Designing web-mobile based solutions for monitoring heart signals

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Through the project I have received support and encouragement from multiple people, my gratitude and thanks go to:

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Abstract

Life changes due to heart signals complications affect a large part of the Norwegian population, indicating the need to monitor heart signals. There are medical indications, such as early symptoms of heart attacks, angina, and heart failure. As many as approximately 40 000 Norwegians annually receive specialist healthcare services related to heart attacks or angina and 16 000 for heart failure (Ariansen *et al.*, 2020). People also monitor themselves remotely because people want to track their behavior and workouts to get the best possible health benefits. For medical staff, this will result in many patients to keep track of, so they will also recognize the advantage of remote self-monitoring without the intermediate help of health personnel.

This project explored possibilities to realize patient self-monitoring, resulting in a prototype that could enable easy-to-use web and mobile solutions for remote heart monitoring. The development went through three design iterations using as the basis of the research conducted through the thesis. The prototype was created using the research of significant health themes, such as remote monitoring, interaction design in the health sector, usability, designing for age-appropriate groups, and development for both patients and physicians. There were conducted interviews with a medical expert and a technical expert to identify user needs. This way, the thesis could get an insight into the systems medical personnel would use it and what a day in their life looks like to establish requirements necessary for both the patient version of the prototype and the physician's side. The second contribution is a framework that presents five themes one needs to consider when creating an application for remote monitoring of health data. These themes are monitoring heart signals, health understanding, interaction design in the health sector, designing for age, web, and mobile solutions. Evaluations were conducted with usability experts and medical experts to measure usability and gather feedback on functions and design of the third, which was a high-fidelity iteration of the prototype. The evaluators gave positive feedback on the concept of creating an application that motivates remote heart monitoring results and their understanding, applying a System Usability Scale, and they graded the prototype with a score of 90 points which is deemed excellent. The medical experts gave the impression that they would welcome such solutions into their work domain if completing product development would involve additional medical staff and patients.

The thesis provides the foundation for future development of an application that promotes health understanding in remote heart monitoring with the indication of a need for such application.

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Abbreviations

SUS – System Usability Scale

PCG – Phonocardiogram

ECG - Electrocardiogram

NSD – Norwegian Center for Research Data

EC – Ethical Committee

1 Introduction

Life changes due to complication of heart signals affects a large part of the Norwegian population, therefore indicating needs for monitoring of heart signals. There are medical indications, such as early symptoms of heart attacks, angina, and heart failure. As many as approximately 40 000 Norwegians annually receive specialist healthcare services related to heart attacks or angina, and 16 000 for heart failure (Ariansen *et al.*, 2020). People also monitor themselves remotely because people want to track their behaviour and workouts to get the best possible health benefits. For medical staff, this will result in many patients to keep track of, so they will also recognize the advantage of remote self-monitoring without the intermediate help of health personnel. This master project covers the following topic: "Designing web-mobile solutions for monitoring heart signals." Heart signals could be monitored using specialized and sophisticated auscultation equipment and used to send the results to mobile phones or web applications. Mobile and web applications can show signal activity to help users determine what and when to monitor their hearts and receive info about when to contact medical personnel. Many patients struggle with basic instructions and information from their health personnel due to health literacy and strive to know what to do and how to interpret findings when they self-monitor. (Graham and Brookey, 2008) This project has explored different design functionality necessary for a health domain, both from patients' and health personnel perspectives. The project also explored different user experiences and how they help patients and health personnel. This project creates a high-fidelity prototype through various iterations for portraying heart signal data to explore the different user experiences. For validating the prototype, an empirical study was designed to evaluate and create the best user experience. The thesis aimed to develop the following contributions:

- Literature overview of the topics important for remote heart monitoring,
- Identifying user needs through an empirical study; two in depth semi-structured expert interviews,
- Set of user design techniques for monitoring heart signals,
- High fidelity prototype artifact to monitor heart signals developed through three iterations and validated by medical and it experts.

1.1.1 Research questions background

When addressing the theme "*Designing web-mobile solutions for monitoring heart signal*," there are three main areas the thesis covers. The first area is how design affects the understanding of the user's heart signal findings. This area is covered by researching how we should portray patients' health information to understand the information represented without losing the data's original meaning. This area's motivation is to create a practical solution, high readability, and understanding by its users, thus providing answers to which design considerations one must pay attention to in the health domain.

