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Mobile informatics in a hospital environment:

Moving from stationary to mobile supporting services in a medical environment

Fredrik A. Bergstrand
Max N. Gabrielsson

CHALMERS | UNIVERSITY OF GOTHENBURG

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Chalmers University of Technology and University of Gothenburg
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Mobile informatics in a hospital environment

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FREDRIK A. BERGSTRAND, MAX N. GABRIELSSON

Supervisors: PhD. Johan Lundin, PhD. Claes Strannegård

Examiner: PhD. Urban Nuldén

Department of Applied Information Technology

IT University of Göteborg

Göteborg University and Chalmers University of Technology

Abstract

Much of the supportive technology developed for use within medical environments is targeted towards stationary computers. In this report we present a study performed to design a mobile client for accessing and interpreting clinical lab results. The study shows that the current stationary system does not efficiently support the time critical and mobile work that is performed at the hospital ward. Healthcare professionals spend much of their time wandering between patients and offices, while the supportive technology stays stationary. The design of the prototype presented in this report reflects how clinicians work with lab results, and it also allows the users to reach the information at any location and at any time. Lab results in the prototype are presented as groups corresponding to the bodily function the lab test are to examine. A graphical view presents trends of a patient's progress and how the patient responds to the treatment. The client also notifies the user on newly arrived results, eliminating the time required to seek out an unoccupied stationary computer in frequent intervals and manually search for new results. The report concludes that the working environment would be improved by supporting the mobile workers with mobile technology. The main result of this report is a proposition of how to design a mobile client for efficient access and interpretation of lab results.

Keywords: mobile informatics, health care, ethnography, prototyping, visualization

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1 Introduction

Handheld computers have been adopted in the medical environments over the last decade, mainly as a lightweight format for reference literature, but also as a time manager and easy access to other information sources such as the Internet (McAlearney & Medow, 2004; Lu, Xiao, Sears, & Jacko, 2005). Most clinicians think that the trend of developing mobile technology in health care will continue. Studies have shown that new clinicians are more comfortable with electronic technologies which may help the future promotion of handheld computers (McAlearney & Medow, 2004). New and improved connectivity services such as third generation mobile networks and local wireless networks allows handheld devices to stay connected at all times to exchange and update information instantly. Technical improvements of handheld devices have also removed the need for purpose build Personal Digital Assistants (PDA) as the same functionality now can be found within smartphones. New technology allows improvements in work practices and adds a new level of mobility to medical support systems.

This Masters project aimed to develop a handheld solution that could support clinicians with up to date lab results. Ethnographic studies have been conducted to put the use of a mobile client in a context and locate the design features required for efficient medical work. In the hospital where this study was conducted the clinicians has stated that accessing lab results today is a time consuming and complicated procedure of navigation and interpretation, nor is there any notification when new lab results have been delivered. The result is said to be dissatisfied users of the current system and in the end patient does not receive optimal care. The system owner at the Health and Care department states:

> *"A large portion of the time patients consider as wait, is in direct correlation with doctors not accessing lab results in a time efficient manner"*

The project is under supervision of Synaps Teknisk Utveckling AB and the intended users are staff members at the central intensive care unit (CIVA) at Sahlgrenska University Hospital (SU) in Göteborg, Sweden. The staff at the ward have expressed that their current work environment is maladjusted with stationary supporting technology in their mobile work environment. They are also concerned when it comes to clinical lab result as they are used in everyday activities at the ward to define a treatment plan for a patient. There are hundreds of different types of lab tests that can be performed. Clinical lab results are currently accessed through stationary computers located throughout the ward so that information can be retrieved without wandering too far away from the patients. The recent decades of technological improvements in health care have been targeted towards the use of stationary computers for more effective distribution and management of medical data, but this process has also undermined collaboration and mobility as information is no longer portable (Luff & Heath, 1998). Accessing the clinical lab results has also become a complicated procedure of navigation and interpretation, and the lab result system currently in use only allows results to be viewed in a vertical spreadsheet, on which two results of the same type can be several screen heights apart on the computer screen. The current lab system's user interface consists of a list of tables where each table has a list of lab types and results. When a specimen, such

as blood in a test tube, is collected the sample can be subject to many analyses. Each analyzed test tube generates a new table in the lab test result view. The outcome of using the current lab system is that it requires much scrolling and makes it hard to interpret and retrieve the results; a user has to log in to the network, start and log into the application, and then input a search query in order to access the information needed.

1.1 Problem Description

The main problem that formed this study was that the clinicians at CIVA were displeased with the current system used for working with clinical lab results. Stated was that here are no way to determine if new results are present without locating an unoccupied computer, going through several log-ins and queries, and to sometimes find that "the analysis is not yet done" (Figure 1).

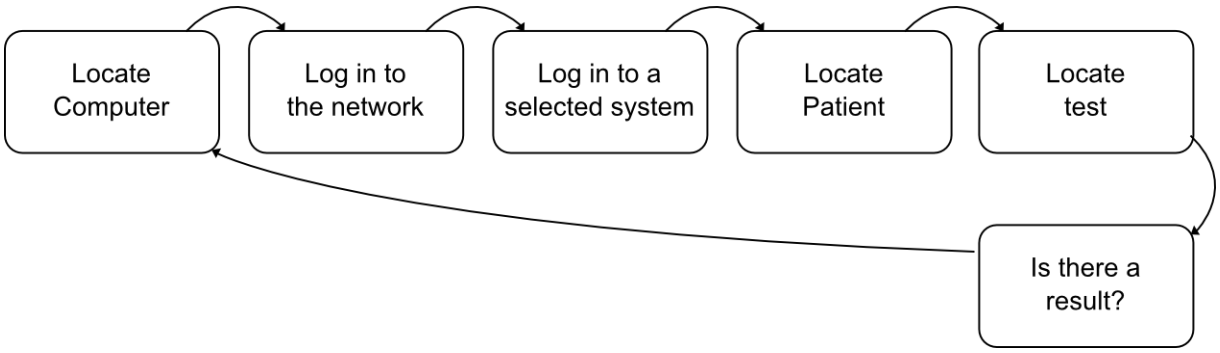

Figure 1. Process for accessing and checking new lab results

This process is said to cause frustration among the staff and it is also economically inefficient. A rough estimate is that nurses and clinicians spend an average of 30 minutes a day looking for results that may not yet be present (Strannegård, Torgersson, & Persson, 2007). The time consuming task of accessing new lab results is a consequence of the lack of notifications linked with the lab result system. The way the lab results are accessed together with the lack of notifications for new lab results generates frustration among the personnel. Another big problem that caused an extra workload is that the current system has a non user friendly interface that makes lab results hard to work with and interpret. Plaisant et al (Plaisant, Milash, Rose, Widoff, & Shneiderman, 1996) has found the same problem with the user interface when exploring how personal records are collected and brought together in a single record. In 1996 Plaisant found that virtually no effort has been made to design an appropriate visualization and navigational technique to present personal history records in the medical field and this study has shown that little has changed.

> *"Once gathered in a single record, the information is often in the form of a puzzle and the reader has to browse the data in order to form the big picture of the record. The reader must pour through lengthy and diverse pages. Missing or overlooking a piece of the puzzle can have dramatic effects."*

This master project was started by a request from CIVA to develop a mobile handheld client able to notify the users of the delivery of new lab results, and to ease the interpretation of lab test results, hopefully by the means of a graphical representation.

1.2 Research Purpose

This master thesis will explore how to design mobile medical supportive technology. The project will examine how a graphical representation of lab data should be presented according to the clients users; a part of the problem has been to find a proper interface for presenting new and older lab results together in order to let the user interpret the results with less effort. Another part of the study will be to explore how clinicians act towards lab results, and also how lab results are commonly used in work practices. Through this study we present how clinicians relate to mobility and mobile IT use in a hospital setting. The main question to be answered through this study is:

What design implications should be considered when developing a mobile client for clinical lab results?

The findings from the study will hopefully be proved valuable to the research and development of mobile informatics and medical support systems.

2 Background

Working at a hospital requires much wandering between patients, offices and even other hospitals, but little or none of the supporting technology supports this type of mobility. Kakihara and Sörensen (2002) argues that being mobile is not just a matter of people travelling, but more importantly being mobile is related to the way people interact with each other. When introducing a mobile supportive technology the role of time and place change, and the effect can have an organizational impact. Supporting technology defines how time and space are used and creates a template for how procedures and work activities are carried out. The work performed during this study has shown that there is much to gain from adapting to new technology. A mobile client would put patient information in reach at every location, and relocation to a home base, or a computer would not be required for simple tasks which lead to more focus on the work at hand, treating patients.

