this was to store all patient record data in a central database, and only use the iPaq for sending and receiving information using HTTP and TCP/IP through a wireless local area network (WLAN), and further over the internet (WAN). The web server sent HTML to the iPaq, and every user was logged using variables in files (cookies), which were created and stored locally. Using cookies allowed to present information tailored to the individual user. Passing patient information over the internet was done to run the prototypes off-campus, in a real version the hospital would have its own web server with a central database, and the whole system would run in-house over WLAN.

The Compaq iPaq could detect infrared light (IR) through one of the serial ports, which enabled transfer of IDstrings. This was key to attaining context awareness with this device. However, IR requires close to free line-of-sight between sender and receiver, which opens up for potential problems such as aiming wrong, and a signal being blocked. The iPaq 3630 does not support bluetooth, which has no such limitation.

Context awareness was simulated in this prototype to test the concept before creating a larger hardware solution. Jscript and information in the HTML code sent from the server was used to simulate, which made it possible to change context manually during the test. The patients were propped with a toy bracelet on their wrist, physically portraying a patient bracelet with an IR tag. The door frame outside the patient room was fitted with a black box with a red blinking signal (LED) to imitate IR light being sent out as regular pulses (see figure 6.10 p. 91).

Access control was also simulated in the prototype, more complex security issues have not been addressed. A log-on name and password was made for all the test users, and they could log on with any role without restrictions. Access control was decided to be an issue best saved for later.
The concept of automatic digital signatures was kept from the first prototype, as there had not been a discussion on how to improve this with users. Digital signatures open up many issues, e.g. that the signing of legal documents should not be too automated; it must keep the nature of a willful action.

6.3.3 Screen Designs (GUIs)

Patient lists were combined with the icons below to provide instant knowledge of medical history and needs (iconizing medical history):

- **!** Patient has a *Clinical problem* that needs attention
- **?** Patient wants *Information* regarding a clinical problem
- M Patient has a *Medications* problem
- O Patient has had *surgery* (**O**peration)
- P There is a *new abnormal test result* from a lab on the patient (**P**røveresultat)

The prototype serviced two main functions for the user: On one hand, to be an assistant in the daily work, on the other hand to be an electronic patient record.

Figure 6.10 shows the iconization of patient history suggested by the focus group. Figure 6.11 shows the user's list of tasks to attend to today, the ToDo. Choosing one patient from Morning Visitation (Morgenvisitt) takes the user to a visitation summary (see figure 6.12), where reason for last visitation is stated. Other tasks (Andre oppgaver) on My ToDo relates to problems patients experience, which is the basis for the icons next to patients in figure 6.10. Test results and medicinal problems in need of attention are flagged to be addressed during Morning Visitation. Figure 6.13 displays Context Information, in this case awareness of location produces a list of patients in room 620.

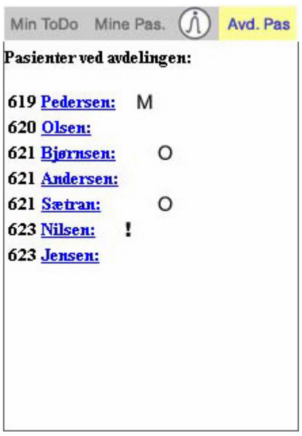

Fig. 6.10: Wards Patients.

Fig. 6.11: My ToDo.

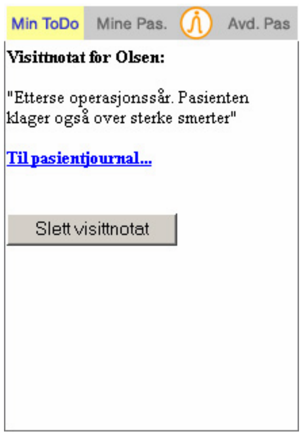

Fig. 6.12: Visitation note.

Fig: 6.13: Context info.

The color codes grey, pale yellow and blue were selected for the user menu. Grey is a passive color, blue is semi-passive, and yellow is active (see figure 6.14). The non-selected state of menu options has two shades of grey, while the selected state is the brighter yellow background with blue fonts. This is intended to afford visual cues on where the user is, as discussed above. The passive grey color is a common color symbol of inactive state. This menu design allows for skipping headers on each page, thus saving screen space and making the interface visually less cluttered with objects.

Fig. 6.14: The user menu (top)

The context button is fitted with an icon that resembles a circled person, to symbolize the action of finding a patient. Figure 6.15 shows context information outside of range—choosing a patient is not available. Figure 6.16 shows context information within range—patient is available, but not selected. Figure 6.17 shows the menu option selected. Initially the available/ not selected state (Figure 6.16) of the context button was designed with grey background and blue icon to conform to the overall color scheme, but soon it was decided that it was too invisible, and the brighter grey/orange solution was selected.

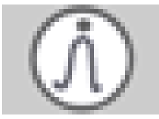

Fig. 6.15: Outside range

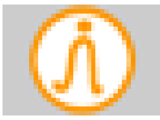

Fig. 6.16: Inside range

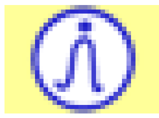

Fig. 6.17: Selected

The patient menu is designed as the suggested archive-tabs, with a different color on each tab and its corresponding page to offer visual cues of the conceptual model. Figure 6.18 depicts how the Users menu and the Patients menu correspond, and the test will show if the users understand the conceptual model of it. Note how all the buttons in the Users menu on top shows inactive state once a specific patient is chosen (except if context information is within range, figure 6.16), and the focus is shifted from assisting the user to entering a patient record. Making the user menu options inactive is meant to communicate this change of focus visually. The user will not get lost as there is no backtracking within navigation, all the menu options are available at all times. The screen interface is a bit longer than the height of the PDA screen; the choice was between making the menu buttons smaller, or accept a tiny bit of scrolling (half of the bottom tab is out of screen (Væske)). Visible buttons were seen as more valuable, so the scrolling was accepted.

When the user chooses a specific patient and enters the electronic patient record, he is by default taken to the Main patient page (Hoved), as shown in figure 6.18. It states basic information about the patient like name, address, phone-number, next of kin, among others.

Fig. 6.18: The two menus each inhabit a margin of the screen.

From the Main page the user can enter the nurse documentation, see figures 6.20 and 6.21. The nurse documentation in use is extensive, so an excerpt of actual forms was made. Still, it was necessary to make two screens to cover the basic information. This was seen as a better solution than considerable scrolling, as only one screen would be quite long (when trying the PDA it gave a negative impression of the scroll function, the slidebar is tiny and requires very fine motor skills of the hand to avoid having the pen just slide off). Creating the nurse documentation is done through a row of screens where text is entered for different "fields," this row is set up as a wizard that guides the user through the process.

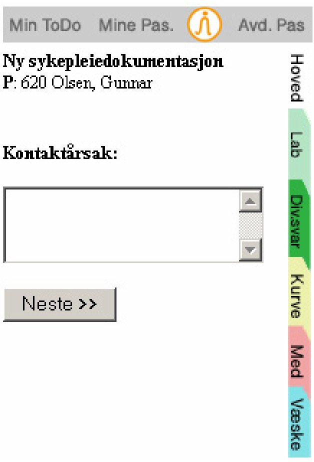

Fig. 6.19: Wizard.

Fig. 6.20: Nurse doc part 1.

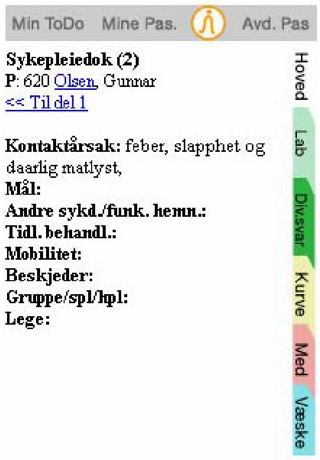

Fig. 6.21: Nurse doc part 2.

See figure 6.19 for an example, where figures 6.20 and 6.21 are the result. Objects such as buttons and text fields are placed on the upper half of the screen in the wizard, so when the virtual keyboard pops up it will not cover these objects.

Fig. 6.22: Evaluate careplan.

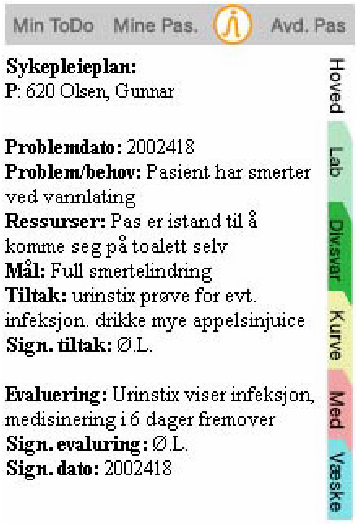

Fig. 6.23: Careplan evaluated.

The careplans to review problems are created in the same manner, where a wizard of linked screens guides the user through the system. Figure 6.23 shows the outcome where text fields have harvested the information under each header. Each careplan is later evaluated with wizards collecting status information. Figure 6.22 shows a list of all problems of a specific patient, listed with a red or green *E* next to them, where the red E symbolizes "evaluation due" and green E symbolizes "evaluation completed." An explanation to these icons is put into the interface, although the concept is good, the design might be less than intuitive. The users may need to learn it.

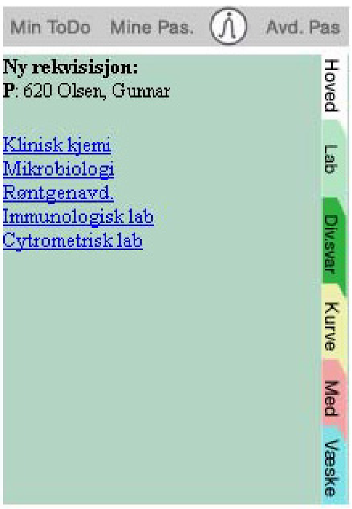

Fig. 6.24: New test – list of Labs.

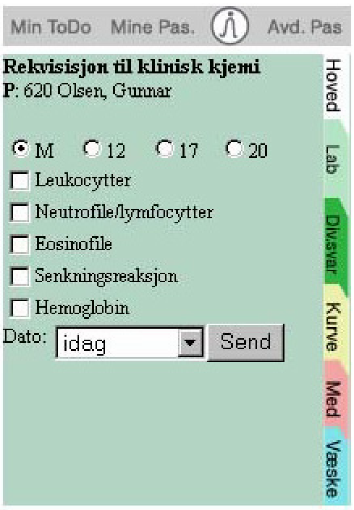

Fig. 6.25: New test – choosing test from clinical chem lab.

Fig. 6.26: Test result is High.

The *Lab screen* offers both to order tests and to view new test results. To order a new test, the user first chooses which lab to order from (see figure 6.24), and then see a menu of which tests the chosen lab offers (see figure 6.25, Clinical Chemistry Lab). The test result is not shown as the usual number (count), but as ratings High, Low, or Normal (see figure 6.26).

The user also chooses *date* and *round* (morning, midday, afternoon, evening) the test should be taken. Date is chosen from a roll-down menu, with “today,” “tomorrow,” “in 2 days,” “in 3 days” …“in 7 days,” instead of actual dates, as it is thought to be closer to how the users think. The computer then establishes which date (e.g. 3 days from now). The user receives “test has been sent” as feedback after ordering a test, which is a simulation of a probable feedback. The feedback is default, and does not discriminate whether input was left out or wrong.

The *Graph* (Kurve) shows the patient’s graph of pulse and temperature. This graph is a still picture posing as a real graph (see fig. 6.27). For this prototype it was not seen as necessary to spend a lot of time developing a real graph where the lines are visibly changing when new information is entered. The user can also enter new biometric readings from this screen: pulse, temperature and blood pressure. This is the same design concept as prototype 1, as the focus group did not give any feedback that it should be changed.

Patient identification is an important issue, with potential dangerous implications for the patient if poorly designed. Figure 6.27 shows the new design; **P: 620 Olsen, Gunnar** meaning *“Patient is: room number + name”* which corresponds to current work practices. A complete set of screen designs can be found in appendix E.

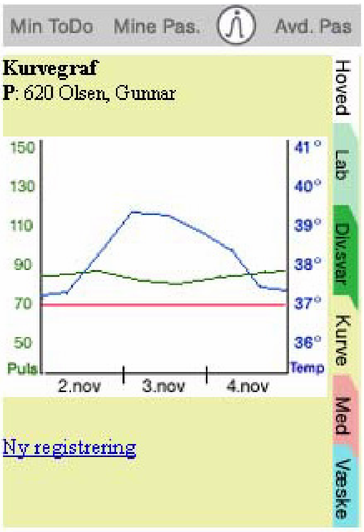

Fig. 6.27: Graph.

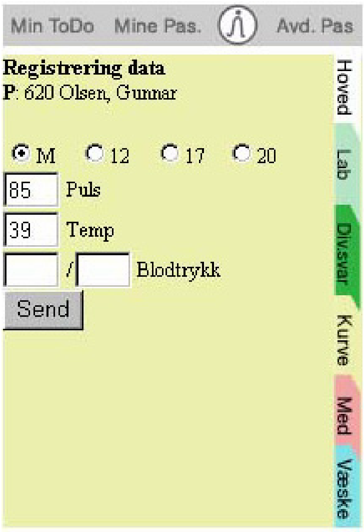

Fig. 6.28: Entering biometric data.

6.4 EVALUATION: USABILITY TEST

Standard procedures for usability testing are designed for stationary computer systems. Lindroth and Nilsson [46] says that applying the same methods to mobile devices might make the results irrelevant, since it fails to consider the context of use. Figure 6.29 shows Nielsen's description of a typical usability lab. The surrounding environment is less important for the success of tests in such a lab.

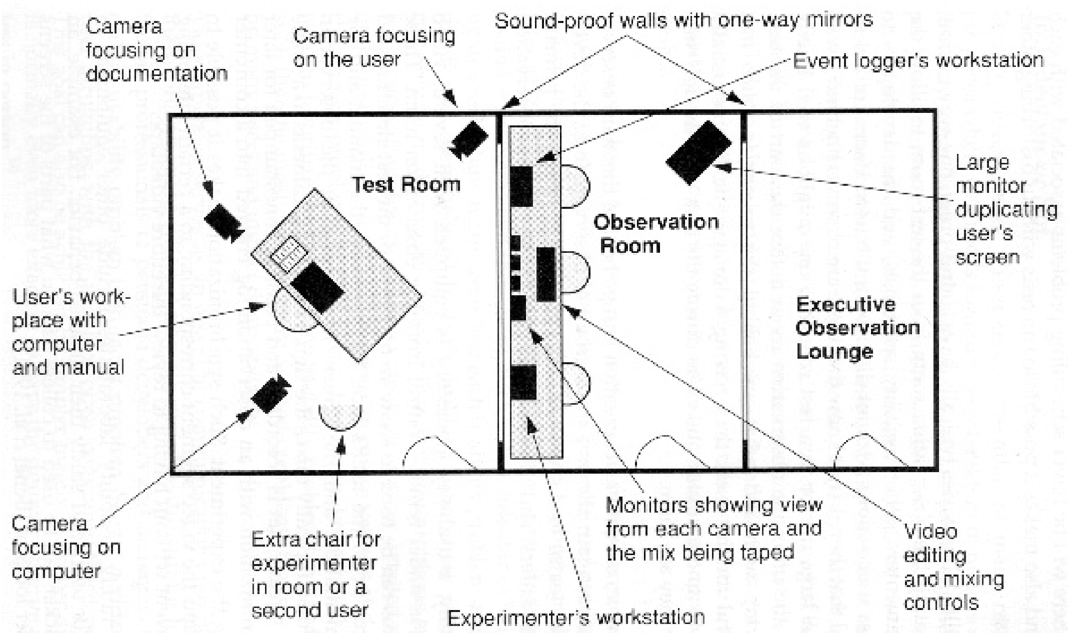

Fig. 6.29: Nielsen's model of a typical, usability lab floor plan [19:201].

This is usually not the case when testing handheld devices, and collecting the data brings forth a challenge. The user is mobile, and the environment is a factor that can influence how the handheld device is handled. Simultaneously, the interaction with the handheld device can influence how the user communicates and interacts with the world around. Mobility and interaction with the world then becomes two important dimensions of the usability test, along with the interaction with the handheld device. Thus, an ordinary usability test is not sufficient to look at all issues of mobile technology.

This has several practical consequences. During the test the environment should be far more realistic than what is common in stationary usability testing. The test incorporated role-play. The user should experience the scenario and environment around the test as realistic; the tasks will be similar to what is normal, and the user can to a great extent act like he usually does. Lindroth and Nilsson conclude their article by recommending some type of role-play where the user interacts with people that would be normal in that situation. They say role-play can be useful if the users do not have a strong mental model of the device, or when traditional methods lack awareness of the context.

6.4.1 Methodology

The goals with this test was to discover problems in screen designs, to test hardware equipment according to the main test objectives stated in 6.1.3, and to get feedback on the choice of tasks supported by the device.

Key Tasks

During the test the participants where asked to:

Doctors:

- Browse to a specific patient's "graph book" documentation from My ToDo
- Browse to a specific patient's "graph book" documentation through context information
- Order blood tests using stylus/virtual keyboard
- Check abnormal test result on My ToDo
- Mount iPaq on physical keyboard and test it

Nurses:

- Browse to a specific patient's "graph book" documentation through context information
- Mount iPaq on physical keyboard
- Establish new nurse record using physical keyboard for data input/ stylus for navigation
- Enter temperature and blood pressure with stylus/ virtual keyboard
- Establish careplan using physical keyboard for input/ stylus for navigation
- Discover alternative way to a specific patient's "graph book" documentation
- Evaluate problem listed on My ToDo using physical keyboard

Documenting the test

Ordinary usability tests focuses on the user's interaction with a stationary computer. Capturing the data is not a problem when the test user is also stationary. The interaction is logged using both a scan converter which converts the feed from the computer screen image to TV video, and cameras focusing on the user (e.g. log user expressions). The surrounding environment is less important for the success of the test.

The logging of the user's actions and reactions had to be fitted to the new mobile situation. The Compaq iPaq was controlled by a stylus that was physically pushed or slid over the screen. One could not follow the mousepointers movements as with a stationary computer. That ruled out the scan converter to register screen actions. Hesitations and searching would not be caught. A single stationary video camera that normally catches facial expressions and movements would be insufficient when the user is moving and turning around. This also applies to documenting the user's interaction with the environment. There are other demands of technical data collection equipment when testing handheld devices. Lindroth and Nilsson also found problems with traditional logging, and saw the need for creating new techniques.

Alternative ways to log the users interaction with the screen had to be found. It was decided that being in the same room as the user, watching the use of the device and the interaction with the patient through a handheld video camera, would be a better solution than literally burying the user in recording equipment, which probably would affect the users feel of the handheld device and create a false impression of the physical interface. This also allowed to alternate filming the test user and the environment. It would be essential to be very attentive while documenting the navigation, the test user's reactions, and the verbal protocol with one camera, hence the problem was moved away from the user and put unto the facilitators. If the user proved to be uncomfortable with a camera up close, the alternative would be to resort to taking notes on paper of the immediate reactions and impressions during the test. The verbal protocol would be a result of the classic *think-aloud* procedure; asking users to vocalize their thoughts, feelings, and opinions while interacting with the prototype during the test. Ultimately, there was opportunity to get the users subjective impressions in the interview afterwards, with a stationary camera for audio in the corner.

Facility

To build a realistic physical environment for the usability test, one of the rooms at an incubation center for research on health and IT in Trondheim was used. The room was furnished with beds, bed linens, and bed stands from the hospital nearby. Coats that the health workers wear daily were made available to help the users fall into the role. Appointments were made with a couple of fellow students to help out by playing the patient.

Participants

The users were 3 female nurses and 2 male doctors. Ideally there would have been at least 5 nurses and 5 doctors of both genders as test users, thus the recruits did not fill a predefined range of traits. There was no luxury of selection. Participants were recruited through the doctor contact (expert user), and through posters at, and a visit to, an institute of health science at NTNU, where several nurses were taking masters in health administration.

- Professional experience ranged from juniors (a resident doctor with 1,5 years experience and a nurse with 3 years experience) to seniors (one nurse with 13 years experience, another with 20 years experience, and a chief doctor) with leading roles in their wards.
- One nurse and one doctor (expert user) came from the Rheumatology ward.
- All participants expressed positive attitudes towards new technology in their workplace, as long as it improved rather than hindered their work..
- The participants were all in their 30s and 40s.

Conducting the Evaluation

A pilot test of the test procedure was held with a nurse the day before the test day. The procedure was done point by point, from welcoming the test user to saying good-bye. The purpose was to find flaws in the test design, and rehearse roles as well. After evaluating the test, several minor corrections were made regarding the practical procedure, conduction of the scenarios, and cosmetic changes of the prototype. The test design then had its final form, and the facilitators were better prepared for unforeseen events. The schedule was tight, hence points to skip if necessary were selected. Roles and responsibilities were decided, so at all times it was known who was responsible for various duties, for example, holding the camera, taking notes, be test leader, and so on.

For each test user care was taken to create an informal and relaxed atmosphere from the beginning. First the PDA was introduced, letting the users briefly see the interface and log on, while making sure not to reveal any of the functionality intended to get feedback on. The bracelet with the "IR tags" that the patient would be wearing was shown, and also the "IR pulse box" with red flashing light affixed by the door. Since the larger technical solution did not exist, it was explained how the bracelet and transmitter box would "send" information to the PDA, and the PDA "send" information to the database through the wireless connection in the room. A drawing was shown of the wireless connection (figure 6.10 p. 91), all of this in order to provide them with a somewhat working mental model of the imaginary system.

The users received an explanation that the test would be carried out as a role-play, where the user should pretend that all of the hardware parts were working together, with encouragement to immerse themselves into their character, drawing on their professional knowledge. If something in the scenario did not seem right, they were encouraged to feel free to improvise. With this the user was prepared on what behaviour was desired, and what to expect in the test. Last, the icon list was introduced (see appendix F-7). In the post-test debriefing, a version of the icon list without explanations would be shown, asking them to explain in their words what the icons represent, thereby getting feedback on the quality of the icon designs. If the icons were hard to remember, they might be giving weak cues.

The user was told he could interrupt the test at any time; and special care was taken to explain that the objective of the test was to explore how well the system matched how people think, not to test the user's skills. The user was made aware that he would not receive help during the test, as it is valuable to see where the problems are, and what alternative actions the user might try, but that all questions would be answered at the end. It was explained that thinking aloud is important to help the observers understand her thought processes, and examples were given of how to do this. See appendix F-1 for test procedure.

During the test there were as few observers in the room as possible, to not disturb the user needlessly, and the observers kept their focus on carrying out the tasks in an impartial manner to get a realistic result. For that reason, care was taken regarding what was said and done during the test. Since users can be insecure in a test situation, special care was taken in making sure that the user participant was done with one task before giving her the next. The user was at times prompted during the test (without helping); this was both to encourage talking aloud if the user was concentrating on tasks, and to understand the background for the user's actions.

Based on the tasks and services listed earlier (see p. 98), a scenario for the test persons was scripted, one for doctors and one for nurses (see appendices F-3 and F-4). The script was not handed to the users, but tasks were read out loud as short and easy instructions by the test leader as the test progressed. This was mostly done for practical reasons, but it also allowed to pace the user and keep the situation calm. If the users are stressing to complete tasks as fast as possible, it will make the results irrelevant. Lindroth and Nilsson [46] argued that if the user is handed a paper with tasks listed on it, the paper becomes a major actor in the situation that does not exist in the real world.

Interview (semi-structured)

The interview was conducted in an informal manner, with pre-determined topics focusing in on desired information. The topics were formulated as questions, but they were attempted to be inserted naturally into the conversation. Keeping the interview informal would give the user freedom to bring up issues and impressions nobody thinks to ask about. Whenever the interviewee digressed, there was the option to draw out more information by prompting the interviewee with a follow-up question, such as "can you tell me more about that?", and "how did you conceive that?". Examples of other device form factors were brought so the participants could compare and more easily judge the iPaq: a Palm V and Nokia mobile phone (3630), along with the iPaq exclusive of expansion jacket.

Fig. 6.30: Nurse in Usability Test.

Fig. 6.31: Close-up of user typing on portable keyboard.

6.4.2 Analysis

The participants were asked to play through prepared scenarios with several different tasks to complete during the test. One scenario was made for doctors, and one for nurses. This section will look at issues the test participants experienced concerning tasks and services, the usability of the PDA, and of the prototyped interface. A detailed account of each participant's test result is offered in appendix F-8. This section is sorted by overall impressions, key functions and concepts, and the five test objectives text entry, data retrieval and presentation, navigation, handling the device, and general suitability.

OVERALL IMPRESSIONS

- The interface had some tasks catering to nurses, and some to doctors. A combined version was tried, seeing that they do have a lot in common, but the realization was that unused functions on a small user interface essentially is clutter.
- The doctors especially liked the test-section, both ordering and receiving results. Beyond that they were both concerned about the size and presentation of information relative to the screen.
- The nurses liked all their functions, although concerned that typing with a keyboard facing away from the patient might be an intrusion. They especially liked entering biometric readings.
- The wire connection of the external keyboard was useless, all the participants were very frustrated.
- All the participants liked the idea of being connected while out in the ward, as it would save them a lot of walking, searching for papers, multiple entries of the same data, and offer updated information whenever desired.

