Development of wearable healthcare device

A user-centred project focused on meeting discovered needs of nurses

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Abstract

The healthcare industry is highly information intense and is progressively adopting information technology (IT) systems. Despite large resources being invested in health information technology, a large percentage of healthcare personnel are dissatisfied with functionality and usability of the systems. One main issue is considered to be the low grade of user involvement in development of health information technology systems and products.

Tieto, the commissioner of the thesis project, develops IT systems for several different industries, amongst them is the healthcare industry. The purpose of the project was in collaboration with Tieto decided to be "By the use of a suitable development process; define work routine problems and potential improvements for nurses working at care units, and to develop a conceptual smart wearable device solving such a problem".

The project was performed using a customised version of a spiral product development process, where different methods suitable for the project were integrated. A lot of focus was put on involving the user, nurses, in the development process and four different hospitals were visited to gather empirical results and to later validate findings and concepts.

The result of the thesis is the conceptual product ELSA, a wearable alarm system developed for nurses. The alarm differs significantly from alarm systems used in care units today and each nurse will wear an ELSA watch which can generate emergency alarms and assistance alarms. The ELSA watch also enables seeing alarms from any location in the care unit. By keeping the alarm buttons close at all times, time can be saved in emergent situations.

KTH Industriell teknik och management

Examensarbete MMK 2014:32 MCE 305

Utveckling av bärbart verktyg för sjukvården

-Ett användarcentrerat projekt fokuserat på att möta upptäckta behov hos sjuksköterskor

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Godkänt	Examinator	Handledare
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Sammanfattning

Sjukvården är som helhet en av de mest informationsintensiva brancherna och inför alltmer informationsteknologi (IT) system. Trots att stora resurser investeras i IT för vården så är en stor andel sjukvårdspersonal missnöjda med funktionalitet och användarvänlighet i dessa. En bidragande faktor tros vara den låga graden av användarinvolvering i utveckling av IT system och produkter för sjukvården.

Tieto, beställaren av examensprojektet, utvecklar IT-system för ett antal olika industrier, varav sjukvården är en. Syftet med projektet var tillsammans med Tieto satt till ”Med användandet av en passande utvecklingsprocess; definiera arbetsrelaterade problem och förbättringsmöjligheter för sjuksköterskor som arbetar på vårdavdelningar, och att utveckla ett koncept för ett smart bärbart verktyg som löser ett sådant problem”.

Projektet utfördes med en skräddarsydd version av en spiralformad produktutvecklingsprocess där olika metoder passande för projektet integrerades. Mycket fokus lades på att involvera användaren, sjuksköterskor, i utvecklingsprocessen och fyra olika sjukhus besöktes för att samla empiri och för att senare i processen även validera empiriska resultat och koncept.

Resultatet av examensarbetet är konceptet ELSA vilket är ett bärbart larmsystem utvecklat för sjuksköterskor. ELSA-systemet skiljer sig betydligt från de larmsystem som används på vårdavdelningar idag. Med ELSA-systemet förses varje sjuksköterska med en ELSA-klocka som kan generera akutlarm och assistanslarm men även ta emot larm från andra ELSA-klockor och patienter. ELSA-klockan bärs hela tiden med av sjuksköterskan vilket gör att möjligheten att larma alltid finns nära till hands.

PREFACE

The master thesis project was performed in collaboration with Tieto and the Royal Institute of Technology. The project is representative of the final course in the authors´ education within Integrated Product Development.

The authors would like to extend their most sincere gratitude towards the persons that have supported and helped the project. To our supervisor at Tieto, Cathrin Svensson, we would like to express our deepest appreciation for your constant flow of ideas and questioning of methods and ways of thinking. To our supervisor at the Royal Institute of Technology, Jon Herman Rismoen we would like to thank you for always giving us new perspectives of the project.

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NOMENCLATURE

This chapter aims to describe the abbreviations and healthcare vocabulary used in this Master thesis report.

Abbreviations

GPS	Global Positioning System
HCI	Human-Computer Interaction
HIT	Health Information Technology
IoT	Internet of Things
IR	Infrared
IT	Information Technology
NFC	Near Field Communication
RFID	Radio Frequency Identification

Vocabulary

Assistant nurse	A nurse having gone through a one year education, or upper secondary school nursing education.
Care unit	Part of the hospital where patients are hospitalised and cared for.
Medicine room	Locked room at the care unit where medication is stored.
Medicine trolley	Trolley with medications, a computer and more used by nurses.
Nurse watch	Watch worn by the breast pocket of the nurse uniform.
Patient list	The list used by nurses for taking notes and remembering.
Registered nurse	A nurse having gone through the three year education.
Smart device	Electronic device connected to other devices or networks usually via wireless communication technologies such as Bluetooth, RFID, NFC, Wifi, 3G etc.

TABLE OF CONTENTS

1. INTRODUCTION

In the introduction chapter the background of the master thesis is presented, along with information about Tieto, the company that the thesis is written in collaboration with. The purpose and delimitations of the project are also presented.

1.1 Background

The healthcare sector is one of the most information intense industries existing. Therefore, the importance of achieving a proper information flow between actors such as doctors, nurses, patients and relatives is crucial for the efficiency and excellence of the area. Information technology (IT) is a natural solution for achieving proper information flow in the modern technology society. (Scandurra, 2013)

Adoption of information technology in healthcare has progressed rapidly during the last decade, which can be exemplified with that in 2005 only one Swedish county council had completely adopted IT-support for healthcare documentation and in 2012 all county councils in Sweden had fully adopted the support. IT-costs for Swedish county councils have also increased with 47% between 2004 and 2011. (Jerlvall & Pehrsson, 2012) According to Dagens Medicin (2010), 32 billion SEK have been invested in health information technology between 2005 and 2010.

Despite the increased adoption and investments in health information technology, there is significant discontent in perception of the current health information technology. According to Vård-IT-rapporten (2010) 36 % of healthcare personnel were dissatisfied with development of the information technology systems used and 46% did not believe IT reduced stress in the work.

Several different approaches have previously been used when developing health IT systems, but the problem is believed to rise from not involving the end-user enough when developing new solutions. Scandurra (2013) claims that, in order to solve the problem with complicated information technology systems, health personnel need to be involved in the development.

Computers currently play an important role in the utilisation of IT in healthcare. However, in recent years mobile smart devices have rapidly been developed and are starting to enter the healthcare sector. Since healthcare personnel often are highly mobile in their occupation; moving between different patients, rooms and care units, mobile devices are welcomed. (Su & Liu, 2010)

An important aspect when developing solutions for the healthcare industry are the high hygiene demands on products used within hospitals and other sensitive environments which automatically applies to this master thesis project, working towards hospitals. In order to limit risks of health-care associated infections, there are regulations set by the Swedish National Board of Health and Welfare (Alexandersson, 2007). These include eleven points concerning working-clothes, accessories, disinfection and protective equipment.

1.1.1 *Tieto*

Due to the many problems with healthcare information technology, the IT consultancy company Tieto aims to target the healthcare industry from several angles. Tieto is the largest Scandinavian company offering IT services, having 14 000 employees in twenty countries and a turn-over of 1.6 billion euro. The aim of Tieto's work is to develop companies and societies using IT and create opportunities for their customers to transform their businesses. Tieto works towards several different industries, among them are healthcare and welfare, telecom, energy utilities and financial services. The company is divided into four groups working with different industries; *Financial Services; Manufacturing, Retail and Logistics; Public, Healthcare and Welfare; and Telecom, Media and energy.* (Tieto, 2014)

1.2 Purpose

The purpose of this master thesis is to, by the use of a suitable development process; define work routine problems and potential improvements for nurses working at care units, and to develop a conceptual smart wearable device solving such a problem.

1.3 Delimitations

The study choses to focus on registered nurses working at care units with hospitalised patients since this are one of the most common sorts of nurses (Socialstyrelsen 1, 2013; Socialstyrelsen 2, 2013). Due to time and traveling limitations four different hospitals were visited where three of them were located in Stockholm and one in Gävle. The project stretched over a limited period of time, 20 weeks, which is why only a concept is developed and not a functioning product.

2. FRAME OF REFERENCE

The frame of reference functions as a platform for the master thesis project and is continuously involved in decisions regarding the project. In this chapter the frame of reference is presented, divided into three main areas important for the project; product development, information technology and information technology within healthcare.

2.1 Product development

Product development is by Ulrich and Eppinger (2012) defined as the interconnected activities starting with a market demand or opportunity and ending with production, sale and delivery of a product. Kahn (2013, p. 462) describes the same concept as "The overall process of strategy, organization, concept generation, product and marketing plan creation and evaluation, and commercialization of a new product." There are, as debated by Ulrich and Eppinger (2012), several definitions of the product development process and, therefore, no universal process that works in all situations. Three different product development processes are presented below due to their appropriateness for the master thesis, as well as different methods of involving the user in product development and ergonomic aspects of product development.

2.1.1 *Product development process*

A product development process is a sequence of phases that are needed for the development of a product (Ulrich & Eppinger, 2012). Magsalay (2012) states that a solid framework must be used when bringing new products to the market in order to ensure quality of the products. A well-defined product development process enhances the quality, coordination, planning and management when used right (Ulrich & Eppinger, 2012). The generic product development process explained by Ulrich and Eppinger (2012) consists of six phases; planning, concept development, system-level design, detail design, testing and refinement and production ramp-up, Figure 1.

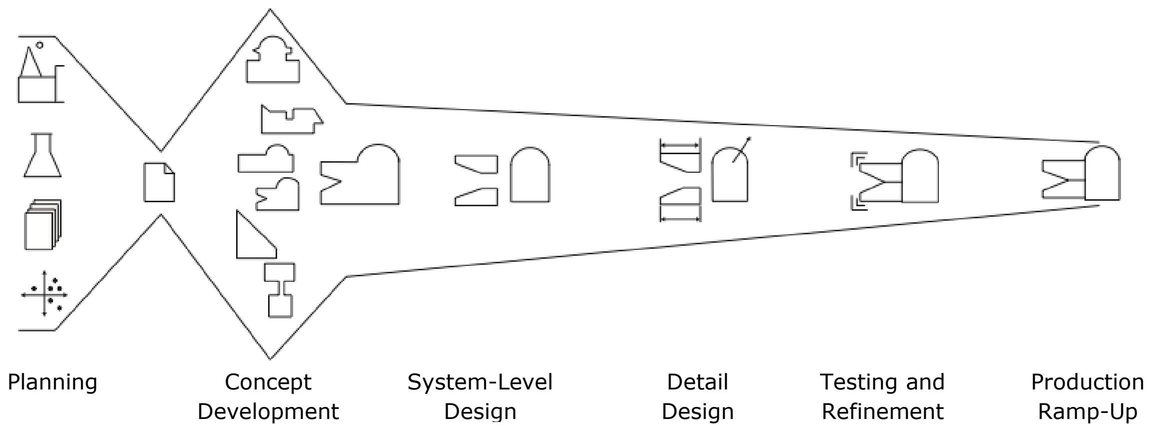

Figure 1. The generic product development process (Ulrich & Eppinger, 2012).

A spiral product development process is also explained by Ulrich and Eppinger (2012), which is suggested for quick-build products. In the spiral development process designing, building and testing are iterated until desired result is accomplished. Ullman (2010) describes another spiral process which begins with an initial concept that is prototyped, evaluated and refined. The second spiral is then started where a second concept is prototyped then evaluated and refined. The process then continues until the final product is developed.

2.1.2 *User involvement in product development*

There are many different definitions of what a user is, ranging from Warell (2001) claiming a user is an individual who interacts with the product at any stage of the product's lifecycle to Karlsson (1996) claiming the user to be defined only as the end user. With Warell's definition individuals such as repair staff, waste handling staff and producers are included as users, along with end users. For this master thesis project, the users are defined as Karlsson's description, being end users.

In a traditional product development project users are not involved until the product reaches market. They will then function as an indicator of the success of the product. (Durugbo & Pawar, 2014) Potentially due to this, nearly nine out of ten products fail within two years on the market (Ericson, et al., 2007). However, involving the user and performing participatory design, has been discussed and debated for several decades (Reich, et al., 1996). When performing traditional product development, customer needs are captured from the perspective of scientists and engineers. In the final stage of a development process, customers are consulted and expected to give feedback on functions and experiences of the product. (Durugbo & Pawar, 2014)

According to von Hippel (2005) more involvement of users in the development process, offers great advantages over the traditional development. In contrast to traditional development, users can create products exactly as they want them, instead of relying on companies acting as their agents. The users give value to companies by sharing their critical input, and sometimes even being the sources of innovation (Bogers, et al., 2010). There are different ways of involving customers and users when developing a product, some methods relevant for the master thesis are explained below.

User-Centred Design

Norman (2000) defines user-centred design as a philosophy based on the needs and interests of the user. This, he claims, emphasises the importance of making products usable and understandable. Summarised, Norman states design should make the determination of possible actions easy and make use of visibility when it comes to alternative actions and results. He also claims design should make the evaluation of current system state easy and follow natural connections between intentions and required actions.

Concept testing

Concept testing is a method physically involving the users already in the development phase. Users are often showed stimulus material such as quick sketches, models and prototypes and the concepts are explained in detail. (Kaulio, 1998) The use of prototypes, models or sketches can generate a deeper understanding of the concept and are, therefore, preferable (Schneider & Stickdorn, 2013). It is important that the concepts are realistically and understandably explained for enabling the users to give proper feedback. Generally, concept testing is well-suited for using in a development project divided into different phases or stages and also good to combine with later beta testing. (Kaulio, 1998)

Scenarios

When developing a product, service or system, there is an importance of understanding situations and settings where the matter is used (Carroll, 2000). This can be done by documenting persons and actions in text, storyboards or videos which is commonly called scenarios (Schneider & Stickdorn, 2013). Scenarios are hypothetical stories giving insight on problems and interpretations of current states (Carroll, 2000). Bødker (2000) emphasizes that scenarios always are made with a purpose relating to both the situation and design solution. There are three proposed main reasons for using scenarios suggested by Bødker (2000); to present and situate the solutions, to illustrate alternative solutions or to identify potential problems.

2.1.3 *Ergonomic aspects of product development*

The definition of ergonomics for this master thesis project is formulated by the International Ergonomics Association (2014) and explains as follows.

> "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance."

Ergonomics is beneficial to include in the product development process both for new products and refinements of old products due to several different reasons. These reasons can be divided into three levels; individual level, organisational level and community level. On an individual level ergonomics can infer decreased stress levels, increased safety, satisfied users and increased well-being. On an organisational level ergonomics can increase productivity, competitiveness, quality and productivity. On a community level ergonomics can infer increased competitiveness, safety and improved economics. (Boghard, et al., 2008)

Due to the purpose of the master thesis, ergonomics concerning human-technique systems are of main interest. Such systems include a human operator and technical product that interact in order to perform a task. Cognitive processes, how humans register information from the surroundings, are therefore important to consider. (Osvalder & Ulfengren, 2008) Several ergonomic aspects and design principles regarding human-technique systems and cognitive processes presented by Boghard et al. (2008) are applicable to this master thesis project and presented below along with supporting references.

Visual ergonomics

The science of visual ergonomics is multidisciplinary and includes understanding the human visual processes and visual registration of the surroundings along with interaction between humans and other parts of the system. Theories and models are used to optimise performance and efficiency of such systems. Some visual ergonomics theories relevant for the master thesis are presented below. (International Ergonomics Association, 2014)

When presenting information on a display, information should be short and concise in order to be apparent. Displays also need good readability which implies high contrast, good lighting and the right angle of vision. (Osvalder & Ulfengren, 2008) According to Arbetsmiljöverket (2012), the ideal contrast for reading on displays is to have dark characters on a seven times as light background. Black background on the display is also dissuaded for most situations due to the large contrasts to the surroundings that often are of a lighter character. Another important aspect for the readability is choice of font. When reading on paper, fonts with serifs increase readability while fonts without serifs are easier to read on displays. Hägg et al. (2008) claims that when researching angle of vision, it has been proven 15º below the horizontal line to be most comfortable. Most individuals prefer an angle of vision of between the horizontal line and 30º below. An angle of vision higher than 45º is not recommended.

Osvalder and Ulfengren (2008) emphasises the importance of colours used when presenting information. Use of colours is a delicate matter and should be treated with caution. Colours can create uncertainty and fatigue and can be perceived as playful and superficial. There are however great benefits of using colour coding such as quicker understanding of information, faster reaction time, attention to specific data and separation of close objects. Certain colours are commonly associated, but the associations can to a certain extent differ because of cultural conditions. In the western world the following colour combinations are commonly used:

Figure 2. Colour combinations commonly used in the western world, adapted from (Osvalder & Ulfengren, 2008).

Apart from colours used in the right way, symbols are efficient communicators of information. In order to improve understanding the symbols need to be well-known and unambiguous. When used right, symbols have several advantages over text; the symbol can be seen from longer distance, information will be perceived faster and with a smaller margin of error, if the symbol is partly destroyed or hidden it can still be found and understood, symbols are often interpreted the same on an international level. (Osvalder & Ulfengren, 2008)

To support design of a visual display, some design principles have been set up by Osvalder and Ulfengren (2008). One of the principles applicable to the master thesis project is the principle of consistent presentation. The principle of consistent presentation emphasises the importance of, when designing new interfaces, using as much previous knowledge the operator has as possible. This means the same symbols, colour coding and placement as in interface previously used by the operator.

Often when designing a visual interface, there are levers and buttons connected to the display. When designing buttons, there are certain guidelines to follow. If the buttons are supposed to be marked with symbols or text, square buttons are to prefer over round. Dimension of the buttons should also be considered in the design phase. The diameter of a button should not be less than 0,64 centimetres and if the button has a diameter between 1,9 and 2,5 centimetres, a concave surface can facilitate localisation of the button. (Woodson, et al., 1992)

Audial ergonomics

When developing technical systems the use of audio for warning is natural due to the inability for humans to, without assisting devices, turn off hearing. One great advantage of using audio for attentive purposes is that; sounds are registered even when not listened for explicitly. However, sounds can also create distraction and communication disablers and on which side of the line a sound is placed depends on the situation and surroundings. There are three substantial perceptive variables of sound; intensity, frequency and direction. Warning signals exist in order to alert the operator and enable judging the nature of the problem, severity and sufficient intervention. Therefore, warning signals need to be easily separated from other noise, easy to understand and remember. The signals need to be well heard but not annoyingly loud or consistent to not be perceived as distracting or disturbing. (Osvalder & Ulfengren, 2008)

Alarm systems

When creating an alarm system both visual and audial components are often used in the combination of an audial alarm being followed by information on a display or screen. Alarm systems are used to alert the operator of deviations and to correct error conditions. It is important to not use the alarm system for planned events, only unexpected incidents. By differing the substantial perspectives of sound; intensity, frequency and direction, different sounds can be created and quickly inform the operator on which incident that has occurred. A maximum of three priority levels is however recommended for alarm systems. This because humans have difficulties separating more sounds than three. The lowest level of priority should alarm at least 10 dB over the normal volume that the product produces. Concluded, Thunberg and Osvalder (2008) describe a good alarm as being:

- Relevant – not a false alarm or alarm of low use.
- Unique – the alarm should not be a duplicate of another alarm.
- Convenient – the alarm should be on the right time.
- Prioritised – the importance of the alarm should be displayed so the operator can prioritise the effort.
- Understandable – simple and easily understandable message.
- Diagnosing – identify the problem that has occurred.
- Advising – indicate the action to be taken.
- Focusing – draw attention to the most important aspects.

Alarm Fatigue

In the current healthcare environment, many different devices are used to assist and serve the patients. All of them using different sounds and lights to attract attention and communicate their information. When the frequency and number of alarms become overwhelming alarm fatigue may occur which can lead to longer responding times. Alarm fatigue also occurs in other environments than healthcare, for example in industries such as nuclear power and aviation, and the consequences are similar. (Solet & Barach, 2012)

A study performed at The John Hopkins Hospital in Baltimore presented there were 350 alarms per patient every day. The purpose of the alarms is to announce when the status of the patient differs from the predetermined normal status (Sendelbach & Funk, 2013). In the healthcare sector, 80 up to 99 percent of the alarms are false which in this context means the patient is not endangered. False alarms often occur because of absent or incorrect patient data which can be caused by patient movement or incorrect positioning of sensors. Recurrent false alarms can result in slower responding time in an emergency (Tanner, 2013). A study made in the U.S. between January 2010 and June 2010 identified 216 deaths linked to alarms on patient monitors, many where results from a delayed response or even the absence of response. In order to eliminate alarm fatigue the number of false alarms needs to decrease. (Solet & Barach, 2012)

2.2 Information technology

Information technology is a concept that regards uses of systems that facilitate storage, processing, transfer and presentation of information. Examples of such systems are computers, smart phones and tablets. Information technology constitutes a large part of the modern society and most institutions rely on the technology. (Gupta, 2010)

2.2.1 *Internet of Things*

Connection to anyone, anywhere and at any time is currently enabled by the use of internet. However, development is about to progress further by adding the new dimension "anything". The addition of "anything" will enable new ways of communication between people and things as well as between things themselves (International Telecommunication Union, 2005). According to Pang (2013) addition of the new dimension will have the same dimension of impact on human life as the internet had in the past decades. The concept Internet of Things (IoT) refers to the idea of seamlessly connecting people and things of interest (Pang, 2013). IoT will affect everyday life in many ways, exemplified in the potential utilisation areas of e-health, assisted living and enhanced learning (Atzori, et al., 2010). To enable such innovation electronics have to be embedded into existing physical objects making them "smart" and allow them to connect with the global network (Miorandi, et al., 2012). Some wireless communication technologies that can contribute to enabling an IoT society are presented below.

Radio Frequency Identification

The first step in connecting things to databases is to find a simple cost effective item identification system (International Telecommunication Union, 2005). Radio frequency identification (RFID) uses wireless communication technology to identified tagged objects. There are three basic components in an RFID system; a tag, a reader and a controller. The tag consists of an antenna and an electronic chip where data can be stored. The tag can communicate with the reader by the use of radio waves. When a tagged object reaches the read zone of the reader it signals the tag to transmit the data stored on the chip. (Hunt, et al., 2007)

The read range on the RFID tag can differ extensively depending on whether the tag is active or passive. An active tag is used when the tag needs to transmit data to the reader. For this to be possible, the tag needs to include a battery which enlarges the tag, makes it more complex and expensive than a passive tag. However, because of this active tags can interact with less powerful readers on a distance up to 30 meters. A passive tag has no battery of its own, instead it derives power from the reader and, therefore, the read range could be as short as 60 centimetres. This also results in a smaller and much cheaper tag. (Hunt, et al., 2007)

Near Field Communication

Near field communication (NFC) is based on the technology used in RFID systems, but it is limited to connect when the devices are up to 10 cm apart (Curran, et al., 2012). The technology can wirelessly connect two devices containing NFC tags by the use of short range radio waves (Sharma, et al., 2013; Curran, et al., 2012). NFC can provide bidirectional communication, meaning it can send and receive information simultaneously. Certain phones are currently equipped with NFC tags, enabling them to communicate with devices containing NFC tags. The phone can be used for payment by placing it in front of a phone reader. The purchase will then automatically be paid from the customer's bank account. (Sharma, et al., 2013) As more manufacturers are equipping their phones with NFC tags the needs and possibilities for new applications are increasing rapidly. NFC is a very natural and user-friendly way of connecting things and only needs the objects physically connected in order to establish communication. (Curran, et al., 2012)

Bluetooth

Bluetooth is one of the most utilised wireless communication techniques in the world (Stirparo & Löschner, 2013). The technique enables wireless communication between small electrical devices without a line of sight connection. Bluetooth is often found in cell phones and enables the phone to connect with external devices such as headsets and computers. To establish a connection the phone simply needs to be in range of the embedded radio transmitters. Bluetooth is often used to connect computers with Bluetooth enabled keyboards, printers, scanners and mice to minimise the use of messy cables on the desktop. (Sauter, 2011) Bluetooth is also used within the healthcare sector; early in 2011, 40 million Bluetooth enabled health and medical devices were on the market. (Stirparo & Löschner, 2013)

Several devices can exchange information simultaneously with the use of Bluetooth, but that affects the transmission speed. Different power classes have been defined; class 3 devices are designed to work on a distance of 10 meters through a single wall and class 1 devices works up to 100 m and can penetrate several walls. Battery driven devices are commonly designed to fit class 3 and devices not concerned of the energy consumption designed for class 1. (Sauter, 2011)

Infrared Communication

Infrared (IR) communication refers to the use of infrared light waves for communication and transmission of information. IR can be used for either communication between portable devices or between a portable device and stationary base point (Carruthers, 2002). Infrared light and visible light are close together in wavelength, resulting in similar properties. They both get absorbed by dark objects and reflected by shiny surfaces. IR signals require a clear line of sight between the transmitter and the detector and, as visual light; it can pass through glass but not walls. IR technology is a cost effective alternative to achieve transmission of high speed. (Kahn & Barry, 1997)

Global Positioning System

The Global Positioning System (GPS) can be used for many different applications but, as indicated in the name, it is a technology used to locate objects, persons and to navigate. There are three components in a GPS system; the space, the control and the user. The space segment refers to the satellites orbiting the earth. Each satellite sends out radio signals that receivers use to calculate the position. The control segment refers to the organisation that has the responsibility to monitor and maintain the satellites since their exact location in space is essential for correct calculations. The last segment is the user who can utilise the information in different ways, for example, to calculate speed or to find a position. (Spencer, et al., 2003) GPS can calculate reliable information of a position independent on weather conditions, but it requires a clear line of sight of a minimum four satellites to obtain highly reliable information (Ordóñez, et al., 2012).