Brown and O'Hara (2003) discusses how work changes when the workers change their workplace by incorporating more technology to support their mobile setting. In a hospital it is hard to make changes, and technology that supports mobile work is not easy to implement as the required information is protected and closed down for security and organizational reasons. The staff at CIVA has two main types of tools that would be considered mobile, papers and phones. Physicians have a cordless phone with them all the time to be able to interact with other staff members regardless of their spatial location. An additional private cell phone for interacting with people outside the hospital such as family is often also carried by staff within the ward. Paper is a crucial tool when treating patients in various ways, it is for example one of the main tools used for reaching a diagnose. Papers with notes on patients that are carried around by clinicians and papers in patient binders in the ward's rooms are used frequently in the daily work at the ward. The paper notes are the clinicians' tool to remember certain things about their patients while binders are patient specific with data such as lab results, medication sheets, and journals.

2.1 Synaps

This Masters project is carried out with a goal to add features for accessing and visualizing lab results for a mobile client-server solution for medical use called Synaps (Strannegård, Torgersson, & Persson, 2007). Synaps is a mobile information platform developed in close collaboration with the emergency medicine ward (MAVA) at SU to support medical work in various situations. The client is concentrated primarily on output rather than input as input on a touch screen with the small touch-screen keyboard or handwriting recognition is a barrier to an efficient use of handheld devices (Fischer, Stewart, Mehta, Wax, & Lapinsky, 2003; McAlearney & Medow, 2004). The platform consists of seventeen modules developed for medical practice. Among the modules there are functionality for accessing the national drug database (FASS), code databases of classifications for various procedures and conditions, and also patient specific information such as radiology requests. The patient specific modules are accessed from a patient overview. Patient specific information can be radiology referrals and patient information. The client puts the patient in center which is not an approach that is used in the systems at SU, where different branches can have their own application. When the client is focused on a patient the user can navigate to the patient's specific information in different medical branches. The Synaps platform started out with the goal to let clinicians gain access to replies on radiology referrals as soon as they have arrived, a feature that was

missing according to a clinician at SU. Radiology referrals are used to determine how the x-ray scan turned out.

Figure 2. Synaps client with patient overview

Synaps has a fully developed user interface (Figure 2) developed together with experts in interaction design and graphic design. The experts developed dummies and prototypes of the graphical user interface and tested it on a user group in an iterative fashion, gradually improving the system (Strannegård et al., 2007).

2.2 Handhelds in Health Care

Handheld computers have shown to be popular in medical practices, and are stated to be so because they allow vast amounts of information to be carried in the pocket (Lu, Xiao, Sears, & Jacko, 2005). A mobile client allows remote access to reference material, clinical lab data and patient health states via a wireless connection.

Berglund et al (2007) have made a study among the staff at a Swedish county hospital where nurses and nurse student had high expectations of mobile information support systems. The study is composed of interviews which showed that nurses and nurse students wanted a mobile tool for accessing information about patients, a knowledge database and functions to ease and standardize everyday tasks. Being able to understand the patient's needs and to quickly answer questions about a patient's condition is the reasons stated for mobile access to the information. The study also showed that the nurses is concerned about not interfering with interaction between the staff and patient, the tool should be easy to use so that the treating staff's focus can remain on the patient and not to the PDA. The nurses and nurse students express that access to test results and reference values has the highest priority when considering patient information.

In (Fischer, Stewart, Mehta, Wax, & Lapinsky, 2003) it is stated that the main resources to improve medical work would be mobile access, and in particular to drug information databases, patient health tracking, cost tracking and prescription of pharmaceuticals. Fischer

et al (2003) and Lu et al (2005) has both conducted research programs to produce review articles on handheld computing used in medical environments up until 2004. The main source for both articles is Medline and other medical reference libraries. The studies do not discuss gains in mobility or collaboration to the extent that would be found in Human Computer Interaction (HCI), Computer Supported Collaborative Work (CSCW) or mobile informatics research fields. The articles reviewed are mainly focused on the practical use of mobile medical applications. Mobility and communication is mentioned but benefits in retrieval and use of patient and medical information is the main theme. Access to medical information where and when needed is the common denominator which would make handheld devices a valuable contribution to medical work.

2.3 Mobility in Health Care

Often stated about mobility in health care is that more mobility would improve patient care and allow hospital personnel to spend more time with patients and less time gathering information (Lu, Xiao, Sears, & Jacko, 2005). A handheld device would give the user more freedom to plan and spend their time. The spatial restrictions imposed by stationary information support systems forces the user into a pattern where a "home base" needs to be visited in intervals to gather information for current and further work activities. A mobile solution aids the user by providing up to date information on any location, and also allowing a more fluent time schedule where important events can be noticed and acted upon. Luff and Heath (1998) have found that participants in studies of various settings rely on their own mobility and the mobility of artifacts to be able to coordinate activities with others. In their study of the introduction of computer based records into the medical consultation they explored how the technology has undermined collaboration. Traditional paper records supports collaboration between both clinicians and other professionals, and between patient and the clinician. Luff and Heath express that paper records serves as an important resource for communication and collaboration and are, even with the introduction of computerized systems, an important resource in professional medical practice. The paper becomes important because of its portability; it can be passed around, be carried around, and be moved between different parts of a location. It is said that when developing mobile technologies to support collaboration between users, developers needs to explore in more detail how objects are used in interaction where mobility is crucial. The field study for this project should give artifacts, such as patient records and binders with forms, significant attention in order for the final product to support the everyday work at the ward; at a first glance what may seem obvious to support with mobile technology may not be what a user needs mobile support with (Luff & Heath, 1998). Lundberg and Sandahl (1999) stress the importance of artifacts in an environment where written paper has a value itself. A paper act as a token and the bookshelf acts as a measure on the work load. Actions such as moving a document from one table to another, face-to-face discussions and the use of boards for scheduling influences different kind of interdependence in medical work. In another article Lundberg and Tellioğlu (1999) concludes that translating the coordinating role of paper documents and other linked artifacts to computer systems is a challenge because artifacts are part of a shared infrastructure and needs to be better understood. Translating the paper based examination requests to computer systems means that the coordination role of a paper also needs to be translated which is in

practice impossible. Lundberg and Tellioglu explain that system designers need to understand the complex coordination of work in an organization in order to support coordination. In this master thesis an attitude towards artifacts must be considered when presenting information on a handheld device instead of the binders used today.

The effect of using handheld devices in medical work rather than stationary computers would be high, because one of the normal modes of operating in a hospital environment is by wandering between different locations of work (Kristoffersent & Ljungberg, 1998). Adding frequent derails to this work flow for visiting a stationary computer would be to minimize the effect, especially if a question cannot be answered while being with a patient and the clinician needs to leave to find the answers for that question.

2.4 Visualization of Medical Data

Custom made applications has been used in specialized fields such as pediatrics, critical care, radiology and cardiology. Most applications in specialty branches have been implemented in the organization so that the clinicians can access a patient's medical background to make better decisions on further treatments. The main reasons for using handheld devices in medical environments is said to be cost savings through time saving, error reduction, education and also clinical improvement through better and more precise decision making. Ardito et al (Ardito, Buono, & Costabile, 2005; Ardito C. , Buono, Costabile, & Lanzilotti, 2006) describes the PHiP tool that aid in diagnosing and finding suitable pharmaceuticals for children with neurological diseases. The strength of the PHiP tool is its graphical interface that is inspired by LifeLines (Plaisant, Milash, Rose, Widoff, & Shneiderman, 1996), which is a general visualization tool for personal histories which can be applied to many fields such as healthcare. PHiP's graphical interface visualizes both an overview of the patient's health record and details about a single incident. The visualization put medical information in a context where periods of medications are overlaid by reported seizures. Together the data creates a view where the patient's response to different medications is easily interpreted. Chittaro (2006) has also worked with visualization of clinical data but has focused on data that usually belong to patient records, such as blood pressure, temperature and observations. Similar to Ardito et al (2005; 2006), Chittaro focused on presenting data on a small screen and presents six different methods of visualization. Four methods are specific to the type of data presented and two are overviews of all types. Most interesting is that the data can be presented in different granularities (hours, day and weeks) and all data points visualized support details on demand. Any plotted value in the interface can be clicked to provide more detailed information. Powsner and Tufte (1994) made an application that displays spreadsheet with an overview of lab test results on a computer screen or printed out on paper. The charts that they used were non-linear, the charts time line is divided into years before the patient's admission and then the two latest weeks since admission to the hospital. The values are individually scaled to allow a uniform axis; the scale is dependent on reference values. To scale the values according to reference values is a very interesting approach, and also the unproportionate axis.

