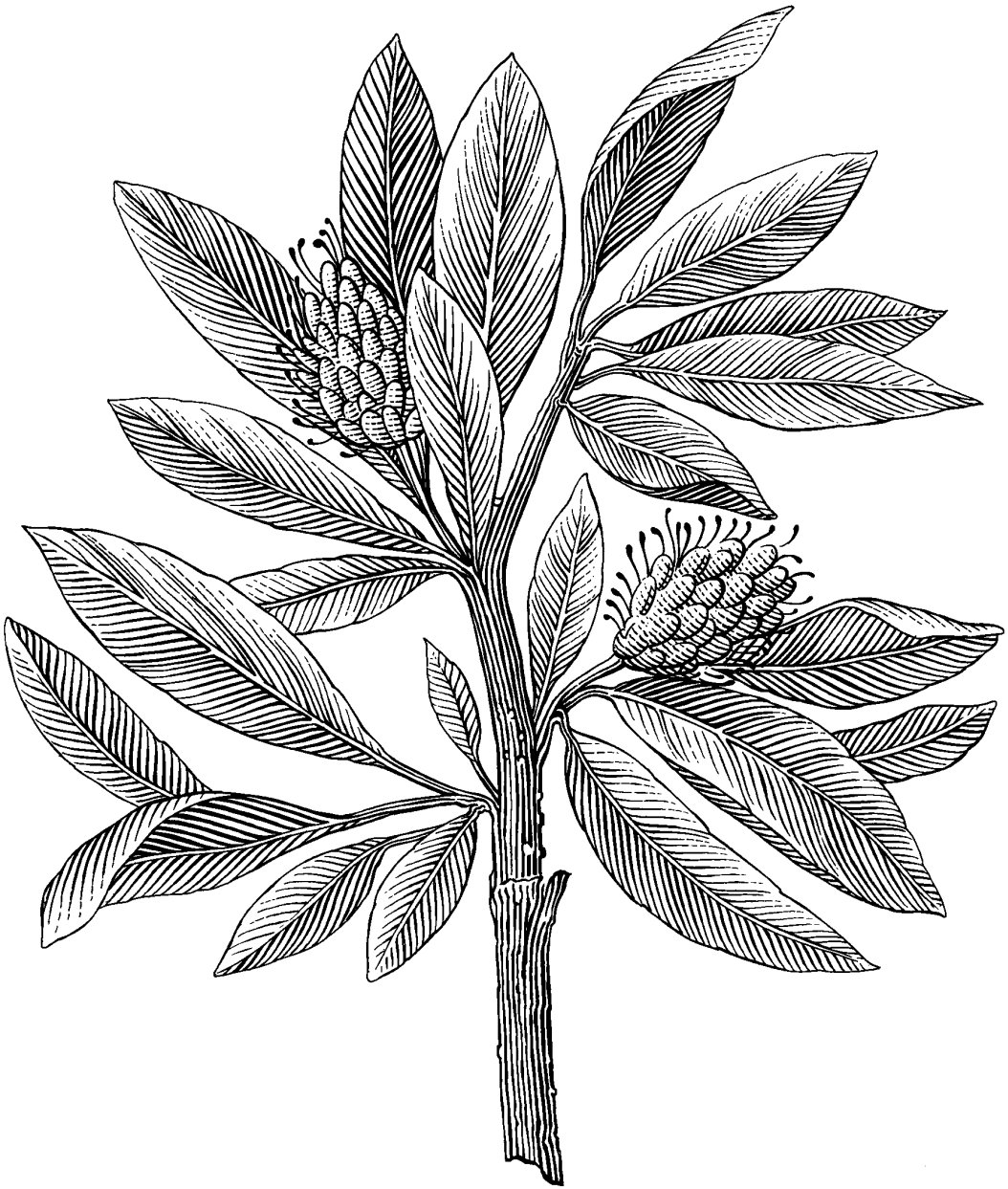
Linnæus University
School of Computer Science, Physics and Mathematics

Bachelor thesis

Designing a tablet application for an emergency department

The implications of context on concept development and interface design



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Abstract

Mobile devices are becoming more common in health care and studies show that they can contribute with a lot of benefits. The purpose of this thesis is to investigate what important factors should be considered when designing an application for a tablet computer to be used at an emergency department. The project involved creating a prototype for an application that would be used as a decision support system for doctors when a stroke patient arrives to the emergency department – a case where time and accuracy are both equally important. Research was conducted by doing field studies and interviews, and the results from these helped to develop a prototype. Usability tests were conducted on the prototype and changes were made accordingly. The study showed that there are many important factors to consider; e.g. identifying the workflows, creating a non-linear system and overview support.

Keywords: Health care IT, emergency department application, tablet application, concept design, interface design, application development

Preface

I want to give a big thank you to Johanna Hultcrantz at Cambio Healthcare Systems AB for all the great support, guidance and invaluable encouragement throughout this project.

I would also like to thank the doctors, nurses and other medical staff that shared their valuable time to participate in this project.

Contents

1 Introduction

Health care is a highly mobile environment where the workers perpetually move while continuously performing their tasks and making decisions at the point of care. This high mobility makes mobile devices ideal platforms to be used in these environments (Arshad et al. 2003 p.1). Several studies have been done on how mobile devices are, and can, be used in health care. Some of these studies have done research within the subjects of quick response, prevention of medical errors and accessibility (Prgomet et al.2009, p. 3). A lot of these studies show that using mobile devices in health care can be beneficial, and some of these benefits have shown to be enhanced productivity, increased information access, improved communication and decreased medical errors (Prgomet et al, 2009, p. 1).

No studies have been found that investigate the development and design of an application to be used in health care. That the number of studies on the matter are few is confirmed by Butz & Kruger (2011 p.2) who say that "research on usability issues of mobile technology in hospitals, however, is somewhat hard to find". Health care providers working at an emergency department (ED) have to do their job under intense pressure and with limited resources. They are frequently multitasking and have to be aware of a lot of things happening around them (Prgomet et al. 2009, p.3). The characteristics of these situations make it important to design a user-friendly system for the context of an emergency department (Karahoca et al. 2010 p.1). Because of the emergence of mobile applications in health care it is essential to identify important factors that need to be considered during the development and design of an application that will be used at an emergency department.

1.1 Purpose

The purpose of this thesis is to investigate how the usage context of an emergency department influences the design and development of a tablet application. This will result in identifying important factors that need to be considered when designing an application for this specific context.

1.2 Research question

What important factors need to be considered during the concept design and development of a tablet application that will be used within the context of an emergency department?

1.3 Limitations

The context of the application is an emergency department (ED). The application developed is used to aid the decision and diagnosing process for when a stroke patient arrives at the ED who is potentially eligible to receive thrombolysis - the treatment for a type of stroke where there is no bleeding in the brain. The context will be analyzed from the users' perspective. Other factors such as business and security factors will not be considered. All names and variables (i.e social security number, vital parameters) in the text and prototype are fictional. The design and development investigated in this work is conceptual, and not technical – which means that programming techniques and other technical factors will not be investigated.