The second area to address is the predicament of web solution vs. mobile application. The thesis explored the possibilities, looking at strength and weaknesses of web and mobile versions of an application. There were conducted user studies and user testing techniques such as interviews, observation, and empirical testing to explore the different options with web vs. app in the health domain.

The third area that is important to cover in a self-monitoring situation is viewing it from a physician's point of view. The physician has an overview of the quality of the patient's self-monitoring. The thesis explores how physicians look at patient's monitoring results considering existing physician monitoring solutions and explore the systems through a literature overview.

1.1.2 Research Questions

RQ1) To what degree do user experience design affect a patient's understanding of heart monitoring results,

RQ2) To what degree do patients prefer web-based over mobile-based solution for monitoring heart signals,

RQ3) What are physicians' attitudes towards patient self-monitoring using mobile-based solutions

RQ4) Are there any systems developed for physicians for monitoring patients who monitor themselves.

2 **Theory**

This section covers the theory relevant for the web-mobile-based application that falls under the categories of health, application, solution, eHealth, and web-based products and the research questions' underlying ideas. The theory through the thesis consists of articles from the Web of Science and Google Scholar. The section categorizes the articles as follows: Monitoring heart signals, heart-related problems in Norway, Health understanding, mobile and web-based health solutions, interaction design in the health sector, and related work. The articles presented were found by the use of keywords such as "health," "eHealth-solutions," "health understanding," and "remote mobile monitoring health." Other articles found are either from respected web pages or trusted sources (*Web of Science [v.5.35] - Web of Science Core Collection Basic Search*, no date; *Google Scholar*, no date).

2.1 Monitoring Heart Signals

This project's work title is “Designing web-mobile-based solutions for monitoring heart signals”, and this section defines what monitoring heart signals means. The thesis introduces and creates an overview of the currently available methods of monitoring heart signals and exploring how it has changed with evolving medical technology. Medical personnel in hospitals measure a patient’s ECG, also known as an electrocardiogram, that record a heart’s rhythm and electrical activity (*EKG – Store medisinske leksikon*, no date). One can use ECG to detect arrhythmias, that is, unregular heartbeats, whether too fast, too slow, or just irregular (*EKG – Store medisinske leksikon*, no date). The ECG can also detect heart attacks, coronary heart disease, or cardiomyopathy. The ECG is measured using sensors placed on specific locations on the chest, and the test produces a highly detailed overview of the heart’s health.

The second method medical personnel can use when monitoring heart signals is recording a phonocardiogram, also known as PCG. A PCG recording is an electrical measurement of heart sounds, present in the heart cycles where certain sounds appear (Arnesen, 2021). One can obtain heart sounds with a stethoscope, a non-digital medical device (*stetoskop – Store medisinske leksikon*, no date). As with the ECG, stethoscopes are placed on specific points of the body to measure sounds made by the heart, lungs, or other intestines. The third method is the heart rate, which can be measured by counting heartbeats per minute.

Mobile phones have developed quickly in the last few decades, and their sensors within are more advanced than ever, thus creating opportunities for remote monitoring of heart signals. Majority of phones today have built-in sensors that can measure heart rate and oxygen levels using infrared light and the in-built camera. Some smartwatches measure the same vitals with ease, thus making monitoring of heart rate easier to conduct.

The ECG and PCG are usually measured with medical personnel's help, typically using heavy and expensive equipment at the hospital, making it impractical for people in need of regular and remote monitoring of heart signals. Luckily, remote solutions can be conducted at home as digital advancement has reached the medical equipment domain. An existing solution for this is Kardia, specified in Section 2.7.4 (*KardiaMobile 1L - ibeat.no*, no date). Stethoscopes have also joined the digital advancement with new and digital wireless stethoscopes that can measure the same vitals and send the data to an application on your mobile phone. An example of a digital stethoscope is the service StethoMe, which the thesis looked upon for inspiration when creating the prototype (*StethoMe® - Smart Stethoscope*, no date).

2.2 Heart-related problems in Norway

The primary motivation for this thesis's theme is the large number of people who are either affected or in close relation with someone with cardiovascular disease in Norway. As of 2016, 515 000 Norwegians in the age range of 0 to 74-year old have been in contact with a doctor or emergency clinic due to cardiovascular disease (Ariansen *et al.*, 2020). Even though this number is decreasing every year, there is still a need to find solutions that can decrease this number. Suppose one creates more digital solutions that can make it more available to monitor health from home. In that case, one can decrease the number of doctor and emergency clinic visits as one can filter the genuine cases from other health-related issues. The next step in this research was to create a prototype to help people who monitor remotely and, in that way, decrease the number of heart-related indications.