3 Method

The research approach selected for the project is derived from the research fields of informatics and human centered design. The research includes observations, interviews and prototyping as a step-by-step approach in an exploratory fashion to get knowledge about the work performed at the hospital, and to find areas of IT use that could be studied, put into context and improved. Dahlbom and Ljungberg (1998) describe informatics research as following:

> *"Informatics research typically begins with ethnographic studies of human activities, such as work, education, health care, or entertainment, with focus on actual and possible use of IT. The aim of such studies is diagnostic, trying to identify possibilities for improvements both in technology, the way it is used, and the way the use is organized. On the basis of such studies, use suggestions are made, application prototypes are designed and developed, and organizational change is initiated. This is the heart of informatics research, the idea generation phase."*

A field study will generate an understanding of the use of the current lab system and bring fourth requirements on a future improved mobile version of the system. Findings and requirements will then be evaluated and further explored in interviews. The design implications and requirements will form the design of a series of prototypes for accessing and visualizing lab results. The client will be developed in two phases though a participatory design process (Dix, Finlay, Abowd, & Beale, 1998). The prototyping phase will begin with paper prototypes that will be used to validate the findings and seek further improvements; secondly a working prototype will be developed to explore the use. An overview of the research process can be viewed in Figure 3. A working prototype can also reveal its impact on the work settings, and be a trigger for discussion and further development (Maguire, 2001).

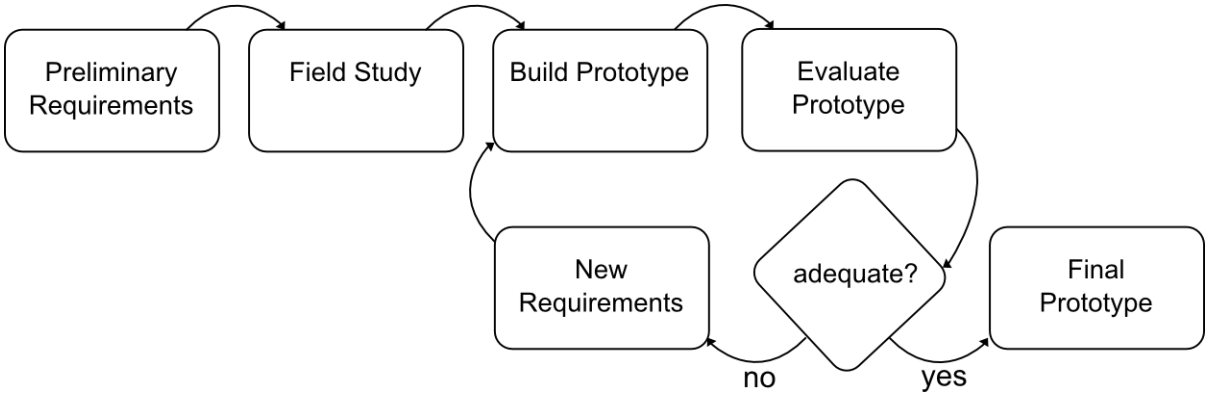

Figure 3. Research process

3.1 Getting Started

Prior to the project start-up a meeting with the projects stakeholders, including the senior clinician of CIVA, the current developer of Synaps and the product owner at Synaps Teknisk Utveckling AB was held. The meeting was conducted to create an overview of the project

and also to grant access to the field. The access to the field was important; researchers often have to get an acknowledgement much like an entrance ticket to get into a hospital and conduct a field study (Repstad, 1999). Even with the prior meetings with the appropriate staff the field studies at SU took several weeks to start. The context in which the field studies are conducted is very busy and the working staff has routines for the everyday treatment of the patients. As only one actor from the hospital were involved from the beginning the field study was delayed, but when the field study started the work at the ward turned out to be interesting and the staff very accommodating.

3.2 Research Settings

The study was conducted at the central intensive care unit (CIVA) at Sahlgrenska University Hospital (SU). Most patients spend an average of two to three days at this ward and are under constant observation of nurses. In some cases though, a patient can be at the ward for two to four months. The short time of patient treatment and the constant observation makes the ward rather special compared to other wards where patients spend most their time in secluded rooms with regular checkups. A request to include nurses in the study could not be complied with a satisfied measure, and the only appointed contact was specialist doctors. Nurses were only studied during their collaboration with the doctors. The staff at the intensive care unit is almost always occupied with patient care activities and this put some constraints to the amount of time that could be spent at the ward. Preparatory development of client in parallel with the field studies also reduced time spent at the ward.

The intensive care unit that was studied has an average of 14 patients but the ward has had 22 patients at the most. Most patients are recovering from an operation, or are in a critical condition which requests constant observation. There are also a few patients who have a more long term critical condition. Post-Op and critical patients are located in rooms of five patients, and these rooms have two nurse stations that hold the medical information about the patients. The long term patients are cared for in rooms of two which give the patients more privacy as there is a less hectic environment. More space is also required as these patients often have more medical equipment by their bedside. These long term rooms also include two nurse stations but they are less staffed.

The main difference between the personnel and patients of this ward is that the situation is constantly more critical. Patients are constantly observed and many more clinical tests are performed. For the ward there is a special extensive set of clinical lab tests. The set includes test for monitoring all major bodily functions such as hematology, infections, livers, kidneys and electrolytes. The amount of lab results this ward handles is considered to be more than other wards.

3.3 Field Study

Observation and qualitative interviews is used to acquire knowledge about the fundamental and the protruding elements in a special context. The focus is on knowledge of the use of these elements, and not on how often. A qualitative study often gives the researcher a way to understand local events, and observations are better suited for studying the social game in context to create a greater understanding of the social relationships compared to quantitative

studies. Observations are studies on human beings intended to see what situations they face and how they usually react in those situations. (Repstad, 1999)

Observations are followed by interviews to further discuss the findings from the observations of what people do, and then see if it confirms the problems earlier stated. The interviews allow more information to be extracted from a situation observed by a researcher, as discussions can be made of why certain actions were taken. Ethnographic studies are preferred in mobile informatics research projects as it focuses on actual and possible use of IT (Dahlbom & Ljungberg, 1998). The field study was used as a mean to get an understanding of how clinical lab results is accessed and handled at CIVA. The goal of the field study was to get an orientation of the ward and to get a description of how work is carried out. The problem areas stated was observed in their natural context and possible improvements of the IT use could be explored. The information gathered was then used to understand how well the current and future supporting technology would fit into the work flow, and designs for improved tools could then be derived.

3.3.1 Observations

The plan for the field studies was to get an understanding of how staff interacts with lab results and the present lab system. Active observations were conducted to observe how the current information system is used at CIVA. Lundberg and Tellioglu (1999) expresses that is it important to map the relationships between users and artifacts since the relationship may have a strong impact on the work flow. When observing the activities in patient rooms, questions about artifacts such as charts and binders were triggered, and the questions were later asked during interviews with the staff.

The observations were divided into three stages according to Cornford and Smithson's (2006) description of observation in the field: descriptive, focused and selective observations. The descriptive observations capture the complexity of the work environment. The focused observations moves focus from the whole picture to a selected part of the field, in this case the lab results and the current lab system. Selective observations are used as a mean to look among artifacts and tasks performed at the ward. The results and findings made during the observations together formed initial design implications for an alternative way of accessing lab results.

Active selective observations were conducted and the researchers were introduced to the staff as observers. Two different teams consisting of clinicians and nurses at CIVA were followed during the rounds to get an understanding of how personnel used the lab system and how the information gathered were used for decision making. The observations included the use of artifacts such as binders, paper sheets, conversations and computers. The observations differed in settings as one team conducted their daily rounds with long term patients and one team with short term patients.

3.3.2 Interviews

According to Repstad (1999) interviews are ways to complement the observations in order to understand why certain actions are taken, he explains that observations on their own have a tendency to leave many questions unanswered. Interviews were done to get detailed answers about the field. Observations were important to find interesting information about the use of the supporting IT systems at the ward, and interviews were used to gain further understanding of the system use and the problem areas it had introduced in the work environment.

Open ended semi structured interviews formed as social discussions with staff members were conducted on scheduled meetings. All questions were taken from prepared theme questions which were the main tool for the interview. The observations were also ended with a discussion where the findings from the observations could be addressed in more detail. The interviews were held in various meeting rooms at the ward in order to make the interviewee more comfortable and close to the patients. The participants' phones could ring at any time for consultations about the patients. The interviews were recorded and transcribed in order to ease the analysis while still capture the atmosphere of the answer. It also gave the researchers time to listen carefully and be more involved in the discussion. Note taking during the discussion was held at a minimal level since it sometimes removes the focus of the discussion. The findings from the interviews and observation were used to capture requirements and wishes for an improved lab system.

3.4 Prototyping

The design of the lab test result client was based on the data gathered during the field study. Multiple prototypes were developed and presented since it allows the users to view several different design approaches and express more direct critique (Tohidi, Buxton, Baecker, & Sellen, 2006). A situation where the user has the possibility to express that something would work better in one way or the other was preferred as the time with the users to conduct evaluations was limited. The direct critique is something that may have been overlooked if only one prototype had been evaluated. The use of several paper prototypes generates as much positive and negative feedback as possible during one single session. Several paper prototypes were produced to introduce a good selection of possible methods for presenting lab results on a mobile lab client. Finally two prototypes were chosen and presented to the appointed doctors and all mock-ups were discussed with the interview subject. This way the limited amount of time with the wards staff was used more effectively.