Wifi

Wireless local area networks (WLAN) provide wireless internet connection and Wifi is the most widely spread WLAN technology. Radio waves are transmitted by a base station which can provide connection over a limited area, but it is possible to connect the stations and create a continuous coverage over a wider area (Lehr & McKnight, 2003). Currently 25% of all homes worldwide have Wifi and two billion Wifi enabled devices were estimated to be sold in 2013 (WiFi Alliance, 2013).

2.3 Information technology within healthcare

Information technology plays a big part even within the healthcare sector; most medical institutions today are using information technology to improve their quality and efficiency (Su & Liu, 2010). Information technology in healthcare is often referred to as health information technology, or HIT (Scandurra, 2013).

2.3.1 *Health information technology in Sweden*

As the name suggests, health information technology (HIT) concerns information technology used within the healthcare sector. When used right, HIT can increase efficiency, improve life quality for both patients and medical staff, and strengthen innovative patterns in healthcare. (Scandurra, 2013) In 2010, the Swedish government adopted a strategy called Nationell eHälsa (2010), a strategy working towards safe and accessible information. The strategy works towards three target groups; the individual including patients, inhabitants and relatives; healthcare personnel; and decision makers within the healthcare sector. Different kinds of support for the different target groups are integrated in the strategy. Individuals are supposed to have easy access to quality secured information regarding healthcare, welfare and personal treatment. Healthcare personnel should be provided with well-functioning and integrated IT-support, facilitating daily work. Decision makers should have tools for reassuring quality and safety, and be provided with a comprehensive foundation to base decisions on. (Socialdepartementet, 2010)

To follow up Nationell eHälsa, Socialdepartementet engaged a review of the strategy in order to find significant areas for development. The review resulted in the study eHälsosystemens användbarhet (Scandurra, 2013) being engaged within the dominating problem area; usability for healthcare personnel in existing systems. eHälsosystemens användbarhet 2013 resulted in a review of current obstacles, important solutions and changes needed to improve the information technology support. Among the suggested priorities for continued work was to involve user experience experts and healthcare personnel to a larger extent, focus on mobility in information accessibility, education of health care personnel, reduce double documentation and continuously optimise HIT systems relative to usability. (Scandurra, 2013)

2.3.2 *Mobile devices used in healthcare*

Computers are currently used on a daily basis in the healthcare sector and are accepted by the medical staff. But as mobile devices are developing in a rapid pace they have also entered the medical field. Since nurses and physicians are very mobile and move frequently between different rooms and locations the use of mobile devices is urgent and welcomed. (Su & Liu, 2010)

Breslin et al. (2004) have studied a wireless product made for hospitals called The Vocera Communications System. The product operates similarly to a portable phone, but there is no need for phone numbers; instead the user can choose a name, function, title or group to call. It also has voice control and the ability to make conference calls. The technologies used are WLAN, IP telephony and a speech recognition software program. The study mentioned above analysed two care units, one who used Vocera and one who used traditional communication tools. The findings of the study were; that the Vocera has a positive impact on the workflow, and was more than five times faster to use than traditional communication methods.

Su and Liu (2010) have investigated utilisation of a personal digital assistant (PDA), a small mobile handheld computer, in healthcare environments. The aim of the product according to Su and Liu (2010, p. 1140) is to "provide the right information to the right health care provider about the right patient at the right time and right place" which is done by wireless communication and networks. Su and Liu argue that PDAs have high potential and predict that they will have a more important role in the future of healthcare. Negative aspects of the PDA were identified to be the user interface; the size of the screen is limited to keep the PDA highly portable. The small screen makes it difficult for the user to interact but when the screen was shown in colour the users performed better.

In a research made by Di Pietro et al. (2012) the use of mobile information technology to improve nurses' access to and use of research evidence is studied from a usability point of view. The software program tested in the study was a clinical decision-support system which aims to improve the quality of care, reduce medical errors and improve clinical practice. The mobile devices used to run the program were a PDA or tablet PC. The findings of the study show that navigation through the program was one of the biggest problems. Di Pietro stresses the importance of providing information to the nurses at point of care, as well as the importance of IT education and future research of usability within the nurses' clinical context.

3. METHODOLOGY

In this chapter theory on the different methods used for the master thesis is presented. To a certain extent, the method theory is presented in chronological order starting with planning, followed by empirical research, concept development and testing and validation.

3.1 Planning

Being the initial phase of a project, the planning phase plays an important part. Planning for a project enables a formalisation of the project process to ensure efficient use of resources. For the plan to function as intended, the project is broken down into tasks that are divided into phases. (Ullman, 2010)

3.1.1 *Time plan*

When the tasks have been listed, the time plan is created. Ullman (2010) suggests using a bar chart or Gantt chart, claiming it to be the most efficient method. On such a chart, tasks are plotted against a timeline.

3.1.2 *Specification of requirements*

When initiating a project, discovering and defining requirements is of significant importance. A project without defined requirements cannot anticipate what needs to be done and the extent of the work. There are two fundamentally different types of requirements; business requirements and product requirements. Business requirements are formulated from the perspective of the business and provide value when met. Product requirements assume one specific solution to meet the business requirement, in the form of a product. These requirements include design of the product and provide value only if they meet the business requirements. The product requirements can be divided into functional and non-functional requirements. The first category includes functions that the product shall or should have. Non-functional requirements include every type of requirement except for functional requirements, for example constraints. (Alexander & Beus-Dukic, 2009)

3.1.3 *Stakeholder analysis*

A stakeholder is anyone with an interest in the project, process or outcome. Usually there are many stakeholders in one project with different objectives and requirements. The first step when conducting a stakeholder analysis is to identify the stakeholders. Stakeholders can be divided into three categories; internal, external and the "rest of the world". Internal stakeholders are typically the members of the project team and the governance structure. External stakeholders are usually those whom the project is being provided for, such as the customers and investors in the project. These people are crucial for the success of the project, but are not a part of the project organisation. The "rest of the world" is a term used to refer to the rest of the stakeholders not that closely involved in the project but still gets affected. Generally it is not hard to identify many stakeholders; the challenge is to know when to stop the process. (Maylor, 2010) Each stakeholder has different requirements and expectations and it is usually not possible to make everyone happy (Alexander & Beus-Dukic, 2009).

Stakeholders are often prioritised by their relative power (Alexander & Beus-Dukic, 2009). In this context power can mean direct authority, indirect authority or an important relationship with the project team. The level of interest and impact are other aspects that are important to take into consideration when managing stakeholders. Interest and impact refer to how much the stakeholder knows about the project and how much they are affected by it. In order to create a stakeholder map the different stakeholder's power and interest are rated and gives a rough idea on how to manage them. (Maylor, 2010)

Competitor identification and analysis

Competitor identification is important and used within many different fields. It can be used to set prices, review the product design and development, investigate competitive advantages, review communication strategies and how to distribute the product. The identification is important to do to increase awareness of competitors' opportunities and threats. In the initial stage, the market should be searched broadly to minimise the risk of being blindsided. When the competitors are identified they should be compared in a competitor analysis on the basis of relevant dimensions. (Bergen & Peteraf, 2002)

3.2 Empirical research

Theory of different empirical research methods is explained in the following section, starting with explaining qualitative and quantitative methods, the method of shadowing, interviews and finally explaining the Customer journey map.

3.2.1 *Qualitative and quantitative methods*

The results that different methods generate can be classified as qualitative or quantitative data (Osvalder, et al., 2008). Quantitative data is usually presented in actual numbers that have been generated by objective methods where the data is gathered by direct measurements. It aims to generate generalised results or to test a hypothesis (Osvalder, et al., 2008; Murray, 2003). Qualitative data aims to generate an understanding for a specific case instead of a generalised result. Qualitative methods can handle a lot of different variables and are often used when only a few cases are investigated (Osvalder, et al., 2008).

3.2.2 *Shadowing*

Shadowing involves a researcher following a subject over an extended period of time (Mcdonald, 2005). The method is utilised to find out first-hand what the events of the subject's life are. It is particularly suited for situations when an individual is not in focus for analysis, rather the interactions with the environment. (Quinlan, 2008) Through shadowing situations where people say one thing but act differently can be identified (Schneider & Stickdorn, 2013). When shadowing, the researcher asks questions for clarification or revealing of purpose. Notes are continuously taken by the researcher for remembrance. Using shadowing as a data collection method gives more detailed data compared to many other approaches. However, there are also problems with using shadowing as a research method. The observer effect, where the subject acts differently due to being observed is continuously present throughout the shadowing. Moreover, the large amount of data collected can present a challenge when compiling information. (Mcdonald, 2005) During shadowing, the subjects can be asked to *think aloud*, a method which is often used to understand the cognitive process not visible to observers (Fonteyn, et al., 1993).

3.2.3 *Interviews*

Interviewing is the most fundamental method to gain qualitative information and find emotional aspects. There are three types of interviews; unstructured, semi-structured and structured interviews. A structured interview primarily generates quantitative data while the result from an unstructured interview is only qualitative data and can be difficult to analyse and compare. In a semi-structured interview, the questions asked is a mix of predetermined and open ended questions to gain deep understanding of the topic, but also to give a foundation to make a systematic analysis of the data. (Osvalder, et al., 2008)

3.2.1 *Customer journey map*

A Customer journey map is a tool used to visualise the user experience of a service or product and involves all the events and activities related from a customer perspective (Schneider & Stickdorn, 2013; Zomerdijk & Voss, 2010). The first step when constructing a Customer journey map is to identify the touchpoints, where the user interacts with the service or product. This could be done by the use of different methods for example interviews or letting the users construct their own map. Examples of touchpoints could be virtual interaction on a website, face to face contact or a trip to a specific place. The next step is to connect the touchpoints into a structured visualisation of the journey. It should incorporate as much information to provide real insights to the journey but still be easy to understand for everyone. (Schneider & Stickdorn, 2013) The map is used to understand what the users feel and how they are behaving across the journey (Zomerdijk & Voss, 2010). A way to make it more personalised is to incorporate personas and user quotes. The map provides an overview of the service and enables identification of problem areas and areas for improvement. (Schneider & Stickdorn, 2013)

3.3 Concept development

There are a great number of concept development methods available both for individuals and groups. Theory of the methods used for this master thesis project is presented in the following section.

3.3.1 *Brainwriting*

Brainwriting is an ideation method where writing and sketching in silence is used. The ideal number of participants for Brainwriting is claimed to be six persons. When the group is ready everyone is provided with a paper divided into three columns. The paper will have as many rows as ideation rounds that will be performed. During the first round of ideation, everyone communicates three different ideas in the three columns. The ideas can be written, sketched or both, as long as they are understandable. (Silverstein, et al., 2009) This round lasts for five minutes and no talking is allowed during that time. When the first round is done, the second round is started by the papers being sent to the person on the right. The ideas already written on the paper are read through and then built upon in the next row of the paper. The rounds will continue until everyone has written on each paper. (Ullman, 2010)

3.3.2 *Systematic inventive thinking*

Systematic inventive thinking is an ideation method taking the elements of the product into consideration rather than the user. Goldenberg et al. (2003) promotes this method to create ingenious and viable ideas. Starting with an existing product, the method lists physical components and attributes of the product. Then one or more out of five different patterns are applied to the listed elements. The first pattern is subtraction where elements of the product, especially desirable ones, are removed and new products and ideas are then generated from that. The next pattern is multiplication where elements are multiplied and the multiplication given a slightly different function. Division is the following pattern and here the product is divided into its component parts which make it possible to see the product in a new light. The next pattern is task unification where new tasks are assigned to existing elements of the product. The last pattern is attribute dependency change and concerns the dependent relationships that already exist between attributes of a product and attributes of its environment. As many or few of the pattern as preferable are chosen to apply on the existing product. Systematic inventive thinking can then generate new and innovative ideas and products when used right. (Goldenberg, et al., 2003)

3.4 Testing and validation

There are different ways to test and validate concepts and ideas in a product development project. Two of them are explained below; storyboards and prototypes.

3.4.1 *Storyboards*

Storyboards can be used to present different stories and scenarios concerning a product or service and utilisation of the same. A storyboard consists of sketches and drawings put in a sequence to explain a specific event or occurrence. The story presented can involve an existing product or a concept of a new product depending on the purpose. Storyboards are made to give insight on the user experience and can provoke meaningful analysis and discussions around the product. For the designer creating the storyboard only the process of creating it gives insight on the user perspective because of the need of understanding the user in order to create a sufficient storyboard. (Schneider & Stickdorn, 2013)

3.4.2 *Prototypes*

Prototypes are used to transform ideas into physical things. A prototype can be anything with a physical form, for example; a wall of Post-It notes, a cardboard model or an interface (Hasso Plattner Institute of Design, 2010). In service design, prototypes are a simulation of a service which can involve everything from roleplay to detailed full-scale recreations with props and physical touchpoints (Schneider & Stickdorn, 2013). Ulrich and Eppinger (2012) states that a prototype is an approximation of the product, referring to one or more interesting dimensions. Anything that shows any aspect of the product of interest can be viewed as a prototype, including sketches, simulations and mathematical models.

Prototypes can be classified in two different dimensions. The first dimension goes from analytical to physical. In an analytical prototype aspects of the product are analysed instead of built. This is made usually by the use of nontangible artefacts such mathematical models, pictures and simulations. Physical prototypes are tangible artefacts where interesting aspects of the product are actually built for testing and experimentation. This includes prototypes that look and feels like the final product as well as rough models used for testing a quick idea. The second dimension goes from focused to comprehensive. A focused prototype is a prototype focused on a specific part or attribute of the product, an example is a foam model exploring the shape and size of the product. In a comprehensive prototype most, or all, of the attributes of the product are included. A comprehensive prototype can be given to users for final testing and to identify design flaws before starting producing the product in full scale. (Ulrich & Eppinger, 2012)

The level of the prototypes should correspond to the state of the project. At the beginning of the project rough and rapid models should be made to investigate a lot of different solutions and options and in the final stage comprehensive models should be made for testing and evaluation (Hasso Plattner Institute of Design, 2010; Ulrich & Eppinger, 2012). Prototypes can be used for many different purposes. They can be used as learning tools to discover if an idea will work or how well it meets customer needs. Prototypes facilitate communication between different actors and stakeholders in a product development project. It is much easier to understand how a product is supposed to work and look like when there is a model or picture available instead of just words. (Ulrich & Eppinger, 2012) A fundamental way of using prototypes is to test them on the intended user to receive feedback on the product and to gain deeper understanding of the user. This can be done iteratively beginning with simple artefacts as prototypes (Hasso Plattner Institute of Design, 2010).

4. IMPLEMENTATION

A large part of the thesis work has been focused on implementation, which is explained in this chapter. The chapter is organised in chronological order where all phases of the project are explained. How different methods were used in the project, along with their respective result, is presented. The only result not presented in this chapter is the very final one, which can be found in chapter 5 Results. Connections to the frame of reference have been made continuously during the implementation and can in this chapter be found.

4.1 Literature study

When initial planning was done, a literature study was initiated. The literature study was performed to find relevant information regarding subjects processed in the project, as well as to support analyses of data obtained in later stages of the project. Scientific databases such as ScienceDirect and Scopus were used in order to find journal articles regarding technical and scientific aspects. Due to the healthcare orientation of the project, medical databases such as SveMed+ and PubMed were also used for extracting information. As a complement to the journal articles, relevant written sources attained from the KTH library were also included in the literature study. The literature study was iterated and more specified along the project because of new information being needed for theoretical support.

Key words: *Internet of things, Health information technology, Smart watch, Smart wearable tool, Alarm fatigue, User involvement, Qualitative methods, Product development process, Usability, Nurse, Mobility, Healthcare, Wireless, Cognitive ergonomics.*

4.2 Planning

In the initial stage of the project, a plan for the timeframe as well as processes and methods that were going to be used was done. Information in planning documents was continuously updated throughout the project and more detailed plans continuously made. The planning phase was important to go through as the first step of the project due to the importance of getting an overview and understanding of the project. It was also important to, as Ullman (2010) states; ensure efficient use of resources.

4.2.1 *Process plan*

The development process chosen for this master thesis project is a spiral development process, adapted from the Ulrich and Eppinger spiral product development process (Ulrich & Eppinger, 2012). The development in this project was meant to be performed in close contact with users because of the advantages explained by von Hippel (2005), Bogars (2010) and Scandurra (2013). The users were to be involved in testing and validation and the received feedback then be used as a foundation for further development. The plan for this project was to perform three iterations of development and testing. A literature study was added to the process and was performed in parallel with other project phases. The reason for the literature study being parallel to other phases was the need for continuously finding research and theory relevant for the project. The full development process is shown in Figure 3.

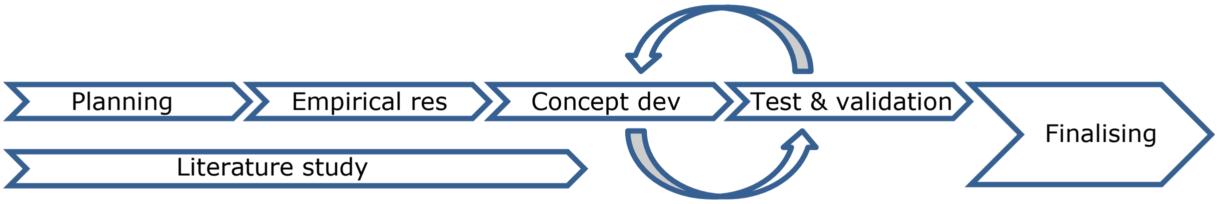

Figure 3. Spiral development process used for the master thesis project.

4.2.2 *Time plan*

After deciding which phases to include in the project a time plan for the length of the different phases was set. The time plan included the different phases and also took into consideration the possible need of overlap of the phases. It was divided into weeks and constructed in Excel, as a Gantt chart. For the time plan, see 0. A detailed time plan divided into days was also done in the planning stage of the project. The detailed time plan was then updated as the project proceeded and more insights obtained.

4.2.3 *Risk analysis*

In order to identify and minimise risks in the project, risk analysis was performed. Risks were listed and graded on likelihood of occurrence as well as consequence if occurring. The value for likelihood and consequence was decided to vary between one, three and nine. One means low likelihood or consequence and nine means high likelihood or consequence. The risk value was then calculated by multiplication of likelihood and consequence. The last step of the risk analysis was to create an action plan in order to prevent the different risks. The two highest rated risks are shown in Table 1. For the entire risk analysis, see Appendix 2.

Table 1. The two highest rated risks in the risk analysis.

Risk	Probability	Consequence	Risk value	Action
Dissatisfaction from KTH	3	9	27	Keep continuous contact and update KTH on development of the project.
Communication problems	9	3	27	Make sure to continuously communicate with all relevant stakeholders.

4.2.4 *Specification of requirements*

In order to narrow the project scope down and to gain understanding of specific goals to work towards a specification of requirements was set by the authors. The requirements were divided into project goal which is a business requirement according to Alexander and Beus-Dukic (2009); functional criteria, limiting criteria and other criteria that are classed as product requirements (Alexander & Beus-Dukic, 2009). The most important requirements are presented in the bullet list below, for the full specification of requirements, see Appendix 3.

- The product shall have the ability to measure time.
- The product shall be able to communicate with other smart devices.
- The product shall be easy to understand.
- The product shall be attachable to the nurse´s uniform.
- The product shall be waterproof.

4.2.5 *Stakeholder analysis*

The stakeholders were identified in a brainstorming session focusing on the three categories of stakeholders identified by Maylor (2010). Internal stakeholders were identified to be Tieto, the Royal Institute of Technology and the authors. External stakeholders were identified to be nurses, hospitals and Stockholms läns landsting. In Table 2 these stakeholders are listed together with the most important "rest of the world" stakeholders; manufacturers, patients and competitors. After listing the stakeholders, they were evaluated on a scale between zero and five according to how much power and interest they had in the project. Zero indicates low power or interest and five indicates high.

Table 2. List of stakeholders rated depending on their power and interest.

Category	Stakeholder	Power	Interest
Internal	Tieto	5	5
	Royal Institute of Technology	3	2
External	Nurses	5	5
	Stockholms läns landsting	3	4
	Hospitals	3	4
Rest of the world	Patients	1	3
	Manufactures	3	1
	Competitors	2	3

The most important stakeholders in this project are the nurses, for whom the project aims to help facilitate their daily work, and Tieto that is paying all expenses and expects a relevant result in return. Stockholms läns landsting and hospitals both have much power and interest in the project since they decide what care units can invest in and are highly interested in increasing quality and saving money. Patients have low power since this product is not supposed to be used by them but they have bigger interest since the project aims to help nurses, which can lead to a better hospital environment with medical staff that have more time for nursing. Manufactures have a relative high power since manufacturing methods and cost can limit the product but their interest is very low. Last are the competitors that have relatively big interest and some power since products existing on the market will affect the result.

Competitor identification and analysis

As mention above existing products and competitors will have an effect on what kind of solution this project will result in. Therefore, a competitor identification and analysis was made to investigate which smart wearable devices exist on the market. According to Bergen and Peteraf (2002), the competitor analysis should be done early in the project and the search broad. Therefore the initial analysis was done in this stage of the project and several different smart devices were analysed and compared.

Four different smart watches were investigated and some of them tested; Pebble, Sony SmartWatch, Samsung Galaxy Gear and Motorola Moto 360. Sony SmartWatch and Samsung Galaxy Gear were chosen because they were available to test in a local store. Pebble was picked because the industrial supervisor of the project talked about it and Motorola Moto 360, which will be launched in the summer of 2014, was read about because it will be the first smart watch with a round display. All watches are designed to be worn around the wrist, have similar features and connect to a smartphone via Bluetooth. They all, except for Pebble, have a colour touch screen. To customize the watches applications can be downloaded and installed and all, except for Samsung Galaxy Gear, enables exchange of the wristband. Picture of the four watches can be seen in Figure 4. (Pebble, 2014; Sony, 2014; Samsung, 2014; Motorola, 2014)

Figure 4. The four smart watches investigated, listed from the left; Pebble, Samsung Galaxy Gear, Sony SmartWatch, Motorola Moto 360. (Pebble, 2014; Sony, 2014; Samsung, 2014; Motorola, 2014)

Different smart wearable exercise devices were also interesting to investigate since several new products recently reached the market. Nike+ Fuelband, Fitbit Flex and Jawbone UP24 are three different products with similar features, see Figure 5. All products are worn around the wrist and contain accelerometers used to track the movement of the user. The information is then sent to a smartphone via Bluetooth where an application compiles the information into comprehensible graphs. They exercise devices are designed like an upgraded pedometer and meant to be worn constantly. Fitbit Flex and Jawbone UP24 are designed to be worn during sleep and incorporate a silent vibrating alarm clock. (Nike, 2014; Fitbit, 2014; Jawbone, 2014)

Figure 5. Listed from the left; Nike+ Fuelband, Fitbit Flex, Jawbone UP24. (Nike, 2014; Fitbit, 2014; Jawbone, 2014)

Later in the project, when the scope was narrowed down, different existing alarm systems were investigated, focusing on mobile wearable alarms. Ascom is a company that delivers different kinds of alarm systems for healthcare and they have one solution that was seen in a neighbouring care unit during the observations at Södersjukhuset. At the unit, the alarm was used in a similar way as the existing alarms at other care units visited. The main difference was that the nurses could receive alarms on a mobile device carried in the pocket of the uniform. (Ascom, 2014) *TryggSenior* is another mobile alarm meant to be used by elderly people. The design of the alarm is simple and it only has one single red button to press in an emergency. When the red button is pressed a speaker call automatically connects to the operator who organise what kind of help action is needed. (Familjelarm 1, 2014) *Vega GPS larm* is an alarm made especially for demented people. It is designed to be worn around the wrist and has a small screen displaying the time, like a digital watch. By the use of GPS, the alarm enables the family to keep track of the user and send a message if the home is left. (Familjelarm 2, 2014) Figure 6 shows all three mobile alarms.

Figure 6. Three different mobile alarms, listed from the left; Ascom alarm, TryggSenior, Vega GPS larm. (Ascom, 2014; Familjelarm 1, 2014; Familjelarm 2, 2014)

4.3 Empirical research

This section explains how empirical data was collected and compiled by the use of earlier described methods.