2.3 Health Understanding

When combing through relevant articles on Web of Science and Google Scholar, multiple articles had an underlying theme of health understanding or the lack of it within the health sector. The lack of understanding can be found in patient-physician communication when giving instructions or feedback from an examination or visit (Graham and Brookey, 2008). This understanding of medical conditions within the health sector is called health literacy. Graham and Brookey define health literacy as "*The degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions*" (Graham and Brookey, 2008). Graham highlights how literacy can go undetected in a health care setting and how severe the effects can be on patients with low reading fluency, as they might misinterpret important instructions from physicians. The authors suggest that physicians' written materials should be created in a patient-friendly manner, using simple words, bullet points, and much white space (Graham and Brookey, 2008).

Graham and Brookey are not the only researchers that have explored the problems surrounding health literacy. Wali and Grindrod explored the significant problems surrounding what low literate adults face. These concerns are limited time with pharmacists and less-to-none understanding of medication information, and more information regarding side effects and instructions. These concerns show a need for more simplified communication, similar to the conclusion from Graham and Brookey (Wali and Grindrod, 2016).

As we can see from both Graham and Brookey and Wali and Grindrod, a lack of understanding needs to be addressed, but how can one approach this problem? Choudhry et al., did it through a qualitative study where they explored whether doctors write trauma discharge summaries at a higher readability level than recommended. Choudhry et al. provided the solution that the discharge notes are too advanced and that doctors' letters should be in a way that a 6th grader should understand them (Choudhry *et al.*, 2016).

2.4 Mobile and web-based health solutions

The second category of articles is related to mobile health solutions. As stated in the research question, the goal is to explore mobile and web-based health application solutions' preferences. The articles collected are studies that use different mobile and web-based health solutions to help patients self-monitor or aid in hospital visits. A question that arises when one thinks of mobile and web-based solutions in the health domain is how efficient they are as compared to standard routine solutions. Gomis et al. explore the impact of mobile health in heart transplant management using a tool called mHeart. The authors compared pharmaceutical interventions' effectiveness through the mHeart tool versus regular pharmaceutical intervention without the tool. The conclusion showed that the effectiveness increased with the tool's use, as it allowed for more supervision and personalized follow-up (Gomis *et al.*, 2019).

This efficiency of patients' remote supervision has also been explored in the adaptability study by Park et al.. They explored the feasibility of using digital health monitoring in a home setting and evaluated the impact over a specific period of time. The researchers found a need for an effective remote monitoring system following heart failure patients who have been discharged from the hospital (Park *et al.*, 2019). Thus showing the lack of an efficient remote mobile monitoring system in the health sector.

Using mobile and web-based health solutions to help patients self-monitor and aid in hospital visits are only a few options one can use such technological solutions. One can also use these remote monitoring devices to conduct randomized health trials explored by Reed et al.. Reed et al. present the potential of removing the need to meet in person as one can measure with a phone, thus making it more randomized (Reed *et al.*, 2018). Bhavnani et al. have also researched this in 2018 suggesting that one can reduce time at the hospital by accessing data through a mobile health device (Bhavnani *et al.*, 2018). The results shown in the trial are that the patients using the mHealth solution were associated with a lower risk of hospitalization and death on follow-ups, as one could detect underlying health problems due to self-monitoring.

The articles listed until now only cover mobile-based solutions, but Lloyd et al. have researched the possibility of a heart assistant that is a web-based application. This web-based application was used by heart failure patients who needed a follow-up after being discharged from the hospital. Lloyd et al. conclude their study suggesting that mobile technology is feasible, acceptable, and a possible cost-effective opportunity to manage heart failure patients’ homes (Lloyd *et al.*, 2019). This application is only for the purpose of the physicians who follow up a discharged patient, not for showing the results to the patient, as well as a lack of focus on understanding results from a patient’s view. This article provides proof of the need for both a web and mobile-based solutions as physicians might need a more advanced view of the collected data, and patients need their view with personalized information.