KEY FUNCTIONS AND CONCEPTS

ToDo list of tasks:

The task list function was well received by all participants as a concept. A nurse participant commented that it is very positive that an unevaluated problem is put on to her task list. She says that makes it very hard to forget doing it. There was no documentation of problems using or understanding the ToDo function.

- One participant wondered if she could enter tasks for her own ToDo list.

Iconization of the patient list view:

Two of the nurses stated that they think iconization of the patient list is a useful concept, while the last nurse did not like the iconization, and did not see any advantage to having information presented in a view like that. Both the doctors liked the function, and thought it would be useful in their work.

- The test showed that several of them expected the icons to be buttons or links to more detailed information of the problem, not realizing they were just symbols without functionality.

- All three of the nurses disapproved of the icon designs, saying "*the letters chosen for icons do not fit their work terminology*." One of the doctors had a relatively good grasp of the icons, while the other found their symbolism to be unclear.
- One doctor stated, "*Icons will get a function much like the task list, they signal that there is something we must do*."

Creating Nurse record, and create Careplan for a problem

Most participants had few issues with creating the nurse record and careplan, the wizard solution seemed to lead them through the process well.

- A couple of the participants were unsure of the terms used in the careplan headers: "*Messages; I am not connected when it comes to this term, I don't understand what information I am supposed to write here*."
- Another participant said she was unfamiliar with the term "biometrikk" (biometrics) from her daily work.
- One participant commented that they don't write "hoveddiagnose" (main diagnosis) and "mål" (goal) in the nurse record, and think this is unnatural.
- One participant said it is very positive that the date shows up automatically onto the established careplan. Also positive that the name of the patient comes along at the top of each page, a control that assures that they are on the right patient.
- One participant was unsure of whether the information she entered was stored after each step of the wizard, but carried on as she saw no invitation to store her information. At the end, she put the iPaq into her pocket and suddenly said "*is everything stored now? It can't be?*"
- One participant tried to figure out how to close the careplan. (That is not possible, moving on is only done by selection in the menus).

Evaluate Careplan of a problem

Evaluating the careplan itself was done easily and error-free, and the participants liked that they were reminded to do this on their task list "ToDo." Maneuvering to where the evaluations were done proved to be more complicated.

- Several participants had problems finding the desired evaluation page. They went from My ToDo to the Nurse Record, but did not see the link leading to evaluations there. They tried various approaches such as follow the link to "create new careplan," in a classic try-everything-and-eventually-I-must-find-it approach. Eventually, all respondents found it.
- They all understood the meaning of the red and green "E" symbols after reading the explanation.
- One participant said she would have liked a different representation of problems (the list of problems) that would make it easier to separate the problems from each other.

- Two participants commented that name and room number is good for patient ID, but they would also like bed number. That would allow them to momentarily forget the name of the patient. When prompting one participant further for the idea of a picture as well for patient ID, she simply said that she did not think people always will appreciate being photographed when in conditions that require admittance to a hospital.

Enter temperature and blood pressure

All participants understood the overall concept of entering temperature and blood pressure readings, and completed the task easily. They all immediately knew to go to "Kurve" for this function, although some participants thought they could click the graph image to update the graph. Their second solution was to look for options, and then spotted the "Ny registrering" (New entry) below.

- The choices for stamping time is four radiobuttons with the options M, 12,17 and 20. The title "M" was misunderstood, one participant thought it could be *Medicine* and another guessed *Man*, and added "*but it can also be morning medicine and 12-medicine.*"

Visitation note

The doctor had two sections on his ToDo list: "Morgenvisitt" (Morning Visitation) and "Andre oppgaver" (other tasks), where incoming test results and updates of medications plan were listed, as well as other items. Choosing a patient under Morning Visitation took the doctor to "Visitation note," a quick summary of what he will focus on for the patient. Both participants found this easily, although one commented that it was hard to go back and look at the note once it had been read (it was moved to a less top-level location, less accessible).

- One participant said he would want previous visitation notes to also be available right there in the main screen.
- One participant said there should be a place to note findings while with the patient.

Ordering Tests

All participants found and completed this task easily and error-free, none of the form fields or names caused hesitation.

- A participant's immediate reaction was that the task was done very fast, and said, "*It is completely intuitive how to do this!* "

Test Result (unormalt prøvesvar fra klinisk lab)

Going from the listing on ToDo onto checking the test result was done easily and without error, but both participants had second thoughts about the function itself.

- One participant did not like that the system interpreted the test and offered the result "Høy" (High). He would rather have a concrete numerical value, and do the interpretation himself.

- One participant tried to push on "Signér" (sign.) but discovered the test was digitally signed by him going into the test result page. He wondered if the same will happen if, for example, a nurse goes into the same page, if the test also then will be signed as "seen." (Only the doctor-role who ordered the test will have the option to see the test result, e.g. Doctor 3)

Network WLAN connectivity model

The participants were e-mailed two additional questions after the test. The first question concerned whether the handheld device should always be connected to the wireless network, or if it would suffice to have a cradle with network connectivity by their stationary computer, and be offline while out in the ward (allows to leave expansion jacket behind).

Most of the participants seemed to lean towards an always-on model, as they valued access to updated, reliable information at all times to be able to make decisions.

- One participant said synchronization is better than paper, but the information will reach others slower. It depends on how important it is that information is spread quickly.
- One participant said it depends on the update frequency. He would be OK if he had to update only once per day, but if he has to keep doing it all day to ensure reliable information, then it is not a good method.
- One participant said he would prefer the device to be connected all the time, as one does not know what information is needed before heading out for the visitations, and it is also desirable to have the option to check fresh test results (clarifying that "fresh test results" is information that is produced in a lab and released after the doctors visitation have started).

TEXT ENTRY

Text entry was done two-ways: with the stylus choosing characters on the on-screen virtual keyboard, and by attaching an external stowaway keyboard. All of the participants were able to enter text with both methods. Most of the participants reported that the stylus was easy or acceptable to use for text entry, while one participant had some problems due to the small size of the target buttons. One participant thought using the stylus was slow, but acknowledged that he was untrained with such a tool. Most of the participants reported that the external keyboard was better for writing than the stylus, while entering small amounts of text (temperature and blood pressure) was done easily with both. One participant commented, "*but it seems feasible to write with the stylus if there is not too much information to enter. We usually don't write so much when we are out in the ward. It can be handy for noting blood pressure and pulse, but not for reporting what happened to the patient during the day.*"

- All the participants were frustrated with attaching the iPaq to the keyboard. The affixing was tricky, almost always resulting in the expansion jacket slipping out of place on the iPaq, consequently resulting in a loss of WLAN connection.

- One participant found it annoying that she had to use the stylus to mark each text field before writing in it (with external keyboard).
- One commented that the stylus would be easy to lose, while another participant put the iPaq in her pocket and left the stylus behind on the table.
- One participant got confused when the virtual keyboard with automatic spellcheck suddenly popped up while she was typing with the external keyboard
- One participant complained that the keyboard did not have Norwegian letters (æ-ø-å) (the keyboard was bought through the internet from USA).
- One participant was skeptical to using the external keyboard in her daily work for hygiene reasons: "*It must be a giant source of bacteria. Imagine if I got blood on my finger, and did not wipe it away before I typed. It can not be available to all.*"

DATA RETRIEVAL AND PRESENTATION

Data retrieval and presentation was controversial for this device, with the amount of information flowing versus screen size. The question is whether there is room for *just enough to be useful*. The graph book was seen as functional and easy to read, but probably should have more information, and one commented that the graph itself was very small. Another said the screen was very small.

- Asking a participant whether she thinks the information is efficiently presented, she said "*Yes*." When asking a nurse participant whether she is given the necessary overview, she said there is a chance that more things need to be in the record.
- One participant said, "*the information is too cryptic, this is just a tool for me.*"
- One of the participants commented that the amount of information a doctor needs may very well be larger than the practical capabilities of the handheld device. He thought it would be possible to structure information so it can be entered, while doing that would hurt work processes.
- No participants had hesitations about retrieving or having simple test results presented on this screen, although one had doubts about looking at x-rays with it. Test result presentation was commented as very efficient.

NAVIGATION

The structure of the menu system worked well overall, and seemed intuitive with acceptable hierarchy depths. All the participants were able to navigate without getting lost.

- The participants did not comment on the items in the top menu, but they did not use "Wards patients" much.
- One participant did not realize that she could not close the care plan (as if it was an application) but only could move on by using menus.
- Most of the participants did not identify all the roads to patient records, most of them saw only two to three (all four top menu buttons were roads to patient records).

- The use of color was well received. One participant said the use of color was important to catch the nuances of the record. Another participant said, "*It gives an illusion that the information is in layers, and one does not have to go back to the hierarchy all the time.*"
- One participant speculated whether the letters in the side menu ought to stand vertical rather than horizontal.
- One participant said the menu concept with archive tabs was fine, but he did not like that he had to scroll to see the last tab.
- One participant said he thought the interface for navigation would probably collapse when one is to find his way among at least 250 different blood tests, record notes, and x-ray results.

Conceptual model for top menu and side menu

Not all the participants could explain the relationship between the top menu and the side menu well, but all of them were able to navigate without difficulty and keep the overview. Two of their descriptions, listed below, suggest they understood the conceptual model:

- "*The menu on the right belongs to the active patient. The top menu belongs to me as a health person.*"
- "*In the top part I find the patient and what I am to do. On the side I find the data I need to carry out those tasks.*"

Context awareness through the context button

Awareness of context was included to be mostly a navigational feature, making things that are physically near also near (easily available) on the screen. Most participants were able to navigate with it, while few of them understood what the concept of context awareness really meant, and the benefits it could offer. One participant concluded that it is a good idea to pick up information from the surroundings, but the solution in the prototype was not intuitive enough.

- Some of the participants saw the context button as a shortcut to patients. One commented "*how the context button works is natural*."
- Some participants avoided using the context button even when the task specified using it, one of them (when asked) said there were two roads to a patient's record, "Mine Pas" and "Avd pas." Another said he had discovered several other roads to the patient record, and did not see any need for the context button.
- One participant did not understand the concept of the context button. He did not find it, looked for a while, and then got help. He said he thought the symbol (button) only told him if he was near enough (the button changes color when near enough to pick up context information). He added that he would have changed the icon to an "i" for "info," and would have liked a clearer indication that he was in a new context; the button was not appealing.

- One participant claimed the context information gave her very little, and that she did not see the purpose with it. "*Usually I know what room I am in, we are used to having names and numbers on the patient's bracelets, and if they are awake, we always ask who they are anyway.*" The participant did not see any other areas where context information could be useful, "*but it could be practical to have a warning if you are away from the patient and something happens to him.*"
- One participant commented that she is glad she does not have to poke the patient with the "gadget" to read off data.
- When asked if other context information could be useful, one participant said that it is nice to be able to go directly to the part of the record that is relevant for the task. She did not elaborate.

HANDLING THE DEVICE

The participants got first hand experience handling the device in the scenarios, where they would use it when holding it, when resting it on a table attached to an external keyboard and putting it in their coat pocket between tasks. They used the iPaq with expansion jacket during scenarios, but were also shown the iPaq without jacket, a Palm V and a Nokia phone as other device-sizes to compare with.

Form factor

- Most of the participants where critical to the iPaq with expansion jacket; descriptive words like "*huge*" were used. Both the size and the weight were mentioned. All of them were positive to the iPaq's size and weight without the jacket, along with the Palm V.
- One said the weight with the jacket was good, with the comment, "*It is like a keychain. You feel it in your pocket, and by that you (have to) remember to pass them on.*"
- One participant said the iPaq design was very slippery, and said it might easily slip out of the pocket.
- One participant said he thought it might slip out of the expansion jacket (and drop), also that he was unsure if it was solid enough, "*it must handle to be in the pocket with 3-4 books, and be robust enough to survive hitting a doorway,*" he said.
- One participant said he was willing to carry a trolley with paper records with him out on rounds to satisfy his need for information, and that this was common some places.

How to carry the device

Most of the participants preferred carrying the iPaq in their coat pocket at all times. One was concerned that the network card might get tangled into other things. Other suggestions were on the waist on a clip, the belt on a clip, and breast pocket of coat (shirt).

- One said if it were to be in the breast pocket, it would have to be attached (to not fall out).
- One participant said that having one keyboard on each table would be too demanding on resources, as they would need cleaning like everything else. But folding the keyboard, carrying it

along, and then unfolding it on the next place would be out of the question. She would rather drag a stationary PC with her on a trolley.

- Two participants said the table by the patient was too low, the angle towards the screen was bad standing up and it was uncomfortable to stand with their back bended. One suggested they could have the iPaq on a tray on their lap.
- One participant said the device should stay in the pocket, so not to demonstrate power towards the patient by showing off hi-tech equipment. She said a PDA can be a power symbol.

GENERAL SUITABILITY

Most of the participants thought it was an advantage to have the patient record available in their pocket. Advantages they saw were having all the patient records available in one place, saved time, saved walking to find papers, saved looking through papers in binders, being able to enter information into the record immediately (and not twice or more), and giving everybody access to fresh data when they need it. The saved time would give more time spent on patients. One participant commented: "*So far it is extremely unpolished, but one can see the contours of something that might work.*"

- One participant said they would save a lot of time by not walking back and forth so much in the ward, and added that the walking is actually one reason why many health workers burn out.
- One doctor participant commented it would be nice if the doctors could easily order tests themselves without middle men, so he knows if it has been done. He also said the prototype is short of some services, but does not say which ones he would like. "*I think you will get different answers from different doctors, depending on problem and ward*," he commented.
- One participant said she does not think the iPaq is suitable for acute situations, but that it works well when time is not a factor.
- One participant said she would prefer a stationary computer in each patient room instead.

Patient Communication

Several participants were hesitant about the device as a tool, saying that while it can make hospital work more productive, it might at the same time create a distance to the patient. One participant pointed out that it is important for nurses to have good communication—both verbal and non-verbal—with the patient, and information can be lost if one is too preoccupied with the technical aspects of the job. She also thought the patient might withdraw and maybe lose some trust over this, and she then identified a complaint often heard: *My primary doctor is only looking at his computer screen*.

- One participant said the keyboard especially makes her focus leave the patient
- Two participants said it is difficult to have an opinion when the scenario was not realistic enough to get them carried away. One added that with a working system, he thinks he would have chosen to draw the PDA into the communication in the patient room, e.g. show the patient his test results

or x-rays. He thinks the iPaq would make him more confident in his communication with the patient, he would feel the system backing him up, and secure access to all information on the patient including the latest.

- One participant said the iPaq was a disturbing factor when used standing by the patient bed. However if sitting down, while letting the patient look at the device and what she wrote, where the patient was in the center of attention and not the device, it would not be a problem.

6.4.8 Recommendations for further Redesign

OVERALL IMPRESSIONS

- Consider separating the interfaces by profession.
- Consider exploring separate hardware for professions. Doctors wander less than nurses. Consider a Tablet PC for doctors, while keeping the PDA for nurses. Nurses could also benefit from a Tablet PC for the larger documentary tasks, but they are good targets for smaller mobile devices that can always accompany them while wandering, as they do record updates continuously.
- Consider trying other modes of data entry. Free handwriting and gestures are good candidates.

KEY FUNCTIONS AND CONCEPTS

ToDo list of tasks:

- Consider letting users add things to their own ToDo list

Iconization of the patient list view:

- Redesign icons so they are obvious to everybody
- Consider making the icons links to more information, not just inactive symbols.

Creating Nurse record, and create Careplan for a problem

- Reconsider what fields are required
- Change terms that are not commonly understood
- Include feedback that information entered is stored automatically in each step
- Date should be presented in a more readable format

Evaluate Careplan of a problem

- Redesign the main page for Careplans, making unevaluated problems more visible
- The explanation over the E-symbols is spacious, and redundant after reading it the first time. The E’s are assumed to be “once learned-always remembered”-type icons. The explanation should either disappear after the first viewing, and/ or be available upon desire. Another option is to

design something that does not require an explanation at all, for instance making the text of the problem title red/ green by evaluatory status.

- A problem is listed as seemingly a row of meaningless numbers "Problem 2002418". Consider using a meaningful descriptive title of the problem (e.g. "Urination pains").
- The patient ID should be extended to include bed number with the room number. A picture is not a candidate to improve patient ID, as there are no good sources of pictures. Most people would not like having blood quickly wiped off their bruised and lacerated face, followed by a photo-shoot.

Enter temperature and blood pressure

- The link to *new entry* should be made more visible in the design.
- Change the "M" to "07" or do an automatic time-stamp on the entry.

Visitation note

- The visitation function should be expanded to offer more text/ fuller descriptions, and also to make previous visitations more available. That would make the service as a whole more useful.
- A participant requested a place to note findings. Consider expanding the visitation note service to include making notes while out on rounds.

Ordering tests

- The next step should be to expand this service to include a wider selection of tests and labs.

Test result (unormalt prøvesvar fra klinisk lab)

- The test result should show both the concrete result and suggest interpretation, so as to be helpful while not hiding information.
- consider suggesting suitable actions upon results as an additional feature.
- The design does not clearly indicate that nurses (or doctors not assigned to the patient) are *not* offered to view test results.
- The signing process should be a willful action, to avoid tests being signed by accident. Such a design would need a constraint to make sure signing the test is not forgotten.

Network WLAN connectivity model

- Assuming all doctors and nurses are out into the ward more than once a day, the always-on approach is recommended, full network coverage in all patient rooms and ward hallways. Making small parts of an otherwise connected ward uncovered might be very confusing and irritating, so such areas should be chosen with care.

TEXT ENTRY

- The connection to the keyboard should be wireless. It has to be very easy and clear how to connect and how to use the keyboard.
- Consider adding cues in the design as to what data entry method is recommended for different tasks in multimodal interfaces.
- The keyboard should offer Norwegian letters. It is annoying for users to compensate.
- Consider attaching the stylus to the iPaq to make it less easy to lose. Constantly misplacing the stylus might prove expensive (buying new ones).
- The virtual keyboard should only be used for small amounts of data, perhaps set the limit to approximately five characters at a time.

DATA RETRIEVAL AND PRESENTATION

- Consider presenting the graph data with text instead.
- X-rays would probably not work. They are very large in size and require a detailed look to be useful, more detail and size than the PDA can offer.

NAVIGATION

- The interface should be scrollfree, as using the stylus on the tiny scrollbar is tedious. All the menu tabs should fit within the confines of the screen.
- Consider trying the letters in the sidemenu standing vertical, and see if it adds usability. It probably will make reading the labels easier, but might also make the labels look like one long row of letters, with that less readable.
- The graphic design for the context button did not provide good enough cues to make it intuitive and understandable. The icon concept and design should be altered to indicate more clearly when context information is available, and where the button takes the user.

HANDLING THE DEVICE

- The keyboard should be wireless with easy connection
- The PDA should have integrated hardware for network connectivity (i.e. integrated network card)
- Expansion jackets are bulky and heavy, and should be avoided.

EVALUATION

- Some of the participants had difficulties immersing into their role. The scenarios should have more detailed patient cases to better mimic reality.
- It could be a good idea to pair doctors with nurses in evaluation experiments. This can allow them to play off each other, as they often do in reality. Other ways to create co-discovery and collaboration should also be considered. Another option could be to have a nurse as a supporting actor like the patient, as part of the test set-up.

CHAPTER 7

Discussion

This discussion will revisit the initial research questions, and highlight what knowledge can be established from this study. Chapters 2 and 3 concluded that the value of this project lies within investigating the user's experiences and opinions of the prospect of having mobile handheld devices as a tool in their workday. Thus, primary sources of knowledge is the empirical evidence from the field study and the two experiments, while secondary (supportive) sources come from related research and products, and the technology exploration. Findings will be seen as suggestive or strong, and defined as guidelines for hospital mobility in chapter 8. This chapter starts with a review of the research design as it pertains to the validity of the empirical evidence.

7.1 Review of the Research Design

The goal of the research strategy was to harvest empirical evidence from real users completing relevant work tasks while being supported by a mobile handheld device. Opinions of the technology and the use situation were also collected. Few hospitals had experience at the time of project, and St. Olav's Hospital did not use any handheld mobile devices for any tasks. This suggested to use prototyping to create the phenomenon of study, thus giving end-users experiences to found opinions on. The study of real users experiencing the phenomenon is the anchor that gives scientific validity to this research.

7.1.1 User Participation

The approach to user participation was to have a participatory design process, where end-users would contribute in a focus group and user tests. The participants where not chosen to be representatives of their colleagues, but based on availability. There was limited funds to finance user participation, while it was important to involve users as much as possible. Initially the first round of UCD aspired to be a group session where realistic and testable scenarios was decided with doctors and nurses, along with a paper mock-up test of the initial screen designs. Time (four hours) and limited availability of users (one doctor and two nurses) required to compromise with a structured focus group on a tight agenda where appropriate scenarios were discussed, feedback was harvested on all the screen designs, and finally a brain-storming session where participants discussed and made design suggestions together.

In a more thorough project with a larger budget, doctors and nurses would likely have been hired to participate in "quick and dirty" design sessions, drawing on paper together and continuously approving or rejecting ideas. They would have helped steer the design in the right direction, allowing to skip basic misunderstandings and errors. That would likely have resulted in more mature design proposals in evaluations (not more advanced prototypes), and more extensive learning about the users and their requirements of tasks and screen designs. In a full project, such a user participation would likely shorten the process to satisfy requirements.

This project did not conduct classic participatory design, but compromises were made to leave room for both testing and participation towards design and contents during evaluations.

7.1.2 Criticism of the Field Study

The field study was carried out with a "quick and dirty" approach, as access to the ward was granted for three days. This limits the thoroughness of the study, as there is a limit to how much two outside observers can grasp of the complex information flow and routines in three days. Instructions were given to not interrupt or bother the staff in their work, thus the field study is not seen as an element in the approach to user participation.

The field study gave sufficient material to begin the process of exploring handheld mobile devices in hospitals. Having had more time in the hospital may have allowed to map work processes more carefully and perhaps assume other angles (follow a record through the day or follow a test result through the day, instead of only observe situations). However, that also may have created an overwhelming amount of data and made the analysis work more challenging.

7.1.3 Criticism of the Focus Group

As mentioned above, the initial hope was to have a group session to decide on realistic scenarios, and a paper mock-up test. Only half the desired time (four hours) and half the desired users (three) were available, so a compromise was made to have a structured focus group in order to make the most of the time and users. A strict agenda was made to assure there would be time to discuss scenarios, evaluate paper screen designs, and have a brainstorming session.

A system to circumvent potentially dominating participants was created. Screen designs of the prototype on A3 papers would be demonstrated, and the participants had green, yellow and pink post-it pads. The participants were asked to write their opinions on post-its and stick them to the screen interface: errors on pink, poor design on yellow, and good design on green post-its. The participants seemed to find the color scheme to be somewhat confusing or overwhelming, and using only one type of post-it pad likely would have sufficed.

The paper prototype became the catalyst for ideas and suggestions. It worked very well to give the users concrete proposals rather than discussing abstract models. The participants were very enthusiastic and creative, and the size of the group was good for discussions. The participants discussed, wrote and drew on the screen designs and post-its, and the sections for design feedback and brainstorming blended. From that point on the participants were allowed to discuss freely, as it was a natural way to communicate for them and they provided necessary feedback, and some new ideas. The least successful part of the evaluation was the scenarios. An example of a scenario was made with the intention to play it through, but the facilitators were unable to catch the participants interest; the participants started discussing functionality instead. It would probably have been better to insist on creating an appropriate scenario together instead of abandoning the section, as it would have been very useful to have later.

7.1.4 Criticism of the Usability Test

The usability test was for mobile devices, while standardized test routines and procedures are for stationary computers. This required to invent how to adjust the test procedure and the data collection techniques to mobility, as there was not much literature available. Lindroth and Nilsson suggest to test mobile devices with techniques such as role-play, having users write diaries of their use, or direct observation of users without their knowledge, thus backing the selected role-play test procedure.

Role-play as a method worked well. It allowed the user to experience the mobile technology and develop empathy, and valuable feedback was collected. One participant commented it was very good that there was a patient in the bed and that situations were played. She thought that made it easier for her to convey her thinking towards the patient. The experience here was that creating good scenarios is the key to success of the role-play method, as it otherwise relied too much on the participants being playful and imaginative, laying the responsibility of the success of the test on the users. The scenarios should be carefully designed to limit the need for improvisation. This because several of the participants said the scenarios they were asked to play gave them too little information about the patient case, making it unrealistic to initiate certain tasks or decisions. The narrow scenario made it difficult for them to fall into their role, and required a lot of improvisation. Thus the role-play and ward scenarios should be rich in information for the situation to appear real, and the patient cases should be extensive even if the prototype is not. Svanæs and Seland put emphasis on drama exercises and teaching participants basic drama skills in their workshop role-play method, which could have benefited the test as it required acting and improvisation.