2 Background

In this chapter the medical condition stroke is explained as well as the process called 'save the brain alarm process'. The application created functions as an aid for this process. Previous work are also discussed.

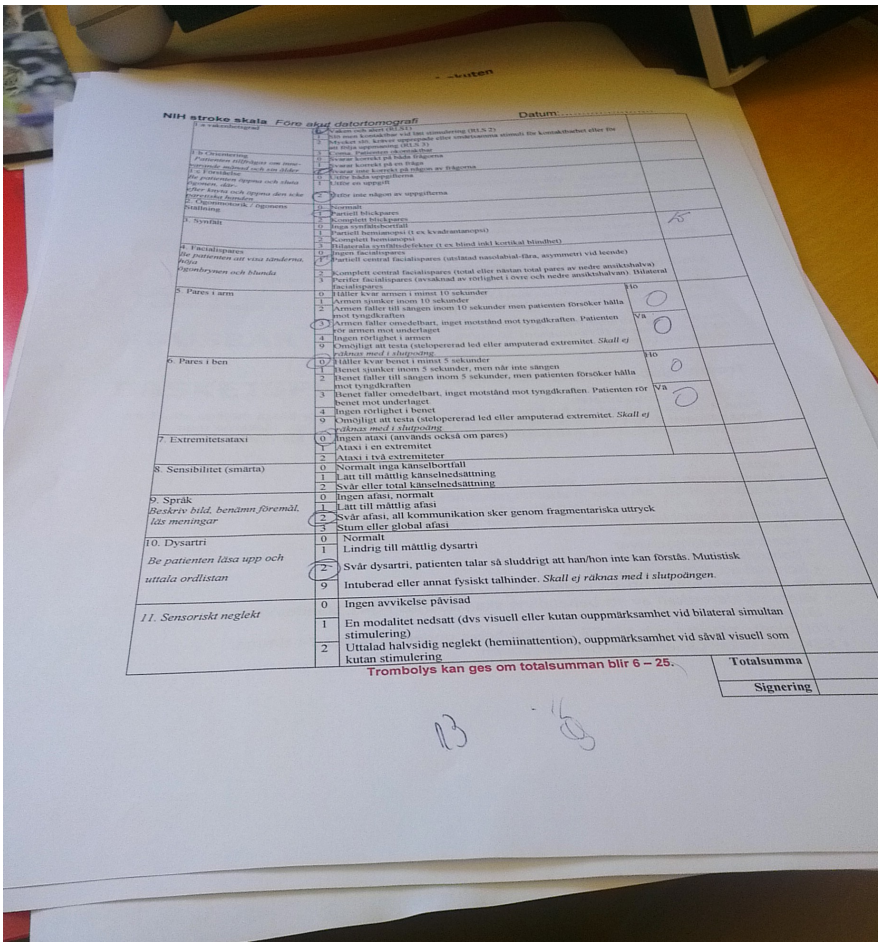
2.1 Stroke

A stroke is a medical condition that occurs if there is a blood clog or bleed in the brain. It is a medical emergency and can leave permanent damage if not treated quickly because it decreases oxygen to the brain . The treatment for stroke is called thrombolysis, a blood thinner, and can be given to some patients. The treatment has to be given within 4,5 hours from when the symptoms first started. If given after that time it increases the risk for complications and usually the benefit of it does not outweigh the risks. To find out if the patient is eligible for treatment doctors go through certain steps that involves x-ray, tests and check lists. If the patient is initially declared (often done in the ambulance) as a potential thrombolysis receiver it is called a 'save the brain alarm'.

2.2 Save the brain alarm process

When a 'save the brain alarm' is declared, time is very precious. To be able to give the patient treatment it can't have passed more than 4.5 hours since symptoms first started. The earlier the patient gets treated, the less permanent damage to the brain. The process starts with the doctor being informed that there is a save the brain alarm coming to the hospital. The doctor then heads to a computer to read the patient's chart to get a clear picture of the patient and their medical history. When the patient arrives at the ER the doctor grabs a

booklet. This booklet is used throughout the examination of the patient and contains the different check lists which are filled out manually with a pen.



Picture 1: One of the check lists in the booklet

X-ray referral and blood samples need to be ordered through the electronic medical record system on a computer. When the check lists are filled out, the doctor calculates the score and depending on that the doctor will order treatment or move the patient to the stroke department.

2.3 Previous work

Previous work by Ståhl (2012) investigates how the stroke process is carried out and which factors affects the decisions made. She also suggests that, for further research, the area of how technology can be used within the process

should be investigated. This means using mobile devices to aid the decision making process; something that is investigated in this thesis.

3 Theory

In this chapter the theory will be presented. It involves previous research about mobile devices in health care, design principles for mobile devices, context of use and a definition of a theoretical framework called goal-directed design that will be the base for the methodology.

3.1 Mobile devices in healthcare

The health care system has recently been identified as a huge informational organization, but it is one of the last fields to undergo full computerization (Siddiqi et al 2009, p. 168). One study shows that doctors spend 30% of their time on paper work, which sometimes include running the same test again because the paper based result got lost (Siddiqi et al. 2009, p. 181). Maintaining the charts is also something that takes up a lot of valuable time; time that instead could be spent on caring for the patients (Saddiqi et al. 2009, p. 175). Studies show that one problem within health care is human errors caused by inaccessibility of patients' information at the time of decision-making (Siddiqi et al. 2009, p. 180). Another study shows that 30% of errors occurring in medication prescription is due to a lack of knowledge about patients' information (Wu & Straus 2006, p. 1). One way of decreasing these problems is to replace the traditional paper based system with a more mobile and interactive system on a tablet computer. Wu and Straus (2006, p. 2) say that “handheld computers may improve quality of care by saving clinicians time in the accessing, retrieving and recording of data, allowing clinicians to focus more on patient care”.

Horng et al. (2012 p. 2) explains that the nature of an emergency department is information driven. Physicians working at an emergency department spend more time on performing administrative tasks and information processing than other specialties in health care. To solve this time-consuming problem, mobile devices can be used to complete information-based tasks at the point of care (Horng et al. 2012 p.2). In their study, Horng et al. (2012 p. 4) found that, by using a mobile device, the physicians spent less time at a workstation, which directly increased the amount of time they could spend bedside. The physicians participating in the study thought that the tablet was useful and portable. Horng

et al. (2012 p.4) say that these benefits can potentially contribute to increased quality of care as well as decreased interruptions and cognitive load.