Parallel design was used during the development of paper prototypes (Nielsen & Desurvire, 1993; Nielsen & Faber, 1996). The goal with parallel design is to explore different design ideas before the design is settled and can be subjected to design iterations. Parallel design is a project model for usability engineering where multiple designers design user interfaces independent of each other. The method is best suited for projects where time-to-market is essential, but the weakness is waste of resources when designers do the same work which generates a higher cost to the project. When engaging parallel design the designers should work independently. After the independent design is made the best ideas of the designs are merged together, although every design should be considered it is not necessary to include ideas from all designs. A potential problem with parallel design is that designers can be too

attached to her own design to fully appreciate another designer's idea. Heuristic evaluations were conducted to pick preferred solutions in a fast and effective manner.

3.4.1 Paper Prototyping

A paper prototype has less prestige than a polished digital prototype and does not signal that it is the final solution. Paper prototypes are better inputs to discussion as the user feels freer to criticize something which signals that less effort has been put into the design (Löwgren, 2004). Another value of using paper prototypes are also that users can focus on the important aspects of the design such as interaction and presentation instead of superficial items such as colors which is found to be discussed when using digital interactive prototypes. It is important that there is an open discussion during the design phase, and that the discussion is focused on what the prototype could become, and not on the present features of the prototype delivered. Polished digital prototypes can also give the impression that the product is almost finished which is a signal not wanted at an early stage of the design phase. Sefelin et al (Sefelin, Tscheligi, & Giller, 2003) states that paper prototypes and low-fidelity digital prototypes results in equal amounts of criticism. It is assumed that this implies that the user is informed in which state the prototype is in.

Paper prototypes were used in this study to make design propositions and verify earlier gathered data. Paper prototypes allowed the design to move ahead in a steady pace and yield multiple designs within a small time frame. Early mock-ups were used to try out and communicate design ideas. Later the findings and design implications found in the field was used to form two prototypes that was presented in an evaluation. Considering the limited access to the staff at the hospital, paper prototypes were considered a better choice than possibly delaying the process by developing digital prototypes.

3.4.2 User Evaluation

When the parallel designed prototypes were made, the next step was to present the ideas to clinicians at the ward in order to see if the design proposals were valid. As the users are the experts in field it was important to involve them in a participatory design process and give the users a say in the clients interface and navigational flow before it would be too late to revise the design. The prototypes were evaluated by end users during one session, and the focus during the evaluation was to locate the features and design requirements that were best suited for the task. The design and features of the prototypes was walked through and several tasks were demonstrated to determine if either design supported the work carried out in the hospital environment. The main features of browsing lab results, viewing the results in a graphical view and adding subscriptions was demonstrated and discussed.

The evaluation of the prototypes was conducted together with the head of CIVA and one of the wards specialist clinicians. Both prototypes were presented and the use and the interaction were discussed. Each prototype had their user interface and specific features described. The users did not have to perform any specific tasks or scenarios during the evaluation but all main features was presented and the most common task was walked trough as it felt more appropriate to present the different navigational flows and presentation designs. The type of evaluation used is called "quick and dirty" (Preece, Rogersm, & Sharp, 2002) and the main

goal is to speed up the feedback process and was considered as this projects timescale were short and the participants have a busy work environment. The data collected when doing this kind of evaluation is usually descriptive and informal, and feedback from the discussion was captured with note taking, and also recorded and transcribed. The "quick and dirty" approach to evaluation is especially appropriate to this project since the focus is on the interface and information visualization rather than usability and the effect of use. The results from the evaluation were used to create a working prototype that included features and design decisions from the prototypes. Comments from the evaluation were used to improve a single design that later aided implementation of the prototype.

4 Results

The field study included six visits to the intensive care unit and included orientations of the work performed, observations of two teams during the morning rounds and two orientations of how the current lab system is used by the staff. Additional meetings with the Health and Care department who is responsible for the maintenance and development of the IT systems was conducted, and also with two doctors from two other wards. The additional meetings were conducted to broaden the view of the use of lab results.

The uses of lab results vary between wards. At some wards the lab results are transferred to patient care forms with pen or pencil located close to the patient. The care forms make it easier to access lab result while working with a treatment plan for a patient, and there is a reduced need to leave a patient when medical information is required. At other wards there is no simple solution, and the lab system has to be used every time a lab result needs to be accessed. A problem with care forms is that there are no ways to access new results without using a computer, and there is also a possibility of adding wrong values when transferring data from the computer screen to the patient care form.

4.1 Notifications on New Labs Results

Keeping up with the latest lab results has been described as major time consuming task and as an object of frustration mainly because the current lab system in use does not have any support for notifying the users when new lab results have arrived. The lack of notifications creates a situation where much time is spent on checking and re-checking for new results. Not all laboratories in the hospital have a networked application to distribute results, and some results are delivered over phone or fax machines. The distribution of lab results by fax machine is said to be more pleasant as it is much easier to check for these results than by accessing clinical lab results in the lab system. The use of fax machines and phones implies that little effort for accessing lab results is a requirement for acceptance by the users, and pushing lab results directly to the user is stated to be ideal. Notifications of lab results on a mobile client are argued to be most efficient when the user can select what information to be notified on, users should be able to select notifications on specific patients or lab items which lead to relevance in the information notified upon. When the laboratory receives lab tests they are inserted in the system and visible in the lab system. When each test has been performed the results are added. The requested tests are all visible in the system but since the tests do not take the same time to perform the results are added as they become available from the lab. If the result is not yet available when a user tries to access a specific test, the user has to log in later and locate that specific test again to see if the result is available. As the lab result system has to be accessed several times a day it would be well suited to notify the user when new results becomes available. Notifications would save much time from this process.

In urgent cases when a lab test result needs to be analyzed at once, clinicians sometimes puts a specimen in a nurse’s hand and have him run down to the clinical lab and ask them to stop an analyze machine in order for the urgent specimen to be analyzed. The nurse then waits until the analysis is done and then goes back to the ward with the lab test result and a decision about treatment can take place. Suggested early was that notifications in a handheld device

could remove the time spent for nurses waiting. The Synaps platform has support for notifying when radiology request has been processed and a similar feature could be used for clinical lab results.

During the observations it was noted that one of the clinicians asked for new x-rays of a patient's chest as she thought the only x-rays available where too old. Then one of the nurses pointed out that there were new x-rays taken the day before, the doctor had only not noticed the notes in the journal where the result of the x-rays where written. This indicates that it is not only a problem keeping the information up to date, but also to know if information is available. A better overview and emphasis on new results could improve readability and in the end patient care.

4.2 Making Information Accessible

If a nurse noticed a severely negative trend that requires a clinician's immediate attention a phone call is made for notification and consultation. At this point it is hard for the clinician to know the patients' condition and background and it is often required that the clinician seeks out an unoccupied work station, or make a personal visit to the patient. During the interviews one participant's phone was constantly ringing with about a ten to twenty minutes interval. Most of the questions could be answered over phone, but some call required the clinician to leave and personally visit the patient. Stated by the clinicians was that it would be great if a patient's health status and lab results could be easily accessed at any location so that a phone consultation could be done even if a computer is unavailable. The problem today during conversations over the phone is that the persons talking do not have the same information or that one of the persons lacks the information all together.

4.3 Lab Results in Paper Charts

The current lab system is not always used today when a diagnosis is reached, instead patient care and observation forms are used where all lab test results are presented by date and time taken. The use of these patients forms were observed during the rounds. The lab test results were also read as if they were grouped and the clinician could state the condition of, for example, the patients level of infection, liver values and kidney condition. It is possible to read the results as groups since the patient form used has divided the spreadsheets into sections leaving a blank row, as seen in Figure 4. It was the spread sheets division that first triggered the discussion about lab test groups which turned out to be an important finding when developing the lab test result client.