Two doctors were recruited for the test, of which only one was from the Rheumatology division. The test worked less well for the other doctor; he commented that he would have liked a scenario from his specific ward background. Wards differ widely in information requirements, type and flow. Scenarios may need to be tailored to the specific participant's ward experience, including tailoring scenarios to each ward if several wards are targets for one system or test. Regardless, the scenarios and the participants' (doctor/ nurse) experience should match quite carefully as work routines vary extensively between wards. If possible, only participants from the target ward should be recruited for tests. Svanæs and Seland also learned that users should have direct experience from the kind of work (or leisure) that is being dealt with in the workshop (see page 29). This easily transfers to this situation: users should have direct experience from the kind of work (or leisure) that is being role-played in the usability test.

Some doctors are accustomed to having a nurse as an integral part of their visitation rounds, and may feel the situation is unreal when asked to play visitation without one (one of the doctors was used to this). If this is the case, the doctor should have a nurse as an actor in the test to make it more realistic (just like the patient was an actor). Participants of the real world situation should be included as actors to make the test situation realistic. Here the nurse was part of the natural context, and should be available for involvement to achieve relevance.

The evaluation tested one participant at a time, and concluded it would have been interesting to pair doctors with nurses for the next evaluation to achieve a multi-user session (two participants, not supportive actor). The *think aloud* dialog (see p. 107) is so valuable to the test that there should be attempts to expand it, especially when testing mobile devices where options for technical data collection is limited. Using a multi-user technique such as co-discovery within the role-play would make the dialog more natural. Some people forget to think aloud when they are alone, as it is more natural to discuss when two people collaborate on solving a problem, and this quite possibly may have removed some of the awkwardness of the acting. Co-discovery would be mainly nurse/ nurse and doctor/ doctor collaborating on the same task, while pairing a doctor and a nurse would not be co-discovery as they would have different tasks alongside one another. There were no opportunities to explore multi-user techniques within role-play, as there were no test users to spare.

A decision was made to not use a camera focusing on the screen nor the user, as there was no camera available that was small enough to be mounted on the user. An attempt was made having one of the facilitators stand behind the participant with a digital video camera aimed over the participant's shoulder and on to the screen for the pilot test. However, this was not a good technique for data collection. The inherent mobility of the PDA made it not always held at a direct screen-to-camera angle, and at certain angles the PDA screen would reflect light rendering it unreadable on tape. It was not appropriate to ask the test user to always keep the PDA within certain angles either; that would alter the user experience and how the user perceived the physical interface. In the end the decision was that as there were two facilitators present, one would be *test leader* and the other *documenter,* taking notes with pen and paper. Audio was recorded in the background so the *think aloud* dialog could be revisited if needed. This approach to documentation was sufficient in this case, as it enabled to identify the major problems. There was also the opportunity to explore finds further during the interview for confirmation. The data collection and documentation can be made more rigorous, even if the test itself is not. This is likely more relevant later into the development process, when the need for detailed analysis is higher. See Øyvind Lillerødvann's thesis for more on data collection and documentation when testing mobile devices.

The interview was semi-structured with an informal, conversational style. Care was taken to bring up questions objectively and not lead the users in any direction, and it is not likely that the interview style or researchers influenced the answers significantly. Some participants tried to emphasize positive things at the end of a row of negatives, but this should not be attributed to social desirability response bias (good bunny), but simply people being polite. For example, a nurse explained how the prototype had too little functionality for her to fall into the role of nursing (obviously did not think much of it), and then added, “but it was very pretty.”

After the evaluation was over came a desire to ask two more questions. An e-mail was sent to all the test participants, and answers came back from all of them. A possible problem lie in the time span between the test and the e-mail replies, it is not possible to know whether the participants have discussed the test with others, i.e. to what extent they had been influenced. However, the answers were all different and each one had trails to the participant’s experiences in the tests, thus outside influence did not seem to be a major issue threatening validity.

There were also other issues that relate to the validity of the test. One of the test participants showed up with a small child. This was not agreed in advance, and the child had to be allowed in the lab during the test as no last-minute childcare could be provided. This disturbed the participant significantly: she had to figure out the device, role-play in front of two strangers, all the while keeping an eye on her child. The test situation was taken a few more steps away from reality, thus her test results were to some extent compromised. This test should have been excluded, but that could not be afforded as the number of participants was low already. That is also the reason why the pilot test was kept as a result for analysis. The pilot test took longer than the others as the test design was not rehearsed, but the process only received cosmetic changes afterwards, such as using pen and paper for data collection rather than the camera. The pilot participant experienced many of the same problems as the other participants, which triangulates the results, and with the participant-situation it was let through with the argument that pilot testing is better than no testing. Ordinarily a pilot test would be excluded.

7.1.5 Summary of Research Review

The study of real users experiencing the phenomenon was the anchor to scientific validity for this research project. Thus the biggest threat to validity —and generalizability— is the low number and mismatched background of the participants recruited for evaluations. Recruiting relevant participants became a problem early on, and as a consequence a focus group was chosen rather than a paper mock-up test for the first evaluation, as it requires less participants. The focus group had one doctor and two nurses, all from the target ward (Rheumatology). The number of participants of the focus group was satisfactory, although the ideal would have been two doctors and two nurses so each profession was represented by more than one view. More than four participants may have lead to chaos, and it was an early test so it was acceptable to be informal and up close.

The standard recommendation for participants of a usability test is 5+/- 2 to identify the major usability problems. Following that, at least three doctors and three nurses from the target ward should have been tested to get valid results, preferably more. In addition, 2 of the participants volunteered for both evaluations, which gave them knowledge that the fresh participants did not have. Two of the nurses had tests that were compromised, one by her child climbing around, the other was the pilot test. The lesson is that a system should be evaluated for each ward it is intended for, as the optimal interface might vary greatly between wards. As Actipidos and WardInHand also point out, this suggests that the test should have five nurses + five doctors from each ward that wants to implement the interface.

Throughout the project an expert user contributed input for the field study, participated in the focus group, and was one of the doctor users of the usability test. This afforded him a lot of influence, and other doctors may not agree with him. The expert user was the strongest opportunity for user participation, which was considered essential to be able to create a useful system. Possible dangers with an expert user is exactly the amount of power he is afforded, unfortunately he may not use this power to the best interest of everybody. The expert user was however not in a position to threaten the validity of the research as a whole, as it was accompanied by empirical evaluations. These evaluations would confirm or disconfirm input from the expert user, and as such act as a check-and-balance of the expert user participation.

A recurring topic during the usability test was that the prototype was too “unfinished” to make the test situation with a patient credible. UCD however relies on doing evaluations early and often. The second prototype was tested in a usability test with elaborate staging, scenarios and a patient actor. The prototype should probably be more mature before an elaborate usability test with extensive scenarios takes place. The second evaluation should probably have been a paper mock-up test (less advanced prototype), and a usability test with an interactive prototype should have been the third or fourth evaluation. The interactive prototype let the users get hands-on experience of the possibilities the mobile devices presented, and as such was both valuable and necessary. But this is a complex area to develop prototypes for, and the process should have an early period with extensive user participation sessions and mock-up tests. There is no need for a technically advanced prototype and a fairly advanced test to eliminate initial misconceptions and errors.

The case study would have benefited from involving users more, both for user participation and as test subjects. Thus, most findings are presented as suggestive rather than conclusive in this and the next chapter.

This case study focused on one specific ward. Validity of results are then limited to that ward, and should only be generalized to other wards where likeness is apparent. This implies that findings are less applicable for wards of faster pace.

7.2 What Characterizes Work that is Useful to Support with a Mobile Handheld Device?

Several tasks and services were included in the prototypes to support work processes. First comes a review of which tasks were encouraged and which were not, before conclusions are drawn on what common characteristics they harbour. This empiric foundation relates to the setting hospital wards, while general conclusions may also be drawn as to what characterizes tasks that are suitable for mobile devices.

The task *enter biometrical readings* (blood pressure, pulse, temperature) was tested in both prototypes, and was very well received and encouraged by both evaluations. This is a task where small amounts of data frequently needs to be entered into the patient record system for each of the patients of the ward. The data is gathered while wandering. Current practices involve a lot of temporary notes in pockets and walking before the data reach the patient records; thus the data are made available for others with a time delay. Neither data input method nor the screen size raised any objections in this task, and the stylus worked well for small data entry. WardInHand also allows to read and update biometrical readings in their PDA system, although offering a wider menu with temperature, pulse rate, blood pressure, glycemia and breath rate.

The task *make test requisitions* was regarded as very useful both by the focus group and in the usability test. The need to do this task often arises while visiting a patient room. Even if the need comes up while sitting at a table (e.g., at pre-visitation), the task is usually not carried out until conferring with the patient out in the ward. Thus the task relies on harvesting essential information while wandering. WardInHand, Actipidos, JetRek, and Turner et al. all include the task of ordering tests while wandering, which suggests that this is a highly desirable task in any mobile hospital system.

There was no experimentation with different designs of test requisitions, and some of the current lab forms require a large amount of information which may suggest a need for large screen space. On the other hand, the current paper forms are standardized to be used by all wards of the hospital, while wards vary greatly both regarding what tests are frequently requisitioned and what information is included. Any computer system will allow more flexibility of screen designs (individualized tailoring) than standardized paper forms do, which then might reduce the need for screen space. WardInHand allows such tailoring of the interface to individual wards, recognizing this need for flexibility. Only small volumes of input for requisitions was tested in the prototypes, and this worked well with the stylus. Turner et al. used drop-down boxes to select test requisitions, which doctors were happy with as they were fast, easy, and inherently accurate. However, it was not considered so effective when the list of options was long, as that required scrolling. The second prototype in this project had checkboxes. Clearly there is a need to develop smart and easy interaction for situations when the number of options is large.

View test results was also regarded as a highly useful and desirable service of a mobile device, both in the focus group and by the usability test. The test users especially liked how a mobile device allows the test result to find the doctor, rather than opposite. However, there was some controversy towards presentation of tests that are visually demanding to screens, such as x-rays, and towards how large amounts of test results can be presented and navigated well on a small screen. The experiments showed that test results with small data contents are both desirable and suitable for a PDA, while test results with higher demands for presentation needs to be further explored. WardInHand and Actipidos did not offer detailed information on this subject.

The usability test incorporated *rating* of test results, by recommendation of the focus group. The usability test was inconclusive of this concept, as only two participants tried and commented on it. One doctor wanted the actual test result hidden if not abnormal, and rated by a scale otherwise (High and Low in this prototype). The other doctor definitely wanted to see the actual test result so he could interpret it himself, but would not mind assistance or suggestions as long as he was in control. Hence, the experiments suggest that ratings are useful as long as they do not take control and block knowledge from the user. The usefulness of rating test results should be further explored with a larger test group. Moore supports rating of tests as abnormal or significant with the principle of progressive disclosure: show rating first, allow user to see more if he wants, and don’t bother the user needlessly.

The task list *My ToDo* was designed to take over the job of various lists in current practices. This service was encouraged in both evaluations, as it supported work while wandering with reminders and specifications of tasks. The task list added value to the system for the individual user, and represented good usability when the system remembered things for the user so she could concentrate on other things. The participants especially liked how the system would further collaboration (when the doctor changed medications, this would add tasks of medications distribution to a nurses task list) and support them with automatic reminders (establishing a careplan would automatically add a reminder to the ToDo list to later evaluate the careplan). Both Ward In Hand and Actipidos make use of task lists to support the users in their work.

The *summary of last visitation* is a service that briefs the doctor of the problems of the patient he is about to see, and shortlists what to be attentive to, e.g. follow up what was tended to at the last visitation. In essence it is a service that makes relevant information available when needed, it supports the desire to keep staff current at all times. As such, it pertains directly to working while wandering, and is both a reminder and a specification of work. Visitation was encouraged in both experiments by users, and they suggested expansions such as being able to make notes of visitation during rounds.

The prototypes used different approaches to visualize status and recent history of biometric information. The first prototype used tables, the second a graph image. The evaluations encouraged having this information available while wandering, but there was no conclusion as to presentation. The graph image was seen as too small to offer any useful information, and the tables did not communicate as well as the graph they are accustomed to using. The problem of presentation lies in the size of the PDA screen, where graphics that require substantial screen space to be presented properly are less suitable. WardInHand uses graphs to visualize biometrics such as temperature in their PDA system, but there was no report to be found how useful users found these graphs. Actipidos uses several types of graphs to visualize patient status on their tablet PC screen, which gives more leeway for rich content graphics.

The first prototype offered to do tasks concerning *Medications*, but this was not encouraged by the nurses and the doctor. Administering medications (view current medical treatments, view information on specific medication, adjust/ introduce medical treatment) was regarded as useful to do on a computer and often done while wandering, such as during patient visits. However, the focus group felt strongly that the screen of the PDA was much too small for this task. Documentation of medicine distribution (nurses) was not included in the first prototype, but was discussed by the focus group. The group discouraged having distribution documentation as a task in a mobile handheld device, as the documentations were done in the medicine room (in this ward), not while wandering. The routine was to prepare cups of prescribed dosages for each patient in the medicine room, document there, and then take a tray with the marked cups out into the ward for distribution. Ward In Hand and Actipidos offer medication administration, which suggests it could be interesting to explore further in other projects, depending on hardware constraints. Medication administration should be considered dependent of ward routines.

Nurse documentation and nurse careplans were processes in the second prototype that offered such tasks as creating and viewing nurse documentation, and creating, viewing and evaluating careplans of problems. The nurses were positive to having these tasks on a mobile device as they often do them next to the patient (so the patient may contribute information). The nurses were hesitant towards input methods (both stylus on virtual keyboard and the physical keyboard), and they were hesitant as to whether the technology might create an unfortunate distance between them and the patient, this by the device requiring a lot of their attention. The documentation was presented over several pages due to size. Users did not give strong encouragement nor discouragement about this task. If proper input methods (such as handwriting) and presentation can be attained, it still may be a useful feature on small handheld mobile devices such as PDAs. Actipidos offer careplans in their system, although the screen is larger.

The tasks and services seen as most useful shared these characteristics:

- Task or service frequently done or used while wandering
- Task or service performed or needed at unpredictable/ non-routine times
- The initiative or need to do the task/ use the service arose while wandering
- Performing the task relied on collecting information while wandering
- The task consisted of collecting information while wandering
- The tasks data entry were of smaller volume
- Task or service did not require large screen display to be presented well
- Task or service supported a goal to keep the user current at all times
- Service supported work while wandering by offering relevant information, reminders and task specifications

Not so interesting were tasks that entailed wandering, but did not use any services nor enter any data while wandering (e.g. medications distribution).

7.3 How well does the Technology Support the User's Work?

Experiments showed that being able to do certain tasks while wandering in the ward marked a positive development. Which technology best hosts these tasks is another question, and will be addressed in this section. How well the PDA supported the users in their work was investigated through five main test objectives: data entry, data presentation, navigation, handling the device, and general suitability.

7.3.1 Data Entry

Two modes of text entry were tested: using the stylus to choose characters on the on-screen virtual keyboard, and by attaching an external physical stowaway keyboard. The experiment showed that all of the users where able to use both modes, although the external keyboard was preferable for writing (i.e. longer pieces, reports), and the stylus was preferable for entry of small amounts of text, such as temperature or blood pressure, as it did not require dragging extra equipment along. The external keyboard was troublesome to attach and connect, and not everybody were experienced typists. In addition, the stylus had to assist for navigation from text field to text field, so the use was far from smooth. The stylus was not ideal either, as it required fine-tuned motor skills of the hand to hit the small character buttons. This is the main reason why the stylus was tedious to use for larger input on the virtual keyboard. WardInHand used stylus on touch screen with a predictive virtual keyboard, which is smart considering how much more efficient T9 is compared to Tripletap on mobile phones. A predictive virtual keyboard likely will extend how much input is efficient to do with stylus. Turner et al. found that the virtual keyboard was satisfactory, although slower than conventional PC keyboards; but most users preferred handwriting with stylus (digital text via handwriting recognition) for text entry of notes, as it was quick and intuitive. WardInHand and Turner et al. also used speech commands, but that was not tested in this project.

WardInHand claims there are no concepts widely applied to collect input data on PDA-type hardware, and data entry is a crucial problem. Users are normally standing, which discourages the use of a keyboard. Similar issues with the external keyboard was found, although a table was set up bedside the patient. Users commented that the table was not ideal; if chosen it would have to be a higher table so users did not have to bend their back while typing. The screen needs to be fairly close to the face to see properly. If further away, such as a PDA resting on a table while the user stands, may be too far away. WardInHand does not consider a virtual keyboard without prediction to be usable, claiming it puts further limitations to an already small display, making it frustrating to use and hardly productive when standing up. WardInHand also focused on using sliders to minimize manual entry of numeric data, while Turner et al. used drop-down boxes for entry of clinical information that required a high degree of accuracy.

The experiment did not conclusively show that it is time to abandon the virtual nor external keyboard for this context; but it would be desirable to test other input methods as neither were ideal solutions. Handwriting with handwriting recognition software is a good candidate that could supersede the pen-paper-casual-scribbling of today. Such stylus-enabled natural cursive handwriting offers a natural intuitive interaction that mirrors the current documentation paradigm, and it is one of the strongest points of the Actipidos system.

7.3.2 Data Presentation

Data retrieval and presentation was tested with relatively small volumes, as the PDA was not expected to present a full patient record, but rather provide certain useful functions. The screen display is small, and there obviously is a limit to what amount of information can be properly presented.

The prototypes hosted several types of information on patients, both textual and graphic. Information that consisted of a limited amount of text, such as basic patient information, visitation summaries, lab results, and task lists were widely approved of by the test participants. Larger textual information required a structure, such as nurse documentation and care plans, thus how well it was received relied on the quality of that structure. The second prototype had a simple structure with linking between pages fitted to the screen, to avoid a very long page that would require substantial scrolling. This webpage-link-structure was understood by the users, and they seemed familiar with the metaphor of surfing the web. The graph book was presented as a patient folder with tabs for different contents, and this was understood by all. The purpose was to conceptually separate the *users toolbox* from *patient records*. The overall metaphors behind the information structure matched the users mental model well. This suggests that creating good concepts for structuring information is the key to make larger textual information work well on a small screen. Good concepts could allow voluminous information on a small screen.

Information presented as a graphic was not approved, with the graph image of biometrics regarded as too small to offer useful information. The size of an image is bound by screen size, which in this case suggests to either zoom in to reach better detail, or reserve such images for larger screens. A graph would likely loose essential overview if the image was zoomed in, thus a graph of biometrics should probably be presented in a different format for PDA, or be used on hardware with a larger screen. WardInHand used a graph on a PDA screen, but there were no comments on how useful this actually was to the users. Actipidos used graphs on its larger screen, and the graphs had good readability. Lifelines used an image to present a large amount of information about a patient at a glance. The image visualized a summary of patient information as a large menu, where concepts of progressive disclosure allowed the user to easily retrieve more information on points of interest. The instant overview of patient history, including current patient status, is the strongest point of the Lifelines system, which helps health professionals to spot trends in patient history. Lifelines is made for a larger screen than PDAs have, and it would probably be difficult to present such a detailed image and visualize the same amount of information well on a small screen.

The second prototype iconized information to be able to present a larger amount of information on each page, giving the user an at-a-glance overview. The concept was well received, although details needed improvement. The visualization in Lifelines is also based on iconizing information to allow room for overview. These icons were symbols without functionality, while Lifelines used icons as active objects to allow progressive disclosure. In Lifelines, the icons represented events such as physical consultations, tests, and progress notes, while icons in this project represented new test result, the patient wants to speak to doctor about general problem, the patient wants to speak to doctor about medical problem, etc. Lifelines applied icons to show status, while icons in this project communicated tasks for the user. The evaluations showed that users expected or desired the icons to lead to more detailed information, which suggests that an interface catering more to the principle of progressive disclosure would be better. WardInHand and Actipidos also use icons and progressive disclosure extensively to efficiently present information, and Moore claims that progressive disclosure is the key to summarize and present information.

7.3.3 Navigation

The navigation system that grew out of the design process had two menu concepts that related to each other. The overall system was built around the user and his work, with a subsystem which moved into patient folders with tabs for content. The conceptual model of the navigation menu systems was understood by all the users, and they seemed satisfied with the overview and hierarchy. The navigation system was kept quite flat on purpose, because depth is often a cause of confusion, and likely even more so on a small screen.

The navigation system was not tested with large amounts of information present simultaneously, such as 250 test results of blood. However, that should not be a goal for a PDA. Careful selection of what is useful top-level information, along with progressive disclosure of more detailed information, is key to efficient navigation here. Having a menu with 250 items in a plain list is not a clever information structure. The prototype shortlisted information extensively by use of icons, and this should be developed further by using the icons as navigational tools also. Lifelines especially does this well, although on a large screen, but the benefits of creating smart navigation should be considerable also for smaller screens. Icons offering progressive disclosure creates efficient navigation.

The test suggested that PDAs should have scroll-free interfaces, as using the stylus on a tiny scrollbar is tedious and annoying for most. That entails designing all pages within the confines of the screen. WardInHand moved outside of the screen with some of their pages, although they do acknowledge that the elevator scrollbar can be very difficult to manipulate with a pen stylus, saying it is not ideal for navigation. WardInHand based most of their navigation on speech commands, allowing handsfree operation, claiming that is very efficient navigation. Speech commands for navigation was not tested. Another option could be to reassign scrolling to the physical interface, i.e. a scroll-wheel on the side, which would likely increase the total usability of the device. A scrollwheel should be fitted with appropriate constraints to make it pleasing to use. Scrollbars were not used in Actipidos, but rather pen gesture commands that were intuitive and efficient, and highly usable. Gesture navigation also saves space on the screen, as there is no need for navigation objects, which is an important point if the screen is small.

The context button and context awareness did not succeed. Some were able to use it, and that might be because the concept was over-explained, they picked up the key term “shortcut” and then did not think more of it. The explanations they gave indicate that they did not understand what context awareness could offer them, most likely due to a poor conceptual model that did not match any mental models they had. The graphic design obviously did not provide sufficient cues to make it intuitive and understandable. The icon concept and design should be altered to indicate more clearly when context information is available, and where the button takes the user. This function would probably prove more useful if the other roads to a patient record were longer due to more information incorporated in the prototype. It might be too early in development to see the possible usefulness of a context button: a shortcut is not a shortcut if all the other roads are also short. It would be interesting to explore further on ubiquitous and pervasive computing functionality, as such seamless integration between technologies and the physical world has potential to be highly useful.

7.3.4 Handling the Device

The users carried the PDA with them during the entire usability test, putting it in their coat pocket when not in use. The users commented on the form factor, and said the expansion jacket was bulky, ugly and heavy, and in addition it provided unstable connectivity. Hence, a PDA should have an integrated network card for WLAN connectivity. It would make the device better suited for coat pockets, and should provide more stable connectivity. The always-on network connectivity model was thought to be most suitable for WLAN in a hospital ward, this is assuming most doctors and nurses wander in the ward more than once a day. The always-on model entails full network coverage in all patient rooms and ward hallways.

One doctor stated he was willing to carry a trolley with paper records with him on rounds. The assumption then is that he would be willing to carry large and bulky objects provided they would satisfy his need for information, which suggests that a computer larger than a PDA, such as a tablet PC, would not be too much to carry around as long as it (1) is very useful to him, and (2) is chosen when to come, not always accompanying him.

The external keyboard was not equally appealing to put in the coat pocket. A keyboard apparently should not have to be carried around. At the very least an external keyboard should be wirelessly attached to avoid any problems. The keyboard (if any) should have a very smooth fold-in/ fold-out function, too much trickery will likely leave it unused or left behind in the office. The stylus, however, is a small object easy to misplace, and perhaps the user should be able to attach the stylus to the iPaq by choice, e.g. a string-like tie between them.

The users said they would like to carry the PDA around at all times while wandering, hence the PDA is a truly mobile device for the wandering modality (see page 13). A Tablet PC, as used in Actipidos, is not really mobile according to Weiss' definition, as it would only be purposefully brought for specific occasions such as rounds, and would not always be with the user. The tablet PC is too large and heavy to be comfortably carried around for an extended period of time. A Tablet PC is still highly useful within it's own wandering use situation, as proven by the popularity of the Actipidos system.

7.3.5 General Suitability

The handheld mobile device was seen as well-suited to integrate and achieve better efficiency for certain work processes. Having synchronous, immediate access to information rather than constantly working without the most recent digital information clearly is an advantage. The prototypes were immature, but still were able to disclose potential. Being able to enter data immediately made the tasks faster, easier, and eliminated double logging of same data; in addition it makes those data available for others sooner. Digitalizing the patient record also offers immense opportunities when it comes to retrieving information (structured or search) and location-independent presentation, a clear advantage to peddling through piles of paper. With this also comes saved time and saved walking which benefits both patients, and the health of the wandering professional.