4.3.1 *Shadowing*

Shadowing was used as a data collection method in an early stage of the project. Six days were used for shadowing six different nurses during their work. The shadowing was conducted at four different hospitals; Danderyds sjukhus, Södersjukhuset, Karolinska sjukhuset and Gävle sjukhus. When choosing where to perform shadowing several hospitals in the Stockholm area were contacted. The Stockholm area was chosen due to the location, close to where the master thesis is performed. More than one hospital was chosen to observe in order to get an overview and better understanding of the general situation. One hospital outside Stockholm was also visited; Gävle sjukhus. This was done in order to understand whether hospitals in Stockholm also represented hospitals in other parts of the country. During the shadowing sessions at Södersjukhuset civilian clothes were used when shadowing but the three other hospitals provided nurse uniforms. As Fonteyn (1993) suggest, the nurses that were shadowed were asked to think aloud as much as possible and explain why and what they were doing, to gain deeper understand of the cognitive process not visible to observers. Questions were asked when needed and notes were continuously taken on notepads.

Compilation of shadowing results

From the information collected during the six days of shadowing, five problem areas were identified; Division of medicines, Information flow, Testing, Location of persons and Medical records system. Division of medicines includes the action of finding, dividing and giving medicines. Information flow involves information communicated both orally and written. The Testing area regards preparing for and performing different kinds of tests such as blood tests, measuring pulse and blood pressure. Location of persons deals with finding persons; mainly staff that need to give or receive information. Medical records system concerns the different systems used by different hospitals and departments. The problem areas all consisted of several sub-problems that were either expressed by nurses or observed while shadowing. For problem areas with all sub-problems, see Table 3.

Table 3. Problem areas with sub-problems

Division of medicines	Information flow	Testing	Location of persons	Medical records system
Locking and unlocking medicine trolley, medicine room and computer is time consuming	Every nurse has their own way of remembering which means they cannot share notes	No automatic measurement of respiratory frequency which makes for faulty measurements	It is difficult and time consuming to find persons you are looking for	Surgery departments have a different system that does not synchronise with the regular system
Medicine division is time consuming	The patient list is frequently used for important notes which create double documentation	Only the ECG-machine can automatically send results to the medical records	The presence button needs to be pressed every time a nurse walks in to a room	Anaesthesia use manual paper medical records which seems old
The charger for the computer needs to be taken out and put in when the medicine trolley is moved	The patient list includes name and social security number and cannot be found by unauthorised persons	Taking blood samples to the lab is time consuming	If the presence button is pressed and a patient presses the alarm, an emergency alarm goes off	The to-do list is divided per patient, not per nurse which makes it more difficult for nurses to understand
Medicines classed as narcotics needs to be counted and documented in a binder	There is a lot of unnecessary running around to get forgotten things	Some patients need to measure amount of fluid they drink, this is written manually on a paper that can easily be lost	Most nurses do not press the presence button due to the risk of false alarms	Not possible to see more than one type of information at once
There is no warning when the wrong amount of medicine is taken out	A lot of oral communication which can cause information to disappear	Some patients need to measure amount of urine, this is written manually on a paper that can easily be lost	The alarm signals constantly and is perceived as disturbing	
The same medicine can have different names which makes for confusion	Manual change of occupied and available signs outside some rooms means risk for mistakes.			
At Karolinska only one medicine automat is used which can create waiting time	Information about patients´ diets is gathered manually on paper and can easily be lost			
The medicine automat only synchronises name and social security number with the medical records system so the documentation is still double	A lot of information is written several times, both on patient list and in medical records system			
Drip rate is calculated manually which makes for mistakes and consumes time				
Two nurses sometimes share a medicine trolley which can create waiting time				

4.3.2 *From problem areas to problems*

When deciding which problems to continue further with, the combination of two different methods was used. First, a Customer journey map was constructed from information obtained at the shadowing sessions. Second, a part time presentation was performed for relevant stakeholders working at Tieto. The problem area of Medical records system was discarded before creating the Customer journey map due to the fact that medical records systems are such complex and large systems that can not realistically be sufficiently covered during a master thesis project.

Customer journey map

In order to identify touchpoints results from the shadowing sessions were analysed and clustered into relevant areas. The touchpoints were then organised in chronological order and marked with red if they included any disturbance perceived by nurses. The touchpoints that were marked red are presented in the bullet list below:

- Read up on patients
- Leave patient at surgery
- Patient alarm
- Find assistant nurse
- Emergency alarm
- Edit medical records system

A short description of all the relevant touchpoints was also provided on the map. By constructing the Customer journey map the problems occurring during a nurse workday were elucidated and the map provided a useful overview of the workday (Schneider & Stickdorn, 2013). For the full Customer journey map, see Appendix 4.

Part time presentation

The part time presentation was performed in order to obtain the perspective of Tieto employees before proceeding with the project. Persons working at the department of Healthcare and Welfare were invited to the presentation, as well as user experience designers. In total, eight persons employed at Tieto participated of which four on telephone. After all participants introduced themselves, each problem area from Table 3 was presented and followed by shorter discussions. At the end of the presentation, a longer and more in detail discussion was held where opinions regarding the most interesting and profitable continuation would be for Tieto. All problem areas were confirmed as relevant by Tieto, but the ones found most interesting from Tieto´s perspective were Information flow and Location of persons.

Problem decision and description

From the presentation and Customer journey map the five problem areas were narrowed into three problems chosen to work further with. These problems were marked as disturbance touchpoints in the Customer journey map and were also considered aligning with Tieto´s strategy. The problems chosen originated from the problem areas; Information flow and Location of persons, and were re-formulated as Patient list, Alarm and Finding persons.

The patient list is used by all observed nurses and includes a list of all patients that is used for remembrance and taking notes. The list is printed when a working period starts and then folded to fit in a pocket where it stays the whole working period. The list is continuously used for taking notes and reading previous notes simply because there is too much information to keep in the head. Notifications written on the patient list are often written again in the medical records system, which means there is double documentation. Some lists have name and social security number printed, which becomes a serious issue when the list is lost.

The alarm includes both the alarm that patients use and the emergency alarm used by staff at the hospitals. Currently most departments use the same kind of alarm system where all patients have an alarm button next to their bed, there is a presence button and an alarm button in all rooms and several displays placed in the ceiling of the corridor where the patient or room that is alarming is displayed. When a nurse enters a room she is supposed to press the presence button which is then shown on the display. If there is an emergency situation while the nurse is in the room, the nurse can press either the patient´s alarm button, or an alarm button on the wall. The emergency alarm will then sound this because of the presence button being activated. One issue with these systems is that the display is not always visible from current position; the staff always have to go out to the corridor to see where the alarm comes from. Another issue is the alarm sound that signals continuously until the alarm is answered which makes the environment noisy. The third and possibly largest issue is the fact that there are so many false emergency alarms. This is due to the current systems where, if the presence button is activated and a patient presses the alarm button, the emergency alarm goes off. The nurses often forget to deactivate the presence button when leaving a room which creates an emergency alarm when the intention from the patient was to alarm regularly.

Finding persons is a problem mainly at the departments without telephones. Because there are many rooms and a lot of closed doors at the hospital departments, finding another staff member can be time consuming. There are many situations where information is needed or needs to be given to other persons which mean the staff needs to look for each other a lot.

4.3.3 *Interviews*

When three problems; Patient list, Alarm and Finding persons had been chosen, more in depth information was to be gathered about the problems. The interview guide can be found in Appendix 5. Interviews were chosen as the method to obtain this information. The interviews were chosen to be semi-structured because of their purpose; to investigate if the problem areas were relevant and to gain deeper understanding on how they affect nurses. That is also why a structured interview, that primarily generates quantitative data, is not chosen. Since the result from an unstructured interview can be difficult to analyse and compose (Osvalder, et al., 2008), a semi-structured interview method was instead chosen.

Eleven interviews were conducted between two and four weeks after the shadowing was performed in order to verify if the findings of problem areas were relevant. They were conducted at the same locations as the shadowing, apart from Gävle sjukhus that was discarded due to distance. Three of the previously shadowed nurses were interviewed along with eight nurses that had not earlier been involved in the study. The interviews consumed approximately 20 minutes of time each. The interview guide was divided into three problem areas; the alarm, patient list and finding persons. In each area questions were formulated but the respondents were also encouraged to discuss relevant information not connected to a specific question. As Osvalder et al. (2008) suggests the questions were a mix of open ended and predetermined questions to gain deeper understanding of the topic, but also to give a foundation to make a systematic analysis of the data. Follow-up questions were asked when needed and the whole interview was recorded and transcribed.

During the interviews, most findings from the shadowing were validated. Some new aspects and issues also arose, but four key findings were predominant throughout the interviews and are presented in the bullet list below.

- There are considerably more false emergency alarms than real ones.
- Very few nurses use the presence button each time they enter a room.
- A lot of time is spent on finding persons on the department.
- Every nurse uses the patient list for taking notes and remembering.

4.3.4 *Summary of empirical research*

The empirical research included gathering data and understanding the user by initially shadowing nurses during their workdays. After shadowing six nurses at different hospitals, the information gathered was compiled, analysed and constructed into a Customer journey map covering a general nurse workday. Five different problem areas containing several sub-problems were identified; Information flow, Testing, Location of persons, Medical records systems and Division of medicines. The compiled information was presented to relevant stakeholders at Tieto. Their opinions together with the insights from the Customer journey map constituted the base for narrowing the five problem areas into three problems; The alarm, Patient list and Finding persons. They were then further examined in interviews with nurses. Figure 7 explains from which problem areas the three problems originates from.

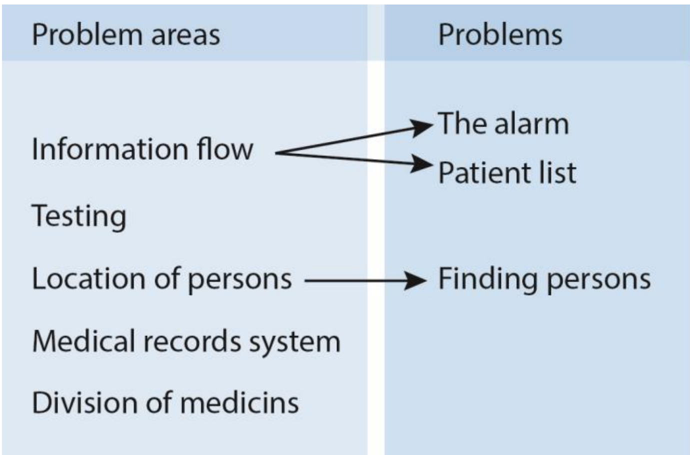

Figure 7. Shows where the three problems selected for further examination originates from.

4.4 Iteration one

The aim of the first iteration was to define which problems the product should solve and which functions it should contain. A suggestion from the industrial supervisor at Tieto was to investigate utilisation of the nurse watch, see Figure 8, and whether it could be developed further by adding more functionality. The nurse watch is the only watch allowed for medical staff due to hygienic reasons (Alexandersson, 2007). It was worn by several nurses seen during hospital visits and it is fastened in the nurse uniform, often close to the breast pocket. It is used for time control when measuring pulse, respiratory frequency et cetera. The nurse watch was taken into consideration when ideating and several concepts came to originate from it.

Figure 8. A classic nurse watch from Tissot. (Uhrzeit, 2014)

4.4.1 *Brainwriting*

Brainwriting was used as the initial ideation method during the master thesis project and regarded the three problems mentioned earlier; Finding persons, Patient list and The alarm. Three different Brainwriting sessions were performed; one for each problem. Only the two authors participated and, therefore, had to write on the same paper several times. This because only two rounds of ideation was not considered enough. As Silverstein (2009) suggests a mix of writing and sketching was chosen for use when communicating the ideas. Also, one paper was used for each idea in order to get more space to draw and write. The session resulted in six rough concepts for each problem that could be clustered into groups with similar functions and solutions. Parts of the result can be seen in

Table 4.

4.4.2 *Systematic inventive thinking*

As a complement to Brainwriting, Systematic inventive thinking was used. Since this method has more of a product focus the session started with exploring the existing solutions that address the problem currently. The identified existing solutions to each problem were: Patient list – the existing patient list combined with a pen, Location of persons – portable phone combined with seeking for persons, The alarm – the existing alarm system. Each of the existing solutions was divided into components and functions and then two innovation patterns, subtraction and multiplication, were used for each of the three problems. Some new ideas were generated and are presented along with the Brainwriting result in

Table 4. However, SIT was discovered not to be a suitable ideation method for this particular project. Why this is, is discussed in 6.1 Discussion of methodology.

4.4.3 *Three problems into two*

The two ideation sessions resulted in several concepts that could be clustered into groups with similar functions and solutions.

Table 4 below shows the compiled result from both the sessions.

Table 4 the compiled result from the ideation sessions.

Problem	Concept
The alarm	Similar nurse watch as the one existing today but with a button for emergency alarm.
	An app to a smartphone that replace the existing alarm system.
	Small sensors that can be worn and can tell when someone is in a room to eliminate the need of the presence button.
	An alarm for patient to use that is not attached to the bed and can be carried around.
Finding persons	A screen that shows where all the staff at the department is located placed in the office.
	A watch similar to the existing nurse watch that can show where other nurses are located.
	A smartphone application that uses the GPS function to tell where the medical staffs are located.
	Place sensors all over the department to be able to tell who is where and display it on a smartphone.
Patient list	A smart pen that can save the information that is written with it.
	A large screen that is placed in the patient room where the nurses can read and write information about the patient.
	A tablet that all nurses can use to make notes and read information about the patients.

In the section 4.3.2 From problem areas to problems, it was described that the problem area Medical records system was decided to not continue with since it is a very large and complex area not realistic to cover during a master thesis project. Many of the concepts related to the problem Patient list need information from the medical records system and would work better if it would be possible to add information to the system through other devices than a computer. One issue discovered during empirical research was the double documentation. The Patient list solution should eliminate this phenomenon to the extent possible, which cannot be done in a good way without involving the medical records system. Due to the previous choice of not continuing with the problem area Medical records system, the Patient list problem was then chosen not to be developed further.

The other two problems, The alarm and Finding persons, are more similar. In both problems the location of the nurses, patients or nurse watches need to be known, which is why both The alarm and Finding persons were decided to develop further and a solution where both problems are solved created.

Product delimitation

During the ideation sessions many concepts regarding The alarm and Finding persons, found in

Table 4, used either a smartphone application or an upgraded nurse watch. However, several problems with using a smartphone application were identified; it cannot be worn in the same way as a nurse watch and, therefore, the screen will not be visible at all times; a smartphone does not have a specific emergency alarm button; all smartphones are not suited to be used in a clinical environment. The smart watches, previously investigated in section 4.2.5 Stakeholder analysis, were rejected because all of them required connection to a smartphone in order to function. Therefore, it was decided to further develop a customised product specific for the purpose of the project. The Ascom alarm system previously investigated provided inspiration for the development. Since nurses already are carrying many items the nurse watch was decided to presuppose for the new product, to not increase the number of things being carried.

4.4.4 *Brainstorming to find functions*

A Brainstorming session was performed to identify functions that could be integrated into the product solving the problem of The alarm and Finding persons. All ideas were written down on Post-it notes and attached to the wall to provide a fast and accessible overview of the situation. Subsequently, the ideas were clustered into groups and some further ideas were added. The information was then compiled into a mind map that was then structured into Figure 9.

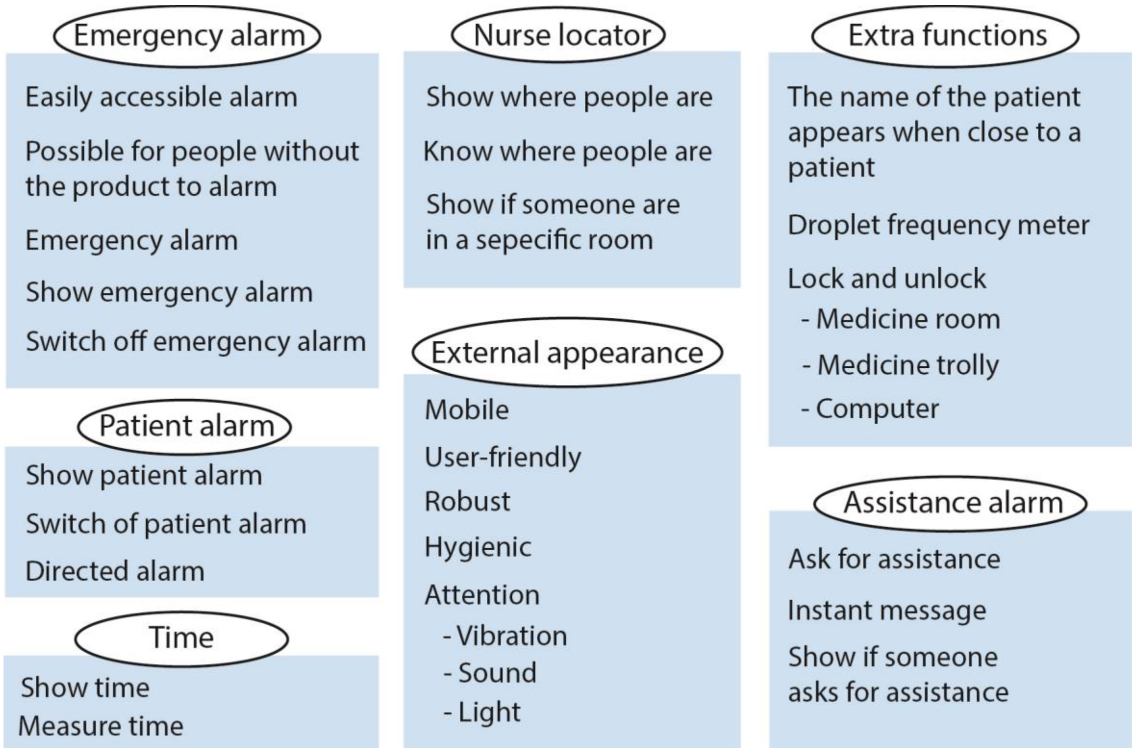

Figure 9. Mind map with ideas of functions clustered into groups that could be integrated in the product.

By analysing the mind map and the different categories that arose during the clustering of ideas the Patient alarm, Assistance alarm, Emergency alarm, Nurse Locator and Time category were chosen to proceed for further development. One function, Lock and unlock, that was added during the brainstorming session originated from the problem area Division of medicine was also chosen for further investigation since it seemed to fit the intended product and could save a lot of time in a simple way. The category External appearance was not considered in this stage since it was decided to focus on the functions and not the external and visual design.

4.4.5 *Concepts of functions*

Storyboards were chosen as the method for explaining and understanding how the functions should work. Six storyboards were constructed showing the different functions: Patient alarm, Emergency alarm, Assistance alarm, Nurse locator, Show time and Lock and unlock. Several sketches of different scenarios when the functions would be used were done before the final stories were decided. The sketches were first done with paper and pencils and then scanned into the computer and coloured in Adobe Photoshop CS6. With the use of Adobe InDesign CS6 the sketches were put together into storyboards and text was added. The final storyboards can be seen in Appendix 6.

All the storyboards used the same personas, a nurse named Petra and an assistant nurse named Anna; they can be seen in Figure 10. They are working in the same team, meaning that they have responsibility of the same patients, at a care unit with hospitalised patients in Sweden.

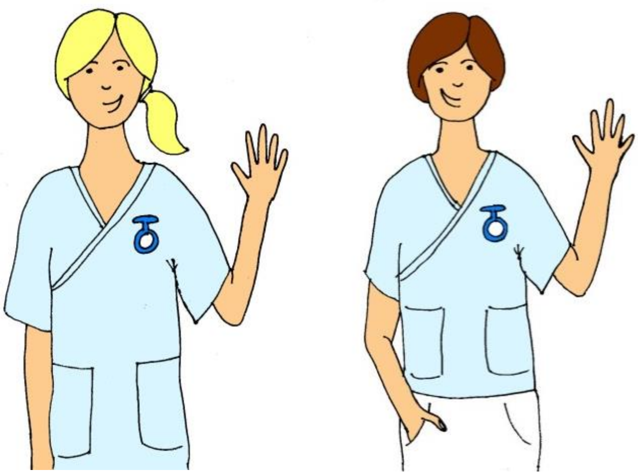

Figure 10. The personas used in the storyboards, nurse Petra to the left and assistant nurse Anna to the right.

4.4.6 *Storyboard review*

To receive feedback on the functions, the storyboards were brought out to hospitals and showed to nurses. Three hospitals that had been visited earlier in the project were visited again: Danderys sjukhus, Karolinska sjukhuset and Södersjukhuset. During the visit, the storyboards were shown to a total of 15 nurses and they were asked to give feedback on each function. At the beginning of the feedback session, the nurses were handed a booklet with an introduction where the personas Petra and Anna were introduced. Then one function at a time was read together and questions asked concerning what they thought of the intended function. They were asked to identify problems with the function and if they thought this was something that could facilitate their daily work. The Show time function was considered to be a sub-function since the time will be visible constantly and, therefore, no questions regarding that function was asked. The sessions were recorded and transcribed and then the results were compiled into Table 5.

Table 5. Feedback from nurses on the storyboards with the intended functions for the product.

Function	Advantages	Development opportunity
Patient alarm	The display is always accessible, no need to go out in the corridor to look at the display there.	Make it possible to forward the alarm if the responsible nurse or assistant nurse is busy.
	Less noise since the nurses only get the alarms that are directed to them.	Allow the patients to send different alarms depending on what they want.
		Make it possible to put the watch in a silent mode and to switch of the alarm.
		If nobody answers the alarm it should be sent forward after a certain time.
Emergency alarm	Saves seconds that save lives since the alarm button always is close by.	Ensure that the button not is too easy to press to minimise false alarms.
	One distinct button for emergency alarm.	Ensure that it is easy to turn off the alarm if it is pressed by mistake.
	Decreases false alarms since there is no need for the presence button.	It should be possible to turn off the sound if the nurse is very busy when the alarm goes off.
		Make it possible for people without a watch to trigger the alarm.
Assistance alarm	A difference between the patient alarm and the assistance alarm resulting in less time spent on waiting.	Make sure it is not too many buttons on the product and that it easy to understand.
	Useful when it is not possible to leave the room and help is needed.	Make it possible to forward the alarm if the responsible nurse or assistant nurse is busy.
	Always close by and easy to access.	
	Improves the team spirit since the assistance alarm always first reaches them who work in the same team.	
Nurse locator	Saves time since the time looking for people decreases.	Make it possible to send short messages to other watches.
		It should be a choice for each nurse if she/he wants to use the function or not due to integrity issues.
		Make it possible to turn off during breaks.
		The new Karolinska sjukhuset is going to have more space for fewer patients, this might lead to that the problem of finding people will increase.
Lock and unlock	Good that the things lock when the nurse leaves.	Ensure that it is safe enough.
	Good that the things unlocks when the nurse get close by.	Might be difficult to convince hospital to stop using the e-tjänstekort that is used today for unlocking and locking some things.
		Enable the hospitals to have control and

		data saved on who did what.

At the end of the feedback sessions, the nurses were asked which functions they thought were the most useful and if they had some ideas on more functions that could be added. The most popular functions turned out to be the three alarm functions and on second place came the Nurse locator and last the Lock and unlock function. Suggestions on functions that could be added were:

- A reminder function where the nurse can set an alarm if there is something she or he needs to remember.
- That the watch could be connected to the nurses private cellphone and receive important messages from for example kindergarten.
- That the watch should have voice recognition if the nurse is in a situation where she cannot use her hands.

Questions that arose were:

- How will it work when students are doing their internship at the department?
- Will it be possible to see the display without touching the watch?
- Will it be hygienic enough?
- Do I have to make new settings every day, how does the watch know with which patients I will work?

The decision was made to continue with focus on the three alarm functions because of the information gained at the feedback sessions but also in order to keep it as simple as possible to follow the KISS admonition. KISS stands for "Keep It Simple Stupid" and stresses the importance of making uncomplicated and simple solutions since the more complex something gets the harder it is to control (Moss & Edmonds, 2005). If the Nurse locator function would have been kept the product would have ended up much more complex since the nurses would have to be able to navigate in some kind of menu to select who they were looking for. The technology to know where all the nurse are located will still exist because when the alarm is pressed the product needs to know where it is located to communicate that to other products. This would make an argument for why the function Nurse locator should be kept, but in order to make a product that can be implemented in hospitals as soon as possible it was decided to keep it as simple as possible and focus on the main function, the alarm. To not reduce the functionality of the original nurse watch, which the concept is thought to replace, the sub-function Show time was also kept.

4.4.7 *Summary of iteration one*

The purpose of the first iteration was to decide which problems to focus on, develop concepts and identify which functions the product should contain. The iteration began with a development phase where ideations methods such as Brainwriting and Systematic inventive thinking were used to develop concepts of solutions. Finding persons and The alarm were chosen for further development and a brainstorming session was performed to identify functions that could be integrated into the product. The session resulted in six functions; Emergency alarm, Patient alarm, Assistance alarm, Nurse locator, Lock and unlock, and the sub-function Show time. Then storyboards were made in order to illustrate the selected functions. At the end of the iteration, the storyboards were brought to hospitals to receive feedback from nurses. Lastly, the final functions to be included in the product were narrowed down to; Emergency alarm, Patient alarm, Assistance alarm and Show time. Figure 11 illustrate the process of finding the final functions, problem areas and problems were defined in.