3.2 Mobile interface design

Gong & Tarasewich (2004 pp.1) describe a set of proposed principles for mobile application design. Some of the principles are transferable from common interface design; including the enabling of shortcuts for frequent users, providing feedback and designing the system to make the users feel in control. They also propose principles specifically designed for mobile devices, which are summarized below (Gong & Tarasewich 2004, p.4-5):

- **Design for different and dynamic contexts.** The context of mobile applications differ from the normally quite static contexts of a desktop application.
- **Design for smaller screens.** The physical limitations of mobile devices need to be considered when designing an application.
- **Design for restricted and divided attention.** The mobile application may not be the sole focus of the user and the user may also be interrupted while using the application.
- **Design for time constraints.** The mobile application needs to consider speed and recovery depending on in which context it used.
- **Design for information limitations**. Due to the limited screen space on mobile devices, the amount of information presented need to be considered and presented accordingly.
- **Design for aesthetic pleasure.** Other factors such as look and feel, also have an influence on the user experience.

Love (2005 p.81) also presents a few principles of designing for mobiles. The first one he mentions is context of use. Love (2005 p.81) says that "when it comes to designing a mobile service or application, you should remember that they will be using these devices in dynamic environments, such as [...] at a work location". He further explains that in such environments, interruptions and distractions are common and this makes it important for the designer to consider the implications of the context and how it might affect how the application will be used. Context of use will be explained further in section 3.3.

Other principles that Love (2005 pp.81) presents are:

- **Consistency and learnability** - the application should correlate to the users' previous experience and mental models
- **Flexibility** - the application should cater for different users' needs and try to accommodate these within reason
- **System feedback and support** - the users should always know where they are and what they are doing by providing feedback and support

More recent research on mobile interface design have been done by Nilsson (2009) that propose a few design patterns for designing for mobile devices. Nilsson (2009 p. 5) discuss text input and the design patterns that are presented are to use auto complete, predefined values or an alternative input mechanism. Other design patterns are to use finger friendly menu choices and to always inform the user about what is happening and where they are.

3.3 Context of use

In the middle of the eighties there was increased attention to the importance of context in design activities. Research found that many products worked well when tested in a laboratory setting, but when tested in their actual context the design appeared to be fallible (Maguire 2000, pp.3). Maguire explains further that during the nineties a project was started to put emphasis on the importance of context. The project was called "Measurement of Usability in Context" and advocated that the usability of a product depends on its context of use, and that a product should be designed for that specific context.

A product or system that is being developed will be used in a specific context and by a group of people with specific characteristics. The users have certain goals and desires to perform certain kinds of tasks. The product or system will also be used within a series of different technical, physical, social or organizational environments that will affect its use (Maguire 2000, p.1). Maguire (2000, p. 2) says it is incorrect to describe a product as usable without also describing within which context it will be used - whom it is designed for, what it will be used for and where it will be used.

There is also an ISO (International Standard Organization) standard adressing these issues. It defines usability as "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" (ISO 9241-11 1998, 3.1). This denotes that the usability of a product is not only affected by its functions, but also the circumstances in which it is used.

3.4 Theoretical framework: Goal-directed design

Cooper (2007) describes the process of goal oriented design and in this chapter the five steps of the process will be described: qualitative research, applying a user model called persona, creating scenarios, defining the design framework and lastly, conducting usability testing.

3.4.1 Qualitative research

The first step in the process of goal-directed design is to conduct qualitative research that is used to give the researcher an overall comprehension of the users and the domain and contexts in which the product will be used. Qualitative research helps to get an understanding of the users behaviors, attitudes, skills and experiences as well as the context and its restraints, demands and possibilities (Cooper 2007, p. 50). Cooper (2007 p. 52) lists different methods that can be used for qualitative research and these include, but are not limited to, interviews, ethnographic studies and literature reviews.

3.4.2 Applying a persona

The second step in goal-directed design is to sort through the, potentially, immense amount of information extracted by the research. The data is analyzed and a user model called persona, is applied. According to Cooper (2007 p. 75) personas "provide us with a precise way of thinking and communicating about how users behave, how they think, what they wish to accomplish, and why". Personas are based on the real-life people that have been observed or interviewed during the research, and encompasses their behaviors, motivations, goals, attitudes, skills as well as previous knowledge and experience (Cooper 2007 p. 81-89).

3.4.3 Creating scenarios

The third step in the process is to create scenarios and a requirements specification. This is where the understanding of the users is synthesized into tangible context scenarios, and from these scenarios a requirement specification is derived and these are in turn used to define the rudimentary

interaction framework (Cooper 2007 p. 109). Context scenarios cover many aspects which include the settings in which the product will be used, the time frame of usage, frequency of interruptions, the amount of users, correlation with other products or systems, primary activities, expected end result and the complexity permitted (Cooper 2007, p. 119).

3.4.4 Defining requirements

The fourth step in the process of goal-directed design involves defining requirements. A requirement specification can include different kinds of requirements and a few mentioned by Cooper (2007 p.122) are data requirements, functional requirements and contextual requirements. A requirement specification should give an overview of how the product will meet the users' goals and objectives (Cooper 2007 p.123).

3.4.5 Developing a prototype

The fifth step in the process of goal-directed design is to define the design frameworks. It starts by first defining the interaction framework and moves through to the visual design framework and lastly the industrial design framework (Cooper 2007, p. 126). The interaction framework defines the high-level structure of the system as well as flow and behavior of the product. This is where form factor, posture, input methods, elements, groupings and hierarchies are defined (Cooper 2007, p. 127). The visual design frameworks is comprised by developing visual language studies and applying chosen visual style to screen archetypes (Cooper 2007, p. 136). During the industrial design frameworks, a rough physical model is produced (Cooper 2007, p. 126).

3.4.6 Usability testing

The sixth step is called usability testing. Cooper (2007) mentions two ways of doing usability tests. The first one is summative evaluations. Summative evaluations is a way of comparing products and is used to gain quantitative data (Cooper 2007 p. 144). The other one is formative evaluation which is quick, qualitative tests conducted during the design process (Cooper 2007, p. 144).

4 Methodology

The methodologies chosen for this thesis were derived from the theoretical framework of goal-directed design. The steps involved were a literature study, a qualitative research in the form of field studies and interviews, applying a persona and creating a scenario, designing and developing a prototype and lastly performing usability tests on the prototype and make changes to the prototype accordingly.

4.1 Ethical aspects

In accordance with ethical principles for conducting research with human participants, the research met the four major requirements stated by Vetenskapsrådet (2002):

- **The information requirements** - the researcher has to inform the participants about how the information will be used. The participants need to be informed that the participation is voluntary.
- **Consent requirement** - the researcher needs to get consent from the participants.
- **Confidentiality requirement** - all information should be presented in a way that does not identify any participants or other persons involved in the study.
- **Utilization requirement** - the information collected shall not be used for commercial or non-scientific purposes.

The participants were informed what the project was about and what the observation data would be used for. They were informed that they could quit at any time and that nothing would be done without their consent. They were informed about how, and what for, the data collected would be used; that all the data collected during the observations and interviews would be analyzed and then presented in a way that would not identify any persons and that the data would not be used for commercial or non-scientific purposes. All the patients that were involved were also informed about why I was in the room and the purpose of it.