The handheld device imposes limitations with the small screen because it is not suitable for all tasks. However, a wide range of test results are likely suitable for a handheld mobile device, especially types of smaller text format. A wide range of requisitions are likely suitable, provided the form can be fitted to the screen (remove redundant fields, automate several fields, etc. With a scroll wheel or gesture recognition the form can be allowed to be a bit longer than the screen). A wide range of small continuous drips of updates are highly suitable to do on a handheld mobile device, because of the great advantage of having all relevant patients records readily available in the pocket, all in one place. The advantages of the handheld device are size and wireless network connectivity, where information is always available regardless of where the wanderer may be in the ward. The system adapts to the user's routine, rather than the other way around. The disadvantage is also size, as it works best for smaller information.

Users expressed a desire for an interface that health personell and patients could meet over, letting the device be a communication enhancer by having both parties look together. However, the small screen makes it necessary to prioritize features, with satisfying the user's needs first, and patient second. Selections on what to present should be carefully tailored to the users needs, and only include such dualism if not intruding on that first priority.

It was seen as important that the technology does not overshadow the primary focus of work, which is taking care of the patients. If the healthcare professionals as users constantly have their attention affixed to the technology, then the mobile device could become an obstacle rather than an aid in patient care. Therefore the technology should fall into the background while users are around patients.

7.4 CONTEXT AWARE HOSPITALS

Bardram saw pervasive healthcare as making surroundings come alive with interactive surfaces where the user can access what he needs everywhere, while he saw context awareness as applications having knowledge about the users' work context and being able to adapt to it. This project used context awareness to have surroundings continuously feed relevant options to the user, hence expand the navigating experience. Kjeldskov and Skov had a slightly different approach, they used context awareness to automatically change content of the screen, which their users found to be annoying and confusing. The usability test of the second prototype gave no indication that users were confused or annoyed with the proposed solution, which likely is because the users were left in control of the interface, merely being offered options they could choose to utilize or ignore.

The project revealed some concerns that are relevant to consider before introducing context awareness through tags in a hospital ward:

- *Patient privacy:* Healthcare workers have restrictions on which patient records they can access—information on patients are limited to those patients in their charge. Context awareness may provide information on patients to which they are not assigned, and privacy is invaded unintentionally.
- *Patient mix-up:* Patients within proximity of tags will be objects in a context aware interface, becoming portals to patient information. Thus, care must be taken to avoid errors due to patient mix-up for both record updates and medical initiatives.
- *Multiple signals:* This may be relevant for wards where patients move around, for example if the user is standing in the doorway to a patient room retrieving the patient in the system, and other patients pass by. This situation may make information of the passing patient pop up due to proximity of the reader, and a scenario where the wrong patient is digitally processed is possible. Annoying navigational hick-ups are likely.
- *Hygiene:* In a hospital context, one must assume soiling and smearing. Any props used to attain awareness of context must be durable enough to sustain both smearing and cleaning.
- *Patient dignity:* This issue relates to how to attain context information of a patient without imposing on a patient's dignity. The conceptual model should afford an unobtrusive read situation.

Solutions to these concerns can be made if the developers are aware of them, for example in the software solution through access limitations and other database associations. Patient mix-up should be addressed in the interface design, where which patient the user is "on" should be visually emphasized. Patient privacy may be solved in the software by making strict database associations between doctors/ nurses and their patients, preventing them from entering other patient records. Multiple signals may be partially solved by leaving the user in control of the user interface along with database associations similar to those enforcing patient privacy. Hygiene and patient dignity were addressed when considering tag technologies (see chapter 5.3 p. 73). These details were neither explored with design solutions nor tested in this project. The scope was to explore the usefulness of context awareness in a hospital ward.

7.5 What would the Ideal Mobile Device in a Hospital be?

The previous section investigated how well-suited the choice of technology was. The project showed potential, as what was tested was often found to be useful and desirable by the users. This may, however, not always relate to good fit of hardware, but rather reflect the user's strong desire for digitalized mobile assistance to make their workday more efficient. Melby described how health professionals continue to lean on paper as information medium despite having EPR systems, which are traditionally made for desktop computers. Her descriptions are in line with findings of the field study: records tend to go missing, information arrive late and cause delays (test results); and most importantly, the time gap between when information is harvested and when it is available electronically creates an EPR recency-vacuum around the hospitalized patient. What data is electronically available is rarely current, which in reality reduces the EPR system to a back-up system. This underlines the need to enter information into the electronic system when it is harvested, thus where it is harvested, setting the scene for mobile and/ or pervasive systems. This also underlines how availability of current information is critical to users' adoption of electronic health systems. The following are topics to consider before implementing mobile devices in hospitals.

The areas found to present most difficulty and concern were input method and presentation of potentially large amounts of information. The screen size of the device is likely to influence what tasks are suitable to be hosted on the machine: the smaller the screen—the less information can be satisfyingly visualized. The input method poses limitations on use situations and tasks. Smaller devices that rely on a stylus and a virtual keyboard solely, are best suited for small amounts of data entry. Reports, etc., require more sophisticated input methods that better afford larger amounts of information, such as a physical keyboard, natural cursive handwriting by stylus, gestural commands, or perhaps speech commands and dictation in the future. Turner et al. enabled doctors to dictate text for letters via PDA, which was uploaded to a server then transcribed via voice recognition. The uploaded data was immediately available for others or printing, and overall worked well. Melby suggested that paper is holding its ground because of better functionality: it is mobile, very flexible and informal, and is an established practice. Instead of fighting work-practices, it might be better to consider hardware and interaction styles that encompasses these traits, as in Actipidos. Mobile devices can be brought anywhere, pervasive systems are available everywhere, and handwriting recognition can offer a flexible and informal style of data entry that embraces the paper metaphor (see page 24).

Identifying user categories are important when evaluating what mobile device is most suitable. Nurses do most of the voluminous documentation and reports on patients, while sitting at a desk making text of notes, or sitting next to a patient conversing directly. Nurses also continuously do small data entries while wandering around the ward providing care for their patients. Doctors of the ward wander less than nurses. Doctors do small data entries while wandering, such as order tests, but mainly require an overview of the information in patient cases in such situations, along with receiving updates. This suggests that not only professions are interesting to identify as user categories, but also certain characteristics of use situations: some situations require voluminous data entry while other situations only require non-voluminous data entry; some situations require large overview of information while other situations only require small overview of information. Thus, type of mobile device should be chosen dependent on the users need for screen and volume of input, not necessarily by profession.

This also has implications for tailoring interfaces to users. The first prototype had one interface for all users. The evaluation revealed that the system should be both role-based and personalized, as several individual users can hold one role at different times. There was uncertainty to what extent the interfaces should be separated, so the second prototype was given a halfway-solution with a log-in function that identified both the individual user and the users work role, to enable tailoring and personalization within the same interface design. Evaluating the second prototype made it clear that doctors and nurses in the ward perform very different functions and have very different needs, thus a separation of both physical and graphical interface might be required. The two professions do not necessarily find the same designs and functions useful. To achieve a highly efficient and intuitive interface, the small screen should not be cluttered by other users' functions, rather be tailored to each users needs.

Finally this has implications for choice of hardware of various users and use situations. The strength of a PDA is the small size, low weight and portability; it is a tool that can always accompany the user while wandering, ready to offer information and for entry of small updates for the duration of the workday. A Tablet PC is opposite, it is not always with the user, but is suitable for planned tasks and handles higher volumes of entry and presentation. Nurses could be good candidates for smaller mobile devices such as PDAs, as they do record updates continuously. Doctors wander less than nurses, and have wandering routines such as visitation where a Tablet PC could be purposefully brought. Nurses could also benefit from a Tablet PC for the larger documentary tasks, which are done routinely, so a Tablet PC could be purposefully brought for those situations. Doctors of the usability study were enthusiastic about being able to order tests instantly while visiting patients, and also receiving test results instantly. However, it cannot be concluded that it was the mobile device they found to be ideal, as all mobile devices can offer wireless connection and instant service.

Bardram saw PDAs as capable of alleviating some of the problems of EPRs by providing specific support for isolated tasks, but had hesitations whether the display size and computing power is sufficient; he did not think PDAs are able to solve the problems of EPRs as a stand-alone solution (see chapter 2.6). This project did not expect the PDA to solve all problems alone, but it has the possibility to be very helpful in its own right. Turner et al. concluded that overall the usability of PDAs are satisfactory relative to data entry and presentation of information, and aims at wide acceptance of the technology in hospitals. WardInHand support that hardware cannot be easily chosen by factors such as profession with the design priority: to have flexibility and device independence, to ensure the longevity of the application, and to allow the end-user to adopt the type of device he/ she prefers, concerning for example screen dimensions and form factor (see page 22).

Different users have different needs, and a solution should allow users to choose the type of device by preference of, for example, form factor, screen dimensions, and data entry method. Further, different wards have different requirements for what information is key, which also calls for flexibility in design if the ambition is to create a solution that transcends wards. An interface can be built as modules that users choose among to cover their specific needs, while instant medicinal library consultation, procedure indexes, reference guides, system-recommended-actions, etc. are added-value options that can make a system that features PDAs *and* devices of larger screens with input methods suitable for voluminous data-entry useful enough to justify the investment.

CHAPTER 8

Conclusion

Chapter 1 identified Nielsen's three levels of guidelines: *general guidelines* applicable to all user interfaces, *category-specific guidelines* for the kind of system being developed, and *product-specific guidelines* for the individual product. The purpose behind such guidelines is to achieve a high degree of usability. The following is a list of suggested guidelines based on empirical findings in this independent study, related to findings from other relevant projects. The list specifies the general-, product-, and category-specific guidelines of Nielsen, Weiss and Moore (see 1.6 and 2.5) and expands with evaluation and contents guidelines, all for handheld mobile devices in the hospital context. Finds are weighted by wording: *should* for strong finds and *consider* for suggestive finds.

These guidelines attempt to draw attention to topics regarding content and technology that should be considered when developing systems with mobile devices for hospitals.

8.1 General Guidelines

Match between system and the real world

- All medical terms used in a hospital system should carefully correspond to medical jargon of reality to ensure the interface is intuitively understood by users.
- The keyboard should offer local (e.g. Norwegian) letters. It is annoying for users to compensate.

Recognition rather than recall

- All icons used for shortlisting information on a screen should be commonly understood, and, “once learned—always remembered” if not intuitive by first trial. This could be achieved by offering explanations on first trials that later are available upon desire.
- Graphic design for a context button should provide good cues to make the concept intuitive and understandable. The icon concept and design should indicate clearly when context information is available, and where the button takes the user.

Visibility of system status

- When information is stored automatically in chained steps such as wizards, there should be visual feedback to inform and assure the user of this in each step.
- Interface elements should have clear and meaningful labels and titles. Problems should have a descriptive title, and Patient ID should appear on each patient page to visually confirm what patient the user is on. Patient ID should consist of name, room number and bed number.
- Images should be used carefully on small screens, and only when visualized well.

Flexibility and efficiency of use

- The interface should be scroll-free when the tool for navigation is a stylus, and all contents should be fitted within the confines of the screen.
- Consider creating other means of scrolling with the physical design of the device.
- Consider making a software solution that affords users tailoring the interface to individual needs.

8.2 DEVICE-SPECIFIC GUIDELINES

Design for users on the go

- Consider context aware concepts in screen designs to augment the user experience.
- Consider attaching the stylus to the iPaq to make it harder to lose.
- Mobile technology should be a background tool when meeting patients, and not an obstacle between patient and health professional.
- A small screen should have shallow navigational hierarchies to afford overview and transparent navigation.

Design stability

- Devices should have wireless network cards integrated to provide stable connectivity and make the device better suited for temporary storage while wandering, for example a coat pocket.
- Any physical keyboard should be wirelessly attached to device, and offer clear feedback when a connection has been established.
- Wards should have full network coverage, so users can be always-on.

"Select" vs. "Type"

- Consider adding cues in the design to recommend data entry method for different tasks in multimodal interfaces.
- The virtual on-screen keyboard operated by the stylus should only be used for small amounts of data. A physical keyboard connected wirelessly can be used for larger data input, but is not ideal. Consider other methods of data entry, such as natural cursive handwriting by stylus and speech.
- Consider a selection mechanism such as sliders rather than requiring typing data where appropriate.

Use metaphors from the real world

- The interface should have an overall metaphor that corresponds to the user's mental model. The patient folder was an effective metaphor to convey conceptually the dual systems of *user* and *patient* interfaces on the handheld device of the hospital ward.

8.3 CATEGORY-SPECIFIC GUIDELINES

Summarize information

Patient journals often embody large amounts of information which largely will exceed any screen, although is not useful to see simultaneously for any user.

- Consider flagging information that is abnormal and put less focus on normal results, also consider to show an interpretation of the results first. However, the concrete result should be easily available if user so desires.
- Interfaces should prioritize presenting useful and recent information to the individual wandering user.
- Information should be visually short-listed through memorable icons that progressively discloses more information to efficiently afford both overview and information availability in a limited screen space.
- Consider using progress bars in patient overviews that indicate how far into the treatment plan patients have gone.

Wrong patient

- Patient identification should be clear and meaningful, where patients are identified by name, room number and bed number.
- Using a picture of the patient's face in the Patient ID likely gives higher usability as people are more visually than textually oriented. Currently there are no proper methods to attain such pictures. Taking a picture after admission is neither socially nor practically acceptable to do routinely.
- Patient mix-up should be addressed in the interface design, where which patient the user is "on" should always be visually emphasized.
- Systems using electronic tags should have strict access limitations through database associations between doctors/ nurses and their assigned patients, to help avoid patient mix-up and ensure patient privacy.

Context awareness

- Any electronic tags to facilitate context awareness should be durable enough to sustain smearing and cleaning to satisfy hygiene standards.
- The read situation should be unobtrusive and not impose on the patient, it should respect the patient's dignity. Consider wireless tags.

- The interface should never override the user, but rather feed options fitted to context and allow the user to choose whether to take advantage of them.

There is no typical user

Users vary in needs for data entry and data presentation, and vary in wandering frequency/ routines.

- Users should be seen as individuals with roles, making systems both role-based and personalized. Identifying a user as a role mirrors how they work, where several users can hold one role at different times.
- Consider making software systems device independent to allow users to adopt the device with form factor, screen dimensions, and data input methods best suited to individual needs. This does not necessarily rely on the user's profession.
- Consider added-value services such as drug consultation and reference guides.

8.4 Guidelines for evaluating Mobile handheld devices in the hospital context

Use actors and role-play

- The test should create a scene for natural dialogue as the *think aloud protocol* is even more valuable in evaluations where options for technical data collection is limited, such as when testing mobile devices. Role-play is a suitable technique to achieve this.
- Participants who are natural in the real world situation should be included as actors to make the test situation realistic. A nurse could be a supporting actor like the patient, if that is what is natural for the doctor, and vice versa.
- Consider using a multi-user technique such as co-discovery with role-play as it allows the test participants to play off each other as they often do in reality. This could be doctor/ doctor, nurse/ nurse or doctor/ nurse.
- The role-play and ward scenarios should be rich in information to make the situation appear real to the user, thus help the user immerse into the role. Patient cases should be extensive and detailed even if the prototype is not.
- Consider using drama exercises or teaching users basic drama skills to make them more comfortable with the situation, and more easily immerse into the role and improvisation.

Beware of ward differences

- Users should have direct experience from the kind of work (or leisure) that is being role-played in the usability test. Scenarios should match the users' professional background, as work routines vary extensively between wards.
- Consider testing systems for each ward it is intended for, as the optimal interface might vary greatly between wards. Also consider testing on five doctors + five nurses from *each ward*.

8.5 Guidelines to Contents of Mobile Handheld Devices in the Hospital Context

Tasks put on a handheld mobile device in a hospital should have the characteristics:

- Task or service is frequently done or used while wandering
- Task or service is performed or needed at unpredictable/ non-routine times
- The initiative or need to do the task/ use the service arise while wandering
- Performing the task relies on collecting data while wandering
- The task consists of collecting information while wandering
- The task entails smaller volume of data entry
- Task or service does not require a large screen display to be presented well
- Task or service supports a goal to keep the user current at all times
- Service supports work while wandering by offering relevant information, reminders and task specifications

Identify the wandering part of a task that would benefit from mobile technology support

Some tasks might require technology for registering data while user is stationary, even if the remainder of the task is carried out while wandering. Example of this is distribution of medicine.

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APPENDIX A

Current Usability Methods

The following is an excerpt from section 3 of the article "Contextual Usability – Rigour meets relevance when usability goes mobile*" by Tomas Lindroth and Stefan Nilsson, Laboratorium for Interaction Technology, University of Trollhättan/Uddevalla, Sweden:*

In this chapter we present all of the applicable methods that we found. They constitute the ground for our methodology study when it came to deciding what sort of usability tests we were going to do.

They belong to three different areas:
- Inspection and evaluation
- Testing
- Inquiry

1 Inspection and Evaluation

Heuristic Evaluation (Nielsen & Mack, 1994)

Identify usability problems early in the design phase . Guidelines vs design. You can provide the experts with paper mockups, or even just design specifications , and still get a good amount of usability problems discovered before actual work begins.

Cognitive Walkthrough (Rowley & Rhoades, 1992), (Spencer, 2000), (Wharton et. al., 1994)

Motivating how or why a person would react in a certain situation. Based on assumption about the users background, knowledge and goal. Great for early stages of development because they can be performed using just a system specification as a basis.

Formal Usability Inspection (Kahn & Prail, 1994) (Freedman & Weinberg, 1990), (Gilb et. Al., 1993), (Wheeler, 1996)

A way to detect errors in the code that the design relies on and documentation defects. The inspector performs tasks and reports any found errors and the lines of code causing the problem. The technique is design to reduce the time required to discover defects in a tight product cycle. Great for early stages since the inspector can work with merely a specification or paper mockups.

Pluralistic Walkthrough (Bias, 1991)

Looks into how users react in different situations. Includes user's, developer and usability experts. Best used in the early stages of development, as the feedback garnered from pluralistic walkthrough sessions is often in the form of user preferences and opinions.

Feature Inspection (Nielsen & Mack, 1994)

Find out if the feature of a product meets the users need and demanding. Best used in the middle stages of development. At this point, the functions of the product and the features that the users will use to produce their desired output are known.

Consistency Inspections (Wixon, et. al., 1994), (Nielsen, 1995)

Looks for consistency across multiple products from the same development effort. Best used in the early stages of development, when the initial development work has not progressed to the point where products that require extensive changes to ensure consistency will not require total overhauls.

Standards Inspection (Wixon, et. al., 1994), (Nielsen, 1995)

Standards Inspection ensures compliance with industry standards. Best used in the middle stages of development, as the actual design is being developed with the given standard in mind.

Guideline Checklist (Wixon, et. al., 1994), (Nielsen, 1995)

Guidelines and checklists help ensure that usability will be considered in a design. Usually, checklists are used in conjunction with a usability inspection method. The checklist gives the inspectors a basis by which to compare the product.

2 Testing

Thinking Aloud (Lewis, 1982), (Dumas & Redish, 1993), (Lindgaard, 1994), (Nielsen, 1994), (Rubin, 1994)

Lets the evaluator understand how the user views the system. The method can be used in any stage of development. Gives a lot of qualitative feedback during testing.

Co-Discovery Method (Dumas & Redish, 1993), (Lindgaard, 1994, (Rubin, 1994)

Idealistic for evaluating groupware programs, CSCW products and other products designed to be used by workers in team environments. Can be used during any phase of development.

Performance Measurement (Nielsen, 1993), (Dumas & Redish, 1993), (Lindgaard, 1994, (Rubin, 1994)

Measures whether a usability goal is reached or not e.g. a kind of bench marketing. Should be used in initial stages of design to provide benchmarks for the design process. It is also used during the design cycle to measure the work done thus far against those benchmarks.

3 Inquiry

Contextual Inquiry (Holtzblatt & Beyer, 1993), (Holtzblatt & Jones, 1993), (Beyer & Holtzblatt, 1995), (Beyer & Holtzblatt, 1997),

Contextual inquiry is used to get a broad knowledge about the environment that you are producing the program or device for. This technique is best used in the early stages of development, since a lot of the information you will get is subjective--how people feel about their jobs, how work or information flows through the organization, etc.

Ethnographic Study/Field Observation (Hammersley & Atkinson, 1995), (Wixon & Ramey, 1996)

Ethnographic Study is used to get a broad knowledge about the environment that you are studying. This technique is best used when you are studying complex situations where ordinary methods would miss to detect important details, for example “unspoken acting” i.e. tacit knowledge. A lot of the information you will get is subjective--how people feel about their jobs, how work or information flows through the organization, etc.

Interviews and Focus groups (Greenbaum, 1997), (Nielsen, 1997), (Templeton, 1994)

This technique can be used at any stage of development, depending on the questions that are asked. Interviews and focus groups are often held at very early stages of development thou, when the *product requirements are still not firm*. Focus groups are then held to *extract user requirements p*rior to initial design.

Customer Research Groups (Lynch & Palmiter, 2000)

Customer Research Groups is an effective alternative to focus groups with the same purpose. (Se above)

Journaled Session (Nielsen, 1993)

Journaled sessions bridges usability inquiry, where you ask people about their experiences with a product, and usability testing, where you observe people experiencing the product's user interface. This technique is best used in the early stages of development, probably even pre-development, where the information you are attempting to gather is more preferential than empirical.

Incident Diaries or Self-Reporting Logs (Nielsen, 1993)

Finds out what kind of problems a user has had during a period of time or what they have used the system/device for.

The Valuation Method

Finds out how important a feature is to a user.

Logging use (Nielsen, 1993)

Gathers information about use and problems without the user knowing about it.