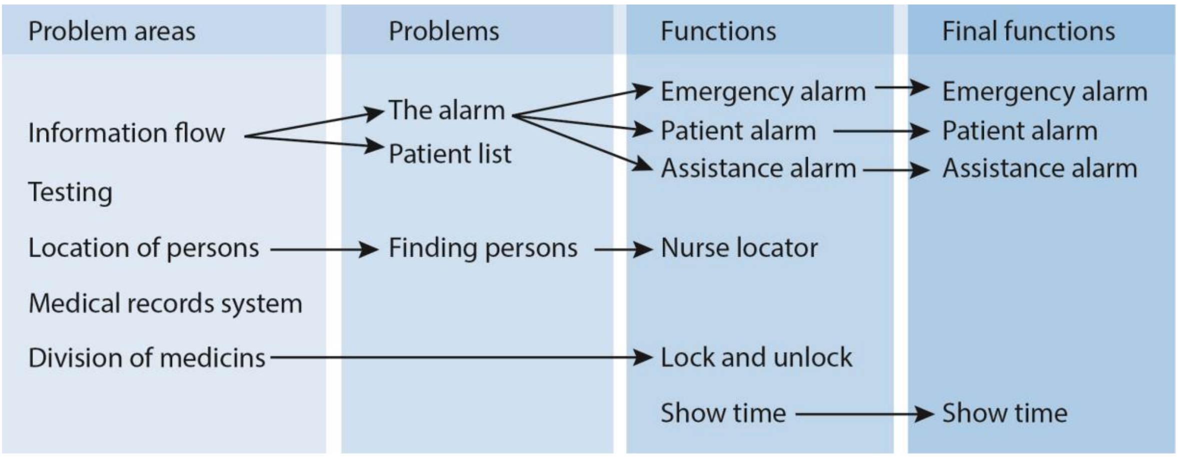

Figure 11. Illustrates from where the final functions originates.

4.5 Iteration two

When functions to be implemented in the product were decided, development of the physical appearance was initiated in iteration two.

4.5.1 *First physical prototypes*

To develop the first physical prototypes, hobby clay was used. It was chosen due to its flexibility and effortlessness. With clay, any shape can be visualised relatively fast. It can be air-dried, is cheap and has a relatively low density. All these qualities were contributing factors to the choice of using hobby clay. Seven different prototypes were created and since the prototypes were designed to work as a foundation for evaluation of which shape was to prefer, all prototypes had different shapes, see Figure 12. When the clay was dry, displays with different messages were printed and glued to the prototypes. The prototypes were also provided with attachment strings and safety pins in order to enable attachment to clothes.

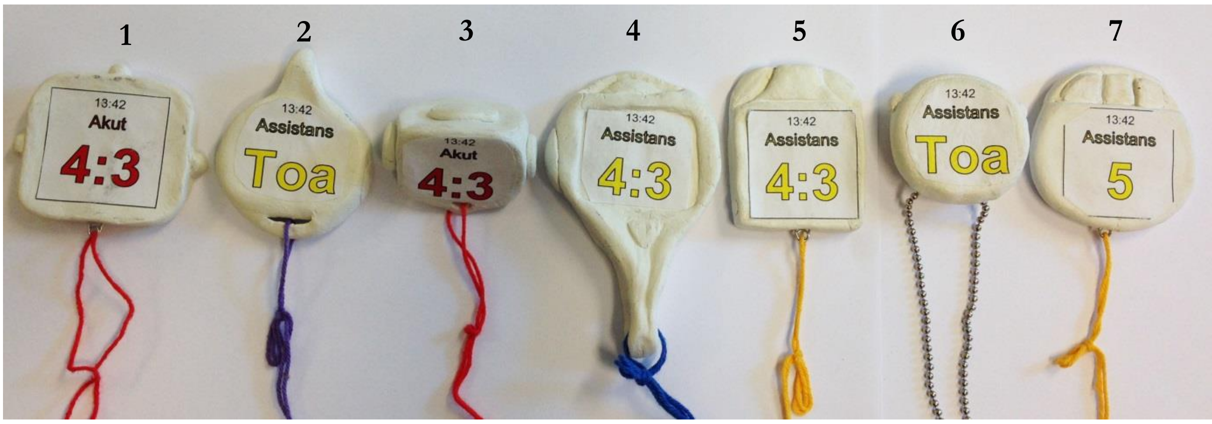

Figure 12. The first seven physical prototypes in numerical order, prototype one starting from the left.

Evaluation of first physical prototypes

The main purpose of the first hobby clay prototypes was to evaluate shape and appearance. All prototypes were tested by fastening them with a safety pin to the clothes, by the breast pocket, where the traditional nurse watch is most commonly worn. Different criteria influencing the perception of the prototypes were listed and the prototypes were rated on the criteria. The criteria were:

- Visibility – In the visibility criteria both size of screen and angle of vision were considered. A large screen was considered positive, whilst a small screen was considered negative. The angle of vision was decided by looking at the prototypes when fastened to the right position. High angle of vision was considered negative for the visibility (Hägg, et al., 2008) and low angle of vision was considered positive for the visibility. Screen size and angle of vision were weighted against each other and the visibility result was decided based on that.
- Weight – A low weight was considered positive while a high weight was considered negative. All prototypes were measured relative to each other and got a plus, minus or zero based on the tests.
- Fit in hand – The fit in hand criteria regards how good the prototype feels to hold in the hand. Several different holding positions were tried and the result concluded from these tests.
- Appealing aesthetic – The appealing aesthetic criteria regarded the appreciation of the physical appearance and design. Previously set value words such as clean and simple were used to evaluate this criterion.
- Buttons – This criteria concerned design and placements of buttons. Both how easy the buttons were to press due to placement, and due to button design was evaluated.
- Ergonomic design – The ergonomic design criteria regarded the entire design and whether it was suitable to have in a hospital environment. Sharp edges were here considered negative while rounded and soft shapes were positive.

When a prototype had a favourable result on the criteria, the prototype was given a plus and a minus was given for the opposite. When the result was neutral, zero was given to the prototype. Result of the evaluation is displayed in Table 6.

Table 6. Evaluation matrix of the seven clay prototypes.

Criteria	Prototype 1	Prototype 2	Prototype 3	Prototype 4	Prototype 5	Prototype 6	Prototype 7
Visibility	+	-	0	+	+	0	+
Weight	+	+	-	-	+	0	+
Fit in hand	-	-	-	+	+	0	+
Appealing aesthetic	+	-	-	-	+	+	+
Buttons	-	+	0	0	0	0	-
Ergonomic	0	-	-	0	+	0	+
Total	**1**	**-2**	**-4**	**0**	**5**	**1**	**4**

The highest scoring prototype was prototype five, followed by prototype seven on second place and prototype one and six on a shared third place. As seen in Figure 13 the highest scoring prototypes all have relatively similar look and feeling, the only difference is the placement of buttons and shape; round or square. Because of this, the next round of prototypes which were shown to nurses was chosen to include one round and one square prototype with several different buttons. The evaluation founded the base for the next prototypes that are explained in the following chapter.

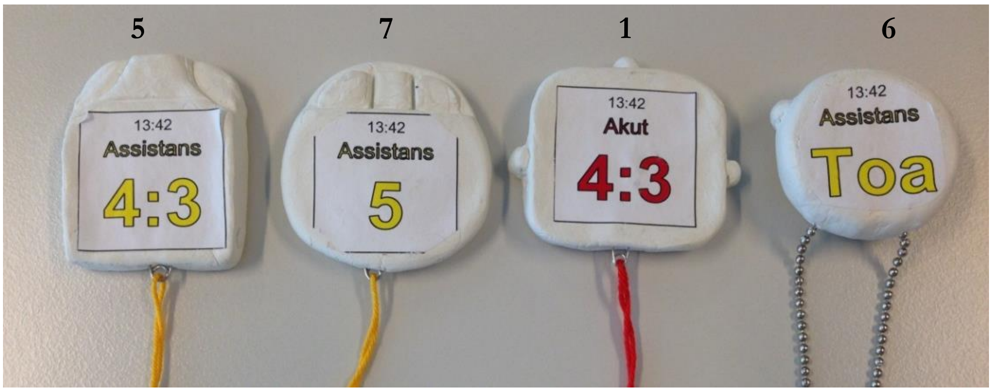

Figure 13. The highest scoring prototypes. From left to right; prototype 5, 7, 1 and 6.

4.5.2 *Second physical prototypes*

Because the round and square shape were graded highest on the evaluation of the first prototypes, one round and one square prototype was created as second physical prototypes, see Figure 14. The prototypes were, as the previous ones, created with hobby clay. The purpose of these prototypes was to gain insights on how to design the product from the perspective of nurses. The two different prototypes were provided with several circles, representing possible buttons. In the final concept, three buttons were decided to be used; one button for emergency alarm, one for assistance alarm and one for muting or forwarding different alarms. So few buttons were used to keep the user interface as simple as possible. The prototypes were also provided with clamps, enabling fast attachment and detachment to the nurse uniforms.

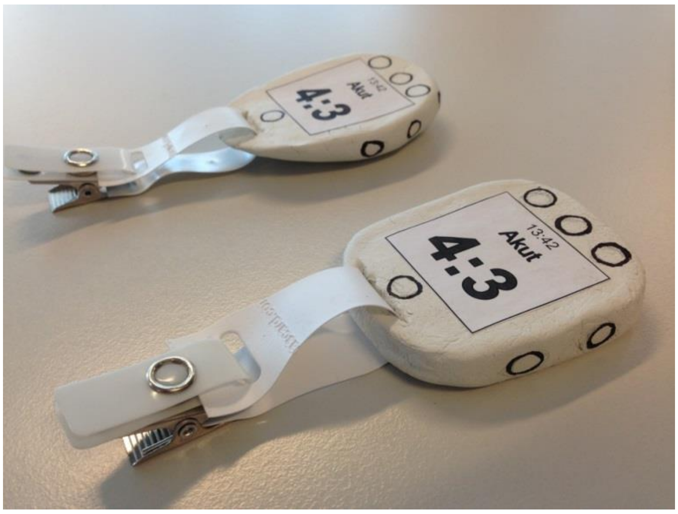

Figure 14. The second round of physical prototypes.

Evaluation of second physical prototypes

Apart from showing the prototypes to nurses in order to evaluate the design, other questions not regarding the prototype but regarding the general layout were also asked. Examples of those questions were colours and symbols. Nurses were chosen to make the evaluation because of their apparent participation in the project as being end users. The questions that needed answers were written in an interview guide along with pictures and symbols needed for some questions.

Hand outs for the nurses with the information, pictures and symbols they needed were created. Three previously visited hospital departments at Karolinska sjukhuset, Danderyds sjukhus and Södersjukhuset were visited. After consulting nurses from the different hospitals, the result was compiled and discussed. The nurses had very varying perception of how to design the watch, but four main findings could be identified and they are presented below. The full result from the evaluation is found in Appendix 7.

- Emergency alarm should be connected to the colour red.
- The mute/send forward button should be connected to an arrow symbol.
- The square shape is preferred.
- An analogue watch is preferred.

4.5.3 *Summary of iteration two*

During iteration two, the first two rounds of physical prototypes were developed. Hobby clay was used to make seven different types of physical prototypes which then were evaluated according to subjective and objective criteria. Based on that result, two new prototypes were then made and showed to nurses to receive feedback on the design. They were also asked more about the general design and where and how they would like to wear the product. After consulting the nurses, the result was compiled. The nurses had varying perception of how to design the product, but some conclusions could be drawn regarding colours, symbols, shape and type of watch.

4.6 Iteration three

The aim of the third iteration is to use the information gained in earlier iterations together with theory and compile into one final concept.

4.6.1 *Decision of physical design*

After consulting nurses regarding design of the product during iteration two, some results were applied to the process of designing the final concept. The fact that most nurses preferred the more squared design and had relevant arguments for the preference was applied to the final concept as well as the argument of keeping buttons far apart not to mix them up. The second round of clay prototypes were by nurses perceived as too large for hanging on the uniform, therefore, the final concept design was made slightly smaller than the prototypes. Two different shapes of the product were modelled in Solid Edge, one with a more square backside and one with more convex backside, see Figure 15. The design chosen after evaluation was the convex one, due to the fact that the emergency alarm button had to be placed more off centre than possible in the square design. The emergency alarm button was placed off-centre to make it easier to reach.

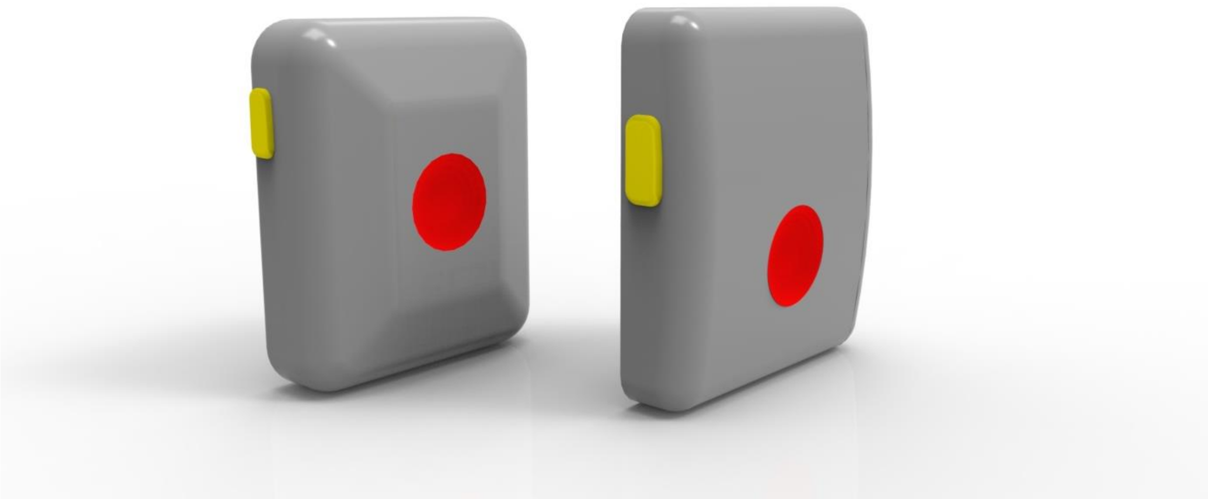

Figure 15. The two different CAD models prototyped in Solid Edge. The emergency alarm button is displayed in red and the assistance alarm button in yellow.

Button design

The nurses evaluating the second round of clay prototypes were asked where to place the three different buttons; emergency alarm, assistance and mute button. However, their answers varied very much and no conclusion on where to put the buttons could be made. The emergency alarm button was finally decided to be placed in the back of the product, having a concave surface to eliminate the risk of accidentally pressing the button and thereby creating a false alarm. Relevant alarms, with no false alarms, are an indicator of a good alarm system according to Thunberg and Osvalder (2008). The concave surface was also chosen to ease finding of the button, which agrees with Woodson (1992). The emergency alarm button got the colour red based on what nurses found suitable, the principle of consistent presentation formulated by Osvalder and Ulfengren (2008) and the general perception of the colour red being associated with danger (Osvalder & Ulfengren, 2008).

The assistance button and mute/forward button was placed one on each side of the watch to reduce the risk of mixing the buttons up. To avoid accidental pressing of the wrong button, the buttons were placed on different levels relative to each other. The assistance button got the colour yellow mainly according to the principle of consistent presentation (Osvalder & Ulfengren, 2008). Some care units already have an assistance function in their alarm system and those assistance buttons are yellow, so making the assistance button yellow aligns with the principle of consistent presentation. The mute button was not designed to have a specific colour, but to be white. This was decided because the nurses answered the question of mute colour so differently. When colours are used wrong they can create uncertainty (Osvalder & Ulfengren, 2008) and because there were no certain answer regarding mute colour, the button was chosen to be white to avoid the uncertainty.

The use of symbols on the buttons was discussed with the nurses and the only apparent symbol was the one for mute/forward, which was an arrow. Because the mute button was white, it was decided to get an arrow as a symbol instead of a specific colour.

4.6.2 *Decision of interface design*

When designing the interface for the alarm, several design principles and guidelines presented in the theory were used. The interface was designed to only display essential information while as extra information, such as current location, was discarded because information presented on a display should be short and concise to be apparent (Osvalder & Ulfengren, 2008). The colour of the interface was chosen to be a mainly white background with black, red or yellow characters. White was chosen as the background colour because of the argument used by Arbetsmiljöverket (2012) that the ideal contrast for reading on a display is to have dark characters on a white background, together with the argument that black backgrounds often are discarded due to large contrasts with the surroundings. As the visited hospitals all had a mainly white interior, black background would have been a too large contrast to the surroundings.

The colours chosen for characters were based on the same arguments as presented in 4.6.1 Decision of physical design. Yellow characters were used for the assistance alarm, red characters were used for the emergency alarm and black characters were used for the patient alarm. The yellow and red characters got a black outline to fulfil the need for dark characters on a white background for good readability. The patient alarm had no obvious connection to colour according to the consulted nurses and black was, therefore, chosen for a neutral and readable alarm presentation. The font chosen for the interface has no serifs and was chosen because of Arbetsmiljöverket (2012) stating fonts without serifs are easier to read on displays.

To alert the nurses about an alarm, there will be a sound from the product. The sound will differ depending on the type of alarm; emergency alarm, assistance alarm and patient alarm. More than three priority levels are dissuaded by Thunberg and Osvalder (2008) because of the humans' inability to distinguish more sound levels. Therefore, the product will not have any other sound to reduce confusion. The assistance alarm and patient alarm will sound once and then only be alerting visually and by vibrations because consistent signals can be perceived as distracting and disturbing according to Osvalder and Ulfengren (2008). The result from designing the interface is presented in 5.3 Interface design.

4.6.3 *Technical solutions*

A number of different technical solutions for identifying the location of the product and thereby the nurse were investigated. The accuracy of the right location was limited to know in which room and by which bed the nurse is located.

Firstly two technologies often used when discussing IoT were investigated, the NFC and RFID. The NFC technique was not chosen since the read range according to Curran (2012) is limited to only 10 centimetres. That would require a nurse to be very close to the transmitter in order to identify which transmitter the product is connected to. Even if the read range of a passive RFID tag is longer than for NFC it is still too short since it can be as short as 60 centimetres according to Hunt et al. (2007). An active tag was not considered since Hunt et al. (2007) argues that it is much more complex, heavier and more expensive than a passive tag.

IR was not chosen since it, according to Kahn and Barry (1997), requires a clear line of sight to transfer data between the transmitter and detector and there is a big chance that there will be objects or persons intercepting the line of sight. GPS is used to identify positions but since this product is made for indoor utilisation satellites are not able to get an unobstructed line of sight to the position and, therefore, according to Ordóñez et al. (2012), it cannot generate highly reliable information.

Bluetooth was the technology chosen to identify the location of the nurses. Since one bed is about two meters long the read range was estimated to require approximately the same length, which could be achieved by using the Bluetooth power class 3. Bluetooth does not need a clear line of sight to connect and is a well-known and used technology. Many devices can be connected to the same transmitter, although it will affect the transmission speed. (Stirparo & Löschner, 2013; Sauter, 2011) The transmission speed will most likely not pose a problem since no big amounts of data will be transferred.

The devices will have to intercommunicate and the solution chosen to solve this was having the devices connect using Wifi to a base station which distributes information to the devices. Wifi was found to be the best option since it is a well-known technology that already exists in the hospitals, which would decrease the implementation cost.

4.6.4 *The system surrounding the product*

The Customer journey map constructed earlier in the process was utilised to define a suitable time to pick up the product and to delegate which patients the nurses will be responsible for. Since it is important that all nurses have the product while they are working a proper time to pick up the product was identified to be directly when they arrive at work after they have changed. To keep the workflow and routines as similar as they are today the delegation of patients will take place at the same time as today, during a meeting at the beginning of each work shift. Different solutions of how to charge the product was discussed and three options were identified:

1. Plugging something into the product, for example a mini USB.
2. Plugging the product into some kind of rack or holder.
3. Induction charging – charging the product wirelessly.

To make the product as durable and water resistant as possible induction charging was chosen because that would make it possible to seal the whole shell together. The result from the decisions made regarding the surrounding system is presented in section 5.4 Surrounding system.

4.6.5 *Final prototype*

For the final prototype, a visual 3D-prototype was created in Solid Edge. The prototype was initially created in one piece, but when refinements were made in later stages it was created as a shell. To understand the size and ergonomic aspects, the prototype was 3D-printed in four iterations, and refined after every printing until the prototype result was satisfying. The main purpose of the 3D-printed models was to get the physical perspective of the design and being able to adjust the design accordingly. In Figure 16, the front and backside of the four physical prototypes are shown. Changes made between the different prototypes include re-positioning of all buttons, re-design of attachment and use of different filler materials.

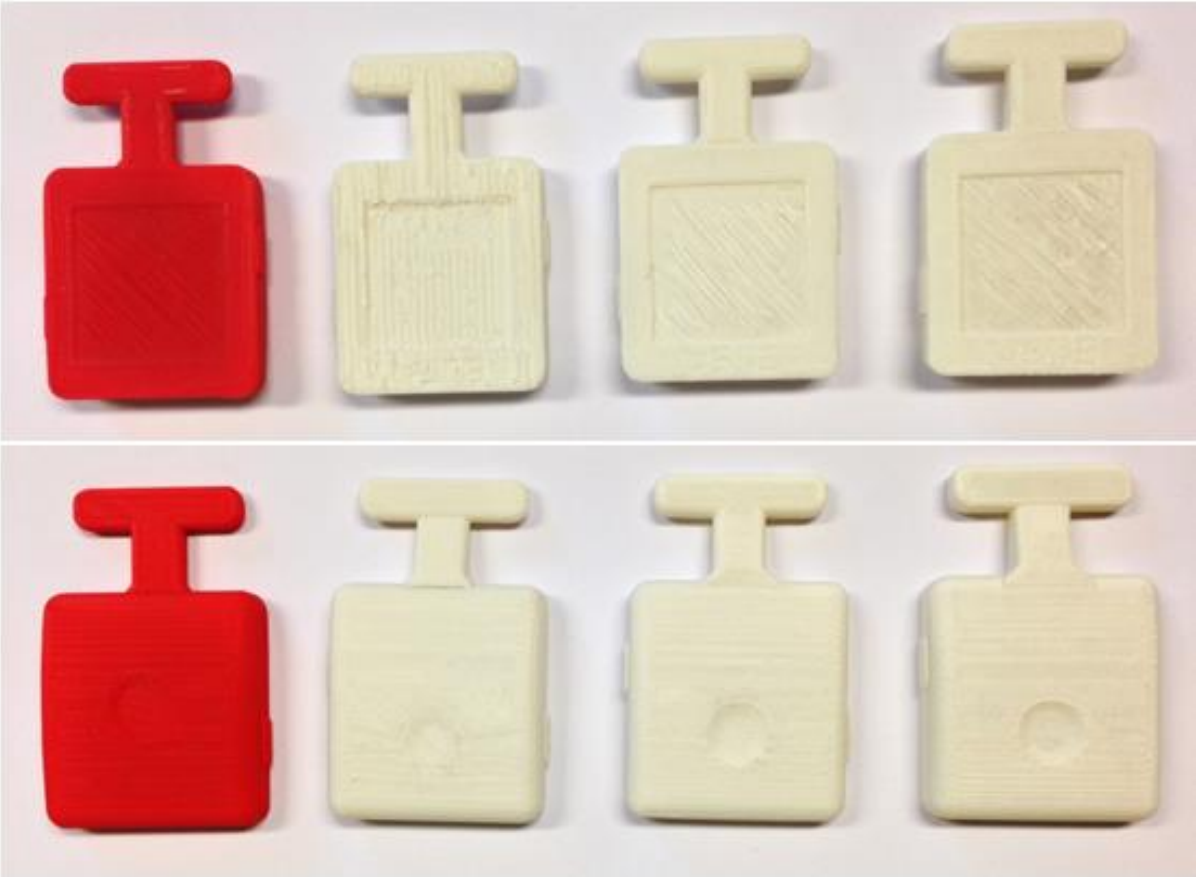

Figure 16. 3D-printed prototypes, starting from the first prototype on the left.

In order to visualise how the actual product will look like the buttons were painted and a picture of the screen in the right size was laminated an attached. On the back of the prototype a safety pin was glued to enable testing the attachment function and to feel how it will feel to wear the product.