4.2 Field studies and interviews

The first step in goal-directed design is to conduct a qualitative research (see section 3.4.1). The qualitative research method chosen for this thesis were field studies and interviews. Field studies are systematic reviews of activities and tasks performed in the environment where they actually occur. The primary goal is to understand these activities and tasks and what meaning they have for the person performing them. To create an understanding of this, information is collected by listening and observing people, environments, activities and tasks that are carried out in a specific context (Bailey, 2007, p.1).

Bailey (2007, p.1) describes a few questions to consider before doing field studies:

- Will the observation be overt or covert?
- Will the observant participate or just observe?
- Where and when will observation take place?
- Will the observation be structured or unstructured?
- What is going to be observed?

Due to ethical reasons the observation was an overt observation. The people who were observed were informed and aware that the observation was taking place. The field studies took place at an emergency department at a regional university hospital in Sweden. Since there was almost no way of knowing what was going to happen at the emergency department, the observation was unstructured which enabled more flexibility (Bailey, 2007, p. 83). This flexibility made it possible to observe situations as they unraveled and adjust the focus of the observation accordingly.

During the field studies, interviews were also conducted. The interviews were unstructured as well, because that gave the interviewee freedom to talk about the subject and relating aspects more freely (Bailey, 2007, p. 96). The unstructured interview method was also chosen because of the earlier mentioned inability to foresee what was going to happen, so the questions were born out of the situations and events that occurred. The nature of the questions were about the users' habits, goals, objectives as well as the working environment, processes and their attitude towards them.

During the field studies I was allocated to follow the doctor responsible for neurological patients coming in to the emergency department. Observations

were made on how the doctors were working, as well as nurses and other staff at the department. Routines, working environment, interactions - both between people and between people and artifacts - and how different situations were handled were observed.

The field studies were conducted during 3 days, for 8 hours each. The time of day differed from early morning to afternoon to noon to night. 3 different doctors were followed and several nurses and other staff were observed.

The process was executed within the frameworks of goal-directed design. The data derived from the field studies and interviews were analyzed and this analysis produced material such as personas, context scenarios and a requirement specification. These tools lay the foundation for the development of the prototype.

4.3 Persona

In chapter 3.4.2, the second step in the process of goal-directed design is described. It involves applying a user model, called a persona, to the information derived from the qualitative research. Below is the persona, created for and used in this thesis, presented.

4.3.1 Meredith - neurological resident

Meredith works as a neurological resident at a regional university hospital. She wants to specialize in neurology so part of her residency involves working at the emergency department (ED). She likes working at the ED because she gets a lot of contact time with patients. She likes that there is always things happening around her, even though it can be stressful and demanding. She finds the field of neurology very interesting, and in the future she would like to be able to do research about stroke to help find a better or more efficient cure or treatment.

A normal day at the ED consists of meeting a lot of patients. When a patient arrives to the ED Meredith first goes through the patient's chart to get a better view of who the patient is, its history and previous medical conditions and incidents. When she feels a bit more acquainted with the patient she goes to meet the patient to examine him or her. After the examination she calls the standby duty for consultation about the case and then she decides what to be

done - if the patient needs medication prescribed, if the patient needs to be hospitalized or if the patient can go home. She returns to the computer room to finalize the steps completed up to this moment, which includes dictating for the chart.

As any other job, Meredith encounters daily moments of vexation. A lot of times these moments occurs when complex procedures need to be done in the electronic medical records system (EMRS). She gets frustrated when the system does not work, because she does not like to ask for help when it comes to technology. Although she faces a lot of troubles with the EMRS, it gives her a vital support for all the decisions she has to make everyday.

Something that wastes a lot of her time is when she has to go looking for personnel or patients in the large hospital. The result of this is that sometimes information gets lost when the communication is spoken, so she has to go find the source of the information to be able to get all the pieces of information that were lost in the communication chain.

When she gets a ‘save the brain alarm’ it is important for Meredith to feel that she has the situation under control; that she is in control. She wants to be able to think and thoroughly understand the patient and its symptoms, but at the same time remain focused on being efficient and save time. She likes that the routines are as established as they are, even though the individual cases differ most of the times.

One important goal she has during the process is to be able to treat the patient as soon as possible and within the time frame that is recommended. It is also important to bring attention to complications that may arise in time. Meredith wants to be able to handle the administrative tasks efficiently so she can use more of her time with the patient, to examine and diagnose the patient correctly.

4.4 Context scenario

Creating a context scenario is the third step in goal-directed design (see section 3.4.3). The scenario is derived from the information gathered during the field studies. The persona created in the previous chapter is the main character.

4.4.1 A save the brain alarm

Meredith is upstairs at the stroke department when her beeper goes off. It is a 'save the brain alarm', which means red priority - the highest priority. She goes to the coordinator's desk where she retrieves one of the tablets. When she starts it the application automatically activates. The first thing she has to do is to sign the alarm so that the system gets a confirmation that the alarm has been confirmed by a doctor, and that the doctor has gotten the information. After she has signed the alarm, she can see the patient's chart, but she chooses to view the notes from the ambulance first where she can see vital status of the patient, the time for when the symptoms started and general notes from the ambulance crew. She starts heading down to the ED and in the elevator she reads the patient's chart to see if the patient has any medical conditions that might be a contraindication to whether the patient is eligible for treatment or not. The patient has a condition that she is not familiar with, so she clicks it and is brought to an external website where she can read about it. It seems to her that the patient's previous medical condition won't affect the possibility to receive treatment. She writes a referral for a cat scan (CT) and signs it. She also orders the blood tests needed, known as a 'stroke package'.

In the application she can see where the patient will be placed so she immediately goes to emergency room number 4 to prepare for the patient's arrival and to talk to the nurses. Within a few minutes the ambulance crew arrives with the patient. They ask if she has any questions, but Meredith says that she's content with the information she has got, but then interjects to ask if any relatives are coming. The ambulance driver George answers her that they are right behind.

Meredith starts talking to the patient and at the same moment, the relatives arrive. The nurse Olivia starts taking blood samples and an EKG from the patient. Meredith opens the list of contraindications on the app. This is a list of things that might inhibit the patient from getting treatment. She starts asking the patient and the relatives about the points to get a comprehensive picture about the patient and its medical history. There is nothing on the list that might suggest that the patient is ineligible for treatment. She switches to the NIHSS form and then puts the tablet on a nearby table. She starts examining the patient according to the criteria on the list. She picks up the tablet again and shows a few sentences for the patient that the patient has to read out loud. She also shows a set of pictures which the patient are to describe. When that is done she opens the NIHSS again and fills it out. The application gives her the patient's score, which is 11 - the score makes the patient eligible for treatment. Olivia

asks Meredith if the needs to order blood tests, but Meredith answers that it's already done and that she can go straight to the lab and deliver the samples.