APPENDIX B

Compaq iPaq 3630 Pocket PC Technical Data

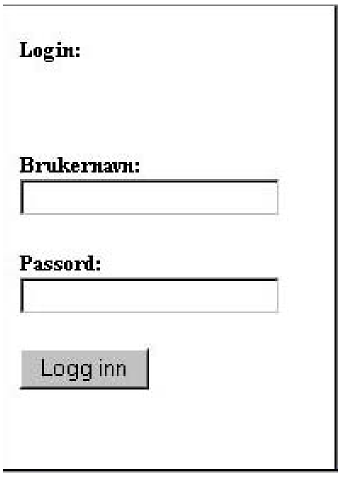
Standard memory: 32 MB RAM, 16 MB ROM
Maximum memory: Up to 64 MB CompactFlash card
CompactFlash memory: Yes
Other expansion memory: No
Display type: Color-reflective TFT (thin film transistor) LCD
Display colors: 4,096 (12-bit)
Display size: 2.26 by 3.02 inches / 5,74cm x 7,67cm
Resolution: 240 by 320 pixels
Display backlight: Yes, ambient-light sensor adjusts automatically
Processor: 206 MHz Intel StrongARM SA-1110 32-bit RISC
Operating system: Microsoft Pocket PC 2000 (Windows CE)
PC compatible: Yes
Handwriting recognition: Yes
Keyboard: On-screen
User controls: On/off, light, menu, speaker/5-way joystick, contacts, calendar
Memo pad: Yes
Address book: Yes
Scheduler: Yes
E-mail: Yes
Web browser: Yes
Security: Password protection
Stereo: Yes
Built-in speaker: Yes
Headset jack: Yes (3.5mm stereo)
Voice recorder: Yes
MP3 playback: Yes
Audible content playback: Yes
AC adapter included: Yes
Battery type: 950 mAh Lithium Polymer
Batteries included: Yes
Average battery life: 12 hours
Desktop import/export formats: Pocket Word, Pocket Excel, Pocket Internet Explorer, Windows Media Player, Inbox, Microsoft Reader, File Explorer, Asset Viewer, Picture Viewer, Packet Video
Serial port: Yes
USB: Yes
Infrared: Yes
Wireless: Yes
Docking cradle: USB cradle included
Software: CD-ROM with Microsoft Active Sync 3.1, Microsoft Money for Pocket PC, Pocket Streets, Outlook 2000, Internet Explorer 5.0, Media Manager, Tscribe, Microsoft Reader e-book samples
Width: 3.28 inches / 8.3 cm
Height: 0.62 inches / 1,6 cm
Depth: 5.11 inches / 13 cm
Weight: 6 ounces / 170 g

First released: June 2000 http://www.pdasupport.com/Ipaq3630.htm

http://www.amazon.com/exec/obidos/tg/detail/-/B000051JUJ/102-0545826-2064909?v=glance:

APPENDIX C

Prototype 1 Screen Images



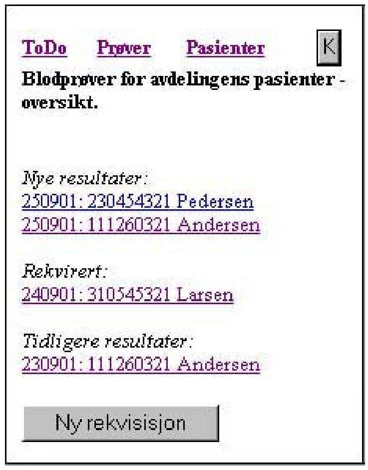
1: Login sequence

2: Welcome info screen

3A: Topmenu: ToDo

3B: Looking at a flagged patient

4A: Topmenu: Testresult lab menu



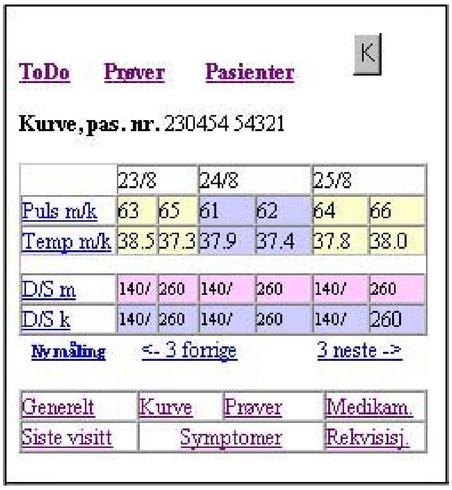
4B: Bloodtests of wards patients

4C: Looking at one patients testresult

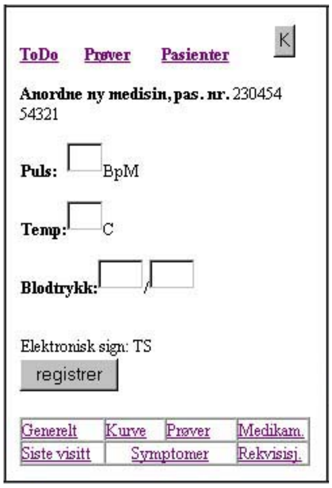
5A: Topmenu: Patients at ward

5B: Looking at one patient

6: Patient menu: General info

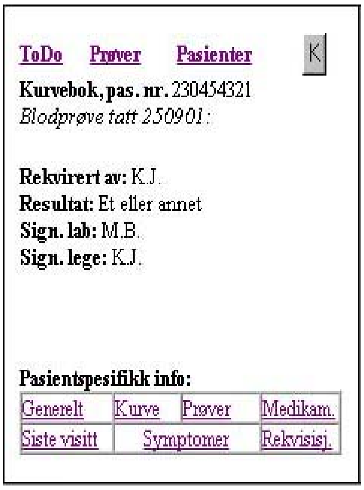


7A: Patient menu: Graph visual

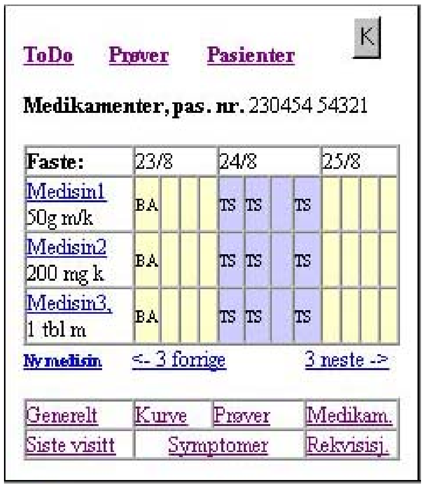


7B: Enter new data (header is wrong)

8A: Patient menu: Testresults



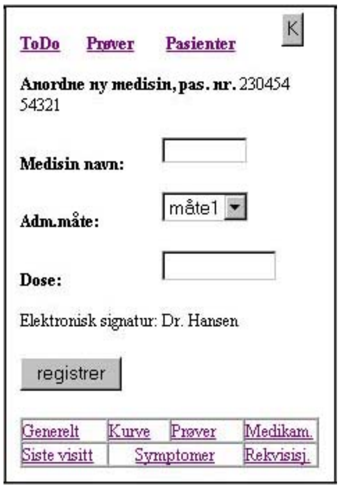
8B: Looking at a testresult



9A: Patient menu: Medications visual

9B: More info on a medicine in use

9C: Alter medicine specs



9D: Ordain new medicine

10: Patient menu: Previsitation note

11: Patient menu: Symptoms

APPENDIX D
Focus Group Material

(*translated from original version*)

D-1 AGENDA

(not to be distributed)

1700-1730:
Welcome. Introduce ourselves, the project, and what will happen today (focus group introduction). Introduction of game rules for the focus group.

1730-1830:
Presentation of the scenario. Remember to put Laila's drawings on the wall. One scenario at a time, while the user writes their opinions and impressions on post-its. This is to ensure that everybody is heard and not just agreeing all around. Group feedback right after each scenario presentation. Gather and keep notes afterwards. We are not looking for agreement—if there is disagreement we take back all views without negotiation.

1830-1845:
Break with coffee, soft drinks, and snacks.

1845-2000:
First a presentation of the Compaq iPaq and what it can do technically, i.e. explain what possibilities lie within the small computer for dictation and playing sound, the color screen with options to show pictures and film of high resolution, and possibilities for data communication via infrared light and wireless networks (towards the internet).

Next, a presentation of proposed screen images on A3-sheets. We explain how we imagine the functionality. For each screen image, as during the scenario bit, the participants are asked to write on post-its, errors on red ones and what is lacking on yellow ones. Everybody put the post-its on the A3 sheets and say their opinion before we move on to the next drawing. Here we do not use green post-its.

2000-2030:
Finally we have a brainstorming where the participants use A3 sheets where the iPaqs have empty screens. Here they can draw any functionality they may imagine. Hence, not only do we get feedback on our proposals, but also let the users contribute creatively with new ideas to the development process. The users don't have to base their ideas on the iPaq. They are free to invent their own black box that enables all sorts of wonderful things. No ideas are too crazy, and it is not allowed to criticize anyone else's suggestions. But it is allowed to build on the ideas of others.

2030-2100:
Possibly discussion of topics we did not have time to cover within 20.30.

Try to book nurses for the test in October. Have Faxvaag arrange two rooms at Digimed.

Closing. Thank you for participating.

D-2 Focus Group Introduction

RiT, 25/9-01

Thank you for taking the time to participate in this workshop.

As you may know, we (Øyvind Lillerødvann, Laila Jøssund, and our councellor Dag Svanæs) have visited you at the Rheumatology Division a few times this past year. The last time was a field study in mid-June. The background for this interest are the Master's thesis's we are writing as informatics students within Human-Computer Interaction, a dicipline where the processes in the communication between computer and user is studied.
Focus in our thesis's is what possibilities and limitations handheld devices like Palm and Compaq iPaq (as we are using), connected to a wireless network, have in the hospital context. Previous work, which we are continuing today, has been to gather enough background information to be able to build a functioning prototype of a handheld, electronic patient record system. In autumn this prototype will be tested by doctors and nurses in a lab in Digimed, hopefully on running, handheld devices communicating with a central server by way of radio waves and internet technology.

It is important to underline that the main point is to test the physical and graphical user interfaces. We are spending a lot of time creating a prototype that is as realistic and believable as possible, but we would never be able to make a full patient record with the time available. There are several parallel research projects where the Hospital and Sintef are involved. They are facing a large problem requiring a lot of work, of which we only can scratch the surface. With this said, it may be easier to understand why we have not put much emphasis on rich details. However, the design is supposed to mirror the reality of the division, and the work processes there.

In our scenarios and screen proposals you will find errors and things missing—guaranteed. Even if we had three days to carry out the field study, we were in reality left with more questions than answers. We formed an overview of how the patient record functions as the "glue" in the work of the ward, but we would love to hire one of you as a full-time consultant to give further insights into each process.
We had to make several assumptions when designing scenarios and paper prototypes, more than we initially wanted. Preferably we would have a separate workshop to discuss scenarios, and one to discuss screen designs. However, this has not been possible, due to time and resources.

Back to the field study and what we discovered: When we visited you in June, the goal was to map your work processes, and in a larger perspective put the finger on situations where handheld devices could be useful.

We considered situations where the users are on their feet around the ward to be the prime targets, for example doctors on visitation rounds, and nurses updating patient data after medications and observation. Doctors need information during visitation, they want to see test results and perhaps order new tests. The graph book may come in handy wherever the user is. This graphbook is easy to update for nurses on the go. They can enter information into the system immediately, as it runs on a central database. The advantage here is that information is available all the time, there is no need to keep patient information on temporary storage (like pockets), the information is always current, and test results can be received very quickly. Not to mention avoiding double bookkeeping and the administrative work of registering patient data electronically afterwards. In addition, all doctors and nurses bring a ToDo list with them everywhere, which keeps an overview of their tasks and what they need to remember.

In offices and during pre-visitation it is reasonable to assume that stationary computers are the best alternative, especially with today’s handheld technology.

Critical points we wish to focus on are:

Data entry: Does entering text with a stylus on virtual keyboard work here? How about a physical keyboard? Is speech input the only alternative? Are there better alternatives?

Data presentation: How does retrieving and presenting data work out? What volumes can efficiently be presented? How does the patient record work on the small screen?

Navigation: Is it possible to navigate without losing the overview in such a small graphical interface, considering the possible amounts of information?

Handling the device: How practical is it to drag the hardware around in their work situation? From room to room? Should the users keep it in their coats? The keyboard also? Will bringing the mobile device be an obstruction in their work? Is the PDA really *mobile* in this situation?

General Suitability: How well-suited is the mobile device at making work processes more efficient, integrated and synchronized regarding test results, requisitions, and others?

Of course we will not find answers to all of these points today, but this workshop will hopefully bring us one step closer. We know computers, but not healthcare. Thus feedback from all of you is highly necessary.

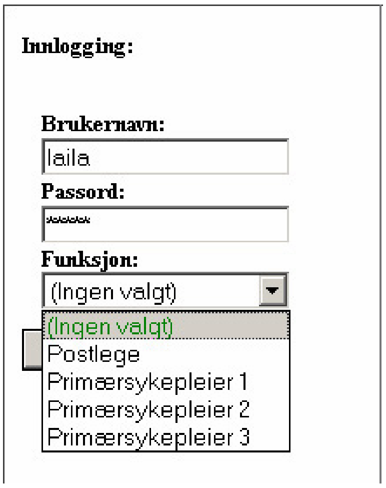
D-4 Scenario

Assistant Doctor Olsen is doing visitation at the Rheumatology ward. After pre-visitation it becomes clear that he needs to speak closer to five of the patients in the ward. After fetching and logging into his handheld device, or iPaq, he clicks into the list of patients that will be visited. He clicks in on the first name on the list, and gets a short brief of the patients symptoms and the nurses' impression of the patients condition. This brief was made during pre-visitation, hence when he enters the room he has an important overview of the patients problems. At the patients' bed he clicks the button "fetch patient info" on the iPaq's screen, and the patients' graphbook automatically appears.

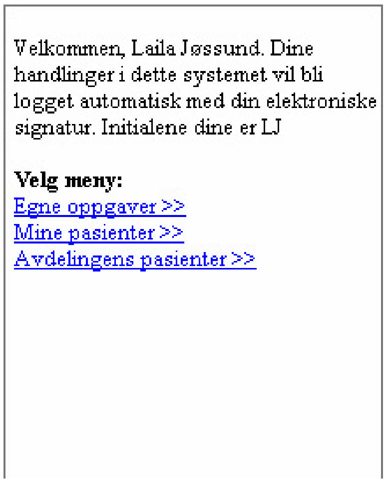
This is possible by way of a small radio transmitter on the patient's wrist, which communicates with the handheld device. The doctor is interested in the patient's temperature and which medication has been administered in what dosages during the past few days. The doctor clicks directly towards these data from a link in the patient's graphbook. The doctor also checks the results of a blood test ordered two days ago. After reviewing these data, the doctor performs a physical check while talking to the patient. A nurse, who has attached her handheld device into one of the keyboards available by each patient, enters all observations into the graphbook. The doctor expresses to the patient what the further treatment should entail. The doctor and patient finally agree, and the doctor, now attaching his iPaq to a different keyboard, clicks on the screen to find a form where new information can be entered. The doctor asks the nurse to find what medications the patient is receiving, and after discussing with her, the doctor makes some changes to the medications program. At the same time, the doctor orders a new blood test that studies values the first test ignored. This information is automatically updated, and will immediately be available to others who enter the system. The test order is automatically sent to the Department of Clinical Chemistry, which will return the result as soon as the test has been sampled and analyzed.

As Olsen put the iPaq in his pocket and is ready to visit the next patient, the iPaq gives a signal of an incoming message. Another nurse at the ward has called him with her own iPaq with the message: "Hurry to room 521." The doctor takes the device out of his pocket, reads the message, and hurries down the corridor. When arriving in room 521, he can automatically fetch a list of all patients in that room, based on the same technology that identifies each patient. Instead he chooses to go straight to the patient's bed and get the patient's graphbook directly via the patient's bracelet.

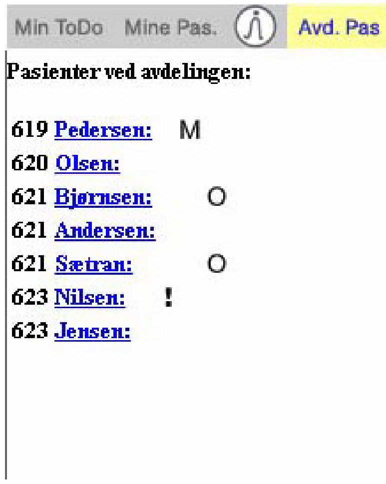
APPENDIX E
Prototype 2 Screen Images



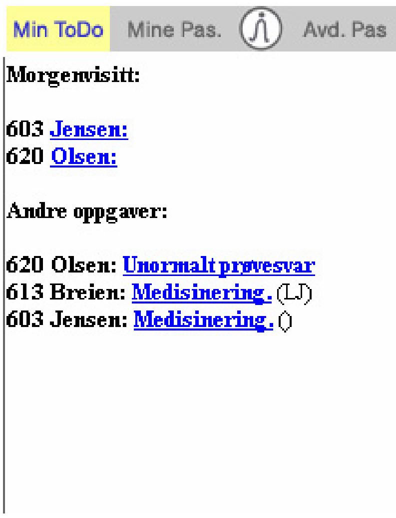
1.Login sequence



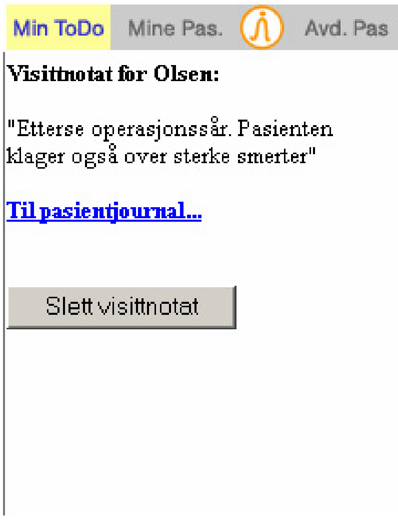
2. Welcome, intro of actions autolog



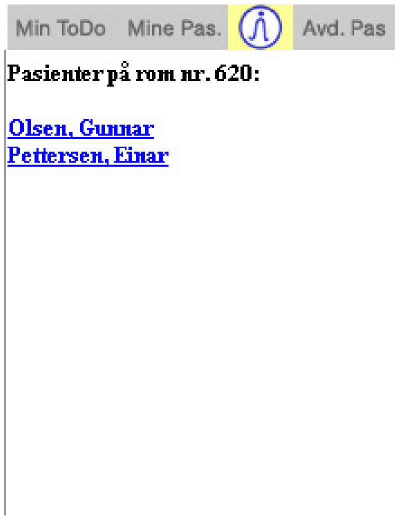
3. Wards Patiens, note iconization



4. My ToDo

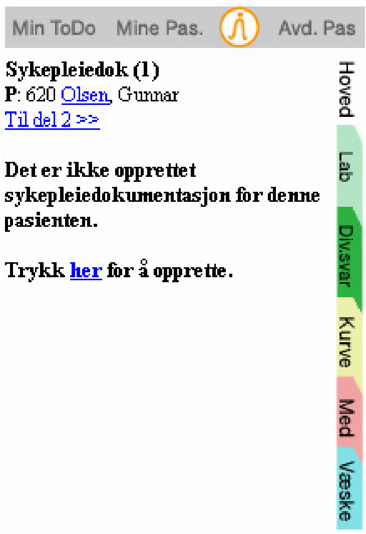


5. Visitation brief on a patient



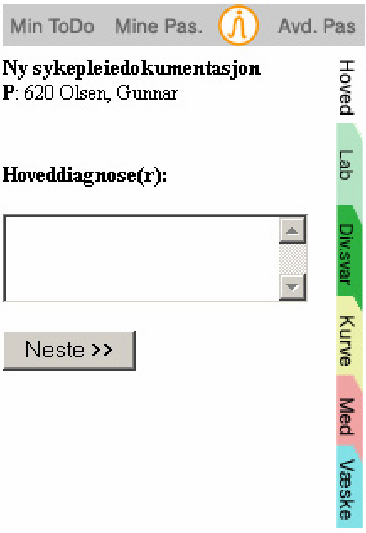
6. Context information selected (room)

7. Main: Patient personal data

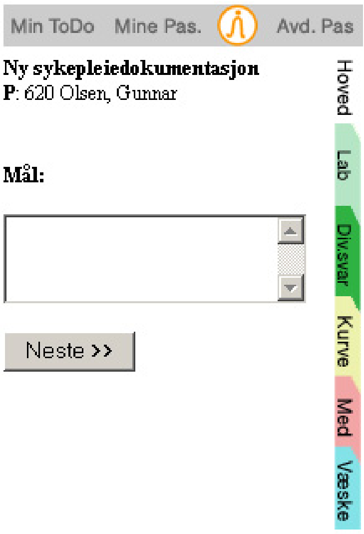


8. Create Nurse documentation- Wizard

9: Wizard: cause of contact

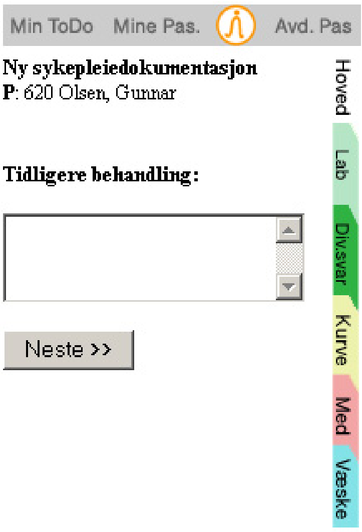


10: Wizard: Main diagnoses

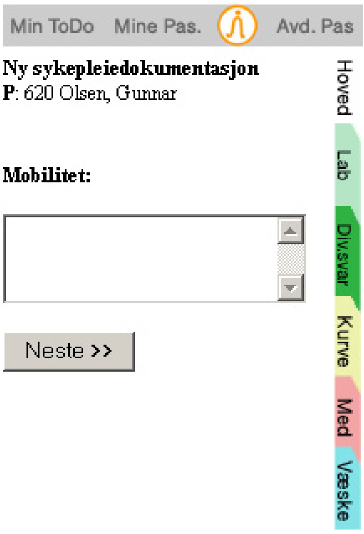


11: Wizard: Goal

12: Wizard:Other diseases/disabilities



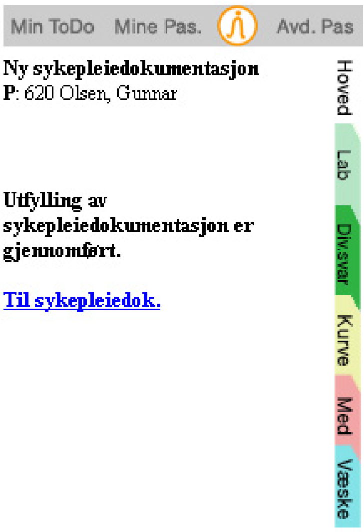
13: Wizard: Previous treatment



14: Wizard: Mobility

15: Wizard: Diet

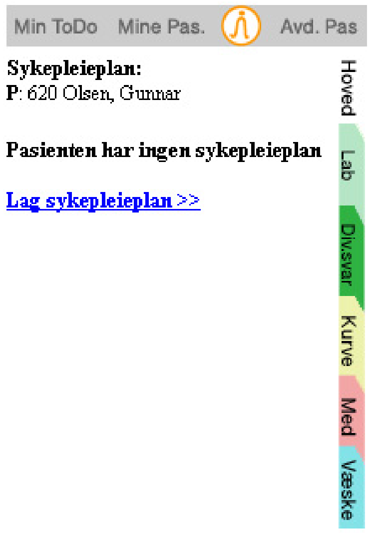
16: Wizard: Messages



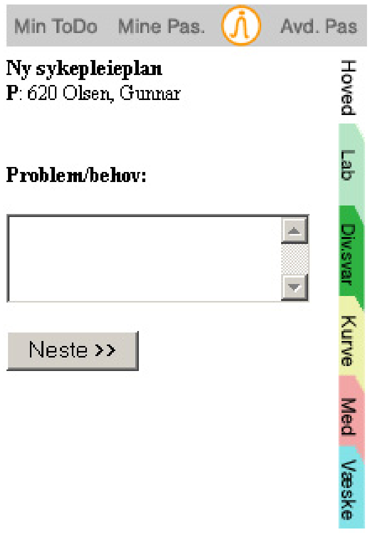
17: Wizard completed

18: Result: Nurse documentation(part 1)

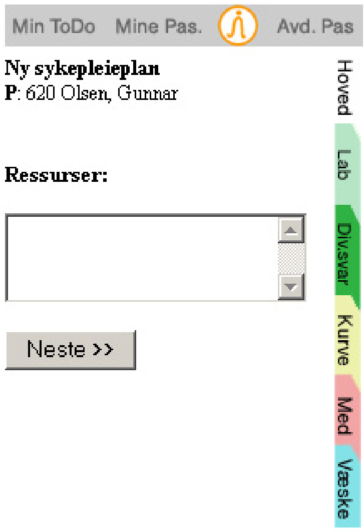
19: *Result: Nurse doc (part 2)*



20: *Create Careplan Wizard*



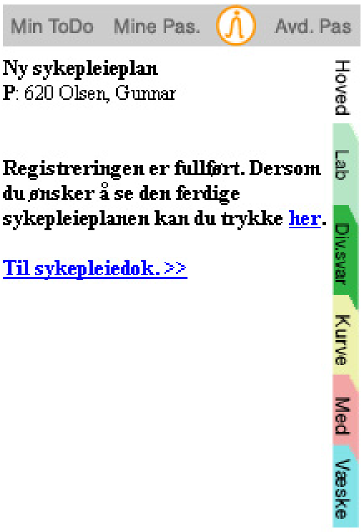
21: *Careplan wizard: Problem/need*



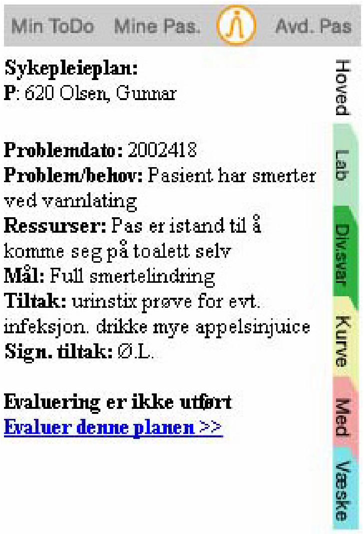
22: *Wizard: Resources*

22: *Wizard: Goal*

23: *Wizard: approaches*



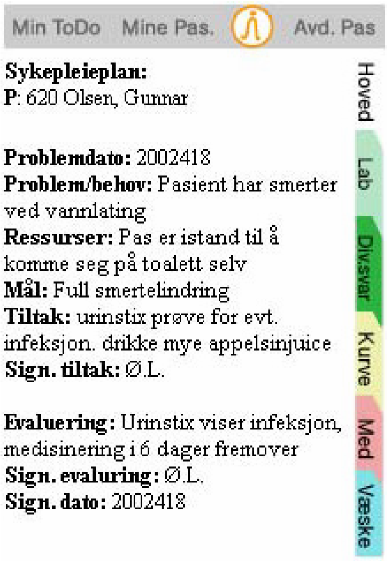
24: *Careplan Wizard completed*



25: *Result:Nurse Careplan (not eval)*

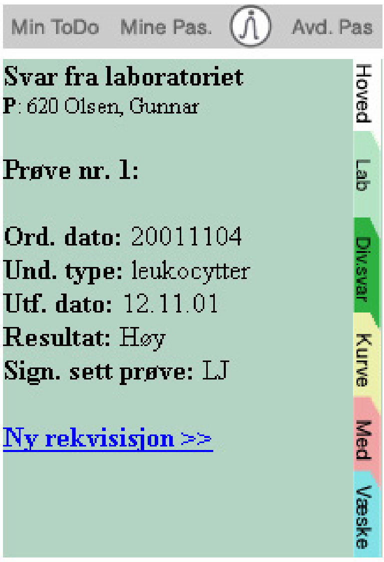
26: *Overview careplans*

27: Evaluating Careplan

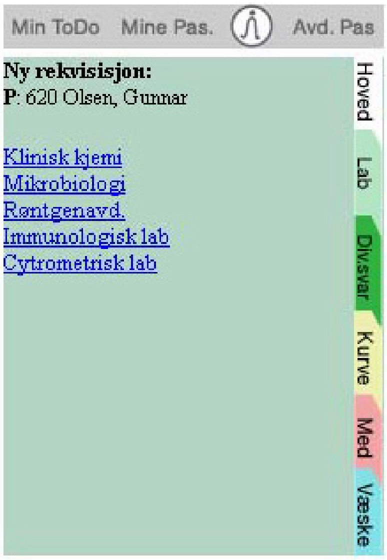


28: Evaluated Careplan

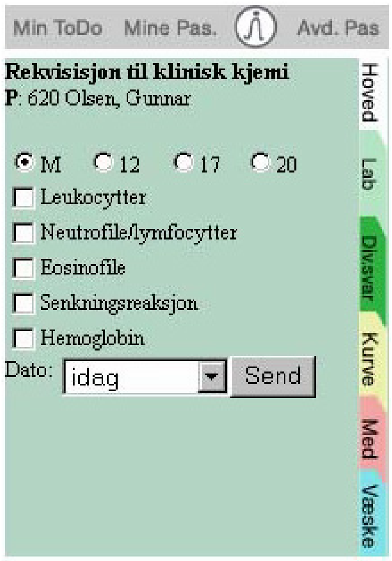
29: Lab: Testresults and New requisitions



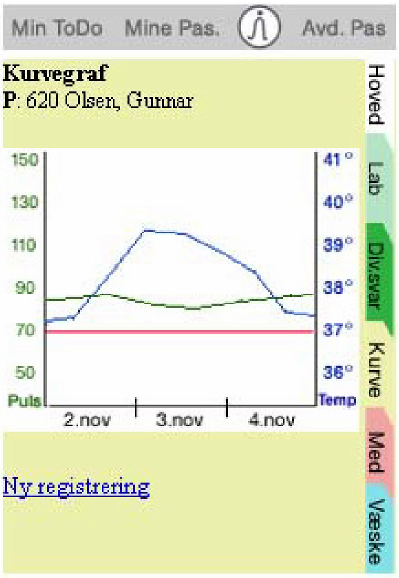
30: Lab: Testresult



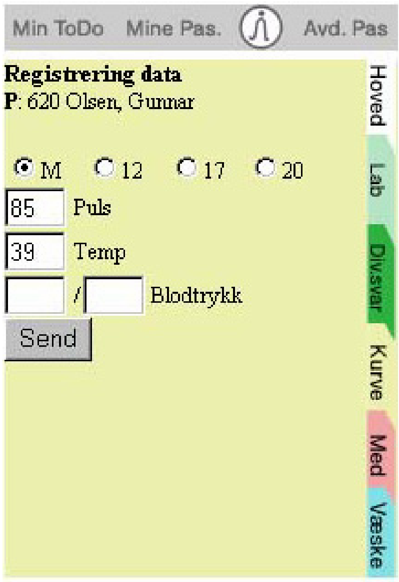
31: New Test: Choose lab



32: Lab – Clinical Chem: Choose test



33: Graph book: The graph



34:Graph book: New data entry

APPENDIX F
Usability Test Material

This is a compilation of written material and forms made for the usability test (*translated from original version*).