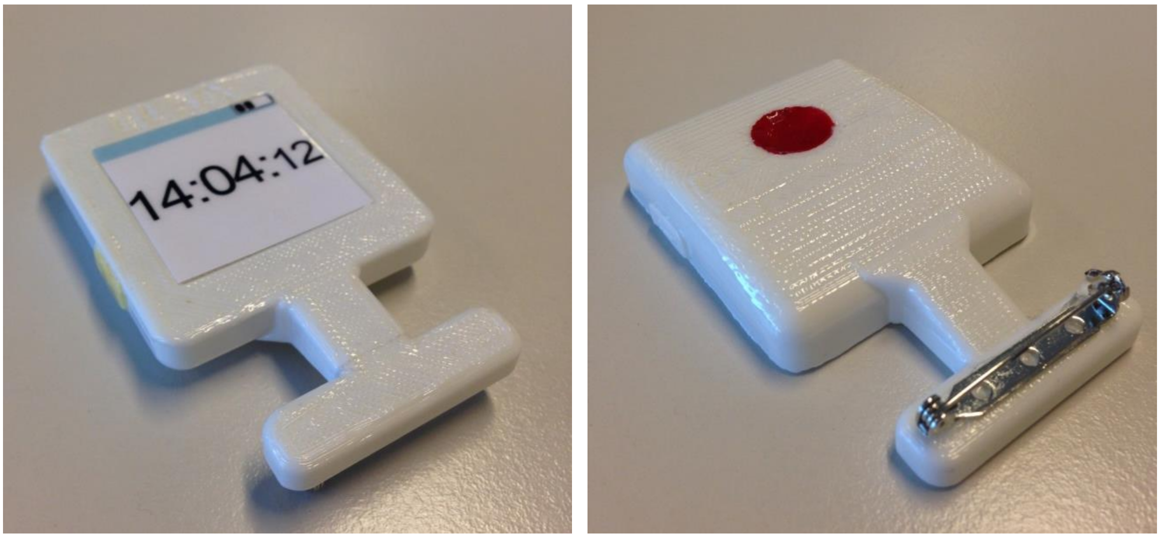

Figure 17. The final prototype seen from the front and the back.

4.6.6 *Conceptual movie*

An explanatory short movie was made in order to illustrate the functions that the final concept will contain. Since the storyboards, that already had been created in section 4.4.5 Concepts of functions received such good feedback it was decided to keep the cartoon characters Petra and Anna. A storyline was created and rough pictures were drawn to visualise how to movie would look like. Pictures to be included in the movie was firstly drawn on paper and then scanned into a computer and coloured in Adobe Photoshop CS6. The programme used to create the movie was Adobe After Effects CS6.

4.6.7 *Concept name*

In order to find a suitable name for the final concept, a brainstorming session on a whiteboard was performed. The session was unstructured and only had the rule of not involving any negativity. All names and words associated with the concept were written on the whiteboard and naturally clustered. The idea of using an abbreviation was started halfway through the brainstorming session and the name finally chosen was an abbreviation, ELSA – Efficient Lifesaving Smart Alarm.

4.6.8 *Summary of iteration three*

The third iteration consisted of finalising of the concept and included designing both the physical design and interface design as well as deciding which technical components to be used along with how the surrounding system would work. Both the physical design and the interface design followed ergonomic guidelines and were designed to be simple and as easy to understand as possible. During iteration three physical prototypes were also 3D printed, the name of the final concept was decided to be ELSA and a concept movie was created. The complete result from the third iteration is presented the next chapter, 5 Results.

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5. Results

In the following chapter, the results obtained from the master thesis project are presented. The project resulted in a conceptual product meant to be used in hospitals, called ELSA. The product has the functions of being an emergency alarm, assistance alarm and showing patient alarms. ELSA is an abbreviation of Efficient Lifesaving Smart Alarm, a short description of the functionalities. The results chapter is divided into five parts, starting with an explanation of functions in the product. Then the physical design and interface design are presented, followed by the surrounding system and finally technology used.

5.1 The functions

ELSA has three main functions that will be explained below. Apart from being an emergency alarm, patient alarm and assistance alarm, ELSA can also function as a regular digital watch. The idea is that care units invest in the ELSA system and all nurses and assistant nurses are provided with an ELSA watch. The watches communicate with each other through a central system.

5.1.1 *Emergency alarm*

ELSA has an emergency alarm button that, when pressed, sends signals to all other ELSAs at the care unit. The other ELSAs notify their user by generating both a sound and vibrating while showing where the alarm is from on the display. The sound for this alarm is loud and persistent in order to notify all nurses. A nurse that is unavailable due to other important tasks can mute the emergency alarm by pressing the mute/forward button on the side of ELSA. This is possible in order to create as little disturbance as possible in the work routines. When there is no longer a need for emergent care, the emergency alarm can be shut off by someone in the alarm zone, which is the zone where the alarm went off from, presses the emergency alarm button.

5.1.2 *Assistance alarm*

The second function of ELSA is the assistance alarm. If a nurse needs assistance when helping a patient and does not have the possibility to search for someone to help, the nurse can press the yellow assistance button. An assistance alarm is then sent to the nurses working in the same team and being responsible for the same patients. The ELSA watches then notify the nurses by sounding, vibrating and showing where the alarm is from on the display. The sound for this alarm has a volume lower than the emergency alarm. A nurse that does not have the possibility to answer the alarm can forward the alarm by pressing the mute/forward button. The alarm is then forwarded to other nurses in the care unit. When a nurse reaches the alarming nurse, the alarm is automatically shut off.

5.1.3 *Patient alarm*

ELSA has the possibility to show directed patient alarms. This means that when a patient presses the alarm button by the bed, the alarm is only shown on the ELSAs worn by the nurses and assistant nurses responsible for the specific patient that is alarming. The nurses are notified by ELSA sounding, vibrating and showing where the alarm is from on the display. The sound for this alarm is different and lower than the emergency alarm. The nurse that goes to answer the alarm shuts the alarm off by only going close to the bed. ELSA then recognises being close to the bed where the alarm is from, and automatically shuts off. As with the assistance alarm, the patient alarm can be forwarded by nurses being unable to answer the alarm. The alarm is then forwarded to nurses that are not responsible for the specific patient.

5.2 Physical design

The watch is designed to fit nurses' workdays. The design is clean, simple and does not have sharp edges due to the physical aspect of the work. Reasons behind design decisions were explained in 4.6.1 Decision of physical design.

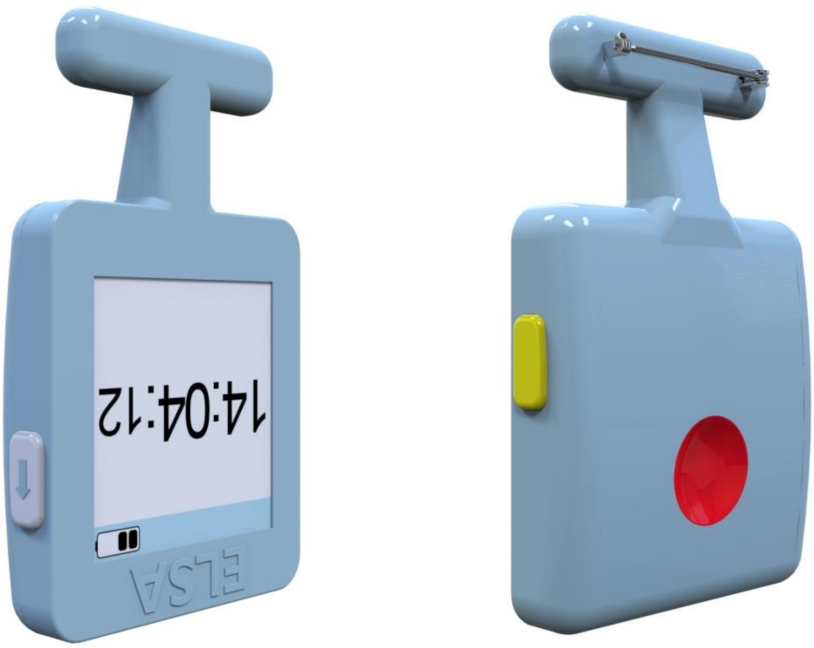

Figure 18. The physical appearance of ELSA, shown from the front and the back.

The watch has three buttons used for controlling the different functions. The first button is red, concave and situated on the back of the watch, see Figure 18. The red button is used for starting the emergency alarm. The second button is yellow and situated on the left side of the watch. The yellow button is used for calling for assistance.

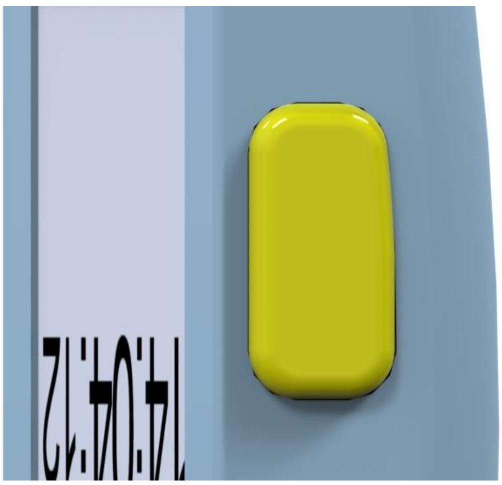

Figure 19. The yellow assistance button.

The third button, the mute/forward button, is situated on the right side of the watch and is used for muting emergency alarms and forwarding assistance and patient alarms. Because no apparent colour can be assigned to this function, the button is white with a forwarding arrow in the same colour as the watch, see Figure 20.

Figure 20. The white forwarding button.

ELSA is fastened to the nurse uniform with a pin, integrated in the design. The pin is fastened from the inside of the plastic shell. The pin is shown in Figure 21.

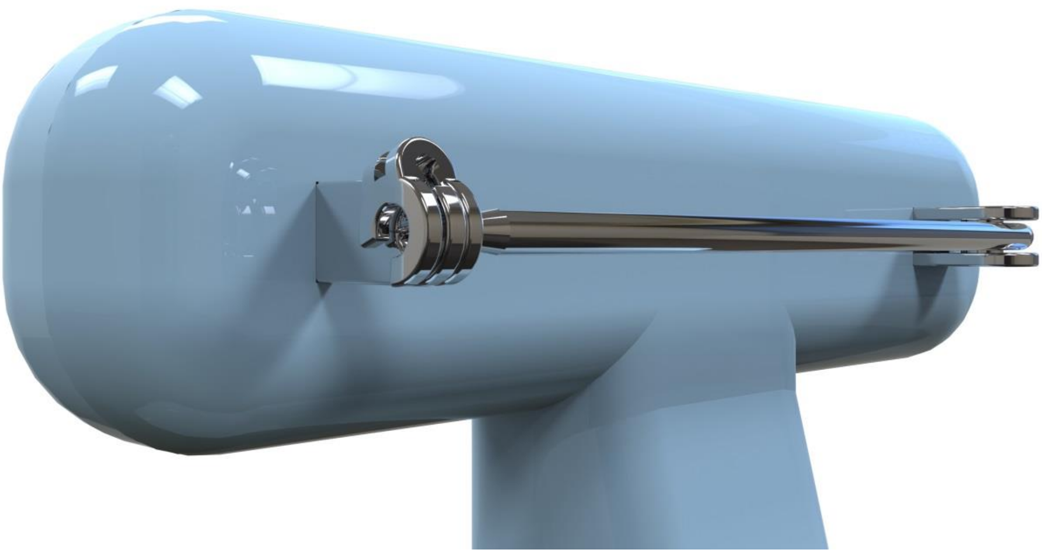

Figure 21. The pin that enables ELSA to be fastened to nurse uniforms.

ELSA is designed to create good readability without being too heavy or large and thereby interfering with the work. The main measurements of ELSA are shown in

Figure 22.

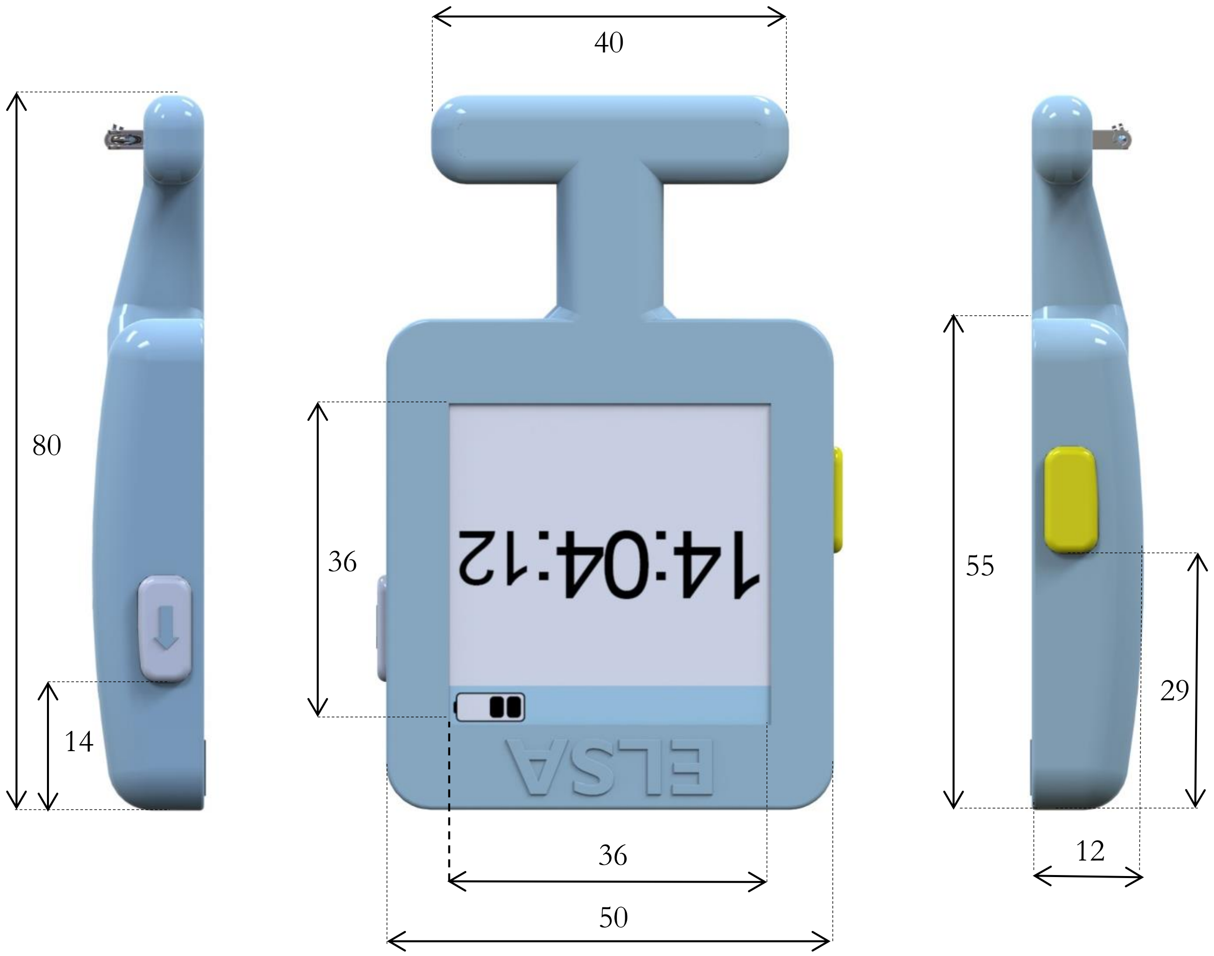

Figure 22. Main measurements of ELSA.

5.3 Interface design

The interface is designed according to preference of the consulted nurses and ergonomic recommendations. The aim of the design is to keep it simple and easy to understand. On the home screen, there will be a digital watch showing the time in hours, minutes and seconds. The nurses stated, during the last hospital visit where they evaluated the prototypes, that they preferred an analogue watch but since it is easier to read a small digital watch than a small analogue watch it was decided to use a digital version. On the top of the screen, there will be a blue bar in the same colour as the physical product. In the bar there is room for the battery level indicator, see Figure 23. For an overview of the interface flow see Appendix 8.

Figure 23. The home screen with a digital watch showing hours, minutes and seconds.

5.3.1 *Incoming alarms*

There are three different incoming alarms; emergency alarm, assistance alarm and patient alarm. An incoming alarm is when someone else presses an alarm button and the alarm shows up on the screen. The incoming emergency alarm looks as the picture to the left in Figure 24. The alarm sounds consistently and loud to alert about the emergency. On the screen the location of the alarming ELSA is shown in red numbers, the first number is the number of the room and the second number is the number of the bed. When this screens shows up the nurse has three different options.

1. If the nurse is occupied with something very important, can not answer the alarm and wants to mute ELSA, the mute/forward button can be pressed and then the screen to the right in Figure 24 will show up for three seconds until it goes back to the left screen. The particular emergency alarm is then completely muted.
2. If the nurse answers the alarm it can be turned off, if needed, when the emergency button is pressed when the nurse is located in the same zone as where the alarm went off. However, if the nurse answering the alarm judges that more personnel are needed to help the emergency alarm, the alarm will keep ringing until anyone presses the emergency alarm button in the emergency zone. When the alarm is turned off the home screen turns up.
3. If another nurse turns off the alarm the screen automatically goes back to the home screen.

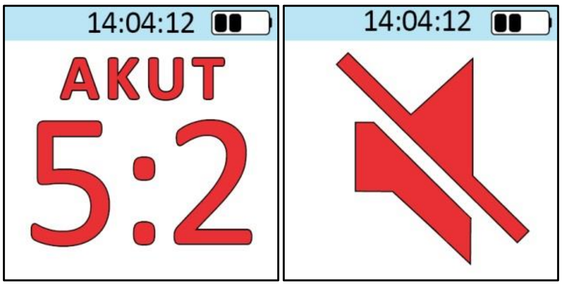

Figure 24. Incoming emergency alarm to the left and how it looks when the mute button is pressed to the right.

The incoming assistance alarm is shown on the left picture in Figure 25. When the assistance alarm goes off, there is a sound lower than the emergency. It will only signal once, then be quite and the location of the alarming nurse is shown on the screen in yellow numbers. When this screen shows up the nurse has two different options.

1. If the nurse is busy and not in a position to help the alarming nurse the mute/forward button can be pressed. The alarm will then be sent forward and the screen to the right in Figure 25 will show up in three seconds before it goes back to the home screen.
2. When the nurse goes to help the alarming nurse the alarm automatically stops when they are close to each other, when both ELSAs are connected to the same Bluetooth transmitter, and the home screen turns up again.

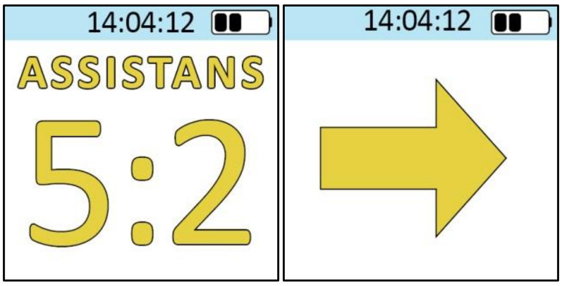

Figure 25. Incoming assistance alarm to the left and how it looks when the mute button is pressed to the right.

When a patient presses their alarm button the screen on ELSA will look like the picture to the left in Figure 26. The alarm will sound once and in a slightly lower tone than the assistance alarm. The location of the patient is shown on the screen in black numbers. The nurse has two options when this screen shows up.

1. The mute/forward button can be pressed if the nurse is busy and cannot take the alarm. Then the alarm will be sent forward and the screen to the right in Figure 26 will be visible for three seconds before automatically returning to the home screen.
2. If the nurse goes to the location of the alarming patient the alarm will turn off automatically and the home screen will turn up.

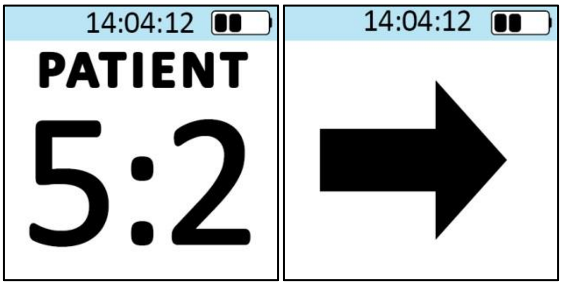

Figure 26. Patient alarm to the left and how it looks when the mute button is pressed to the right.

It is possible for ELSA to receive several alarms at the same time. The different types of alarms have different priorities. If several patient alarms are received they will appear as shown in Figure 27 with a maximum of four alarms on the screen simultaneously. The newest alarm will be placed in the left upper corner and the oldest alarm in the right lower corner. The assistance alarm has higher priority due to often being more urgent, and will therefore always be shown in the upper left corner if several alarms are received at once. The emergency alarm has the highest priority and will therefore be shown as in Figure 24 and no other alarms will be shown until it is turned off. If more than four alarms are received at once the screen will scroll to the left to show up to four other alarms at the next page. Each time a new assistance or patient alarm is received it will first be shown as in Figure 25 to the left or Figure 26 to the left for three seconds before it shrinks down to fit the structure in Figure 27. If a nurse presses the mute/forward button when the screen looks as Figure 27 the upper left alarm will be sent forward.

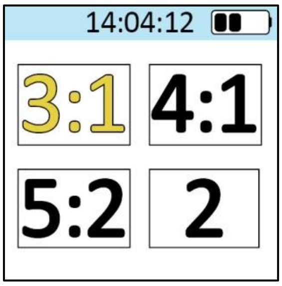

Figure 27.Four different incoming alarms at once shown in one screen.

5.3.2 *Outgoing alarms*

An outgoing alarm occurs when the nurse using the product presses any of the alarm buttons. There are two different outgoing alarms, the emergency alarm and the assistance alarm. When the emergency button is pressed there are two ways to turn off the alarm, either to stop the alarm by pressing the emergency button again or letting anyone else that is located in the same zone as the alarm stop it by pressing their emergency button. In the picture to the left in Figure 28, the screen is shown for how it will look when the emergency button is pressed.

There are also two ways for the user to turn off the alarm when the assistance button is pressed. Either the assistance button is pressed again or the alarm will automatically turn off when another nurse comes into the zone of the alarm to help. The picture to the right in Figure 28 shows how the screen will look when the assistance button is pressed. When the alarms are turned off the screen will go back to showing the home screen.

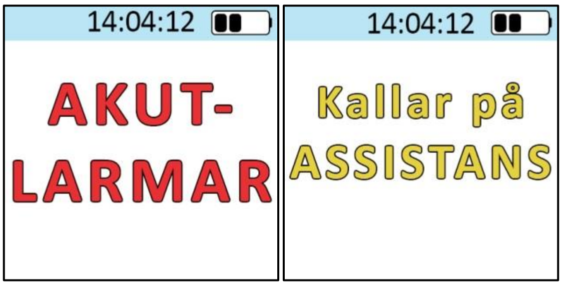

Figure 28. How the screen will look when the emergency button is pressed is shown to the left and how it will look when the assistance button is press is shown to the right.

5.3.3 *Pause mode*

It is possible for the nurses to turn the ELSA watch into pause mode when they have breaks by pressing the mute/forward button for five seconds. Then the screen in Figure 29 will show up and only emergency alarms can be received and sent. To go back to the normal state the mute/forward button is pressed for five seconds again and the home screen will appear. When ELSA is in pause mode all alarms are automatically sent forward.

Figure 29. How the screen looks when ELSA is switched into pause mode.

5.4 Surrounding system

The ELSA system enables recognition of which nurse is using which ELSA watch, which patients that nurse is responsible for and which nurses work in the same team. The ELSA system also includes charging routines of the ELSA watches. In Figure 30 the process of utilising ELSA for a work shift is divided into six steps and each step is described below.

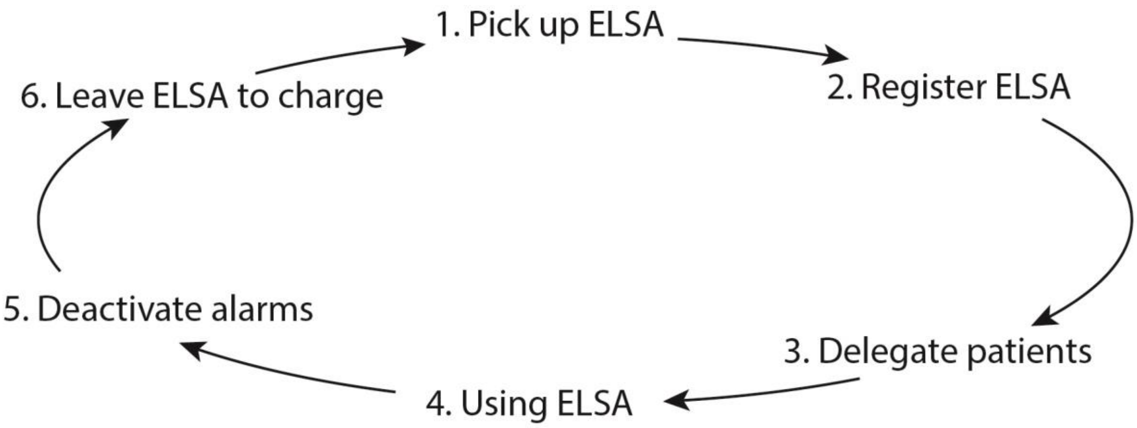

Figure 30. Different stages that the ELSA watch goes through each work shift.