When the examination is done Meredith goes to the office in the ED and sits down. She calls a nurse up at the stroke department to prepare them that there might be a patient needing thrombolysis. This is not a mandatory thing to do, but Meredith prefers to do it so that the stroke department is aware that they might have to head down to the x-ray department. While she's waiting for the result from the CT, she finishes up some things she was handling before the alarm came in. After a while the app beeps and indicates that there is a result from the CT. The results shows no indication of bleeding, which gives a green light for treatment. She orders the thrombolysis treatment through the app and the information is sent directly to the stroke department where nurses prepare the treatment kit and heads down to the CT where the patient gets her first treatment. Meredith meets up with the nurses at the CT to talk to the patient and relatives to tell them what is happening and what will happen. The patient will be taken to the stroke department where the treatment will continue. Meredith heads back to the ED as she gets a new alarm on her beeper.

4.5 Requirement specification

Defining requirements and creating a requirement specification is the fourth step in goal-directed design (see section 3.4.4). The requirements presented in this chapter were derived from the persona and context scenario. The functional requirements are the required steps that need to be completed in the process and are therefore non negotiable. The information requirements are derived from the information presented in applications and artifacts used in the process today, which is essential for the doctors to be able to make a decision. The usability requirements are derived from the goals and needs of the persona during the process.

Functional requirements
The application should enable the users to:

- Write a referral for an x-ray
- Order blood sample tests
- View and fill out a list of contraindications
- Fill out the NIHSS and see the resulting score
- Order thrombolysis treatment

Data requirements
The information that the application needs to accommodate is:

- Personal information about the patient
- The patient's chart
- Vital parameters of the patient
- The time of when symptoms started

Usability requirements

- Because of the time constraint, it is important to minimize the time needed to operate the application to complete tasks.
- The big amounts of information make it important to present all this data in a manner that suits the users and aids them in the process

4.6 Prototyping

A prototype was developed using the results found during the field studies and interviews. The persona and scenario, as well as the requirement specification, were also used to develop the prototype. In the first step a simple paper prototype was developed and discussed with one doctor and Johanna Hultcrantz, interaction architecture at Cambio Healthcare Systems AB. After the discussion a few changes were made and the development of the first version of the prototype started.

The prototype was developed with HTML5, JavaScript and CSS as a mobile adapted website. A simple browser application was created in Java so that the website would feel like a real application on the Android based tablet that was used during the project.

The first version of the application was very simple and focus lay on incorporating all the requirements. Less focus lay on interactivity and usability which would be considered more during the development of the second prototype. The first prototype was used during usability tests (see next section) and from the results of these tests, a second version of the prototype was created.

The second version of the prototype implemented more interactivity and solved usability issues that arose during the usability tests.

4.7 Usability testing

Usability testing is the sixth step in the process of goal-directed design (see section 3.4.6). A formative evaluation approach was chosen for this thesis. A test plan was developed for the usability testing. It is important to develop a test plan because it functions as a blueprint for the test - the how, what, where, when and with whom (Rubin & Chisnell 2008 p. 66). The test plan can be found in appendix I.

The usability tests were conducted at a hospital with 5 doctors familiar with the save the brain alarm process. The tests were divided into 4 different parts. The first part was an introduction where the doctor was informed about the project , what would happen during the test and what the data would be used for. The second part was a pre-interview where a few questions were asked. The interview included general questions about the save the brain process.

The third part was the actual tests where the participant conducted certain tasks and in some cases follow up questions were used. Audio recording was used during the tests so that no results would go lost. The tasks involved creating certain steps in the process.

The fourth part was a post-interview about the general experience of the application. Discussions were held about how this technology would fit into their everyday endeavors at the emergency department.

The results of the usability tests were used to develop the second version of the prototype. The results were also used to draw general conclusions about the results of the study.

5 Results

The purpose of this thesis was to identify important factors that need to be considered during the development and design of a tablet application used at an emergency department. In this chapter the results are presented.

5.1 Results from field studies

The field studies revealed a lot of important facts about how the work is carried out in the ED. It was possible to map the workflows of different doctors to identify common patterns of how they worked and interacted. It was possible to identify different steps in various processes. Because of the many interruptions occurring at an ED, it was important for the doctors to remember where in the process they were; which steps they had already completed and which steps still needed to be done. The doctors observed executed various processes differently. Although every doctor went through the same steps in a process; they completed them in a different order and manner. For example - one doctor sent the x-ray referral right away, while another doctor wanted to examine the patient first and go through the lists before sending the referral.

Another finding made during the field studies was the identification of the major information flow that is an emergency department and the need for information at the point of care. The information about the patient, its vital parameters and the chart are pieces of information that the doctors want accessible at the point of care and at the time of making decisions. The doctors process huge chunks of information daily and every step in a process produces more information. Firstly, the patient's chart is a major information system and has a lot of flowing text to go through. Secondly, when ordering an x-ray referral or blood sample tests - the doctors get results back and thus more information is created.

It was also clear that even though the current system is not working perfectly - the users feel a certain trust towards it since it is what they are used to. The users think that the look and feel of it also contributes to this feeling of trust. The system has a simple, sterile design with no extra fuss. The system has only the necessary visual cues.

5.2 Prototyping

The biggest challenge during the prototyping was the visualization and representation of information. Due to the earlier mentioned huge information flow, decisions had to be made on how to handle and present all the information that is part of a certain process. The information flow involves both static and dynamic information, represented as both text and pictures. This correlates to one of the earlier mentioned design principle that says that due to the limited screen space on mobile devices, information needs to be presented in a thought through way.

The first version of the prototype (see Appendix II) had the patient's chart, vital parameters and general information as the start screen. In an attempt to better visualize the information, the different parts of information were divided into different sections. One section for the general information about the patient, one section for the vital parameters and one section for the patient's chart presented as flowing text.

Picture 2: Visualization of information

Two different menus were used and are explained below.

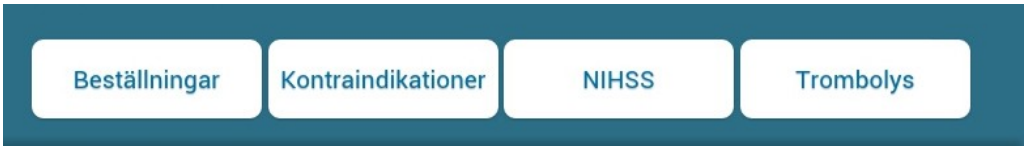
First menu (on top):

- **Overview** - this leads back to the start screen with all the information
- **Results** - this leads to a screen where results from x-rays and blood samples are presented
- **Ambulance notes** - this opens a pop-up box with the information about vital parameters

Picture 3: Top menu

Second menu (on bottom):

- **Orders** - leads to a screen where an x-ray referral can be sent as well as ordering blood sample tests. The forms are automatically filled out with the standard information.
- **Contraindications** - leads to a screen where the list of contraindications is displayed as a static list.
- **NIHSS** - leads to a screen where the form called NIHSS is presented and gives the user the possibility to fill it out and get the total score
- **Thrombolysis** - leads to the screen where the user can order the treatment. The forms are automatically filled out with the standard information.