F-1 PROCEDURE

B r i e f i n g

- L: Welcome, give coat.
- Ø: Describe product.
- L: Show and explain bracelet.
- Ø: The test will function as a role-play between doctor/ nurse and patient. It would be great if you could improvise and try to be in the situation with your professional background for us. The prototype is not fully developed in all directions, only so that it works fully on the tasks we give you. Laila will use this iPaq a bit during the test.
- L: You can give us a fresh view so we can improve this product. This is not a test of you and your skills, but a test of the usability of the product. The results of the test are confidential, and will not be published or displayed.
- L: Try to think out loud while carrying out the tasks. We would very much like to hear your trains of thought. (offer example: “Now I am going into the patient record, I wonder where that is? Maybe this button? Let’s give it a try and see where it takes me,” etc.)
- L: You may withdraw from the test anytime. You may ask questions at any time during the test.
- L: We will not be overly helpful during the test, as we are looking for bottlenecks and problem areas in the design where users get stuck, but also where users can manage by looking around a bit.
- L: The icon list. These are icons we have designed for the system (show form with text).
- Ø: Give a tour. Show both rooms, patient room with two beds and night stands; and the test room with table and chairs that also functions as “hallway” outside the patient room. Also show the box on the door with the “IR blinking.”
- Questions ?

D e b r i e f i n g :

Go over to the table, have some coffee and biscuits. Strike up a conversation around questions in interview guide.

- You were a good help to us. How did you experience the test?
- General aspects of the system first, then move towards more concrete ones.
- Move on to points noted during the test.
- Focus on understanding the problems, not solving them.
- Do not force the user to become defensive and having to justify actions.

Use the icon list without text to test learning curve.

Agenda:

- Briefing: de-stressing, informative. We appreciate the help.
- Test.
- Debriefing. Let the participant express any thoughts or feelings about the test, and ask any questions they have. Set an informal atmosphere.
- Interview.

Test participants will not be offered information on the results of the test.

The ethical aspect

Mental stress, important to do before test:
Have everything ready for when the user arrives

- Underline that it is the system being tested, not the user.
- Make the user aware that the system is new, and may have bugs.
- Make the user aware that s/he may withdraw from test at any time.
- Explain what data is registered during the test (introduce all equipment).
- Explain to user that results are confidential, and how they will be used.
- Make sure all questions the user has are answered before the test starts.

During the test

- Give the user feelings of success early (easy tasks).
- Present one task at a time.
- Keep a relaxed and informal atmosphere in the room (serve coffee).
- Avoid all disturbances; close doors and put notes on doors. Turn off phones.
- Never give hints to user that s/he is doing something wrong or working slowly.
- Minimize the number of observers in the room (perhaps a monitor to the room next door).
- Never let superiors to the user observe the user.
- If the test leader gets the impression that the test situation is a strain for the user, end the test.
- Observe the test impartially; do not let the user get a feeling of preferences.
- Be aware of how things are said and body language. Very subtle hints are often enough to make users understand.
- Treat each user as an individual. Take a break between users.
- Don’t be afraid of the users when they are struggling with a problem.
- Be sure that the user has finished a task before moving on. Users are often very insecure, even if s/he has carried out the correct response.
- Interact with the user during the test to ensure good verbalization.

At all times be on the hunt to understand the rationale behind the users actions. If the user indicates a different design solution, follow up (then or later in interview).

F-2 USER PRE-TEST FORM

7.nov.01

Gender: Age: Job position/ how long: Experience with IT (how long/ often): Attitudes to technology: Experience/ Knowledge of handheld devices?
During the test
Discussion/ Interview after the test

F-3 TASK SCENARIO FOR DOCTOR

(not for distribution, read to test user during the test)
(Test leader: Enter visitation information for Gunnar Olsen! Remember to give the user a white coat!)

Day 1:
Task 1:

Log on to your handheld device with user name, password, and position “Postlege.”

Task 2:
You are on morning visitation. You pick up your iPaq and find your way to “Min ToDo” (My ToDo). You choose the first name on the visitation list, Gunnar Olsen, and look at the description of the patients problems. Enter his graph book. Then you go into the room to see him.

Task 3:
You greet the patient, talk with him and explain that you wish to order a blood test for leucocytes. It will be taken the following day. You go into the graph book, and enter the information.

(Test leader: Enter contextual information!)

Task 4:
Do the previous task over again. This time you first go to the overview of the ward’s patients. Then you hold the iPaq within a meter from the patient, so that contextual information is available. Then try to use the context information to navigate towards filling the test order.

In the hallway after:

Ask the doctor if he sees other approaches to navigating towards the patient’s graph book directly after logging in.

(Test leader: Clear the init-field in the undersok-table! Clear visitation information, but store it in a safe place)

Day 2:
Task 5:
Check the ToDo-list. You receive a message from Clinical Chemistry that Olsen has an abnormal blood result. Enter the system to check it. You visit the patient and brief him of this result. You find the graph sheet and show this to the patient. His temperature is still high. Explain your thoughts on the further diagnostics. Suggest to the patient to order a new test for leucocytes to be taken 3 days later. Fill the form.

Task 6:
Try to attach the iPaq to the keyboard. Try to write with this. Impressions?

F-4 TASK SCENARIO FOR NURSE

(Test leader: Remember white coat for the user!)

“Day 1”:

Task 1:

Log on to your handheld device with user name, password, and position “Primærsykepleier 1” (Primary nurse 1). You have a patient with the name Gunnar Olsen, who was admitted the day before.

(Test leader: Enter contextual information!)

Task 2:

Greet the patient. Keep the iPaq near the patient’s bracelet-ID. Click to bring up context information.

Task 3:

Put the handheld device into the portable keyboard. Go to the part of the graph book where a new nurse record can be established. Enter the information that is collected through dialogue with the patient.

(Test leader: Clear context information!)

Task 4:

Lift the iPaq off the keyboard. Measure the patient’s temperature and blood pressure. Enter the data into the graph book by using the stylus. Then put the iPaq into your coat pocket and leave the room.

In the hallway after “Day 1”:

Ask the nurse if she sees other approaches to navigating towards the patient’s graph book directly after logging in.

“Day 2”:

Task 5:

(Test leader: Enter context information!)

You enter the room the next day and ask the patient how he is doing. The patient is complaining over a specific problem. You register the problem as a careplan and enter the information by using the portable keyboard. Try to navigate to the patients graph book in a different way than you did in Day 1. After this is done, you leave the room.

"Day 3":

Task 6:

Look at the ToDo-list. Gunnar Olsen has a problem that needs to be evaluated. Find his graph book, navigate to it by your own choice. Find the problem, put the iPaq into the keyboard and enter the evaluation after talking with the patient.

Test leader: Delete nurse documentation and careplan before next test participant!

F-5 "Patient" role-play Instructions

Instructions to "patient," role-play with NURSE

Follow this instruction during the communication with the Nurse. This is to ensure that the role-play is carried out as realistic as possible. But use your own words, and improvise if the nurse asks follow-up questions and for other unforeseen events. Your name is Gunnar Olsen.

"Day 1":

The nurse enters the room and greets you. She sweeps the iPaq over your wrist, and attaches the iPaq to the keyboard, before she starts asking you questions.

Why are you admitted? —**I am bothered by pains in my right knee.**
What is the goal with your stay? —**Get rid of my pains.**
Do you have other illnesses? —**No.**
Do you have any allergies? —**Yes, pollen.**
Do you have any other problems? —**I have a heart condition and have high blood pressure.**
How mobile are you? — **I can walk, but quickly experience pain so I don't get very far.**
Are you on any special diet? — **No**.
Messages? **— Ole Olsen, phone number 12345678**

The nurse measures temperature and blood pressure, then leaves the room.

"Day 2":

The nurse comes in and ask you how you are feeling. Answer: **My knee is swollen. It hurts, and I can't bend it. I barely made it to the bathroom before.**

The nurse will create a careplan. She asks what goals you have. Answer: **Become pain-free as much as possible, and get some mobility back.**

"Day 3":

The problem with your knee from "yesterday" is to be evaluated. **The nurse asks you how you are doing. Answer: It is better (answer follow-up questions whichever way seems natural).**

Instructions to "patient," role-play with DOCTOR

The scenario for communicating with the doctor is more open than the communication with the nurse. You are feeling low on energy, have poor appetite, and fever. If the doctor makes suggestions to exams, you should agree.

F-6 INTERVIEW QUESTIONS GUIDE

Sit down by the table immediately after the test. Have some coffee and biscuits to create a break. We bring the dialogue to our topics, avoid strict interview-format and keep it as a conversation.

- What do you think?
- When you are around in the ward, what do you think you would most appreciate with a device like this? Which of the services seemed most useful? Which have no value to you?
- What relationship did you see between the top menu and the graph book in the system? What do each do? (= what conceptual model are they left with).
- Was it a problem that the pages were colored, would you prefer it with an illusion of white sheets of paper laying on top?

Handling the device

- What about the physical properties of the PDA? How do you think it would be to carry it around from room to room? On your arm, in your coat pocket, how is the weight? With the portable keyboard? Is it a hindrance to you? Is the PDA really *mobile* in your situation?
- Is it big without the jacket too? (show). How is it in relation to these (show Palm V, Nokia phone), what is the right weight/ size/ where is the limit?
- How do you think it would be natural to carry it? Affix it to your arm, around your waist?

Context

- What did you think about getting information from the surroundings?
- What information from the physical world do you think could be useful to you? From objects, from people, from rooms?
- What relationship did you see between the “odd round button” and the information you possibly were offered?
- Do you see any disadvantages if this is made available for you?

Iconization + text design

- Was the use of icons understandable?
- Is it positive for you to have information presented in this manner?

Navigation

- How do you think navigating on the iPaq worked out?
- Do you feel you kept overview during navigation?

Data entry

- How do you think entering data with the stylus was? With keyboard?

Data presentation

- How do you think fetching data worked out?
- Choices have been made upon what information is presented. Do you think the amount of information was little or enough? Was it efficiently presented?
- How do you think the graph book worked out on the small screen?

Suitability

- How suitable do you think this mobile device is to make your work more efficient? Integrate and synchronize?

(Doctors only)

- Do you think requisitioning tests is useful for you from a mobile device?
- Is being able to check test results useful to you from a mobile device?

F-7 ICON FORM

This form was shown to the user in the pre-test briefing to try to familiarize the user with the icons as the focus group put strong leads on iconizing the interface, while icons can be tricky the first time they are seen. In the post-test session the same form was shown without the text cues, and the user was asked to interpret them to show an informal measurement of the quality of the icons.

! Patient has a clinical problem
? Patient wants information about a clinical problem

M Patient has a medical problem
O Patient has had surgery (Operation)
P A new abnormal test result has come back from the lab on patient

E Evaluation of problem in careplan is not done
E Evaluation of problem in careplan is done

You are not near a radio transmitter that offers contextual information

You are near a radio transmitter that offers contextual information, and you may choose this by clicking the icon

F-8 TRANSCRIPTS FROM USABILITY TEST AND INTERVIEW

Test participant 1:

Female, 45 years old. Nurse for 22 years. Has taken data courses at the hospital she works at, and daily enters information into systems at work. Surfs the net sometimes. Characterizes herself as very positive to new technology, and thinks it is exciting with all new things. She thinks it is important that technology saves her time and makes things happen quicker. No experience with handheld technology. Participated in the previous workshop. (Pilot test).

Day 1:
I can see what patients belong to which rooms, but I cannot see how many patients are in the rooms. It is important to know if the patient is in the I or II bed (620-I, 620-II). If one forgets names and is about to talk about the patient on the left, one can use roman numbers. We all know that I is left and II is right.

The user thought she could click each symbol (M, O, P, etc.) and get the problems up directly. She holds the iPaq by the patient's bracelet and click from the context button directly on to the right patient, upon which she immediately understands how to establish nurse documentation. She struggles to affix the iPaq into the keyboard. The data entry works OK, but the table is a bit low so she has to bend while typing. While she is typing, the virtual keyboard pops up, and the automatic spell-check confuses her a bit.

When seeing the word *messages* in the nurse record she says: "I am not connected when it comes to this term, I don't understand what information I am supposed to write here."

When the data entry is completed:
She reads aloud the feedback she is getting from the system. "To part 2 (of the nurse record). I don't quite know what that means."

She removes the iPaq from the keyboard. She is about to enter temperature and pulse, and immediately clicks into the place named "graph." She sees the graph, but also the link "new registry biometrics." She says, "that is a nice word I am not familiar with from the hospital." She clicks the link, and finds the field for entering data. She does not understand the symbols for entering time of measurements, and thinks "M" can stand for "Man" (actually "Morning"). She adds, "but it can also be morning medicine and 12-medicine. If that is what it is, I would prefer clock times instead. I don't understand this." To enter pulse and temperature with the virtual keyboard works fine. She clicks to send in the information, gets a confirmation, and then goes into the graph book to review.

"How does it feel to stand with your back bended?" (We talked a bit with her in the test room, by the table where the keyboard is.) She demonstrates and say it was not comfortable, and that the table was too low. Perhaps I could have had it on a tray in my lap, she suggests.

Day 2:
She clicks in to the list of the ward's patients, and to the patient Olsen. She is again struggling to affix the iPaq to the keyboard (practice does not seem to make perfect), and during the affixing the jacket slips, with the result that the network connection falls out.

Problems is a part of the nurse record, she reflects, and then goes into the nurse journal. But she does not see the link to fill the careplan at the bottom of the page. She clicks to "part 2" before using the back-button of the browser. By coincidence she discovers that she can use the scrollbar to get overview of the part of the patient record dealing with Fluids (Væske). She does not quit, and is convinced that the problem link must be under the nurse documentation. Suddenly she sees it, at the bottom of the page, and clicks forward. She begins to fill the text fields. Entering data works OK, she has no problems using the wizard. But she finds it annoying that she has to use the stylus to mark the text field every time she moves to a new one. After entering data: She clicks directly to the completed careplan, and says, “Date shows up automatically, uhu.”

Day 3:
We have come to task 6, and the test participant is about to go from the ToDo-list to the patient. “Do I go all the way out then?” she wonders, and pushes the right button. “Oh yes, my tasks. There the problem I entered shows up. Clever. Then we don’t get the option to forget anything, and that is a strength.”
She clicks “evaluate problem” under ToDo, and gets up what she calls “some codes.”
“Why do two E’s come up?” she wonders. She reads the description of what is meant by red and green E, and immediately understands the symbols. She clicks in to write the evaluation, and seems to find it intuitively.
“It is good that the name (of the patient) comes along on top of the page. That assures that we are on the right patient.”

Now she is about to affix the iPaq on to the keyboard, but experiences problems. The jacket slips, the network connection is broken and the program running the keyboard needs to be restarted. When she finally gets to enter the data, which is done without problems, she then clicks her way to the main picture of the nurse record.

“Then I am back. What I am thinking about now is how I got to where the problem was established. I would like to find the problem right away.” This time she does it without problems. Now she gets to see the list of problems, but expresses that she would have chosen a different representation (of problem ID) that would make it easier to separate several problems from each other.

Conversation after:
The test participant thinks she understood the structure of the menu system very quickly. She thinks it was quick to get used to using the stylus, but points out that it is easy to lose.
However, it troubles her that the iPaq so easily lost connection to the wireless network. She also is left with a feeling that the handheld device does not cover all areas. She thinks that there is no time to use a handheld device to document during an acute situation, but thinks it will work well when the user has plenty of time.
She also comments the test itself, and says it is good that there actually is a patient in the bed in the test room, rather than us discussing the problem around a table. “You have to understand how we think in relation to the patient,” the nurse says.

Interview:
In general she thinks that the system is good, but the shortcomings pointed out during the test pulls down the overall impression. However, she thinks it is good that she was eventually able to locate the careplan without help, and that the screen interfaces gave her signals to help her accomplish this.

She thinks she would appreciated such a system in her job, and that it is an advantage to have the patient records available in her pocket rather than having to go to the office to locate the patient’s papers. It would save her time, and lead to being able to spend more time closer to the patient. She is skeptical to the weight of the device. She is given a Palm V and iPaq without expansion jacket for comparison. She is more positive towards handheld devices of that size. She thinks it is OK to have it in her pocket, but that one also could have it in her waist in a clip.

About the relationship between the top menu and the patient menu she says: “When I am on the task list and click Olsen, I go straight to Olsen and get information about Olsen, when clicking in

the other menu. If I want to go to someone else, I have to go back to the main menu." (Analysis: her description suggests that she understood the conceptual model).
When questioning the use of color, she says she thinks that is important to see nuances of the patient record.

When asked how she would describe this system to a colleague: **"**I would say this was a small edition of a computer where one can go into the ward's patients and mark things on the device like blood tests, temperature, and pulse. And I think it all seems time saving."

She thinks the context button simplifies the system: "I don't have to look for names when moving from patient to patient. But I have to be sure I am not getting signals from the next bed." She adds that she is happy she does not have to poke the patient with the "gadget" to read data.
When asked if other context information could be useful, she says that it is nice to be able to go directly to the part of the record relevant for the task. She does not elaborate.

Pictures in the journal: She does not think that people always will appreciate being photographed when in conditions that require admittance to a hospital.

Use of icons on the patient overview: She did not like it very much. Says the letters do not match their daily vocabulary. She does not see any specific advantages by having information presented in such a manner.

Navigation: She thinks this seems OK once she figured out the stylus, even if it was a bit clumsy at first. Moving around the system went very well without needing help. She says she never fell far off, and could get herself back if she did.

Entering data with stylus went OK.

The keyboard was better for writing than the stylus. But she thought it was problematic to affix this.

Data presentation: The nurse thought it was positive that reminders appeared of things that were not done.

Does the nurse get enough information?: **"**As a rough draft to walk around among patients it is a good help." When asked if she thinks information is presented efficiently, she says **"**yes."

How the graph book worked: **"**It seemed functional and was easy to read on the screen. It seemed nice and handy, aside from the weight."

<u>Test participant 2:</u>

Female, 30 years. Have worked as a nurse for three years. Uses PC as a tool for writing. Some experience with email and surfing the world wide web. Has a positive attitude towards technology as an aid. Have not previous experience with handheld, digital devices. (Participant brought a toddler to the test).

The user struggled to affix the iPaq to the keyboard, and the driver has to be restarted. As soon as this is taken care of, she goes directly into the nurse record by clicking "My Patients." She comments that they do not usually write up *main diagnosis* and *goals* in the nurse record, and thinks this is unnatural. Aside from that, the data entry goes without problems. "I don't take care of the patient very well. I am more concerned about this keyboard," she says while entering the information.

Entering pulse and temperature goes without problems.

Outside the test room she is asked to offer alternative ways to navigate towards a patient. She mentions Ward's Patients, but cannot think of any other options.

Then it is time to establish careplan, and the user clicks into the nurse record via the context button. The user comments that it is difficult to create a careplan when she does not know what investigations have been done (she is not entirely comfortable with the role-play—but different practices in different wards probably would force us to create a test for users of a specific ward). She also says that she needs to know what the user is being treated for. The test leader asks her to improvise, but ends up having to do it herself. The nurse then puts the iPaq on to the keyboard, but the jacket slips and the network falls out. When this is fixed, the entry of information is done without problems. She takes the iPaq out of the keyboard, puts it in her pocket, but forgets the stylus on the table.

When entering temperature and pulse, she thinks for three seconds before going directly to graph book. She is to enter temperature, and tries to click directly on the image of the graph. "It does not work," she says. Then she discovers the link "new registry." She clicks on it, enters the measurements, and hits "send" without hesitation.

Then the test participant is to go into the task list ToDo and find the problem to be evaluated. She talks to the patient and says she has to see what the problem is. She clicks directly on the link to the patient's problem, but does not see the link that can be clicked to evaluate the problem right away. She clicks back to ToDo, and clicks the evaluation of problem over. Now she sees the link, but then says that she cannot evaluate a problem without clinical data. Upon being encouraged by the test leader, she carries on by improvisation, and clicks on the link to evaluate the careplan. Once again the iPaq disconnects from the network when the user affixes it to the keyboard.

Interview:

"At nursing school we are taught to think very categorically, maybe a bit too categorically. If I could see what operation the patient had gone through the test would not be a problem for me. But the information available steers your questions and what you plan to do. I would have liked a more detailed scenario, I had a bit too little data to be able to play out the role completely."

She would have liked more data to play out the role, and also thinks the prototype should be more detailed.

On the plus-side, the nurse comments that it is an advantage with a handheld device compared to looking through papers in a binder.

When it comes to the physical qualities of the device, the nurse thinks the iPaq is of right weight. "It is like a keychain. You feel it in your pocket, and by that you (have to) remember to pass them on." But she would have preferred a stationary computer on each room.
The nurse thinks the handheld device should be carried in the pocket, to not demonstrate power with "high-tech equipment" towards the patient. **"**It becomes a power symbol," she says. She thinks such a technical aid could have made the work in the division more efficient, but at the same time thinks it creates an unfortunate distance to the patient.

Entering date with keyboard went OK. But she is skeptical, for hygiene reasons, to using the keyboard in daily work. "It must be a giant source of bacteria. Imagine if I got blood on my finger, and did not wipe it away before I typed. It can not be available to all."

The stylus was easy to use.
She also thinks that the patient should have better access to information from the system.

Regarding the relationship between the top menu and the patient menu she says that the top menu is more technical, while pointing to the vertical line of options, "while the top menu is more nurse information."

When looking at the icon list, she remembers two icons correctly. A third icon she was unsure of, but was close.
She also understands the point of the context button. “I think it was natural to push the button and then patient information came up.”

She thinks the navigation went well, and she feels she had a good overview of the system at all times.

<u>Test participant 3:</u>

Female, 47 years old. Ph.D. student in sociology, quit nursing three years ago after ten years. Works daily with text processors and statistical analysis. Feels comfortable with computers, and has a positive attitude towards technology. No experience with handheld devices, except from a digital diary.