1. The ELSAs will be owned by the hospital and each nurse has to collect their ELSA watch the first thing they do when they arrive. At that time, the product will not be connected to any specific patients or nurses and it will only react on emergency alarms since there always are other nurses that have the responsibility of the patients when new staff arrives. The product will be kept at the department in a locker where they get charged.
2. All ELSAs will be marked with a number in the back and when a nurse picks up an ELSA he or she registers in a computer program which ELSA he or she picked.
3. During the meeting initiating the work shift, the head nurse will delegate which nurse that will have the responsibility for which patient and who will work in the same team. At the same time, the head nurse writes the information in the computer program and all the ELSA watches will be connected to a specific nurse and all the nurses are connected to a specific team and specific patients.
4. The nurses use the ELSAs as described earlier in this chapter.
5. When the next work shift begins and the new nursing staff has had their meeting and got their teams and patients all alarms except for the emergency alarm will be deactivated on the ELSAs that the nurses from the previous shift has.

6. When it is time to go home the nurse leaves the ELSAs in the same place as they got them and they will get charged by induction charging. When an ELSA is charging it does not react on any alarms.

Each care unit will have double the amount of ELSAs as the numbers of nurses working in one work shift since the work shifts are overlapping each other and all nurses need an ELSA. This will also enable the products to be fully charged each time a nurse picks up an ELSA. The care unit should also have some extra ELSAs for interns to borrow.

5.5 Technical solutions

In order to make the functions work different technologies are used in the product to identify the location and connect the ELSAs with each other and several different components is needed to make the product function as intended.

5.5.1 *Location identification*

The technology used for identifying the location of the nurses is Bluetooth. Bluetooth transmitters will be placed close to the bed either on the wall above the bed or in the bedside table that often is located next to the bed. It is not convenient to place the transmitter on the bed since beds often are moved around in the hospital and then the information of the location would be incorrect. Bluetooth transmitters are also placed in the doorpost of each room to enable the location to be known even if the nurse is not close to any bed. Each Bluetooth transmitter represents an alarm zone. The ELSA watch will be equipped with a Bluetooth receiver that will know which transmitter it was connected to most recently and by this the approximate location will be known of each ELSA. Each transmitter will have a range of approximately two meters.

5.5.2 *Interconnection*

Wifi is the technology used to connect the products with each other and the server. The ELSAs needs to constantly be connected and it will be possible to send and receive information from the server. The information will always pass through the central system and the server before it is sent out to the ELSAs. It will be the central system that has all the information regarding who should receive which alarm and the different priorities of the alarms. Here it will be possible to edit which nurse that has the responsibility for which patient.

5.5.3 *Combination of technologies*

The ELSA system uses a combination of Bluetooth and Wifi to communicate and identify the location. In Figure 31 and Figure 32 the blue box by the bed represent the Bluetooth transmitter and the red dot the patient alarm button. Figure 31 illustrates how the signals will be sent when an assistance alarm button is pressed. The ELSA is located in the zone of bed two in room four, the zone is defined by the Bluetooth transmitters range of two meters. When the assistance button is pressed the information about which Bluetooth transmitter the ELSA is connected to is sent to the server and the central system by Wifi. The central system sends out the information to the other ELSAs that belong to the same team as the alarming ELSA by the use of Wifi.

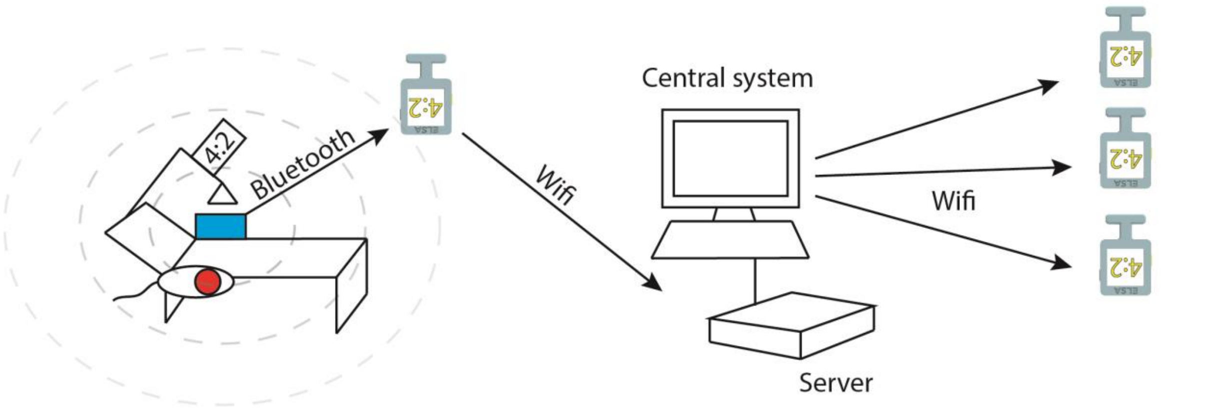

Figure 31. ELSA connects with the Bluetooth transmitter by the bed and to the server and central system by Wifi.

In Figure 32, the scenario of when a patient alarms is illustrated. The patient presses the alarm button, the signal is sent to the server and the central system which sends out the information by Wifi of which button that were pressed to the ELSAs that are connected to the specific patient.

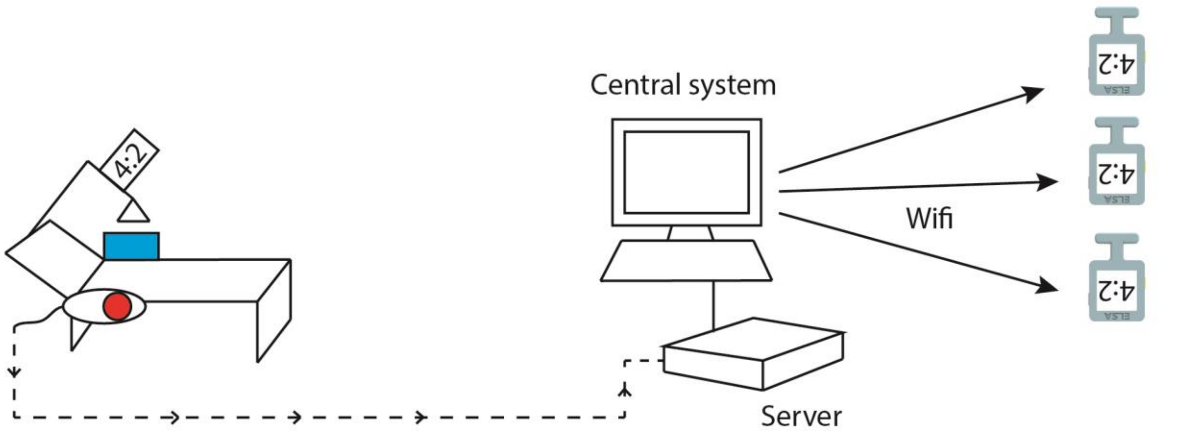

Figure 32.Shows how the signal goes from the patient alarm to the server and central system before it is sent out by Wifi to the ELSAs.

5.5.4 *Components*

The product will contain a range of different components in order to make it work. Figure 33 shows a suggestion of how the components could be placed in the product. The sizes are not exact.

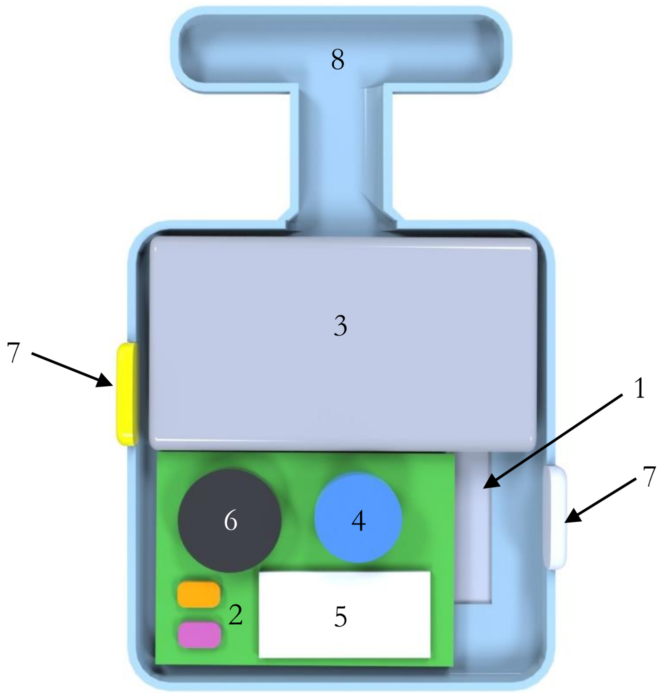

Figure 33. The front case with components.

1. **Display**: The display will be a small full colour pixel screen.
2. **Circuit board**: The circuit board will contain a Bluetooth module and a Wifi module, shown in pink and orange, to enable the two technologies to work.
3. **Battery**: The battery will be rechargeable and last for at least a work shift of 8 hours.
4. **Induction charger coil**: The battery will be charged by induction charging.
5. **Vibrator**: A small vibrator will be placed in the product and used to enhance the alarm effect.
6. **Speaker**: A small speaker is needed to generate sound when an alarm goes off.
7. **Buttons**: The product will have three buttons which will be made in ABS plastic.
8. **Case**: The case will be manufactured in ABS plastic by injection moulding. The case will consist of two parts and glued together to protect the components on the inside from impacts and water. The part line of the product will be placed through the buttons as shown in Figure 34, to facilitate the assembling.

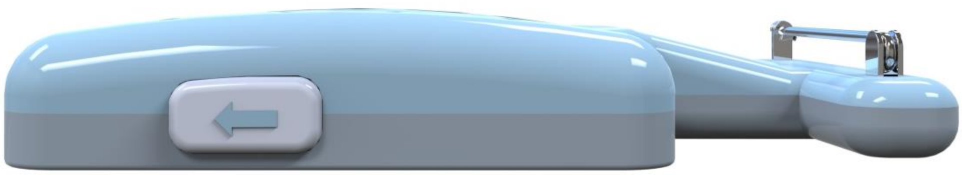

Figure 34. Side view of ELSA showing where the part line will be placed. To visualise where the part line will be placed one half of ELSA were made in grey.

5.6 Conceptual movie

The final movie that explains how the ELSA system will work with a focus on the three functions can be seen by visiting the link or scanning the QR code below.

Figure 35.QR code for the conceptual movie. The movie can also be viewed through http://vimeo.com/98121010

5.7 Validation of the final concept

To investigate if the final concept fulfils the requirements set early in the project, validation against the specification of requirements, which can be found in Appendix 3, was done. The specification of requirements stated that the product shall be able to; measure time, communicate with other smart devices, be attached to the nurse's uniform, be waterproof and easy to clean. Since this project only resulted in a conceptual product it is not possible to certainly determine whether the product actually meets the requirement or not. But as the concept is designed the intention is that all the requirements mentioned above will be met.

The final concept is designed according to ergonomic and usability guidelines, described in section 4.6.1 Decision of physical design and 4.6.2 Decision of interface design, to be simple and easy to understand. Further investigations are however needed to determine how user-friendly and ergonomically designed the concept is considered by nurses.

A desire on the product, according to the specification of requirements, was that it should be adjustable to fit the nurse using it. The developed concept is not adjustable but should be kept in mind when developing the product further.

Whether the product will withstand a drop from 1.50 meters, last for a minimum of three years and fulfil hygiene standards will have to be further investigated when a comprehensive prototype has been developed.

6. DISCUSSION AND CONCLUSION

A discussion regarding the methodology and result of the master thesis is in this chapter presented along with connections to the Frame of Reference. The conclusions are based on discussion and the result and intend to answer whether the purpose of the master thesis has been fulfilled.

6.1 Discussion of methodology

The process of developing ELSA has been very focused on finding user needs and understanding the user. In the stakeholder analysis found in 4.2.5 Stakeholder analysis, nurses that are the end users were rated as having the highest power and interest along with Tieto. End users have been observed and interviewed in several iterations. According to *eHälsosystemens användbarhet* (Scandurra, 2013), engaged by Socialdepartementet, work with information technology in healthcare should focus on involving user experience experts and healthcare personnel to a larger extent. By in this master thesis project involving the end user to such a large extent, ELSA has an extensively increased chance of being user friendly. The idea of involving users to develop better products and systems is also supported by von Hippel (2005).

When choosing hospitals for observation and interviews, there was a desire to involve as many hospitals as possible within the set time constraints. Therefore, the three largest hospitals in Stockholm were chosen; Danderyds sjukhus, Karolinska sjukhuset and Södersjukhuset. One hospital outside Stockholm, Gävle sjukhus, was chosen to find if there were significant differences between Stockholm and the rest of Sweden. Ideally, more hospitals outside Stockholm should have been visited to gain higher accuracy on the study. However, during the observations no vital differences between Gävle sjukhus and the hospitals located in Stockholm were identified and, therefore, the remaining hospital visits took place in Stockholm to save time. All hospitals were visited for observation during the daytime work shift, apart from Gävle sjukhus that was visited during the evening work shift due to logistic reasons. This may have affected the result of the observations and more evening work shifts could have been observed to improve reliability of the study.

During the process of gathering empirical information through shadowing and interviews one other important finding was discovered. This was the importance of observing the user in its natural environment to understand behaviours, find problems and reflecting on potential improvements. When the shadowing was performed several problems and potential improvements were found but during the subsequent interviews, few of the observed issues were expressed as problems by the nurses. Schneider and Stickdorn (2013) agree with this and states observations to be a good method for finding when an object says one thing and does another. McDonald (2005) presents this as observation being a method giving more detailed data compared to many other methods.

When consulting nurses for evaluation and input on design of the product, there was no obvious preference for all nurses, as stated earlier. By the first look, this might seem like a failed result. However, there are several learnings to appreciate from this. Firstly, the fact that the nurses answered so differently proves there is a need for individual adjustment of the product. However, if doing the project again, designers or persons more used to thinking of design should have been consulted. It also became obvious that there would be a need for beta testing the product because many nurses found it difficult to imagine wearing the product for a complete day. Performing beta testing on the product would go in line with Kaulio (1998) who finds concept testing combined with later beta testing to give relevant input on utilisation of the product.

Another discovery made when interviewing and consulting nurses was the fact that they have a stronger tendency to give the same answer when being asked in a group than when asked individually. The interview process differed from the different care units because some preferred everyone to be interviewed at once and some preferred individual interviews due to time constraints. The fact that some nurses were interviewed in groups probably influenced the result of all interviews and more accuracy would have been achieved with all interviews being individual.

The ideation sessions in the project had varying result, to a large extent because of the method used for ideating. The ideation method that did not give the desired result was Systematic Inventive Thinking, SIT. SIT is focused on the product and its elements (Goldenberg, et al., 2003) so the reason for SIT not being successful in this project, may be because the project was very user centred. There may be other ways of using SIT and thereby applying it to user centred projects, but no such alternations were found.

One risk highly rated in the project, was communication problems. It appeared to become a problem in a different way than expected. The supervisor at Tieto started working on a different location than the main office during the master thesis project. Even though telephone meetings were continuously held, there was a feeling of not having enough communication and the physical meetings held were perceived as more profitable.

6.2 Discussion of results

The purpose of the master thesis project was to "By the use of a suitable development process; define work routine problems and potential improvements for nurses working at care units, and to develop a conceptual smart wearable device solving such a problem.". A conceptual smart wearable device has been developed, if smart is defined as being able to communicate with several other products. However, whether the product can facilitate work for nurses is not yet scientifically proven. Theory can support the product being helpful and creating a better atmosphere for nurses, which is discussed below, but to ensure the helping effect of the product, statistic tests and observations need to be performed.

During the process of observing and interviewing nurses, it was found that false emergency alarms are very common, which is also stated by Tanner (2013). Such a large percentage of false alarms can result in the personnel responding slower to the alarms and alarm fatigue (Solet & Barach, 2012). Because of the healthcare sector being such a sensitive industry and seconds sometimes being the difference between life and death, the importance of reducing false alarms is high. ELSA has a completely different alarm system than the ones currently found in Swedish hospitals and one main idea when developing it was to reduce the number of false emergency alarms. This is done by removing the major cause of false alarms today; the presence button, and placing the emergency button close to the nurse. If the concept works as intended it will potentially decrease the level of alarm fatigue on hospitals since fewer false alarms will occur.

When the storyboards with all the intended functions were presented to the nurses, discussions arose regarding integrity issues and being monitored. Many nurses argued that they would not have any problems being monitored the way the concept described, but they thought some people would not approve of it. In the end, it was decided to not continue with the Nurse locator function even though many nurses thought that the problem of spending much time searching for colleagues was important. A solution for finding each other that does not intrude the integrity would be to prefer, perhaps something similar to the Voicera Communication System that works more like a portable phone that were shown to work five times faster than traditional communication methods (Su & Liu, 2010).

A highly demanded function amongst medical staff is to have access to information from the medical records system at any time. The result from observations and interviews showed that the lack of information at the right time lead to double documentation, the risk of forgetting important information and unnecessary running around. The study eHälsosystemens användbarhet (2013) also identified these problems and prioritised them for continued work. Both theory and the empirical research stress the importance of improving the accessibility of the medical record system from mobile devices. This is an area that should be more investigated and, as a suggestion, another master thesis project could be done focusing on this problem area.

When working with developing a product it is important not to only consider technical, but also social aspects of implementation. One social aspect for this project is integrity. However, there are other social aspects involved in the ELSA system that are worth discussing. The work environment for nurses is one with significant importance. With the ELSA system replacing old alarm systems, there would be fewer alarms being heard by all nurses. The environment would therefore be calmer and stress levels among nurses could decrease.

The assistance alarm function of ELSA is something that only some nurses had experienced before because not all care units have an assistance function in their current alarm system. The function was added to ELSA because of an apparent user need. During the shadowing, it was observed that nurses had to shout for help if in need of assistance. The assistance function was, therefore, put into the storyboards shown to nurses and received positive reactions. When showing the assistance storyboard to the nurses they easily identified themselves in the situations when assistance could be needed and explained how they would do in such a situation with the current system. This goes along with Schneider and Stickdorn (2013) stating storyboards can provoke meaningful discussion.

ELSA is to be used as a tool at hospitals and possibly other healthcare environments. Therefore, focus was making the product as easy as possible to understand and use. The design followed the function in this product and it was primarily designed to function in the hospital environment. This does not only apply to the physical design of ELSA, but also the interface design.

Hägg et al. (2008) states that most individuals prefer an angle of vision between the horizontal line and 30º below and that an angle higher than 45º is not recommended. If the ELSA watch is attached to the nurse's uniform at the intended place the angle of vision will probably be high, it might even be higher than 45º depending on the exact placement. However, the nurses are not supposed to look at the watch for a long period of time and the screen is designed with big numbers in different colours, depending on the type of alarm, to enable a quick glimpse to be enough.

Since the alarm system in a hospital is a vital function there has to be some kind of backup system ensuring the system to work even if something unexpected happens. Most often, in care units, it is the nurses that trigger the emergency alarm and that is why the product is designed to be used by nurses. But there have to be a way for other medical staff like physician and physiotherapists to trigger the emergency alarm. Therefore, there will still be an emergency alarm button installed in each room, the same way as today. That button will not have to use any Bluetooth and it will be somewhat more reliable.

Information technology today is used to improve quality and efficiency in hospitals (Su & Liu, 2010) and according to Socialdepartementet (2010) healthcare personnel should be provided with electronic support to facilitate their daily work which the ELSA system does since it saves time and has a simple and clear design and interface. Internet of Things (IoT) is an aspect of information technology that is growing rapidly and is predicted to have a large impact on human life and healthcare is not an exception (Atzori, et al., 2010). The ELSA system is a mobile solution using different wireless communication technologies which goes in line with the predicted evolution since mobility and wireless connection is essential building blocks to enable an IoT society. Su and Liu (2010) states that hospitals are moving towards a more mobile environment and that nurses are moving frequently during work and, therefore, mobile devices are welcoming. During meetings with Tieto, they also stressed the importance of mobility.

6.1 Discussion of delimitations

As presented in 1.3 Delimitations, the thesis project only intended to develop a conceptual solution to a problem discovered. During the project, delimitations based on the initial delimitation regarding a conceptual solution arose and were concretised. These concretised delimitations are discussed in the following section.

The main factor limiting the work performed during the master thesis was time. The time constraint in combination with the project´s focus on involving nurses has, as stated in 1.3 Delimitations, resulted in a conceptual product. One point interesting and valuable to the project would have been to verify the final concept by consulting the earlier involved nurses. However, the time constraints hindered this. If performing the thesis project again, the current last hospital visit, where nurses were consulted regarding the design of clay prototypes, could have been replaced with a later validation of the final concept. With current learnings, this would potentially have been more valuable to the project. The nurses will now be given information about the result of the project and Tieto will keep the contact and possibly verify later concepts and prototypes with the involved nurses.

There are several aspects of the project that have not been investigated fully due to the time constraints. Examples of such aspects are induction charging, whether it is a feasible solution. The reason why induction charging was chosen was due to the apparent waterproof product case. However, a cost analysis is necessary to perform to determine whether induction charging would be suitable. A cost analysis is needed for the entire system, but was chosen not to focus on in this conceptual phase. The components in the product in 5.5.4 Components are not exact in size, as explained, but the image was rather created to inspire further thoughts on how the hardware would be produced. Finding exactly the right components was not put in focus because of the conceptual stage of the project. Time was evaluated to be better used to develop other aspects.

6.2 Conclusions

The main conclusions obtain from the thesis project are listed below, divided into three different areas; methodology, empirical result and final result.

6.2.1 *Methodology conclusions*

- To better understand a user, it is important to both observe and consult the user.
- If a user centred development process is used it is crucial to establish a good relation with the intended user in order to reach a good result since it is desirable to repeatedly involve them in the process.
- Shadowing is an efficient method for finding problems and possible solutions not recognised by the user.
- When choosing methods to use in a project it is important to consider focus of the project and if the methods are applicable to such areas.

6.2.2 *Conclusions from empirical studies*

- The healthcare industry is generally not up to date with technology. There are many technologies available that could be implemented in healthcare and improve work conditions and patient care.
- Information at point of care is a large and important issue where the medical records system currently constitutes a large and limiting part.
- Double documentation is a time consuming problem at visited care units.
- Several problem areas were discovered in care units that can be improved to save time and effort for nurses.
- There are a considerably larger amount of false emergency alarms than real ones in visited care units.
- Patient lists are used by all nurses and they contain social security number and sensitive information and can therefore not be lost.

6.2.3 *Conclusions from final result*

- Within Swedish care units at hospitals, many false alarms occur due to nurses forgetting to deactivate the presence button when leaving a patient room. The ELSA concept has the possibility to decrease the number of false alarms by removing the need of using any kind of presence button.
- Nurses are exposed to a lot of different alarms during a work shift which causes stress and disturbing sounds. The ELSA system potentially decreases the number of alarms by using alarms directed to only the relevant nurses.
- Nurses are carrying a lot of items in their pockets and by integrating the ELSA alarm system and the nurse watch the amount of items being carried will not increase.
- Theory presented in this report suggests that ELSA will improve nurses work environment, but there is still work to be done to prove that. To do this, the concept needs to be realised and be tested and evaluated in the right context.

7. RECOMMENDATIONS AND FUTURE WORK

In this chapter, recommendations on more detailed solutions and future work in this field are presented.

7.1 Recommendations

ELSA currently has three functions, but the idea is to add functions gradually and depending on need of the user. There are already ideas of functions to include in the product; finding persons and using ELSA for locking and unlocking computers, medicine trolleys and doors. There will probably be more ideas of possible functions during utilisation of ELSA and those should also be possible to include in the product.

To enable more functions to be added, a recommendation for the product is to make it open and ensuring the ability to update. This would be done to enable development of the product without the need of buying new products. It would be a more sustainable solution both environmentally and economically when the same physical product can be used for updates and new features.

A more general recommendation for future work within the healthcare industry is to consult the users in their work environment more to better understand their needs. There is a lot to find out only by spending time at hospitals and by understanding the user, more successful products and services can be developed.

7.2 Future work

Several more detailed investigations on the product and the market should be done in order to develop a successful and realisable product. The next step would be to develop a functioning prototype to explore the technology. This could be done by programming an application to an existing smart device, such as a smartphone or a smart watch. Then components that will be used in the product should be investigated according to price, quality and performance and a manufacturing study should be done on the different parts and the assembly process to estimate the price to be sure that the product meets the goal of robustness and water resistance.

To successfully sell the ELSA system to hospitals a business case should be formed investigating how much time and money it is possible for care units to save each year. To do this care units should be observed with focus on the existing alarm systems and counting how many false alarms that occurs during a period of time and how much time the nurses spend on false alarms.

The next step is to create a beta prototype to let nurses try the product for a longer period of time. This would generate more information about how the shape of the product feels, if the size of the screen is comfortable and if the nurses think that the product facilitates their daily work. Observations should be done during the beta test to be able to compare the prototype with the existing alarm system to see if the product tends to save time. Hopefully, the test will show that the ELSA system reduces the number of false alarms and facilitate the daily work for nurses.