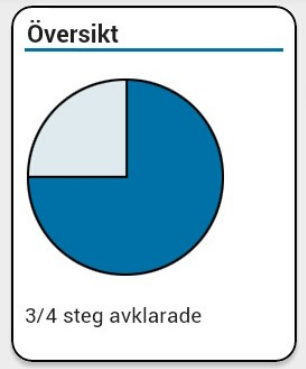
Picture 4: Bottom menu

All the input forms are automated as much as possible to decrease the need for input from the user.

5.3 Usability testing

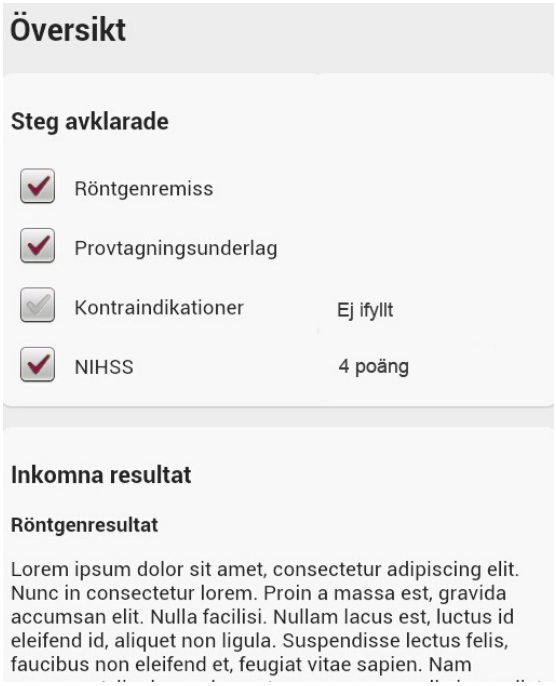
The usability tests showed that the users were satisfied with the prototype's functions, but that visual changes needed to be done. All users agreed that they

wanted a better overview of the process - which steps they had completed and which steps they had not completed. They felt that is was important to have visual access to this overview at all time so that they could continuously be reminded about the progress. This is confirmed by what Love (2005) explains about system feedback and support.



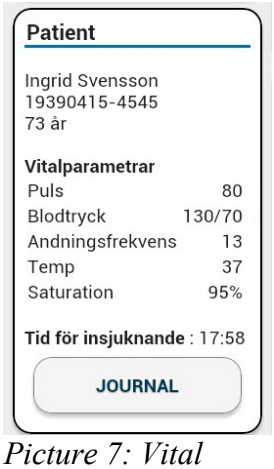
Picture 5: Overview - steps completed

This led to changes in the visual appearance of the prototype. It was redesigned to fit the new requirements by creating a visual cue on how many steps they had finished. A more resourceful overview screen was also created where the user can see which steps they have completed, the results of those steps and also see results from x-ray and blood samples (see Appendix III).



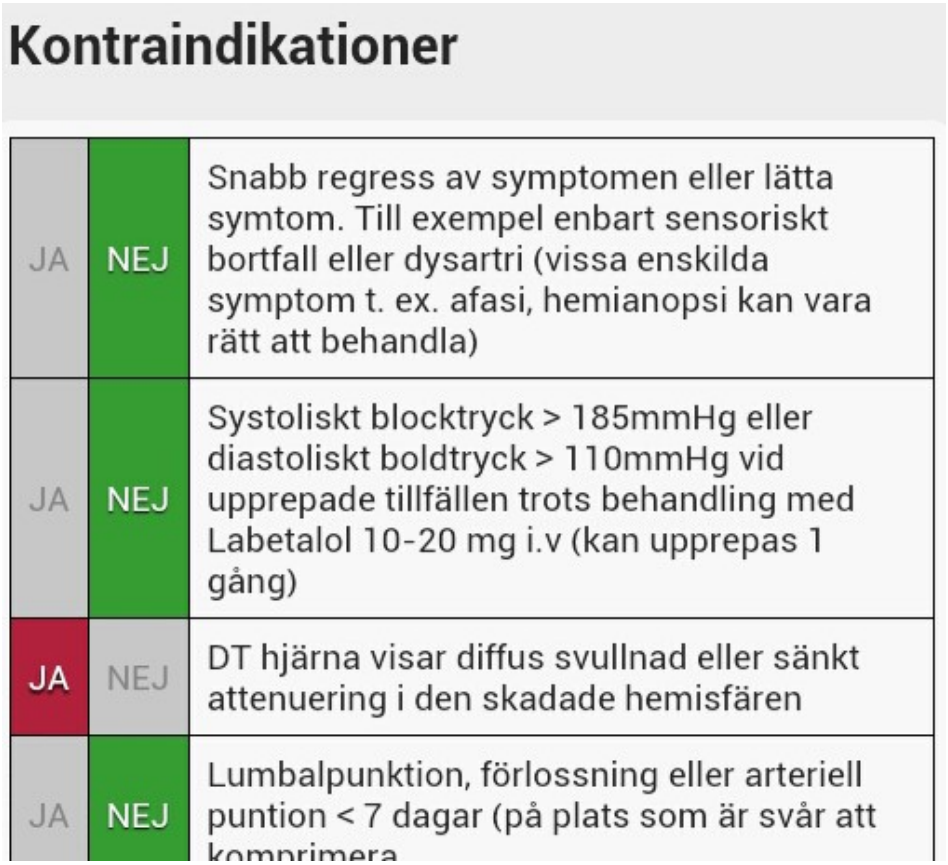
Picture 6: Overview - steps completed and results

The vital parameters are, in the same way as the pie chart overview, visible on every screen of the application (see Appendix III). This means that in whichever step the user is, the user always has access to this information without having to go to another view or open a pop-up window.



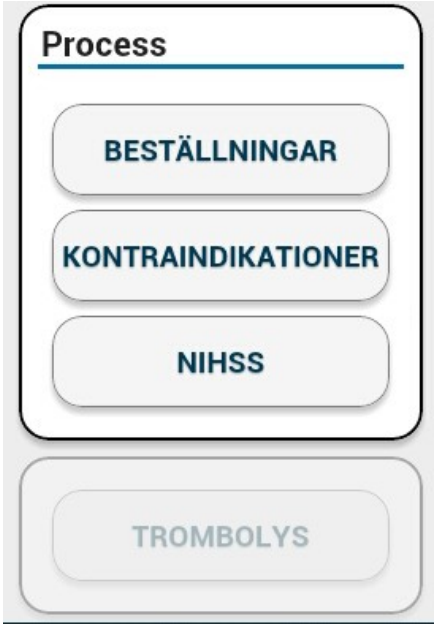
Picture 7: Vital parameters

Another change was made in this aspect to the contraindication list (see Appendix IV). In the first prototype this was just a static list, but the users wanted a better overview and better visual representation of which items in the list had been checked as well as the nature of the answer. The questions are yes or no questions, so to make a better visual representation of it the colors red and green were used. If all questions are answered no, it's a green light for treatment whereas if any of the questions are answered yes it is represented by the color red which will indicate to the user that treatment needs to be considered with caution.



Picture 8: Contraindications list

To ensure that no mistakes are made, the button to order thrombolysis only has function when all steps are completed. So before that, a treatment can not be ordered.