The test:

The test participant goes directly to the patient’s graph book from My Patients. She puts the iPaq on to the keyboard, but the jacket slips. When the equipment again works, she finds the nurse documentation and writes in main diagnosis, no problems. She wonders if the information should be stored in any way, but clicks the button “Next” after each step of entering information. She bends back and forward between the keyboard and the patient as she is asking questions and writing. She complains that there are no Norwegian letters on the keyboard, which is imported from the USA. During the test we notice that the patient is not quite following the scenario we scripted. For some reason the actor does not answer as we asked him to, but the nurse does not seem to notice this particularly.

She takes temperature and pulse of the patient, and immediately understands where to go to enter the date—the graph book. She looks at the graph for a bit and thinks, before clicking “new registry.” She says “I don’t understand what M means.” (symbol means Morning measurement). “That is what was a *medical problem*,” she continues. The temperature and pulse is entered without problems, and she clicks to send the data to the database. She puts the iPaq into her pocket and is about to leave when she asks: “Is everything stored now? It can’t be?”

Outside the test room she expresses that she would have liked the numbering of beds in the different rooms to be included. When asked about alternative ways to navigate to the same patient, she answers that there are two ways, either through My Patients or Ward’s Patients. She did not use the context button at all earlier in the test, but went in through My Patients.

When she got back into the room, she went straight to nurse documentation and clicked correctly on Careplan to create a new one. She talks with the patients and enters information, at the same time she is unsure of the terms used in the careplan. Entering the data is done quickly. She clicks further to review the complete careplan, and then try to figure out how to close it. That is not possible, she can only move on by using the top menu or right menu.

Then the nurse goes from the ToDo-list to the nurse documentation to evaluate a problem. But she makes a mistake and first enters Careplan where a new one is created. While she is pondering what went wrong she also wonders if is meant to write in tasks that go directly to the ToDo list.

The nurse quickly learns to navigate, but she has problems handling the stylus.

Interview:

The test participant thought it was odd to stand by the bed and type on the keyboard. She is used to noting medical information on a piece of paper, that is later entered into the records. She thinks it is an advantage to get access to information she needs immediately, rather than go look for them in paper journals. “It is supposed to be registered digitally where a patient record is and who took it, but this is often not done,” she explains. She also thinks that it is an advantage that data is entered into the journal immediately so that everybody has access to fresh data.

She comments that the graph on the graph image was very small.

About navigation: she says she had to think a bit, but thinks this will be easy after working with the system for some time. When asked whether she has the overview she needs, she says that more things may need to be included. “But we don’t bring the patient record on rounds anyhow,” she adds.

She thinks the size of the iPaq is OK, without the jacket that is. With the jacket she describes it as “huge.” She prefers to have the iPaq in her pocket rather than her waist.
She thinks having one keyboard on each table is too demanding on resources, as these will need to be cleaned in addition to everything else. She also thinks it is not feasible to fold-up the keyboard, carry it along, and then fold it out the next place. She would rather drag an ordinary laptop on a trolley. “But it seems feasible to write with the stylus if there is not too much information to enter. We usually don’t write so much when we are out in the ward. It can be handy for noting blood pressure and pulse, but not for reporting what happened to the patient during the day.”

She is unsure of how the icons functions, but the concept with a quick overview supposedly is OK.

Context information did not give her much. And she did not see much purpose with it. “Usually I know what room I am in, we are used to having names and numbers on the patient’s bracelets, and if they are awake, we always ask who they are anyway.” She could not imagine other areas where context information could be useful, “but it could be practical to have a warning if you are away from the patient and something happens to him.”

Test participant 4:

Male, 31 years old. Doctor for 1.5 years, was a Ph.D. student during the test period. Broad knowledge of computers. Experience with different programming languages. Describes himself as very positive to new technology. Has programmed handheld devices, and uses an electronic day-planner daily.

The Test

The test participant says before the test starts that he would have wanted a concrete scenario from a medical ward working on infectious diseases, of which he used to work before. He also said that he would have wanted a nurse to be a part of the test, as a doctor never goes on visitation without a nurse coming along taking notes. The doctor agrees to take part in the scenario we have developed, but with his own twist.

He goes to the task list, then directly to the visitation list. Then he enters the patient system and into the graph book without hesitation. He looks at the graph image to get an overview of the patient’s condition, this is improvised as the graph is only a static image in the prototype. Then the doctor “examines” the patient and decides to order a blood test. He immediately understands that the link to ordering blood test is under “Lab.” He also immediately understands all the fields in the order form, which he fills and sends off. Then he is to do the same task over again, but this time to look up the patient in the system by context information. The doctor finds his way without problems, but does not use the context button. He says he had discovered other ways to the patient’s records when we ask him about this.

For the next task, he is to check an abnormal test result that shows up on his ToDo-list. He finds it immediately, but hesitates over the type of feedback. Instead of “High” he would have preferred a concrete number value. The doctor improvises well, he also tries to enter temperature on his own. He does this without problems, but the test leader has to stop him when he is moving towards functionality that the prototype does not support. Finally, he tries to affix the iPaq to the keyboard, with the result that the jacket slips.

Interview:
The doctor says that even if the physical surroundings were realistic, it is necessary with more available information and more medical staff to make the scenario realistic.

At the same time he says that the amount of information a doctor needs may override the practical capacity of the handheld device. The information can be structured enough to enable entry, but this may hurt work processes, thus the system may be sabotaged by doctors.

Overall he says that the navigation worked well, and he thought the interface design with tabs was OK. However, he did not like that he had to scroll to see the last tab.

What the doctor first and foremost would like with such a handheld device was to have all patient records available at one place. He would like to get the text up, at least a brief, and updated lab results. He thinks this prototype was lacking some services. “But I think you will get different answers from different doctors, depending on problem and ward.”

He explains the relationship between the top- and side menu like this: “In the top part I find the patient and what I am to do. On the side I find the data I need to carry out those tasks.”

The doctor thinks the iPaq is too heavy with the expansion jacket. He thinks he should be able to keep it in his pocket, but the network card sticking out would likely get stuck in things. He also fears that the iPaq is to smooth so that it may easily fall out of a pocket.

He had a relative good recollection of the icons, but forgot what two of them meant. The doctor liked the function and thinks iconization would be an advantage in his daily work. “Icons will get a function much like the task list, they signal that there is something we must do.” But he thinks there was too little data in the prototype to give him any feeling of how this worked out. He adds that there should be a place to note findings made while with the patient.

He thinks the keyboard should be connected wirelessly to the iPaq to hinder problems establishing the connection.

In relation to the navigation he remarks that it is difficult to get back to viewing the visitation note after reading it. He would have liked to have the previous visitation note also in the main interface.

He did not notice the context button. He did not click it, but says it could be “handy,” and save many annoyances.

The doctor thinks he personally would have liked ordering tests, to be sure that everything is done.

Test participant 5:

Male, 42 years old. Chief doctor, but primary position is Associate Professor. Positive attitude to technology, and not afraid to start using new things if it helps him in his work. Little experience with handheld devices. Participated in the focus group.

The test:
Goes without problems to the visitation list, then on to the first patient there. Then moves straight into the patient record, to Lab and Clinical Chemistry without hesitation. This all seems natural. He fills the test order, and clicks **"**send." His immediate reaction is that this was very quick. Then the task is to be done over again, but the doctor is to hold the iPaq near the patient to use the context button. The test participant expresses that he is not on top of things anymore. He cannot find the symbol. After looking for a while, the test leader shows him the button. "Now I understand. But I had no chance before. I thought the symbol only told me if I was near enough."

Then the doctor checks the task list. He sees that he has received a message from the lab of an abnormal test result. He clicks the link, then is taken directly to the page with the abnormal result. He tries to sign having seen the test by clicking "Sign," but then sees that his signature shows up automatically as he enters the test. This makes him wonder what happens if a nurse goes into that page—will the test be signed as "seen" then? (Nurses do not have access to test results as such). Now the test user is to find the graph image, and show this to the patient. He talks to the patient and demonstrates, but points out that he may not be inclined to do this in reality. The screen is very small, he says, "the information is too cryptic, this is just a tool for me." Besides, the temperature is shown as going down on the graph image, which may not give the patient proper motivation to continue treatment. The doctor orders a new test, and says: "It is completely intuitive how to do this!"

Interview:
The doctor says he would have kept the context button as an "i" for "info." He says he also would have liked a stronger indication that something is new in the context, the button is too invisible. He thinks it is a good idea to harvest information from the surroundings, but the solution is not intuitive enough.

He also thinks the relationship between top- and side menu was intuitive: "The menu on the right belongs to the active patient. The top menu belongs to me as a health person." He felt it was easy to keep overview during navigation.

He wonders if the letters in the side menu should rather be vertical than horizontal, but likes the color scheme. "It gives an illusion that the information is in layers, and one does not have to go back to the hierarchy all the time."
He thinks using the stylus was slow, but admits that he is not used to such tools so that may be the reason. Retrieving data, among other things checking test results, he thought was very efficient.

He thinks it is a good idea to use icons in the patient lists. But something should happen when clicking the symbols, and the test participant also has problems associating information with the icon designs used.

The test user thinks the iPaq is a bit large and heavy, he is also worried it might slip out of the coat, and he is unsure whether it is solid enough. "It must handle to be in the pocket with 3-4 books, and be robust enough to survive hitting a doorway." He would prefer to keep it in his coat pocket, but also thinks it could be fastened on the waist to a belt. If it is to be kept in the breast pocket, it should be affixed. When prompted if he thinks such a device can help make his work more efficient, he says: "So far it is extremely unpolished, but one can see the contours of something that might work." The user remarks that the table near the patient was too low, considering the angle the iPaq had in the keyboard.

F-9 E-MAIL QUESTIONS AND REPLIES

Question 1:

The prototype you tried was at all times connected to a central server through a wireless connection, so that all the information you entered, and the information you retrieved, for example test results, at all times was updated.

Another possible implementation of this system could be based on synchronizing patient record data by connecting the handheld device via cable (cradle) to a stationary computer that is connected to the main database for patient records. Before entering the ward, you would disconnect the handheld device from the network. The information you entered into the handheld device while out, would be uploaded and registered in the main database once you got back and reconnected the device to a stationary computer. This will also make the unit lighter, as the network expansion jacket could be left behind. What do you think of this?

Question 2:

How did you think the use of the device affected your communication with the patient? And contrary, how did you think that the communication with the patient affected your ability to use the system?

Test participant 1 (nurse):

(1) Whether the iPaq should be online: Then information would reach others later, it depends on how important it is to spread information to others. But better than paper.

(2) How the iPaq affected patient communication: I was very busy, was not trained on system beforehand, and had to figure out the system on my own. This takes attention away from patient. Should have good training, and train on ones own to make this smoother.

Test participant 2 (nurse):

I think it is important that users at all times get access to new information of the patients, as decisions often have to be made quickly. If one has to at all times relate to a stationary desktop, it is back to the slowness of the system that exists today: too little room/ availability of computers, or lack of physical work space for nurses. In addition one would save a lot of time walking back and forth in the ward, which actually is a reason why many health workers burn out. Another issue is that the time interval often is longer if one has to go back to a stationary desktop to plot in the data, or it is easier to forget to do this, perhaps because one does not note things with pencil anymore but only relies on keyboard.

How did you think the use of the device affected your communication with the patient?
It was a disturbance if using it while standing up, for example when standing next to the patient's bed. But if one would sit down, let the patient see the device and what was written, thus making the patient central rather than the device, I don't see this as a problem. There always is a risk when using electronic equipment while interacting with others; it may appear as a symbol of power, competency, or just a distraction.

How did you think that the communication with the patient affected your ability to use the system?
If one can go back later and correct what was written, it is ok, but it is definitely hard to concentrate on giving the patient the attention he deserves while plotting in all sorts of information about him in a system.

Test participant 3 (nurse):

1. It is an advantage that the handheld device is connected to a network/ main records and that what is written in the patient room is entered directly to where it belongs. This to avoid writing twice, and to have access to information.

2. I think that the communication with the patient became poorer. This is probably because it was an unusual situation, and that I did not know the little device and had to use energy figuring it out. I think this will work out once one gets some experience. It is important for nurses to have good communication, both verbal and non-verbal, with the patient, and information can be lost here if the user is too occupied with the technical stuff. I also think (lots of thinking here ;)) that the patient will withdraw/ perhaps lose some trust if the nurse is too pre-occupied with technical gadgets (ref. all the patients who complain that their primary doctor is only looking at his computer screen).

Test participant 4 (doctor):

(1) It depends on the update-frequency of information. If I non-stop have to synchronize in a cradle to get information I can rely on, the method is not good. If one synchronization per day is enough, that is fine.

(2) The device demanded quite some attention compared to what little I could use it for (one single blood test result...). I also strongly feel the situation will be radically more challenging when navigating with realistic amounts of information. I am sorry, but your prototype is too unfinished to make the test situation realistic regarding patient communication. There is a danger that the interface for navigation would collapse when trying to maneuver among at least 250 different blood tests + record notes + x-ray images +++. But good luck to you :-)

Test participant 5 (doctor)

1

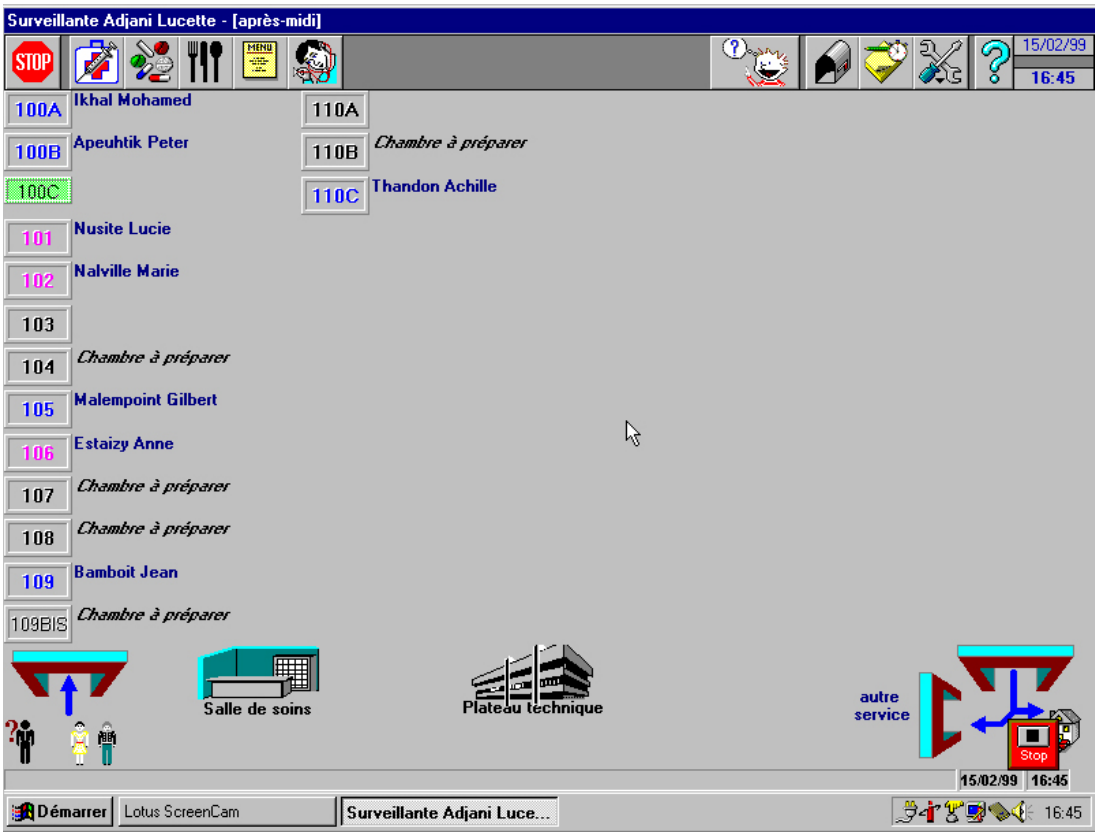
No, I would prefer that it was online the whole time. One never knows what kind of information will be needed before starting visitation rounds, and it is also desirable to be able to check brand fresh test results (that is, information produced in a laboratory and released from the laboratory after the doctor starts visitation).

2

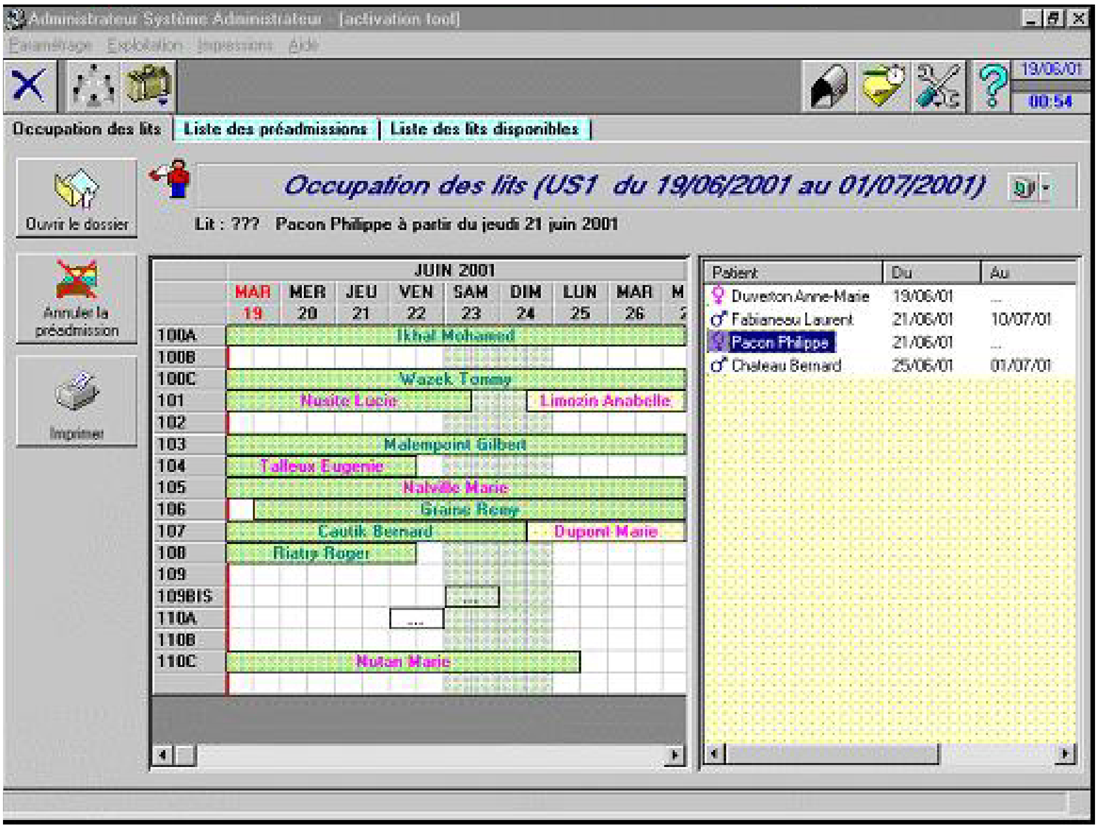
This is a bit difficult to say as I felt the scenario was not realistic enough to get me “carried away.” I think that I—with a functioning system, would have chosen to draw the PDA into the communication in the patient room, for example to show the patient his test results or his x-ray images.

With a functioning system I would probably feel more comfortable in my communication with the patient. I would experience the system as a back-up, ensuring access to all information on the patient, also the freshest.