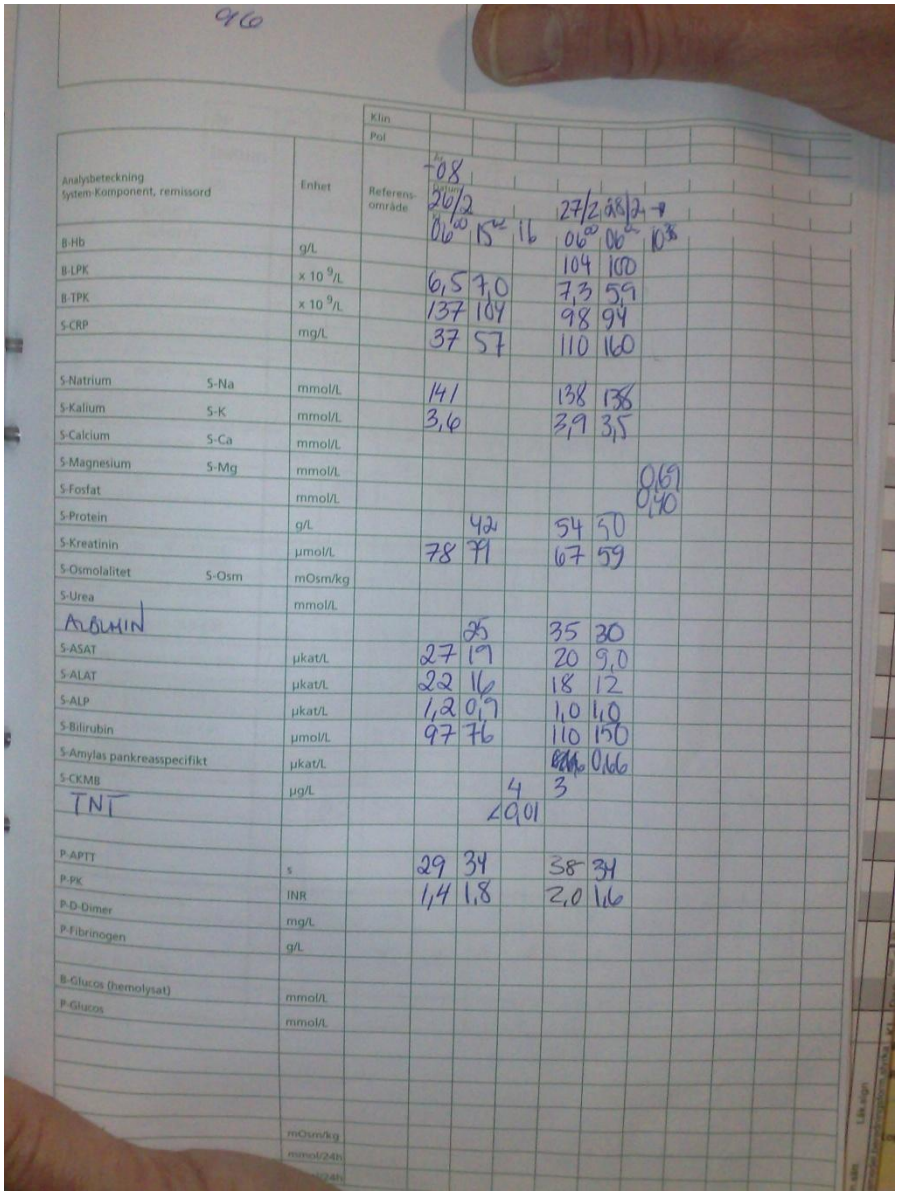

Figure 4. Care form displaying lab results

Forms, marked with pen or pencil, are today used as they are more convenient to work with compared to the computerized lab system. The forms are filled out by nurses during the day as new lab test results become available. The results are transferred from the screen by pen or pencil to a paper record. These records present the lab test type with its data in a horizontal manner which makes the data much easier to read and interpret. Patient records also include observational data such as body temperature, blood pressure and urea volume. These tests are not held by the lab result system as they are analyzed at the ward. Medicine distributed to the patient is also added to the form. Observational data, medicines and lab results are all equally important when reaching the diagnosis of the patient and planning for future care. The forms are collected in binders specific for each patient. The binders are easy to use and pass around during the rounds and as stated before Lundberg and Tellioglu (1999) explains that certain artifacts, such as binders, can support coordination in itself. During rounds the binders are sometimes the center of attention where discussion is backed up by the data in the binders. At times when patients have visitors the binders are useful since no digital data is mobile at the

ward and the discussion can be delicate and not suited for neither the visitors nor the patient to hear at that moment. The staff doing the rounds can use the binders to have a discussion outside a patient's room and still coordinate the treatment of a patient successfully.

4.4 Working with the Current Lab System

The current lab system has usability problem as stated earlier. The graphical interface (Figure 5) consists of a single view where the labs are listed chronologically and this created problems for the user when working with the patient lab results. When reaching a diagnosis of a patient or when creating a treatment plan much scrolling is required as the results from a single lab type can be several screen heights apart. One of the clinicians expressed the problem:

> *"Scrolling is the main task when getting to know a patient"*

The scrolling is required as a single lab value is not enough input to form an overview of the patient's health status. Several lab results with the same type are preferred as it tells something about the trend of a patient's progress.

To make the lab results mobile today is a problem as there is no good way to print the results, and the most efficient method is to write the results on a piece of paper. Printing results is far from easy as the system does not allow print outs to be made from specific parts of a document. The only way to print a patients lab results is to print the patient's entire lab history.

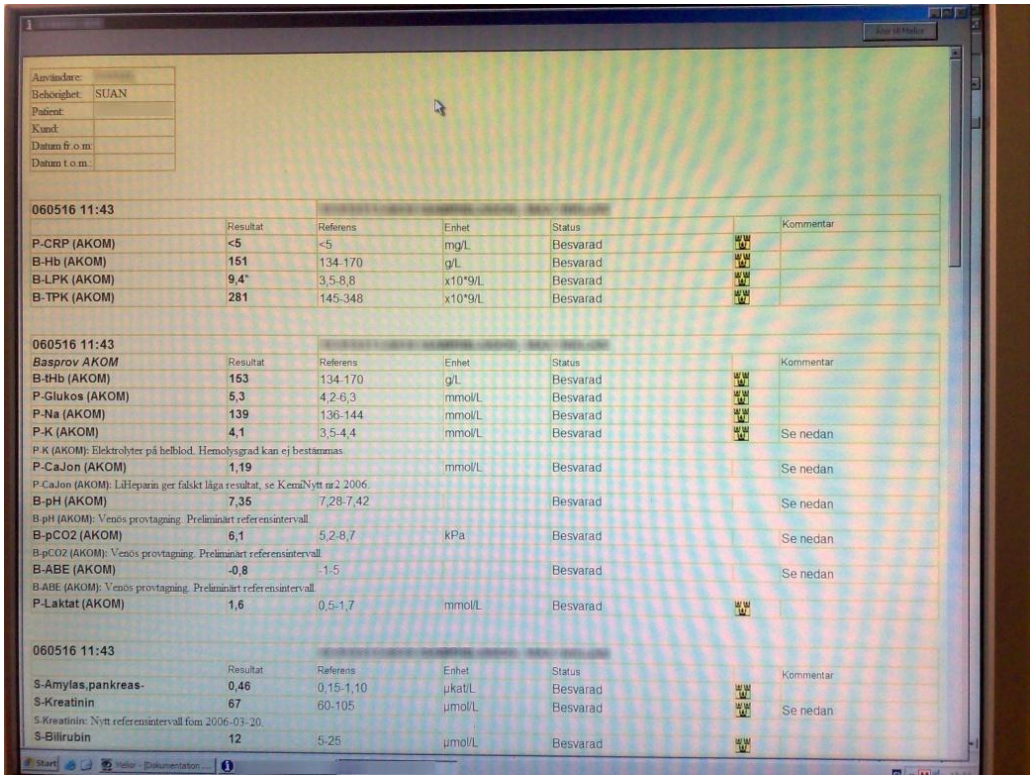

Figure 5. Digital view of lab results

One clinician at CIVA expressed that it is important to have notes about all patient because a nurse can have question about one patient since the nurse is often focused on only one patient when a clinician has several more. The clinician can look at the notes and get an orientation about the patient where lab result is one factor of orientation. Although notes have been taken it is hard to keep notes on everything about a patient which falls into a visit to a stationary computer. Noted about the use of client in this cases is that there are special forms for taking notes on a patient, the patients bed and room number is the key together with the name and personal number which is a feature on the implementation list when looking at patient specific information in Synaps.

4.5 Working with Lab Results

When treating a patient and making a diagnosis it is important to get an understanding of the patient's health status, and the last exact value is not always the most important factor. The most significant information to determine a patient's health status is trends in the lab results. These trends are able to answer questions such as:

"Are the values getting better or worse?"

"Is he responding to the treatment?"

Another aspect of trends is that it places the lab results in a context. During the initial stages of the study it was pointed out that the lab results must be put in context as one result may be really bad but an earlier result could be even worse, which indicates a positive trend.

It turned out that, among the hundreds of lab tests that can be analyzed at the hospital, sets of tests can be identified. CIVA has their own set of tests that they have defined to be the most important and that set are analyzed on almost all patients on a daily basis. This finding made during the discussion led to the final interface with focus on an overview of predefined lab groups instead of the latest result or an overview of several lab types. A lab group was defined as a set of lab types that put together would tell the status of a single aspect of a patients well being. The main interest was on groups for hematology, liver, kidneys, infections, and electrolytes.

The need of an improved representation of lab results was also shown several times during the observations. This method with the manually printed horizontal patient forms is used by clinicians to follow the progress of a patient, for example one of the clinicians read though the horizontal line of lab test result values using her index finger to keep track of the numbers. While she was reading her finger moved slightly up and down while following the numbers as if she visualized the values as a graph in her mind. The values are written down on the observation sheet by a nurse prior to the arrival of the treating clinicians round. Study of the patient observation sheet confirmed that the progress or tangent of the values is used, just as stated by interviewees.

4.6 Graphical View of the Patient's Progress

A graphical representation of lab test results was often discussed during the interviews, and several design ideas was presented by the interviewees. Some of the problems discussed

involved how several lab types could be presented together in a single graph. Another problem stated during the interviews was how to track a lab type after a plotted line intersects with another line, if both trends were similar.