Picture 9: Thrombolysis button

5.4 Conclusions

The important factors to consider during the development of a tablet application used in an emergency department are presented below.

Clearly identifying workflows and creating flexible interactions
The mapping of workflows is essential to the development of the system as it provides guidelines to how the application should work to accurately match the already existing mental models and perceptions of a process that the users already have. The purpose of the application is to aid the users in a process, rather than redesigning a process - therefore it is important to create an application that reflects the already existing workflows. Clearly identifying the workflows also provides a more comprehensive understanding of the users and their needs which can help to improve the overall development and design process. The identification of workflows during the field studies showed that it is important to create a non-linear system, which is discussed below. It also helped map the functionality and different views that the application needed to facilitate; ordering x-ray referral and blood samples, going through the contraindication list and filling out the NIHSS form, as well as ordering the

thrombolysis treatment. This was also clear when testing the prototype with the users; they recognized the workflows portrayed by the application which made it easier for them to understand.

Non-linear system
Although the processes in healthcare are pretty straightforward, the individual cases differ from each other as well as the users' way of going about it. The users accommodate the established process to be executed with an approach that suits the way they like to work. An application that presents the users with a number of steps needed to be completed in a certain order would therefore inhibit some users and also confuse them as the application would suggest that the process is to be carried out in a manner unlike the one they are used to. It is important to accommodate to the representational models already established by the users to create a harmony between application and user, thus making the application an aid rather than an obstacle. The observations showed that all the doctors completed the process in a different order. By creating a non-linear system no users are neglected and the doctors can follow their already established representational models of how to complete the process. The usability tests also proved this to be true. During the usability tests the doctors completed the different steps in different orders.

Visualization and representation of information
Information is, as discovered in both observations and literature, a big part of health care and health care systems. Through the usability tests it was clear that it is important to visualize the information in a manner that suits the users needs, goals and objectives. It is important to find a balance between the amount of information available and the amount of information chosen to be displayed. The user needs the right information at the right time and sifting through major amounts of information to find the right information will only inhibit the user and the goal of the application. Which information needs to be displayed and in what way it should be represented needs to be identified to efficiently provide the user with accurate and relevant information in a certain situation or in a certain step of a process. From the usability tests it was clear that the vital parameters were essential throughout the process and therefore were given a permanent view in the application. The information needs to be reduced to a certain amount where only the necessary information is displayed in a way that is easily and quickly comprehended by the user to ensure that the application aids the user in an efficient way. Since the target user group is doctors, medical abbreviations can be used to save screen space and present the information in a better way. This makes it important to involve the users in the design process to be able to make use of the right language appropriate for the

applications usage and purpose.

Detailed and easily comprehended overview
Gong & Tarasewich (2004) says in one of their design principles that it is important to design for restricted and divided attention - something that is very common within the context of an emergency department. During both field studies and usability testing it was clear that the users encounter a lot of interruptions during different processes and it is important to cater for these by providing an application that gives them an overview. This overview helps the users to know which steps they have completed and which steps still need to be done. It also gives them a comprehensive overview of the situation to recall information lost during the interruptions. This is important for both the users and the health care in general. The advantages for the users are that this overview can help them going through the entire process without any loss of information and without missing any of the crucial steps. The benefits for health care is that, by ensuring that the users go through all of the steps, a higher quality of care is provided by decreasing the risks of mistakes.

Accurate and instantaneous feedback
The feedback associates with the overview. This also has a function of ensuring that the users go through the steps correctly and without missing anything. Feedback provides an aid for the user giving warnings, confirmations and questions. It is important to design the feedback features so that they can be easily understood by the users and unable for the users to miss. The users want to know that they've completed each step correctly. When they have ordered a x-ray referral they want visual feedback that tells them they have done it correctly. They also want the system to warn them about things that might stand in the way of treatment - for example if the patient is already taking blood thinners. This will also help to decrease human errors in the process.

Perception of trust
It is important that the focus of the application is towards what needs to be done. This needs to be demonstrated within the application in shape of design and presentation. It is of utter importance to always consider the context of an emergency department during the development of the application, thus keeping the focus on the tasks and information needs. This focus will enhance the feeling of trust and security towards the application amongst the users. This was clear when discussing the patient chart system currently in use at the hospital. Although it didn't work perfectly and could at times be tricky, the users trusted the system because of its long establishment and its sterile look.

Automation
Another thing that was clear from the field studies was that a lot of the steps involved in the different tasks can be automated, especially those tasks that involve user input. When ordering a x-ray referral for a stroke patient the filled out information in the form is usually always the same. By automating this valuable time can be saved and it can help decrease frustration from the users towards the application.

6 Discussion

Even though the test persons had positive opinions about the application and this new way of using technology, there was a subtle skepticism towards it. This shows the importance of designing a system that correlates to the users' already existing mental models of how a process is carried out and how the tasks within it are performed. It is important to design a user friendly application by following the factors mentioned in the previous chapter, but it is also important to design an application that is perceived as trustworthy. This element of trust in the design carries as much weight as usability within this context. This will be achieved by thoroughly observing the context to create an application that contains all the important elements and lets the users perform the tasks that are required for the process.

This context also demands more from the designer, because of the specific language, expressions and context specific abbreviations. It is therefore important to closely observe the context and collect as much data as possible. It is also important to let the users be a part of the design process. This will enable continuous feedback as well as expert perspective on the language of the application.

By isolating one process for the design, a lot of automation can be done to enhance the efficiency and effectiveness of the process. Automation helps decreasing the input needed by the user and in the process of treating a stroke where time is invaluable, this could be a determining factor. Creating this kind of application can help the users' save time which means that more patients may get treatment faster. Using an application can also help prevent human errors, which, as discussed in section 3.1, causes 30% of errors in medication prescription.

As mentioned in section 3.1, health care is one of the last fields to undergo full computerization. As shown during this project, taking advantage of the possibilities of media technology to the existing work flows can help streamline the processes as well as help doctors to accurately perform their tasks. The use of tablets and smart phones could provide a lot of benefits to this context since it is a highly mobile environment where the actors are continuously moving and performing tasks at different places.

6.1 Methodology discussion

The results of this thesis shows that it is important to clearly investigate the context and the users' needs and goals. The qualitative research in the form of field studies were therefore very usable for designing for this context. The field studies presented an inside view of the organization, the people in it and how they worked that solely interviews would not have. It also provided a good knowledge base around their current systems and artifacts to deepen the understanding of the users' goals, objectives and needs. Observing and following a doctor for a whole day also makes it easier to find out things that maybe would not have come up in interviews, because questions can be adapted to the situation. When interviewing, a person answers from memory and might leave things out. Therefore, by observing the situation, things may be revealed that would not have been by only using interviews.

Although the observations revealed a lot of valuable and useful information, they should probably have been conducted for a longer amount of time to be able to observe more save the brain alarms. It would also be valuable to observe more doctors, to be able to get a more accurate view of the target users.