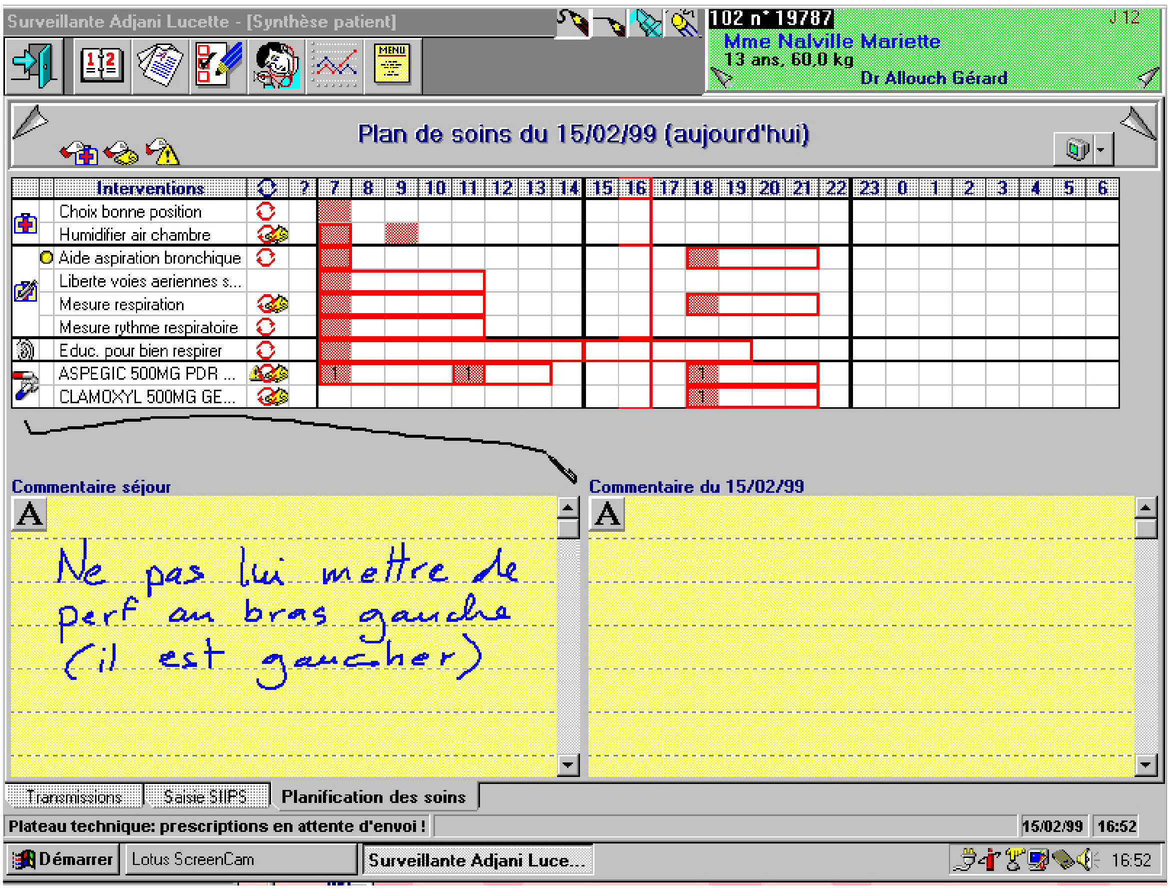
APPENDIX G
Actipidos Screen Images



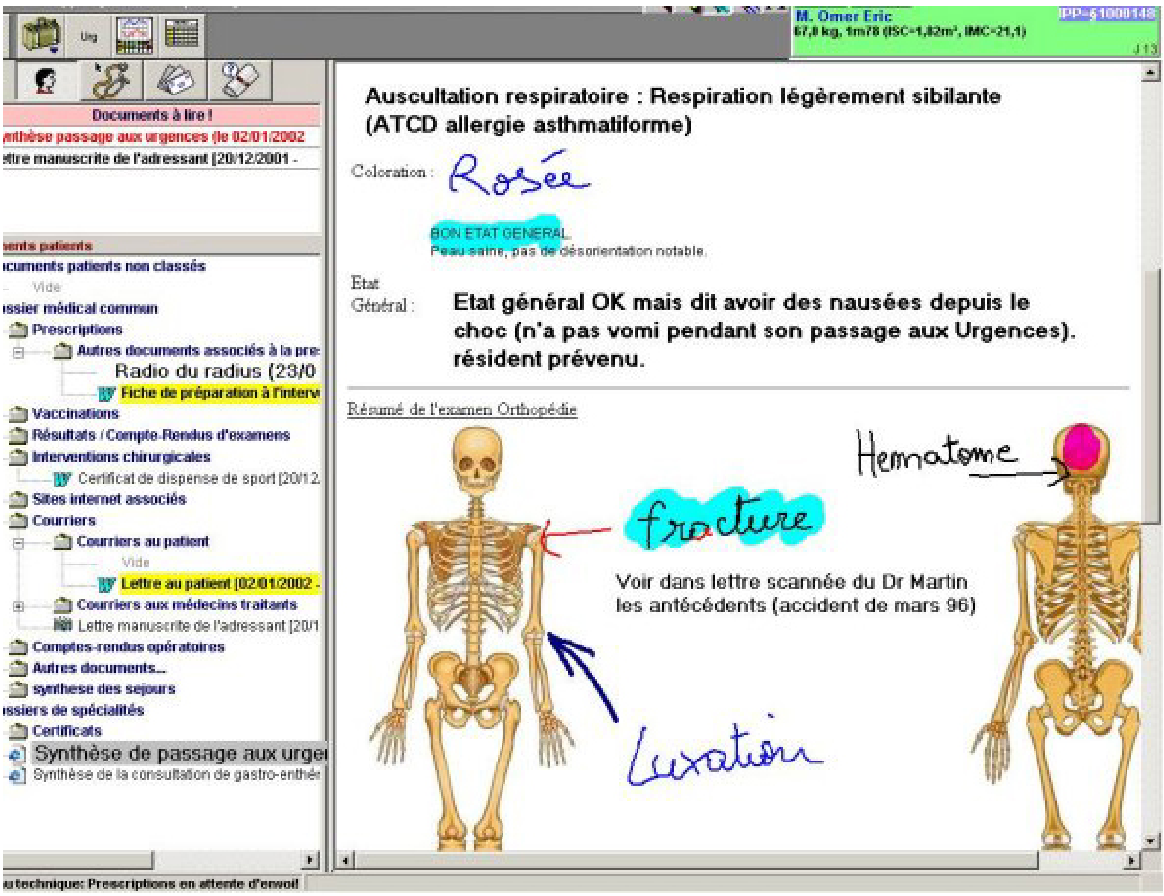
Actipidos: Main Workscreen



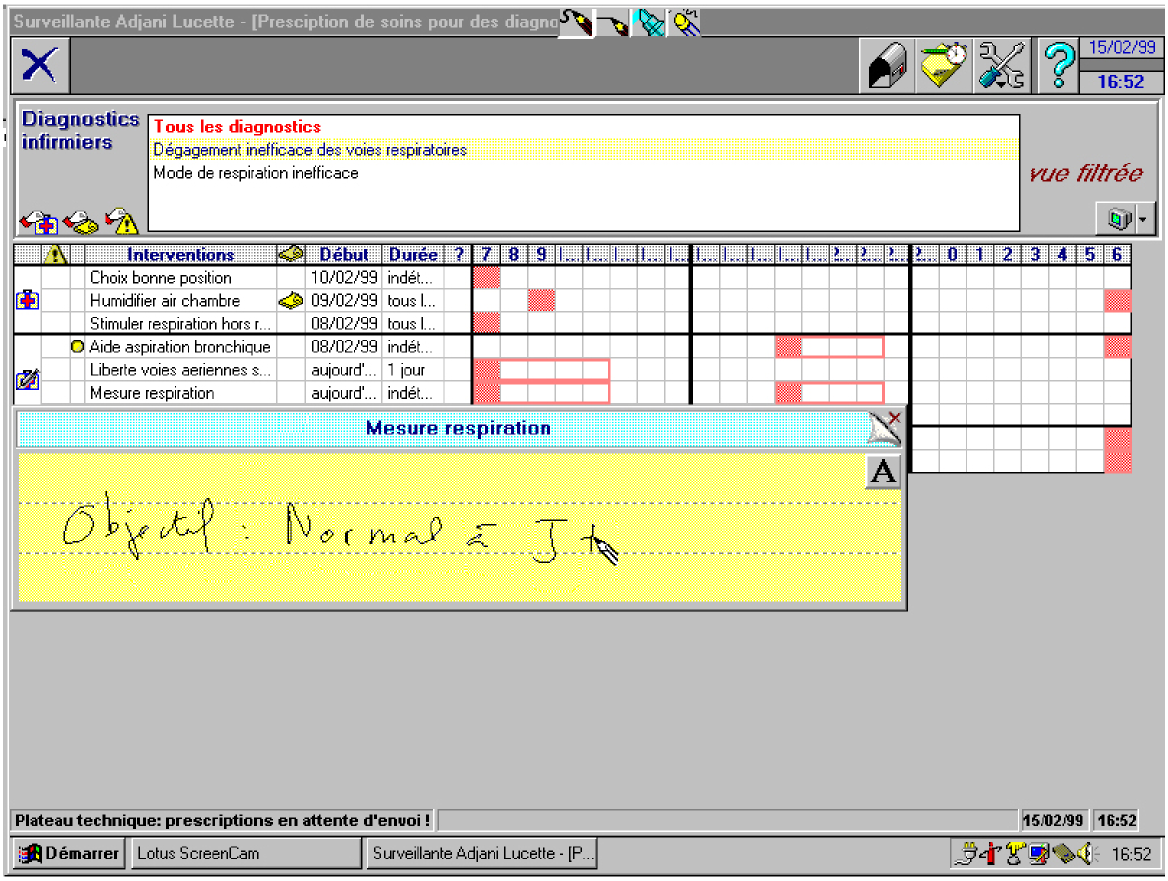
Actipidos: Bed Management



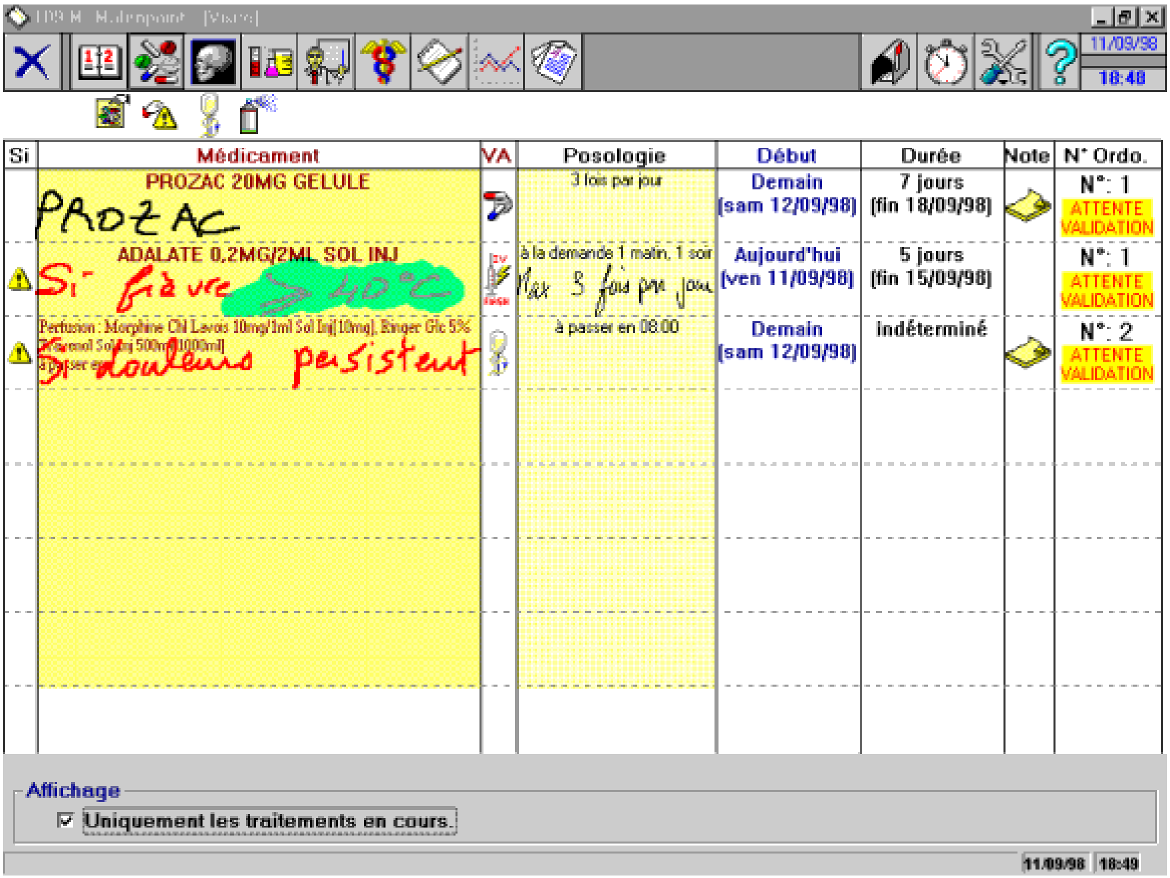
Actipidos: Careplan



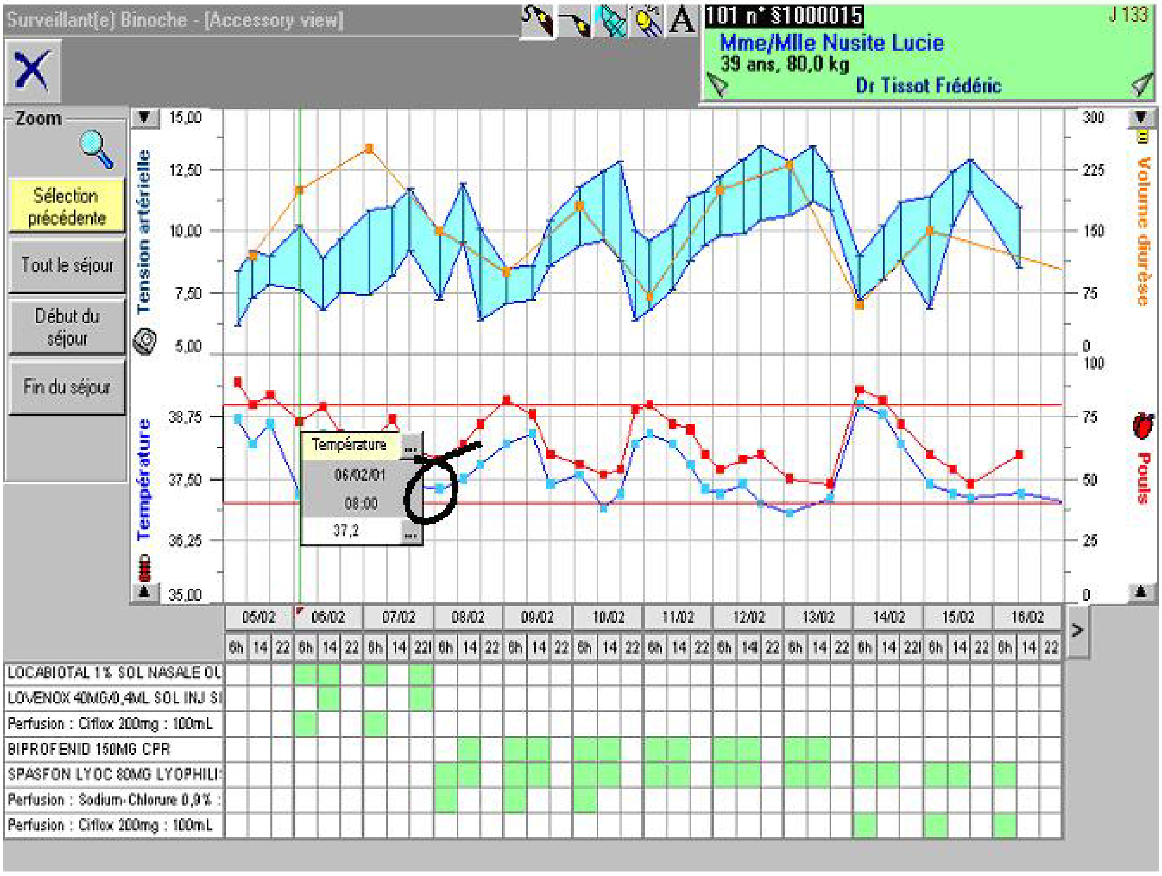
Actipidos: Patient history (recent urgencies first)



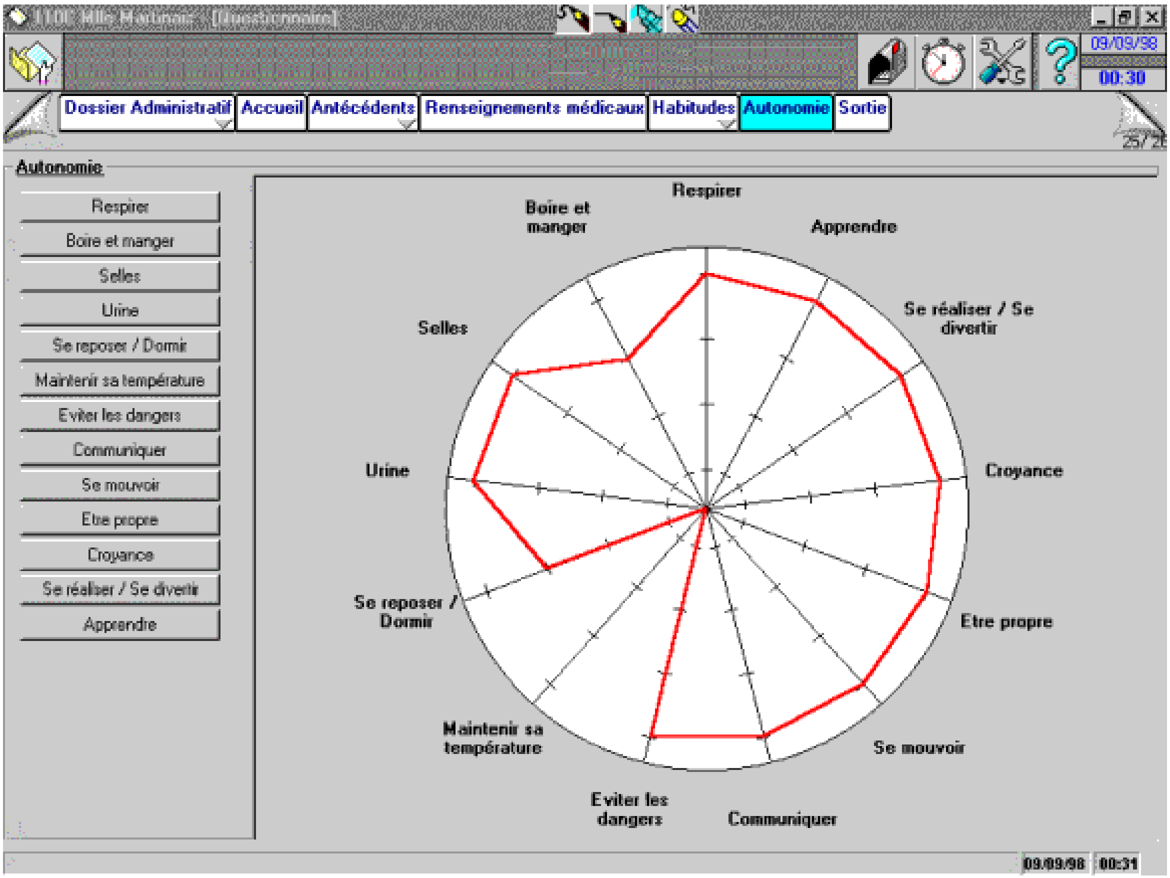
Actipidos: Diagnostics and interventions



Actipidos: Medicament prescriptions



Actipidos: Graphsheet with graph display (kurveark m/graf)

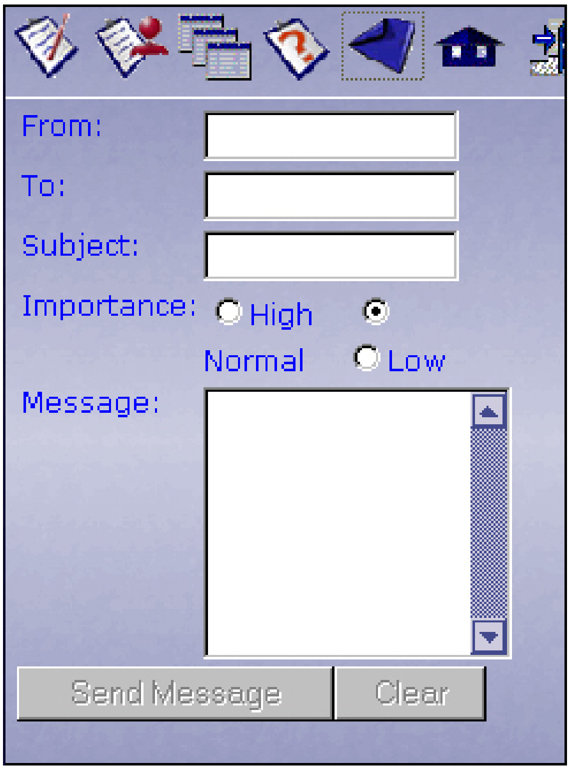


Actipidos: Graph display – ideal is a wide circle. This patient has a high fever and reduced food intake.

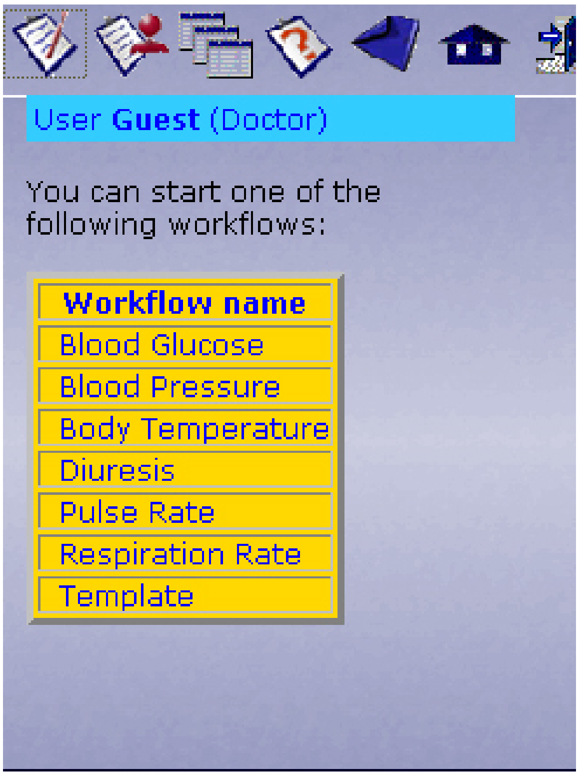
APPENDIX H
WardInHand Screen Images

WardInHand.

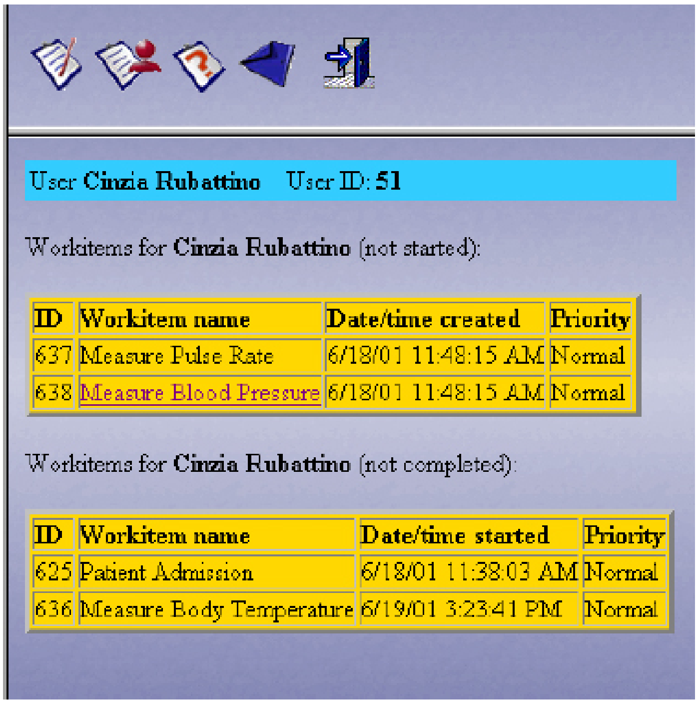
WardInHand: Main workscreen.



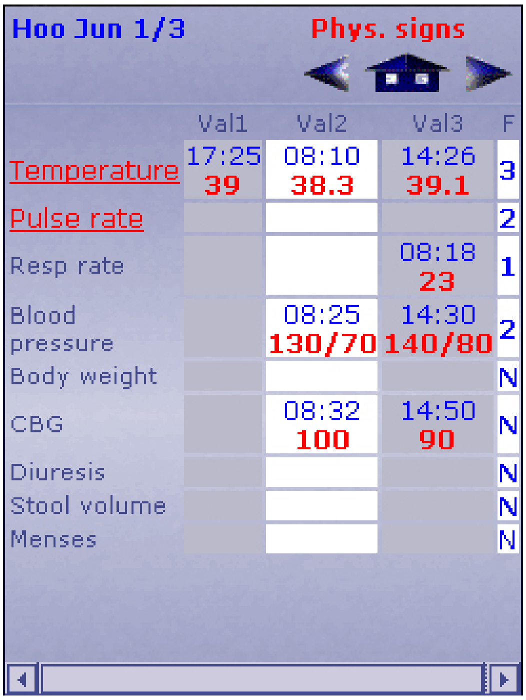
WardInHand: Message system.



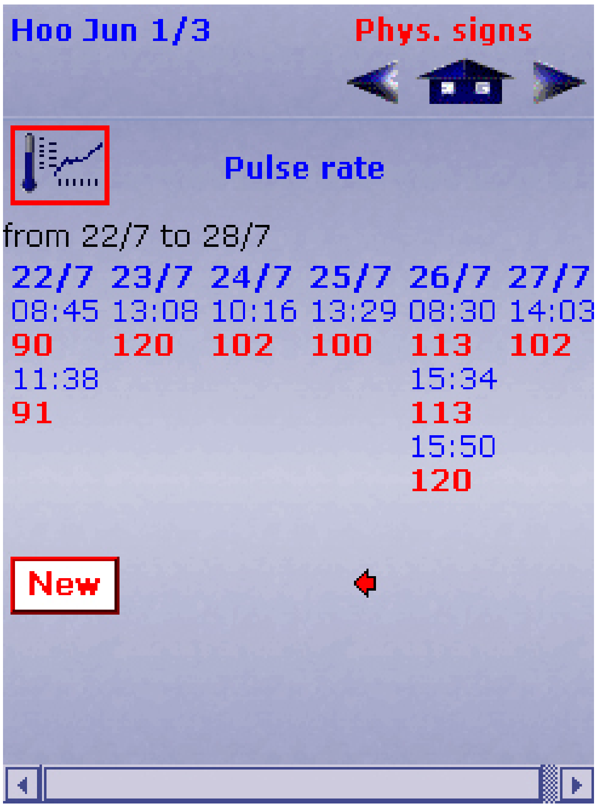
WardInHand: Workflow wizards.



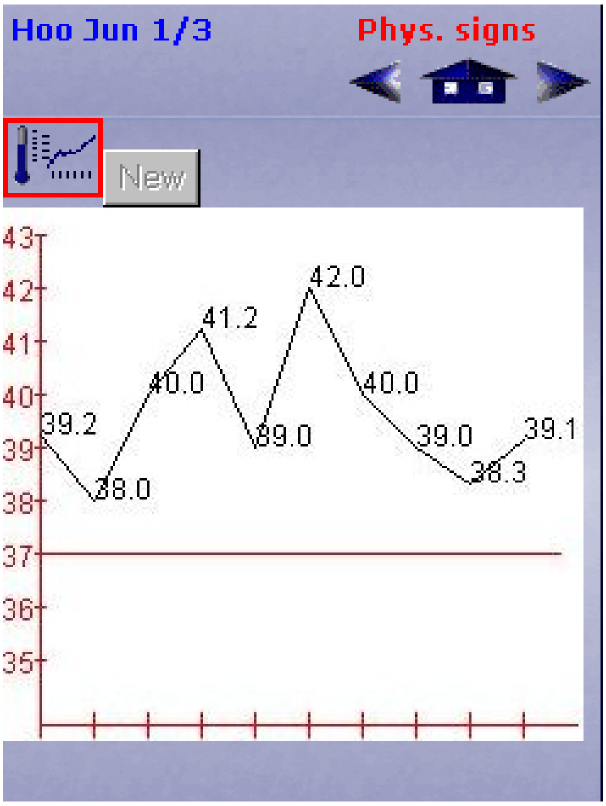
WardInHand: Tasklist for user.



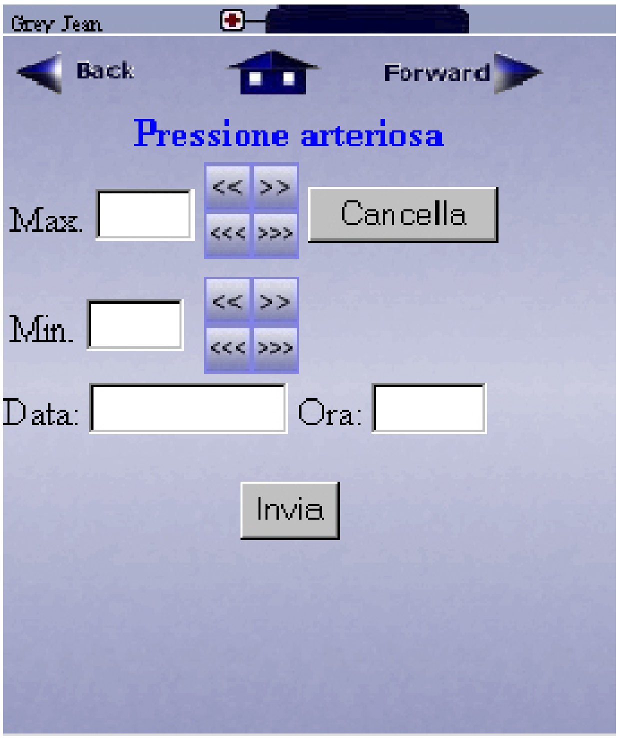
WardInHand: Physical signs.



WardInHand: Pulse rate.



WardInHand: Temperature graph.



WardInHand: Blood pressure entry.