One of the main inputs when evaluating a patient's progress is stated to be how the lab values have changed over time, which is described by the trend of the result values. The progress is determined by the type of change, either if values are dropping, rising or stabilizing within a predefined reference range. The lab system used today does not present the values where the trend is easily estimated because lab results are several screen heights high which makes gathering of each entry for a specific lab type hard and requires much scrolling (Figure 5). Determining the trends for several lab types at once becomes almost impossible if the values are not noted down. Suggested during the first meeting and the following interview was that a graphical representation could be used. Figure 6 is a drawing made by a clinician during an interview to illustrate how lab results could be presented.

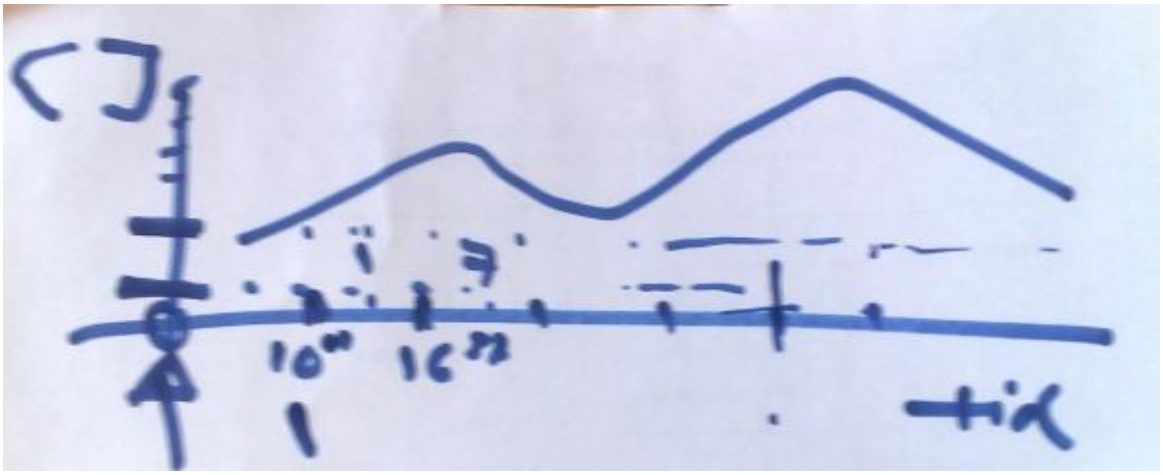

Figure 6. Drawing of a graphical lab results view made during an interview

4.7 Lab Results and Drugs

Lab results and administration of pharmaceutical has a strong relationship as changes in the lab results value can be a direct effect of drugs received by the patient. Visualizing this relationship at normal care wards is said to ease the interpretation of the patient's health status and the changes of the lab results. It is said and, also observed that it is important to be able to cross-check lab results with the administration of pharmaceuticals to know how a patient responds to the treatments.

The administration of pharmaceuticals is today only covered in paper charts, and for a mobile client to offer optimal support this information has to be digitized and electronically accessible in the future. During the evaluation of the prototype this was discussed and it was suggested that no information about pharmaceutics administration should be mixed with the clinical lab results as it could compromise the overview. It was however stated during a

discussion with two doctors from other wards that this would be an essential feature for interpreting the patient's progress. The difference in opinion may be that the intensive care unit visited during the observations has a rigorous set of labs taken on each patient daily. This set of labs covers main bodily functions such as hematology, liver, kidneys, electrolytes, and infections. Pharmaceuticals can have any number of interactions and it is hard to determine which pharmaceutical that changed the outcome of a lab result and it is therefore stated that it may not make much sense to highlighting this.

4.8 Making Change

Operating in a known environment with known tools is what allows the clinicians to handle the chaos which in they operate. When introducing new tools it is important to recognize that health workers operate in a chaos they have learned to manage. Established routines helps to handle events and events are not handled through ad-hoc solutions but well known routines. The tools that surround them are well known and can be trusted to work as expected. When introducing new artifacts and equipment you also introduce a new level of uncertainty. These facts was stated early in the study and considered throughout the project. As the feedback for initiating this problem was positive it was considered that this change would be accepted and not create a situation where more frustration would be added.

Not all laboratories consulted by the ward have electronic delivery methods, but some uses the phone or fax for delivery. Not all tests tends to end up in the patients journal, some lab results can be delivered over phone or fax and if the result did not confirm anything it may not be transferred to the journal as it was no input to further treatment. This problem was observed during the rounds as one clinician could not find the results for a bacteria lab request. Luckily, the clinician who ordered the test entered the room just at that point and the negative results was delivered orally. As the Synaps platform is still in development it could be suggested that and more laboratories are added to the solution and by that make more information accessible.

One of the problems seen during the observations was that the lab results that were not written to the journal were "lost" when the patient was transferred between the wards. The clinician originally treating the patient was well aware of the patient's condition, but this knowledge was lost during the transfer of patients between wards. The study has also shown that a change from the current work flow is hard to generate as there have been too few incitements to why a change should be made and changes has to be performed through a long process governed and slowed down by the organization. The feedback from the field study suggests that some changes would be appropriate and user involvement has been proved to generate ideas of change.

5 Prototypes

The development of the prototypes started with sketching of clients who were accommodated to the initial requirements of a handheld client able to notify the user on newly available lab results and present the results in a graphical view. The first prototypes were mainly developed to vent ideas and to be used as an object of discussion. As more findings and design implications from the field study was added to the knowledge base requirements grew. When the results from the field study had been gathered and analyzed a parallel development of paper prototypes began. The paper prototypes were developed to verify the findings from the field and to discuss the features and design with the intended users. The feedback from the evaluation and additional discussions included new requirements and design alternatives that formed the final executable prototype that was implemented in the Synaps framework.

5.1 Paper Prototypes

The initial requirements from the problem description given during the first meeting included features for notifying the user on newly available lab results and an improved interface for reading the results. Stated was that accessing and interpreting lab results was a too time consuming activity and the findings from the study confirmed this statement. The entry point for both prototypes was a patient specific screen where radiology requests, lab results and journal data can be reached (Figure 7). The Synaps platform includes this view and is navigated to through either selected a patient at a specific ward or searching for the patient by either name or personal identification number.

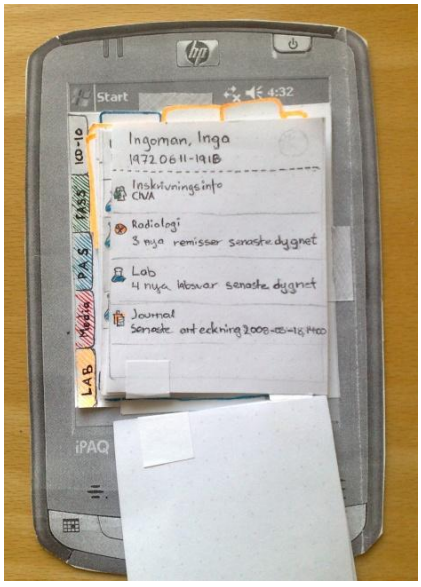

Figure 7. Patient overview screen

5.1.1 Browsing Labs Results

The user interface of the system used at the ward requires much scrolling to locate lab results of the same type and it is also hard to make a set of results mobile as the system could not print specific lab items. This was the main input for designing a view for browsing lab results on a small screen that would give the user an overview of the available results while not requiring scrolling and navigation. The two design propositions made included one view

where an overview of all recent lab tests were displayed (Figure 8), and another view where more details of each analysis was presented according to the date and time taken (Figure 9).

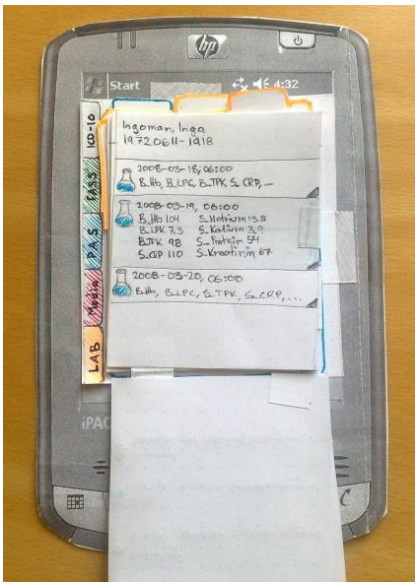

Figure 8. Lab results overview by date

The browse view focusing on overview was design with overview and detail in mind. The interface consists of an interactive list where each list item describes results by date and time taken, and also what tests the analysis included. Each list item is interactive and a click on an item would make the list item fold out and present a table with the results for the specific date. The concept of the list was based on a simple navigation to any lab result for a specific patient, and two clicks would only be required to locate a specific result.