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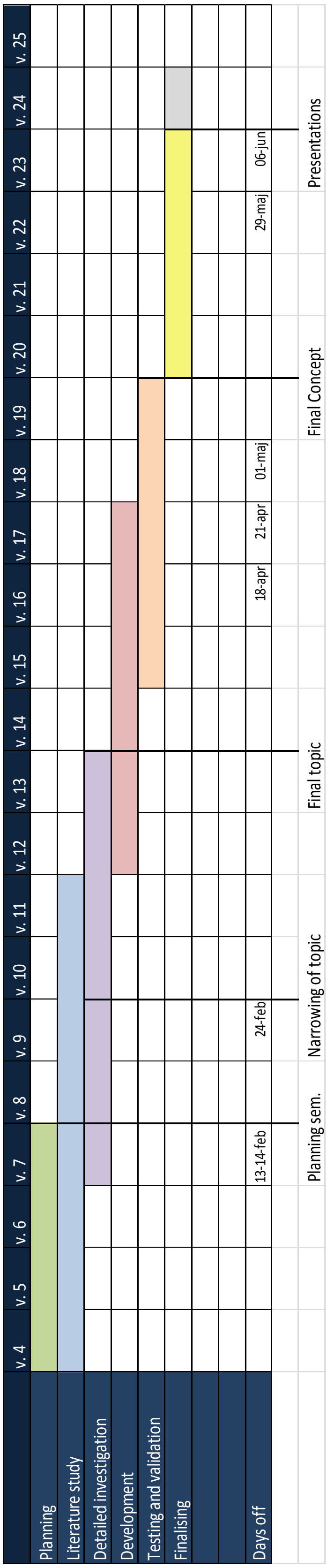
APPENDIX

APPENDIX 1. TIME PLAN



APPENDIX 2. RISK ANALYSIS

Risk	Probability	Consequence	Risk value	Action
Dissatisfaction from KTH	3	9	27	Keep continuous contact and update KTH on development of the project.
Communication problems	9	3	27	Make sure to continuously communicate with all relevant stakeholders.
No interview participants	1	9	9	Make sure to book the interviews early.
Improper guidance from KTH	3	3	9	Keep contact with more actors at KTH, not only the supervisor.
Improper guidance from Tieto	3	3	9	Keep regular contact with several actors at Tieto.
Confidentiality issues	3	3	9	Ask Tieto early what can be published and not.
No access to hospitals for observatoin	1	9	9	Make sure to contact hospitals early.
Cannot find relevant litterature	1	9	9	Search for literature early and continuously during the project.
Delays in the project	9	1	9	Make a spacious time plan.
Dissatisfaction from Tieto	3	3	9	Keep regular contact with several actors at Tieto. Perform several short presentations at Tieto.
Get stuck in one way of thoughts	3	3	9	Keep an open mind.
Not enough documentation	3	3	9	Have reminders of documentation and write journal after each day.
Insufficient resources	3	3	9	Plan well in time for which resources are needed.
Conflicts	9	1	9	Address the conflict immediately.
Information overload	9	1	9	Compile information often.
Force majeure	1	9	9	
Insufficient result	1	3	3	
Lack of time	1	3	3	
Low business benefits	3	1	3	
Insufficient competence	1	3	3	
Insufficient market analysis	3	1	3	
Differing level of ambition	1	3	3	
Too much documentation	1	1	1	

APPENDIX 3. REQUIREMENTS

Product goal

The product shall facilitate daily work regarding information technology for registered nurses working at hospital departments with hospitalised patients.

Functional criteria

Requirements

- The product shall have the ability to measure time.
- The product shall be able to communicate with other smart devices.
- The product shall be easy to understand.
- The product shall be attachable to the nurse´s uniform.
- The product shall be waterproof.
- The product shall be easy to clean.

Desires

- The product should be adjustable to fit the nurse using it.
- The product should be ergonomically designed.

Limiting criteria

Requirements

- The product shall fulfil the hygiene standards set by the National Board of Health and Welfare. (Alexandersson, 2007)

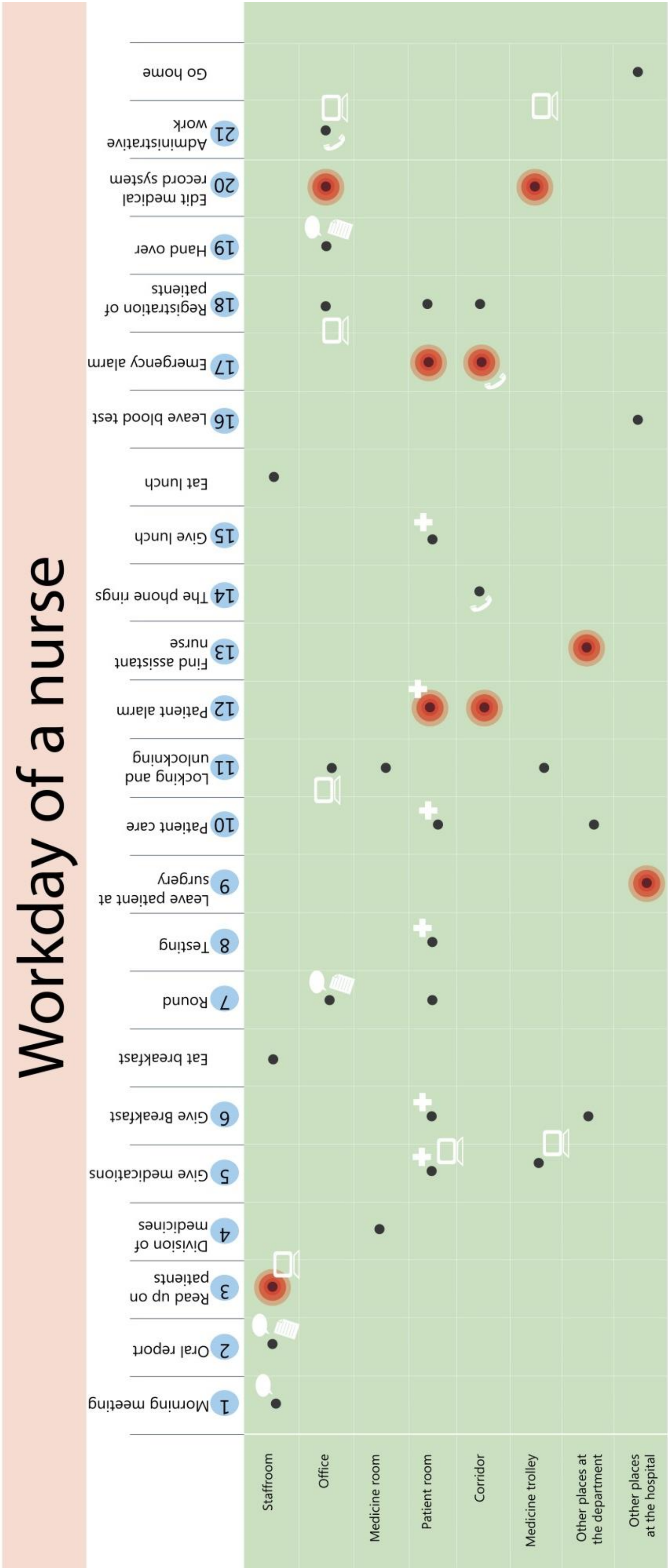
Desires

- The product should last for a minimum of three years.
- The product should be robust and withstand a drop from 1.50 meters of height.

Other criteria

- Should be aesthetically pleasing.

APPENDIX 4. CUSTOMER JOURNEY MAP



1

- Patient responsibility is divided by the head nurse.
- Short oral information about special events during the work shift.
- Division of lunch times and registration of new patients

2

- Meeting with the night nurse and assistant nurse to go through status on all patients.
- The most important info is noted on the patient list.
- Oral report is more appreciated than written because a better direct overview is given.

3

- Sitting down and reading up on the patients in the medical records system. Time for reading up can differ greatly depending on status of the patients.
- The most important info is noted on the patient list.

4

- Reading in the medical records system which medicines to be given to which patients. Medicines are placed in small cups marked with names of the patients.
- At Karolinska hospital there is a medicine automat helping to find the correct medicine by lighting lamps in the right shelves and boxes. The medicine automat can synchronise patient names and social security number with the medical records sytem, but not which medicines they are supposed to take.
- At geriatric units division of medicines is considered too time consuming due to the number of medicines given to each patient.
- A medicine can have several differen names which makes finding the right medicine difficult. There is a book where all medicines with the same name are listed.
- Registered nurses, but not assistant nurses have access to the medicine room. To get in a card and code is required.
- Medicines calssed as narcotics need to be marked or locked in and when using such a medicine, it needs to be written in a binder.

5

- The nurse goes to all patients and give them theur medicine.
- When a medicine is taken it is signed by the nurse in the medical recors system.
- The medicine trolley should be locked when walking away from it to prevent unauthorised persons to get access to medicines.

6

- Breakfast is given to the patients. Patients that have the ability walk to get their own breakfast.
- Fasting patients get a sign over their bed with crossed-out cutlery.

7

- At the sitting round the nurse and doctors are in the doctors expedition and go through all patients. The doctors use computers and the nurse looks at the screen.
- At the walking round doctors and nurses walk around to the patients.
- The forenoon round is often longer than the afternoon round.
- The most important info is noted on the patient list.

8

- For taking blood tests, a testing trolley is used.
- For measuring respiratory frequence, the nurse watch is used, there is no automatic measurement on the care units.
- For controls, a MEWS-pillar is used.

9

- Drive patients to operation and there hand over a folder with information.
- Operation units use a different medical records system that doen not synchronise with TakeCare.
- Medical records for anesthesia is written on paper and then scanned in to the computer.

10

- Helping patients to the bathroom, shower, bandage wounds et cetera.

11

- The medicine room, medicine trolleys and computers always need to be locked to avoid access by unauthorised persons. This means a lot of time is spent locking and unlocking those things.

12

- Patients call for nurses by pressing their alarm button situatied by their bed. The alarm is then showing up on displays in the corridor and sounds until a nurse answers the alarm.
- The patient alarm sounds almost the entire day due to different patients alarming at different times.

13

- A lot of time is spent on looking for other nurses and assistant nurses. The reasons vary from needing information or assistance to giving or recieveing physical objects.
- The care units where the nurses are provided with telephones generally have less problems with finding eachother.

14

- All care units do not provide telephones to all nurses.
- Some that do, have the telephones connected to specific rooms.
- The coordinator transfers the telephone to the right person.

15

- Lunch is given to the patients by the nurses. Patients that have the ability walk to get their own lunch.
- Small cards with information about food preferences for new patients are sent with the food cart to the kitchen.

16

- Either the nurse walks with blood samples to the lab, or someone else from the medical staff.
- At Karolinska there is a mailing tube where blood samples can be sent to the lab.
- Blood samples are registered in the lab through the bar code on the sample.

17

- The presence button should always be pressed when entering a room.
- If the presence button is activated and a patient presses the alarm button, the emergency alarm goes off.
- Most nurses do not press the presence button due to the risk of false alarms.
- When a patient presses the alarm button their position is shown on a display in the corridor.
- One care unit at SÖS has a new alarm system that is carried in the pocket and alarms only go to nurses responsible for the specific patient.
- All rooms have an alarm button.
- The sound from the alarm is percieved as disturbing.

18

- Before new patients arrive the nurse reads up on them in the medical records system and recieves a folder with papers.
- Patients about to be warded always arrive early.
- A new patient that arrives recieves a bracelet with name, social security number and bar code.
- The bar code can be scanned by the EKG machine to automatically be registered in the medical records system.
- When a patient has left the care unit all documents with name and social security number should be destroyed so unauthorised persons cannot find out.

19

- The nurse working dayshift hands over to the nurse working the evening shift. It is done with a written report complemented with oral information.
- The evening shift nurse takes notes on the patient list.

20

- The medical records system used are TakeCare and Melior.
- To log in, username and password is needed. It is important to log out when leaving the computer.
- Notes about patients are written. There is a frequently used to do list for each patient in Take Care. New information can be written to the next nurse there.
- Editing the medical records system is done continuously throughout the day and can be completed during administrative work.

21

- Time to do administrative work that there was no time for during the day, or to utilise a health maitenance hour.
- No patient responsibility.

APPENDIX 5. INTERVIEW GUIDE

Patient list

- What is your name for the list used for notes and information about patients that all nurses use?
- Do you use the list? Why?
    - What do you write on the list?
    - Do you use any specific system for your notes, such as colour codes?
- Is all information on the list transferred to the medical records system?
- Where is the list obtained?
- Where do you leave your list when the work day is over?
- How often do you look at your list?
- How often do you write on your list?
- Do you use anything other than the list for taking notes?
- Would your work be accomplishable without the list? Why/why not?
- Did you ever mislay your list?
    - What did you do then?
- Do you believe using the list as today is a sustainable way of working?

Finding persons

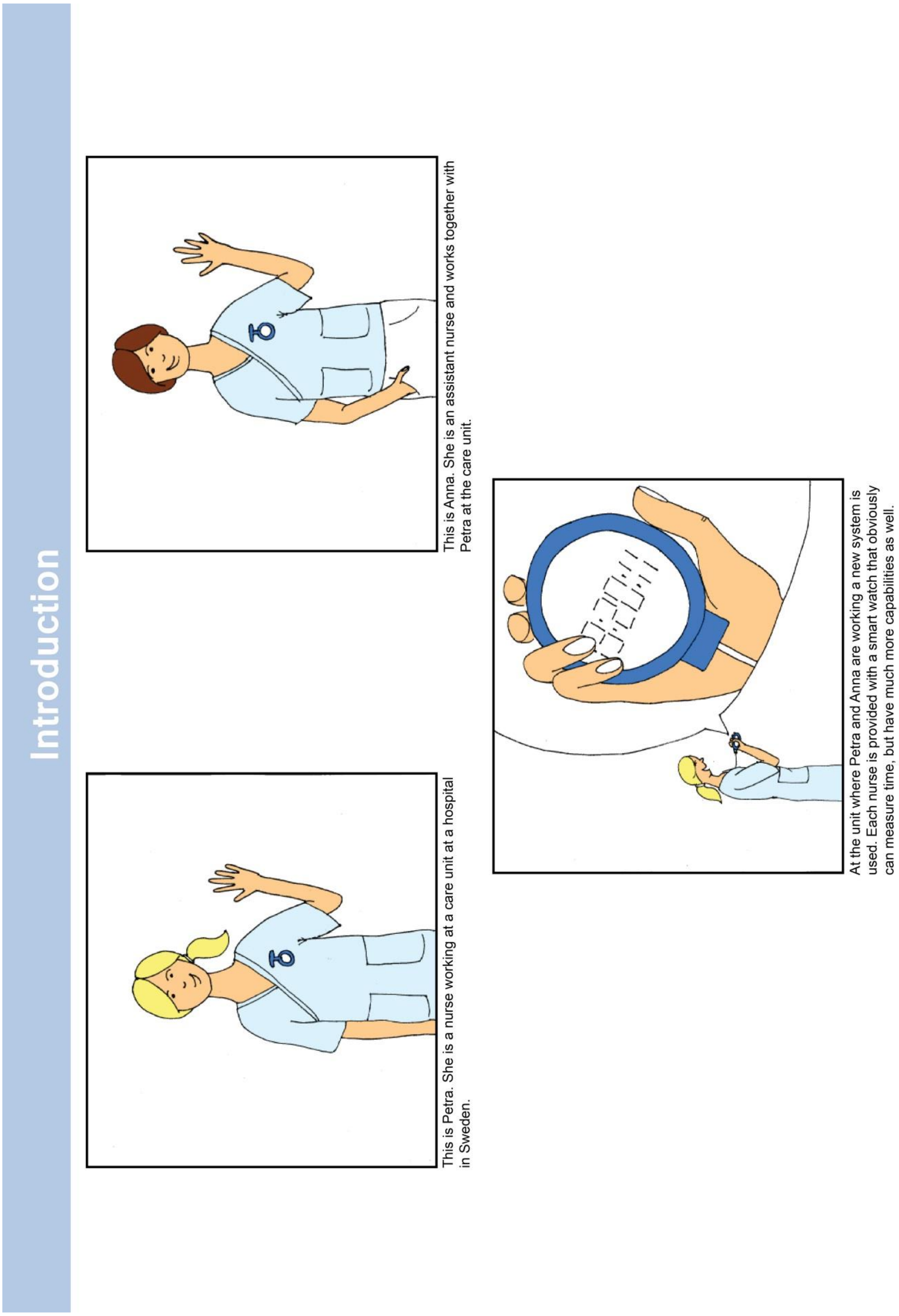
- Do you spend time searching for persons during your work day?
- Whom do you regularly search for?
    - Why do you usually search for a person?
- Does it ever happen that you cannot find a person you are looking for?
- What could be the reason you do not find a person?
- Who is most often looking for you?
- Which methods and tools are there to find persons at the unit today?
- Do you think the method for finding persons used today is good?

The alarm

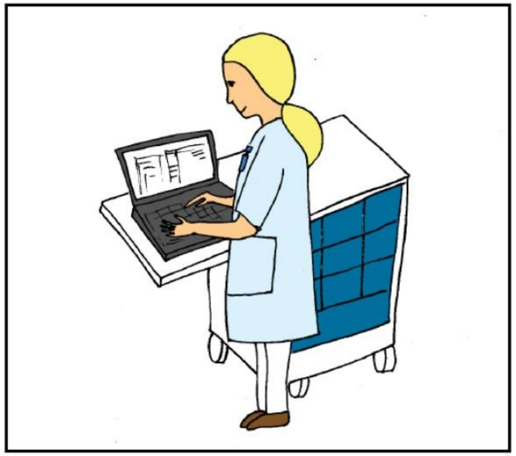
- Can you explain the functionality of the alarm system at this unit?
- Is the alarm system used frequently?
- Do you regularly press the precence button when you enter a room? Why/why not?
- Is there an assistance button on this unit?
    - If yes, do you use it?
- What is most common for the patients to need when alarming?
- How many real emergency alarms are there every week?
- How many false emergency alarms are there every week?
- How well do you believe the alarm system is functioning?
- Do you have any experience from the function of other alarm systems?
- Do doctors ever use the alarm on your unit?
    - Are the doctors ever alone with patients in the room?

APPENDIX 6. STORYBOARDS

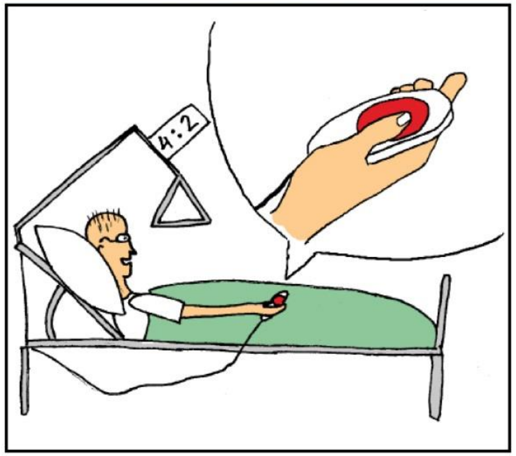
Storyboards that illustrate ideas of functions that the product could contain. These were shown to nurses to receive feedback on the ideas.



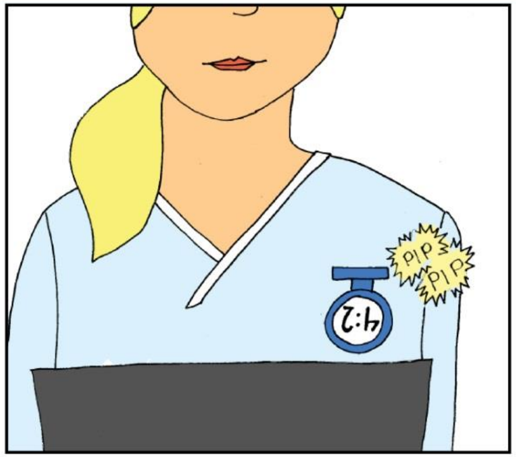
Patient alarm



Petra is standing by the computer at the medicine trolley and writes notifications in the medical records system.

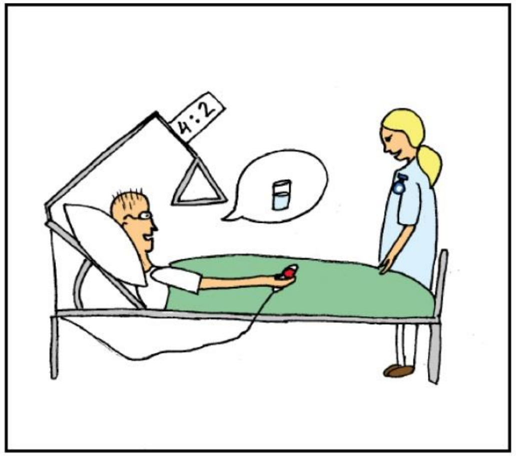


At the same time the patient in room 4 bed 2 calls for attention by pressing his alarm button.



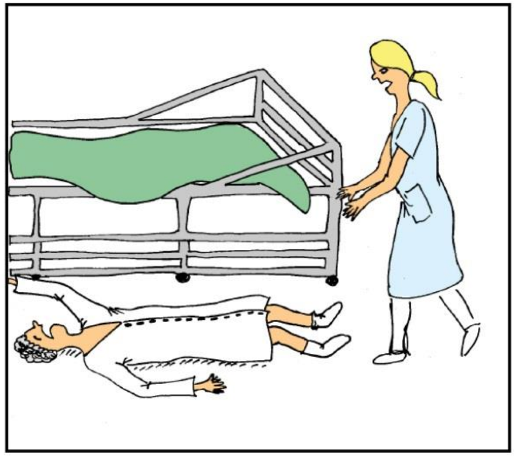
When the patient presses the alarm button, Petras watch beeps and the screen is lit.

Petra pulls out the watch and sees at the screen that the patient in room 4 bed 2 calls for care. Primarily, this alarm goes out to the nurses and assistant nurses that are responsible for the specific patient.

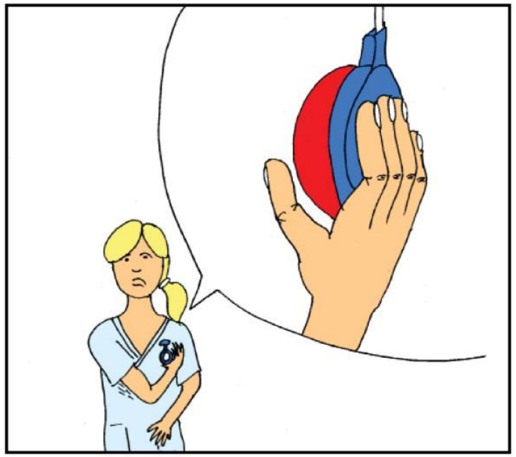


Petra walks in to the patient and the alarm is automatically shut off when she gets close to the bed. The patient asks for a glass of water.

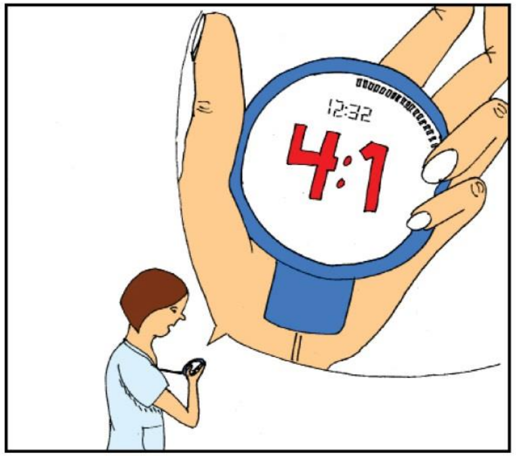
Emergency alarm



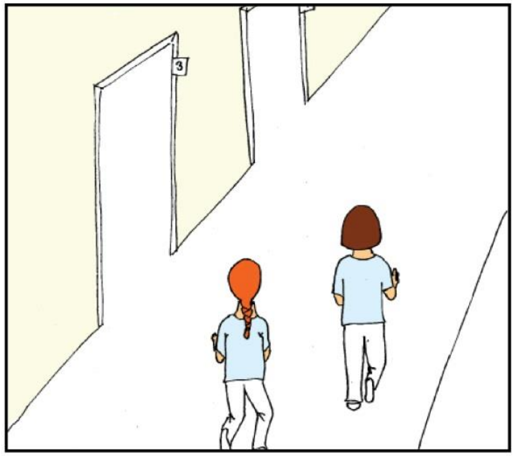
Petra walks in to a patient and notices she has fallen out of the bed and seems to be in a lot of pain.



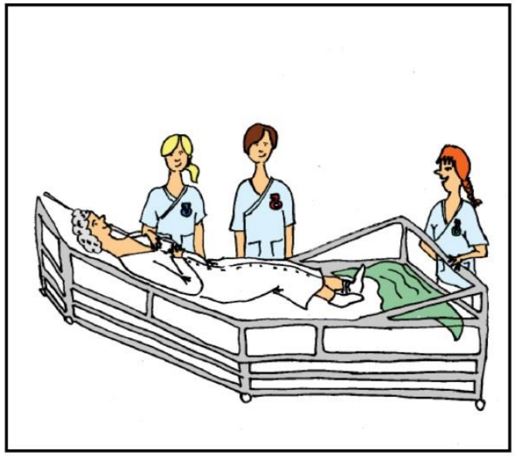
Petra understands she needs help fast and starts an emergency alarm by pressing the red button on the watch.