Creating a persona provided a good way to summarize the information derived about the users into a helpful tool that was used throughout the process. This was very useful as the target users within this context are very different and have a lot of specific needs. Using a persona throughout the process helps to keep focus on the target users' needs without getting lost in flashy interface elements and other things that might only inhibit the goal of the application.

The goal-directed design framework described in section 3.4 has been useful as guidelines to follow to stay on track of what needs to be done. The downside to this approach is that it is very time-consuming; creating personas and scenarios

take up a lot of valuable time. Time that could instead be spent on developing the prototype further, but in that case it might not have been as accurate towards the context.

6.2 Further research

Further research should go into more detail on specific interface elements and input methods. This could be done by analyzing how to construct the interface; where to put buttons, input fields etc., and this analysis could be conducted by using eye-tracking devices to see how the users' interact with an application during the execution of a process. This should be combined with research about which finger input types might be best suited for this kind of context; tap, double tap, drag etc., as well as different text input methods.

Health care is a major field and within it a lot of processes that could benefit from digitalization. More research should be done on which processes might benefit by using a tablet application instead of how they currently are carried out. It could also be possible to research how processes can be redesigned by using a tablet application, to enhance efficiency and effectiveness as well as decreasing human errors. This research should also include investigating issues related to implementation of mobile systems such as security and confidentiality. Although most of the participants in this study were positive towards the introduction of this new technology, the fear of 'the new' was still there. This makes it important not just to look at the technology, but to also involve and remember the importance of the users. No matter how well designed an application is, it won't be effective if the users can't figure it out.

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Appendix I - Test plan

1. Introduction

This prototype is developed as a part of my bachelor thesis. The project is being conducted together with Cambio Healthcare Systems. The use of the application will be when a save the brain alarm arrives to the ED.

This is the first version of the prototype and the tests are conducted to get a better understanding of how the function, structure and interface reflects the mental models of the users and how it would fit into their work environment. The information from these tests will be used for further development of the application.

The way the test will work is that I will give you tasks to perform and when performing these you will think out loud - try to picture how it would be used in an actual

After the test we will have a brief discussion about the overall impression.

2. Pre-test interview

- Previous experience with mobile devices, both private and at work
- How does the save the brain process look like today? What tools are used? How do you think it works?

3. Tasks

When doing the tasks, imagine how it would work in a real situation with a real patient.

1 Start the app. What is your first impression? Describe what it is you see. What do you know about the patient so far?
2 What would your next step be?
3 Order a x-ray REMISS? and blood samples. How did you experience that?
4 Go through the list with contraindications.
4.1 You remember something in the ambulance notes that might be relevant. How would you go about to read that again?
5 Fill out the NIHSS. How was it?
6 How would you go about to see the results from the x-ray?
7 What would your next step be?
8 Now it’s time to prescribe thrombolysis. How would you go about that?

8.1 Where can you find the patient's weight?

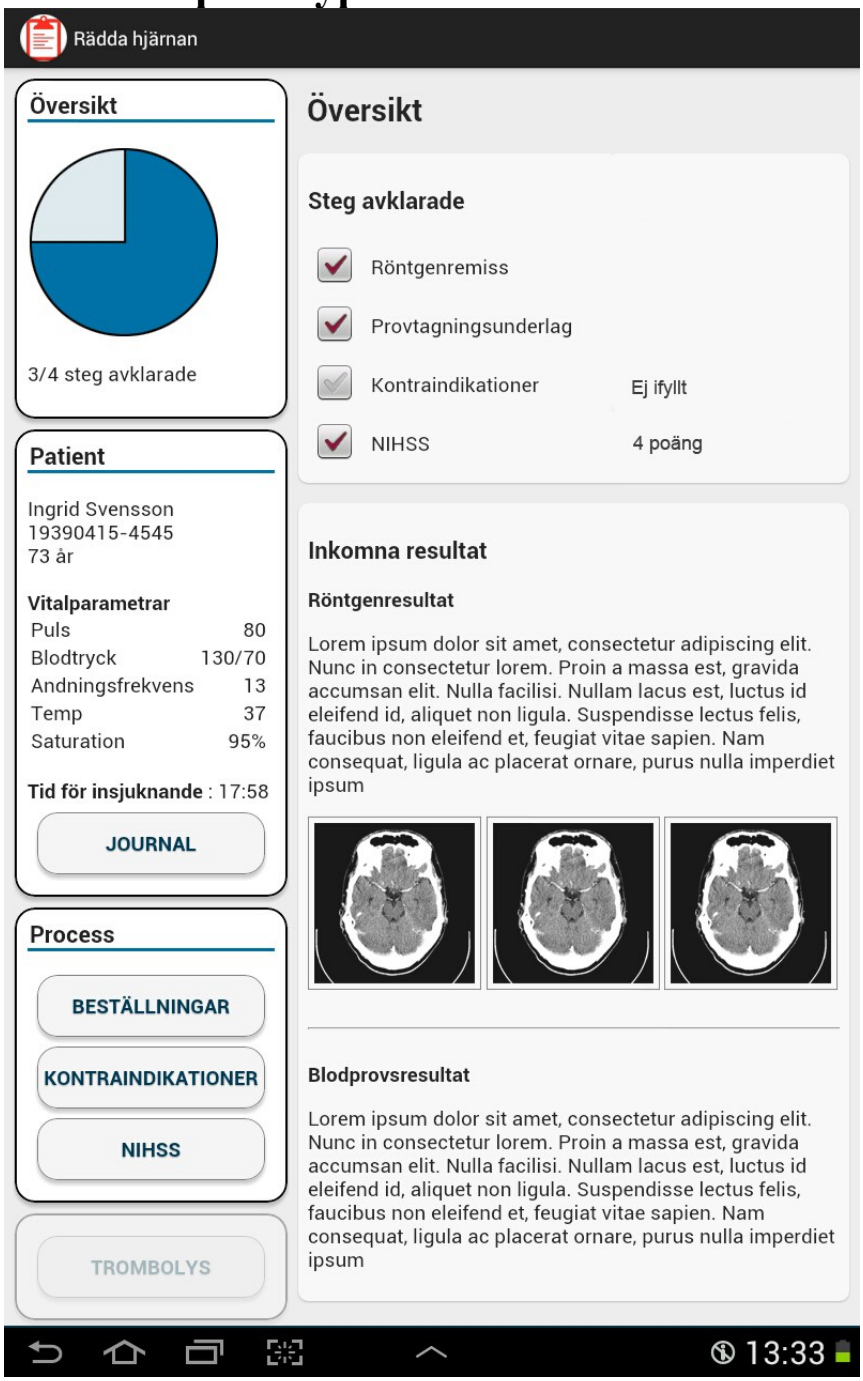
4. Post-test interview

1. What was your overall impression?
2. What was good? What was bad?

    2.1 Is there anything you thought were missing?
3. Did you find anything difficult?
4. How would this app fit into a real situation?

Appendix II – First version of the prototype

Appendix III – Overview screen of the second version of the prototype



Appendix IV – List of contraindications on the second version of the prototype