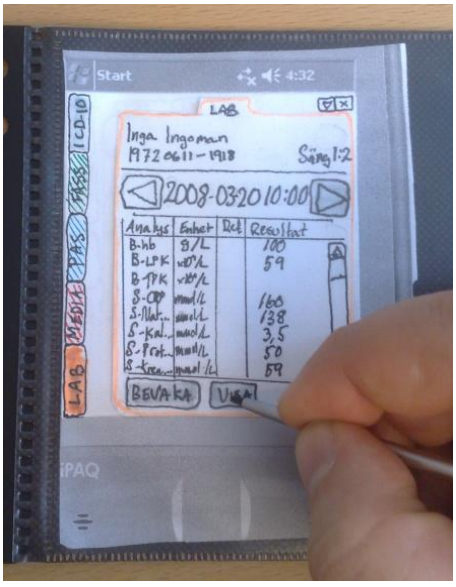

Figure 9. Lab results by date

The main idea behind the second prototype was to make a client as similar to the current system as possible but with the functionality sought after. The similarities begins with a list that is shown which is dependent on the occasion that specimen for the test was collected.

Instead of showing all lab test results in one document the list is concentrated on one single occasion with the possibility of navigating back and forth in time. All lab types were presented in a horizontal list with column for lab name, unit of measurement, result value and reference values. The date and time when a specimen was taken is presented as a header for the list. This view is similar to the stationary system but with additional navigation features. The stationary system only allows results to be searched through scrolling up and down until the specific date and result is located. The prototype navigates the results by stepping through date by date. The view also allows individual lab results to be selected and either displayed in a graphical view together with historical data from the types selected, or a subscription can be added if the results are not yet available.

5.1.2 Subscriptions and Notifications

Both prototypes supported subscriptions at several levels of the lab results hierarchy. It was stated that the number of notifications received should be kept at a minimum if possible. The level of notification can be set depending on a patient's health status and the users' relation to the patient. For example can the nurses caring for the patient set a subscription to a patient-level and be notified upon all results so that the progress could be closely monitored, and a specialist doctor can set a subscription to a specific lab type to monitor a specific item of interest.

5.1.3 Graphical View

The graphical view ended up similar for the both prototypes, but with some difference in features and thought. The design for the prototype displayed in Figure 10 focused on presenting both an overview and details. The top items in the view describe the color representing each lab type, and the graph below plots the lab result values. Each data point in graph can be interacted with and a click would present a pop-up with detailed information about the lab type, exact value, date and reference values.

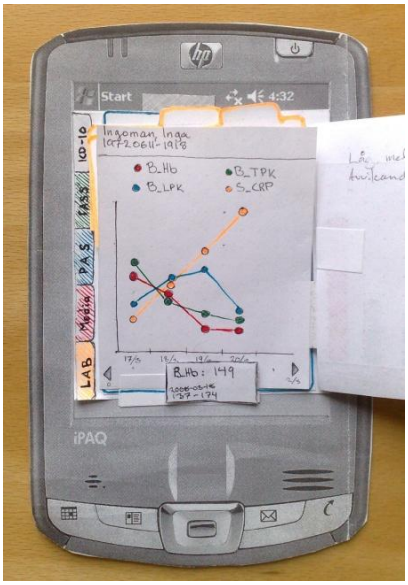

Figure 10. Graph with multiple lab types and details on demand

The second prototype in Figure 11 focused more on the trends and the value for each data point in the graph could be read from the y-axis. If multiple types were to be displayed no values is visible on the y-axis as the units of measurement is different for each lab type, but the trends can still be interpreted.

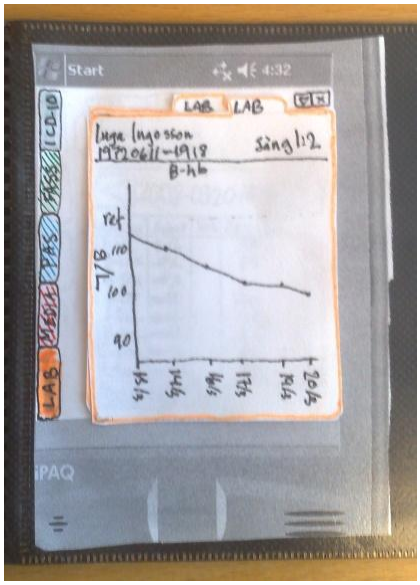

Figure 11. Graph with a single lab type and graded y-axis

An additional graphical view of the lab results was also suggested. This view focused on displaying lab in a bar chart where the columns had color indications for how they related to lab types reference values. The motivation for this design was to present a view where it with minimal effort could be determined if a lab result was outside the reference value and would be an indicator for the patient's state of health (Figure 12).

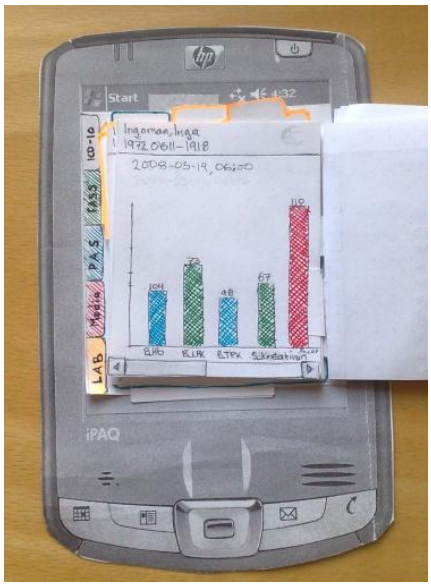

Figure 12. Lab results ordered by date and high/low values indicated by color

5.1.4 Feedback from the Evaluation

The main feedback from the evaluation was that focus should rather be on the predefined groups of labs, instead of the date the test were taken. Both prototypes was said to perform well but none of them captured the correct design considering how the clinicians thought about the labs. The set of labs used at the ward included tests for hematology, infections, liver, kidney and electrolytes as these are the main indications of their patients' health and progress. Suggested was that the main view of lab results should display these groups and that you would proceed from this view to the graphical view and display the group of labs selected.

Excerpt from an interview with the Head of CIVA:

"If you select the lab module, you will get to a view of the groups. If you then select a group such as kidneys, you will get all the types included in that group presented in a graphical view. If you then would like to have more exact information you could select the type if they are listed somewhere in the view, and then you will be presented with a list view of all the values for that type."

Each user was also said to have their own personal preferences for how to reach their diagnosis, and a user may also have patients with special needs and labs test required other than the standard. The use of groups is said to be optimal if the in included lab types could be modified to fit the users need, and also if new groups could be created by the user. The main reason for modifying and creating own groups is said to be patients with special needs. Groups would make navigation of the lab results and the treatment of the patient less complicated. It was commented that all roads leads to Rome; a diagnosis can be reached in many ways, consequently clinicians can be interested in different groups depending on their preferences.

The graphical histogram view were disregarded and said to be redundant as the same information could be received from the graphs. There was also no need to add a graphical representation in the graphical view as the clinicians who works with lab results every day are aware of the reference values of most lab types.

The use of paper prototypes proved valuable during the evaluation. Several times when negative critique against a design was mentioned, it was asked to change the design, but only if it would not be too big of a programming problem, which often was conceived as a more complicated design. It the prototypes had been developed as interactive digital prototypes these suggestion to change the design may have been left out or toned down as it can be harder to criticize a design that embodies more prestige.

5.2 Interactive Prototype

The final prototype implemented in the Synaps framework focused on groups of predefined lab types as a result of the user evaluation. The design were evaluated in two stages, first during a meeting with two doctors who had never seen the client before, and a second stage with the original group who helped to derive the design. Mainly noted during the first

evaluation was that requirements diverge between user groups. It was said that the client would solve many of the problems experienced with lack of mobility today, but that different groups of users would have other requirements on presentation and navigation of lab results. The main view was suggested to be a list of all available lab types, instead of only groups. It was also said that reference values should be visualized in the graphical view as it would help to interpret the results. This statement diverge from the first reference groups statements which was that the reference values were known to all and that the trends in the results was the main object of interest. The following sections describe the use of the client presented during the evaluation.

5.2.1 Groups

As groups were suggested during the evaluation of the first prototypes the implementation started with defining what information that should be presented to the user when the lab module is reached. The first feature to be implemented on the executable version of prototype was the patient specific lab test result page. The evaluation of the paper prototype pointed out that groups were important and should be in focus in the final prototype. The first screen (Figure 13), the lab test result page, was implemented with groups of lab test types as the main feature. A list of groups was developed with expandable rows similar to the idea that was formed during the paper prototyping stage. When a row is focused, by clicking it with the stylus, the list is unfolded and reveals the different lab test types that forms the group. Most types are visible by default, but if the names of the lab types are long, some may not fit on a single row.

Figure 13. Lab results presented as groups

To make it easy to get an overview of the lab test results only groups with available lab results are shown. This feature might not be that important at the intensive care where a set of all lab types included in the default groups are processed regularly, but for other wards that do not have a specific set of tests that are performed on every patient a minimal view where only available results are listed could be preferred.