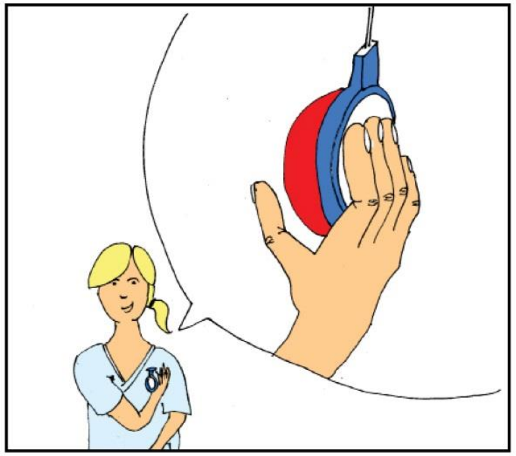
The alarm goes out to all other watches that sounds and vibrates while the alarming room is shown at the screen.



All the nurses at the department rushes to help Petra.

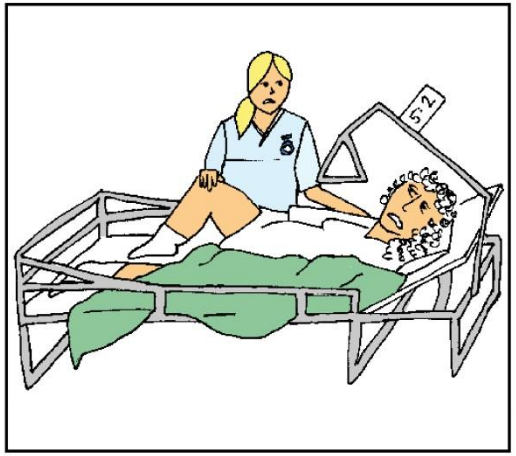


Together they help putting the patient back in the bed and calm her down.

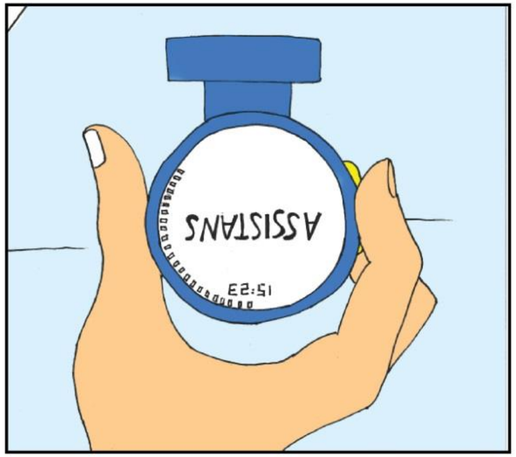


Petra turns off the alarm by pressing the alarm button again.

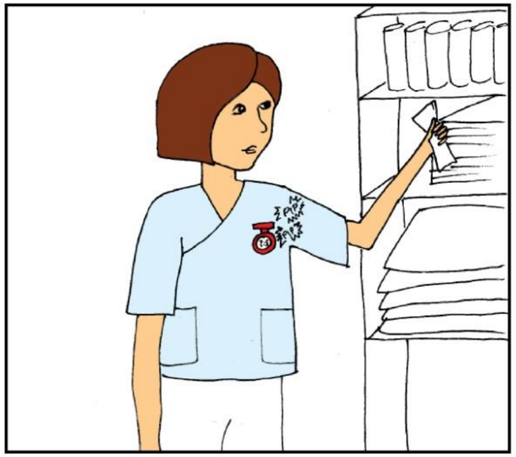
Assistance alarm



Petra is helping a patient to turn in the bed. Halfway through the procedure she finds it is too heavy for her to do alone.

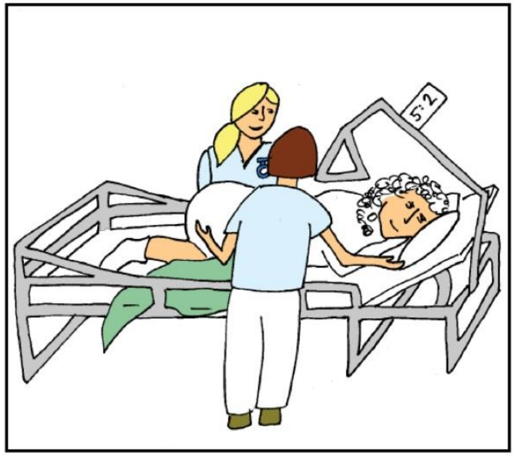


Petra calls for assistance by pressing a button on the watch.



Anna is in the storage room and getting a compress when her watch suddenly beeps.

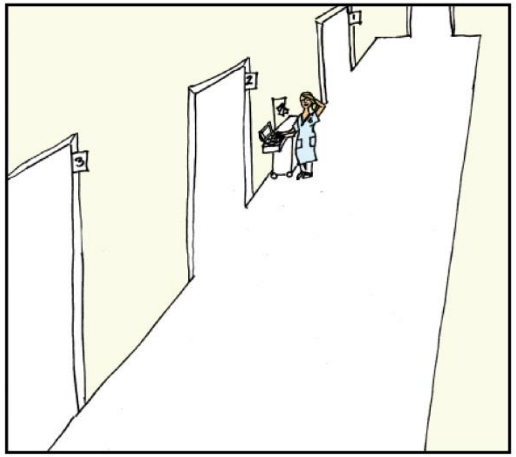
Anna looks at her watch and sees that someone is calling for assistance from room 5 by bed 2. She hurries to get there.



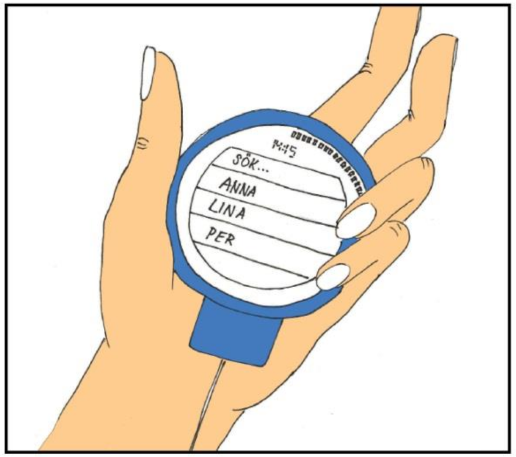
When Anna reaches the bed the alarm is automatically turned off. Anna can then help Petra to turn the patient.

Nurse locator

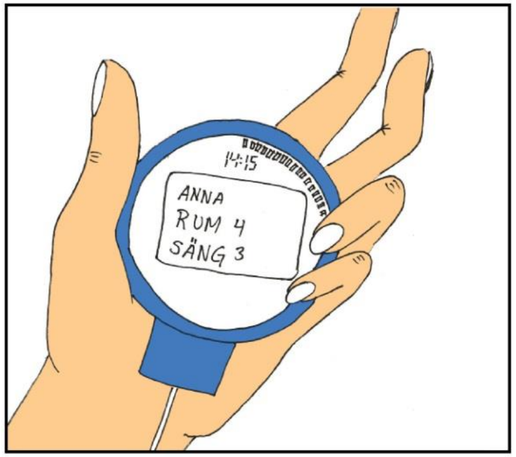
Petra can in the medical records system see that the blood sugar level of a patient with diabetes has not been registered.



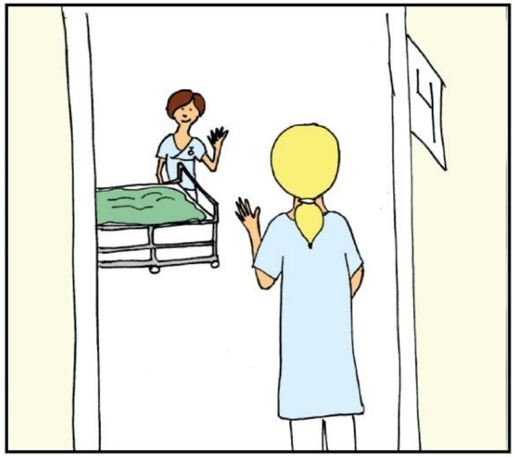
To ensure the test has not been taken and is just not registered, she wants to ask her assistant nurse Anna if she took the test. But Anna is not nearby.



Petra pulls out her watch and searches for Annas position with a few simple klicks.

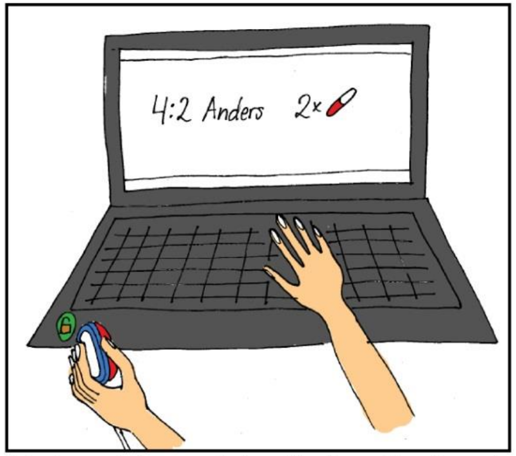


The watch shows that Anna is in room 4, by bed 2 which is the patient with diabetes!

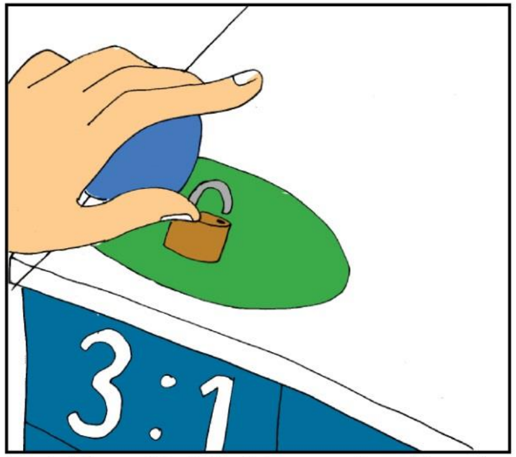


Petra immediately goes to the room and sees that Anna just did the blood sugar measurement and she is about to register it in the medical records system.

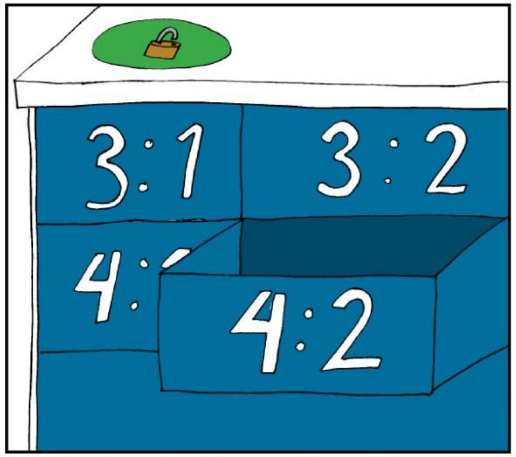
Lock and unlock



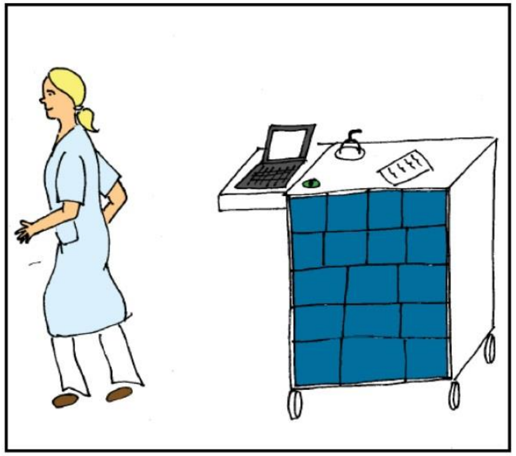
Petra logs on to the computer by putting the watch on the mark on the computer.She can see that the patient Anders needs to take his medication.



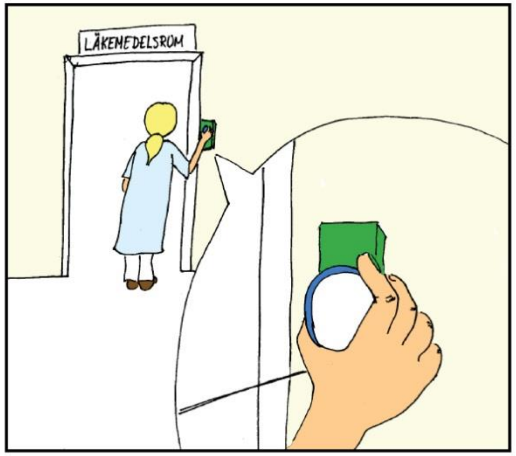
To unlock the medicine trolley Petra sweeps the watch over the unlock mark.



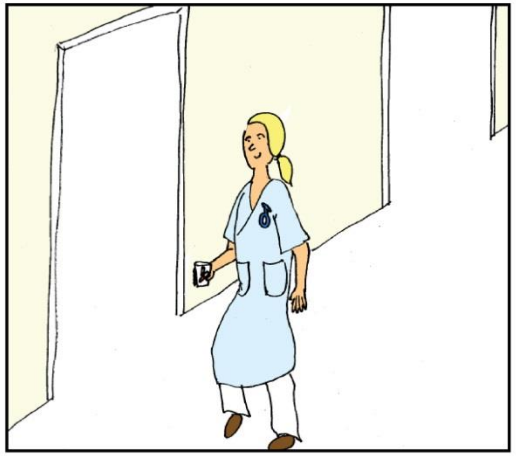
Anders box does not contain any medicine so Petra needs to go to the medicine room to get more.



When Petra leaves the medicine trolley, it is automatically locked along with the computer.



The door to the medicine room is unlocked in the same way as the computer, by placing the watch to the mark.



Now Petra can give Anders his medicine.

APPENDIX 7. DESIGN EVALUATION

Introductory questions

1. Which of the two models do you prefer holding in your hand?

The square	The round
7	4
Easier to push the buttons Because it is smaller than the round one	Slips out of the hand easier

2. Where on the body would you like to place the watch?

By the breast pocket	By the lower pocket on the jumper	By the pant pocket
5	5	1

3. Would you prefer an analogue or digital watch layout when the watch does not alarm?

Digital	Analogue
4	7
Easier to understand Like it more	

Placement of buttons

Two clay prototypes with marks as Figure 1 shows were given to the nurses that decided where they would like to place the emergency alarm button, the assistance alarm button and the mute and forward button. The result is presented in Figure 2, where the horizontal line represents buttons and the vertical line represents number of nurses. The buttons that were not chosen for any of the functions are not shown in the chart.

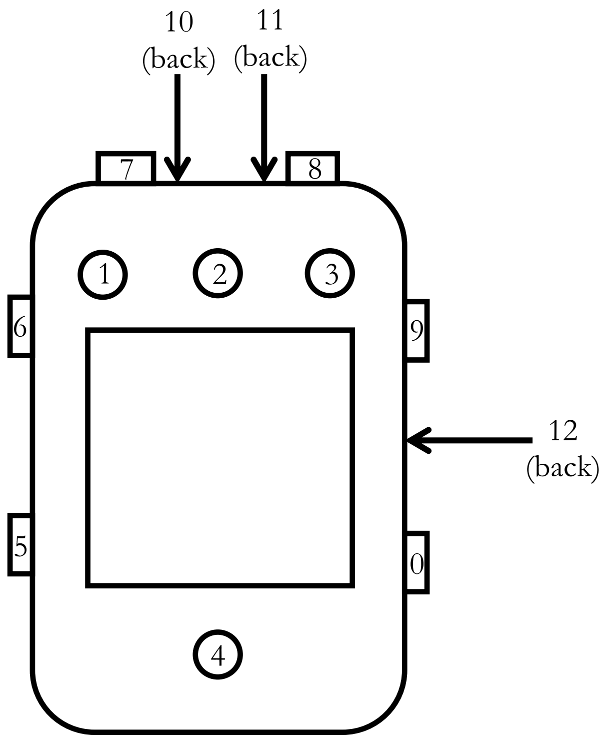


Figure 1. Illustration of the marked button placements.

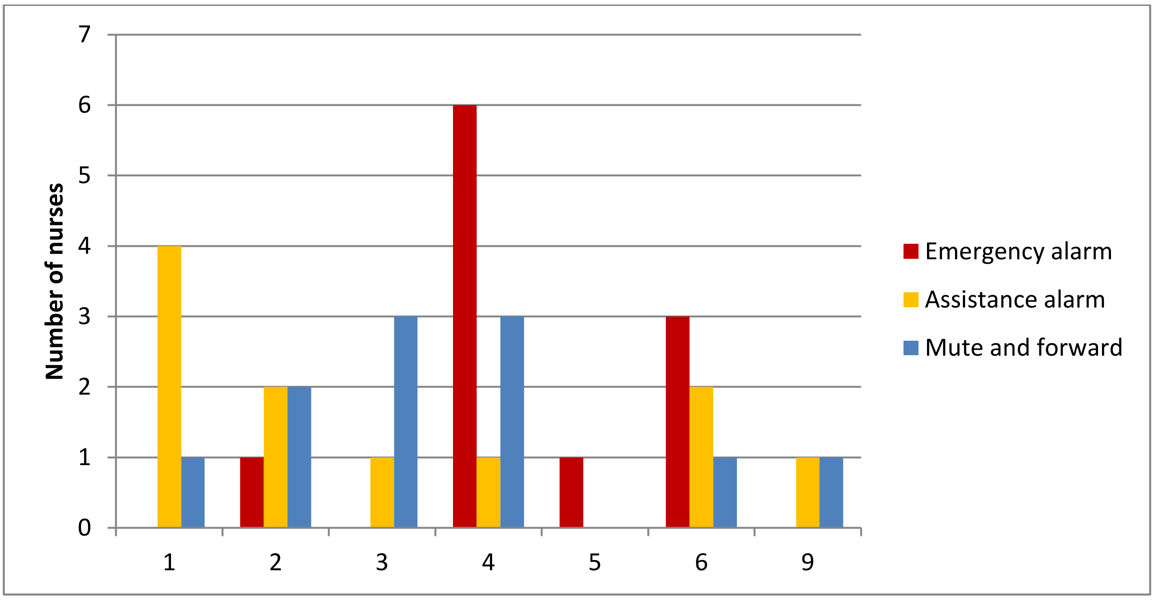
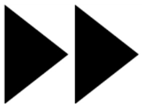


Figure 2. Placement of buttons preferred by 14 nurses.

Symbols

The symbols in Table 1 were shown to the nurses that pointed out their favorite symbol representing emergency alarm, assistance alarm and mute or forward. In Figure 3, 4 and 5 the preferred symbols are explained in separate charts. The symbols that received no votes and the different questions are not taken into the charts.

Table 1. The symbols showed for nurses for evaluation.

	1	2	3	4
A				
B				
C				
D				
E				
F				

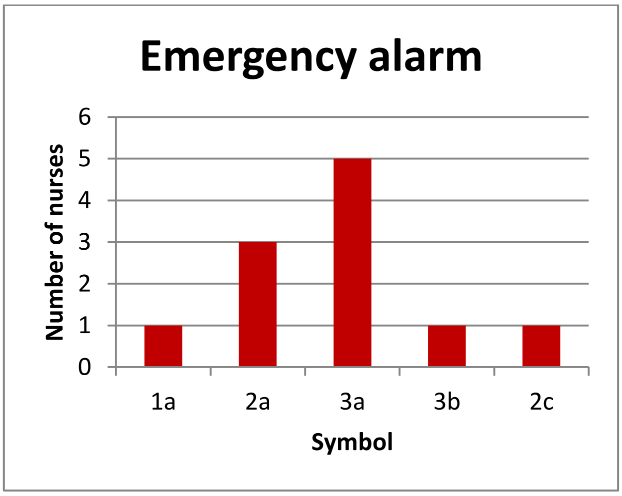


Figure 3. Result from the nurses being asked which symbol was preferred for emergency alarm.

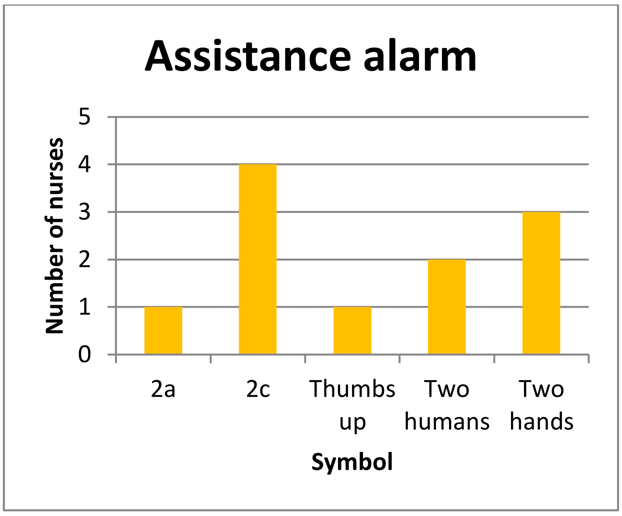


Figure 4. Result from the nurses being asked which symbol was preferred for assistance alarm.

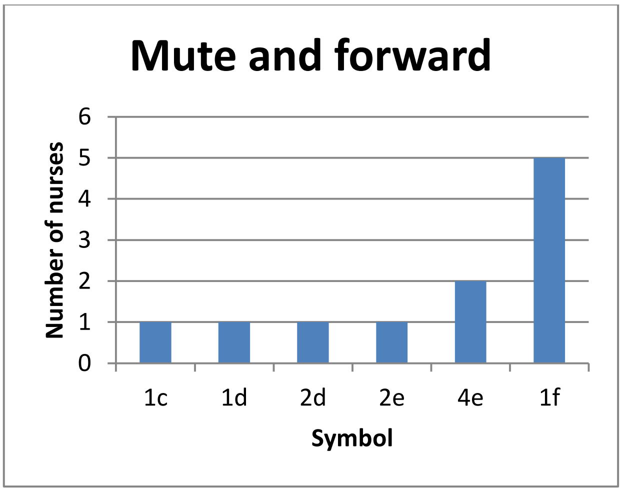


Figure 5. Result from the nurses being asked which symbol was preferred for muting and forwarding.

Colour associations

The nurses were asked which colours that were associated with emergency alarm, assistance alarm, mute and forward, and patient alarm. The result is presented in Figure 4.

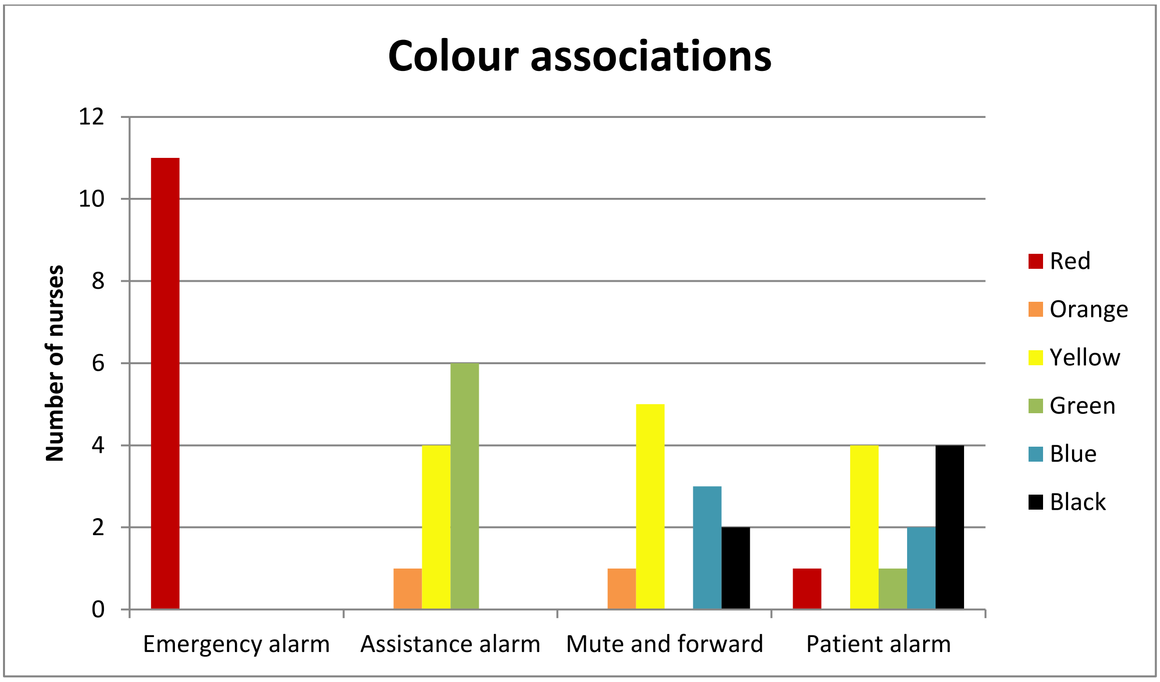


Figure 4. Result from colour associations by nurses.

APPENDIX 8. INTERFACE DESIGN