A group row appears when one or more lab test results belonging to that group are available. With a populated group the user can click with the stylus on the group and the group will expand. The expanded group shows a list of the available lab types in that group. Since the actual value of the lab test result is uninteresting at first when acquiring an overview of a patient's health, only the name of the lab type available is displayed for the user. To see the health progress from this view requires additional navigation to a graphical view, seeing what lab tests that have been conducted on the patient is a feature to be able to see what kind of tests that are available and then make a decision on what group to view.

Subscriptions on lab results can be added on a group level. Stated during first evaluation was that some patient may have a condition directly linked to a specific group, and then you would like to be notified on all results included that specific group.

Excerpt from an interview with the Head of CIVA:

"If I treat a patient with blood poisoning I will look at the lab results CRP, LPK and also PK. If I could follow those values I could be able to view where the patients' status is heading"

5.2.2 Graphical View

The graphical view of the lab results shows a linear graph of each lab type, and each graph is presented on the screen relative to the lab type's reference values (Figure 14). Each lab value is presented as data points on the screen, and as the user clicks on the point more detailed information is presented at the bottom of the screen. This information includes the lab name or type, the result value and also the date and time when the lab was taken.

Figure 14. Lab results plotted in graph with details at the bottom of the screen

The plotted values are weighted according to the lab type's reference values. Lab results that are above the reference value are drawn closer to the charts top, and lower values are drawn closer to the bottom. This design makes it easier to assess where on the reference scale a lab result set is located. As several lab types with different scales uses the same Y-axis no

information about the scale is shown. As stated by the clinicians the progress and change of the values are more relevant than the exact value. For more detailed information the user can click a plotted value on the graph.

5.2.3 Supplemental View

As found at the ward the binders are used to stress important elements of a patient when discussing a daily treatment plan. The binders are also used to provide an overview of the lab test results with the values easily read. In the prototype there is a view reached from the graph view with additional information about a single lab type. If a user has identified that the a negative trend in a specific lab type with the assistance of the graph view the values of each lab result could be read by selecting each data point in the graph. If user instead wants to see detailed information about the lab test result by a simpler manner a supplemental view can be reached by clicking selecting a specific type in the lab type legend. The supplemental view (Figure 15) consists of a list sorted by date complete with reference values, unit, date and exact result.

Figure 15. Lab results of specific type with detailed information

The list has little functionality embedded as it is meant to be used as means to provide the same information that the binders have. This view does not support any specific features and is only used to view the numerical values of a lab type. The single feature that exists is that a value can be highlighted in order to have a discussion around a value with bystanders.

5.2.4 Browse by Date

Little change was made to the view focused on browsing lab results by date (Figure 16). The view was included as it displays the results in a view that is easy to read if results are to be accessed according to the date. The groups and graphical views cannot list all results from a specific date and if all most current values are to be accessed this is the most effective view to use.

Figure 16. Lab results browsed by date

5.2.5 Subscriptions

Subscriptions were added to different levels in the patient lab result hierarchy. A user can either subscribe to patient, and then the user would be notified when any new lab result were available for a patient. A subscription can also be added to specific items such as a lab group or a single lab type. If a patient has a health issue related to a specific area, then a subscription to that area might be sufficient in order for the clinician to be updated on a patient's progress, or if a single lab result is due late, a single subscription to that type could be sufficient. The user is notified when new results are available through a sound, at the same time there will be a new tab on the client that includes describing text and links to the patient and to the specific requested item.

5.2.6 User Specified Groups

Found during the observations and evaluation of the first prototypes was that clinicians have diverse preferences when it comes to groups as stated in the results of this thesis. The implementation of the groups in the final prototype is based on the chief clinician at CIVA classification of groups. A future iteration of the prototype should enable an option of creating a user's own settings when it comes to groups. When presenting the prototype to clinicians at other wards and hospitals the lack of this feature becomes obvious as other clinicians states that they are interested in other aspects of the lab test results. User specified groups is said to be of importance if a patient for example is in need of additional tests different from the standard set of tests. The user can then add the additional tests to a predefined group, or create a group specific for the patients need.

6 Discussion and Conclusions

The goal for this master thesis was to develop a mobile client for lab test results in the medical field and to provide one proposition of how to design such a client. We believe that we have attained the goal.

The work setting as a clinician or nurse is much about being mobile, wandering between rooms and wards, between patients and office, and also between hospitals. At some locations problems caused by local wandering has been solved by mounting a laptop computer onto a trolley so that a computer can be moved from room to room. At some wards issues with keeping patient data within reach has been solved by keeping patient observation forms close to the patient, but this also causes extra work as the lab system needs to be checked regularly for new results to be transferred to the forms. Another problem is that there is not possible to access patient information without visiting an unoccupied computer while being on the move.

Allowing the hospital staff to access patient data where ever and when ever through a mobile client is argued to be the most suited solution as it conforms to the mobility of the users. Also by adding a feature to the mobile client to notify the users on newly available lab results, and presenting them in a graphical view further reduces the work load and eliminates objects of frustration from the work environment.

6.1 The Need for Mobility

The literature review performed during this study concluded that mobile access is the main resource to improve medical work. Mobile technologies would improve the patient care as well as for a working staff at a hospital. The tools at a hospital should be mobile to be able to coordinate collaborate activities among staff; the tools that are mobile today at the hospital visited during this project are almost solely phones and papers. Papers support collaboration between clinicians and other professionals, and between clinician and patient. The mobile client for lab test results developed during this project also support collaboration as the use of papers was regarded during the design. By minimizing visits to stationary tools less interruptions of the work flow will be achieved and the clinician with a mobile client for lab test results can have a more fluent time schedule. Gained mobility and less time spent in front of the computer is said to have several positive effects, mainly that an object of frustration is removed, but also that more time can be spent with the patients. During a discussion with a clinician it was stated that the current lab system required time away from the patient, sometimes patient questions about test results cannot be answered until the clinician leaves and find the answer at a computer station. One clinician stated that the time saved by using a mobile information source could be spent with patients to improve their care, rather than shorten the time for treating patients. The lack of time able to be spent with patients causes frustration not only among treating staff but also among patients.

6.2 Trends and Notifications

Graphical visualization of lab test results is a feature that is not in use at the ward, but is a feature sought after by the staff. A graphical visualization is wanted because the main input when evaluating a patient's progress is to see how lab values have changed over time. A chart

with lab results in a graph will do just that, and was one of the first things that a clinician drew during an interview Figure 6.

The clinicians described their work with some lab results as though of groups for the main bodily functions. Hematology, infections, liver and kidney conditions are examples of groups that put the lab results in context. The lab results describe the condition of the groups when viewed over time as trends emerge. These trends describe the patients' progress and how they respond to the treatments. The study has shown that a graphical view of the lab results in specified groups presents these trends with little effort needed for interpretation.

To keep up with the latest results is a major time consuming task that causes frustration among the staff. A solution for this task would be to send notification as soon as a result of interest has been made available to a mobile client, e.g. by a sound. A notification feature would reduce the time a patient is admitted to the ward (Strannegård, Torgersson, & Persson, 2007). Notifications together with visualization of lab test results is a feature that, implemented in a way suitable for the hospital, would improve working conditions for staff and treatment quality for patients.

6.3 Personal Preferences

The way physicians reach a diagnosis may differ between them. It is therefore necessary to allow each user to customize the use and content of the client, especially when it comes to grouping lab types. User specified groups is said to be of importance if a patient for example is in need of additional tests different from the standard set of tests. The user can then add the additional tests to a predefined group, or create a group specific for the patient's need. Stated was also that users at different wards has different needs and they work with lab results differently. The main input was that not all users think of groups of labs, and the user should be able to select a default lab presentation. Some customizations may be required at different levels of the application, and the design has to support user specific preferences.

6.4 Possible Impact on the Organization

Time, order and place define the template for organizing behaviors at a work place (Kakihara & Sørensen, 2002). The current settings and supporting technology used in hospitals today defines how tasks such as rounds are carried out. When adding mobile supportive technology these templates change and have an effect on organizations as a whole. When redundant and time consuming tasks are stripped from the template more time is freed, time which should preferably from an organizational standpoint is used to serve more patients.

The field study and implementation of the lab client has shown that changing or removing inconvenient obstacles in a work setting is possible with rather small means. A preliminary study (Strannegård, Torgersson, & Persson, 2007) showed that changing from the current time consuming stationary system that a mobile client would increase care capacity with about 2%. The cost of improving the assisting computerized equipment is rather small compared to the cost of the time that could be saved. A more effective lab client is calculated to save 8.5 M SEK or $1.4 M in a single year only at the CIVA ward. Not only would the organization save money but the system developed would also have a positive effect on the

staff as an object of frustration would be removed, or no longer needed to same degree in the normal work activities. All parties involved in the study have expressed a great desire to start using the client as soon as possible. Significant signs that improvements are needed have been shown throughout this project. The current lack of technology supporting the needs of a group of mobile professionals is causing many obstacles at the ward, obstacles that can be removed with the introduction of a mobile client.

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