Mobile and web-based applications show great promise, but one can ask, how reliable and efficient are they in practice? In a prospective study by Tayfur and Afacan in 2019, the authors evaluated heart rate accuracy and collected oxygen saturation data using a smartphone. They could conclude that using a smartphone for measuring gave consistent results compared to the other measurement devices, showing equally good performance using both methods (Tayfur and Afacan, 2019). Using a smartphone for this type of vital measurement will create an opportunity for future patients, who can assess themselves at home before arriving at a hospital, thus skipping a step that can save time for patients and hospital personnel. Gropler et al. measured the accuracy of interval measurements on the Kardia Mobile device. The authors found that the mobile device produces accurate, single-led ECG tracing, showing that measurement devices on the market for mHealth are promising for the future (Gropler *et al.*, 2018).

Using health applications regarding physician-patient communication is in its early stages but shows great promise, so the question is how does it affect everyday life? Lorca-Cabrera et al. explore the effectiveness of health web- and mobile app-based interventions regarding the level of well-being and quality of life. Their findings show that the health web-based intervention in informal caregivers mainly affects welfare. However, one should be conducting more studies to explore mobile app-based interventions to examine their effectiveness (Lorca-Cabrera *et al.*, 2020). One can argue from the Lorca-Cabrera article that more studies should be conducted, but incorporating this gadget can give health care workers a more efficient way of remote observation. Specifically regarding pulse and temperature, bridging the gap between patients and specialists while being remote from hospitals (Andrews, Raja and Shanmugasundaram, 2019).

An essential key point to consider when creating web- and mobile solutions in the health sector is the different age groups. Children are not accustomed to doctors' appointments and measuring health data, making it challenging to monitor heart signals at home. In a study by Ho et al., the authors focused on measuring children's pulse rates with a mobile application. They concluded that the apps should not replace routine medical use, as children might create inaccurate results. Note that this article is from 2014, and technology has made advancements in the mobile application domain, however it is essential to consider findings of this study (Ho *et al.*, 2014).

2.5 Interaction Design in the health sector

In this section, there is a collection of articles regarding interaction design and web- and mobile solutions in the health domain. Visual and interaction design themes can be different from regular applications than health applications, as explored by Falchuk, who explores different healthcare applications and identified overarching themes to mobile healthcare services (Falchuk, 2009). Falchuk explores interaction techniques that use the human-computer interaction interface to encourage movement and activity and use graphics to improve medical information understanding. The article collected a few broad interaction design themes one should consider when designing for healthcare (Falchuk, 2009):

- Designing for a range of novel and familiar interfaces,
- Designing to encourage physical and mental activity,
- Designing for the simple conveyance of health information.

Modern applications usually have both a mobile and web-based solution so users can interact and change between devices, but for health care applications, are there any underlying preferences? Preferences of mobile vs. web-based applications in the health domain are explored by Selvarajah et al. in the article “Native apps versus web apps.” The authors compare mobile app and web application design alternatives when using an in vitro fertilization treatment. The authors had some factors they used to compare the other options. The pre-defined elements were user interface, ease of development, capabilities, performance, cost, and potential problems (Selvarajah *et al.*, 2013). A takeback from this is that creating a reliable website that can work across multiple platforms costs less than creating numerous applications for different devices. In conclusion, if one has the time and budget, a web application should be the most cost-effective solution if the software is capable to process the information in a timely manner.

2.6 Related Work

Monitoring heart signals are not a new concept, and there are years of research using both mobile and web-based application to monitor health. It is essential to look for similar work to create the best possible solution. Al-Omary and Elmedany introduce a system architecture to monitor heart disease in real-time as they extract signals from patients and store signals into a hospital database (Al-Omary and Elmedany, 2007). They have an application on the phone with a few functions and services, such as schedule, condition, relevant information, and general information. It also has an event detection system where the hospital can warn the patient if it detects something abnormal.

The articles reviewed have little-to-none information about what kind of functions one should implement in an application that remotely monitors heart signals. Therefore, the thesis explores the article "*Determining minimum set of features for diabetes mobile apps*" by Safari et al. (Salari *et al.*, 2019). Even though the article is not directly about monitoring heart signals, one can take inspiration from the functions as it is comparable with regard to frequency and demands of monitoring. The study produced a set of 23 minimum features, here we are presenting only those that are relevant for this research:

- **Blood Glucose Tracking**: can be translated to heart signal tracking.
- **Educational Material:** Information about the heart signal results and other information relevant to the heart-problems.
- **Reminder:** reminder of when to monitor heart signals.
- **Alert:** Alert both the physician and patient that something is abnormal in the tracking of the heart signal.
- **Reducing Risk:** Information of what the patient can do to keep the heart healthy
- **Medication tracking:** when they take medication for heart problems.
- **Trend chart view:** systematic overview of results of tracking.
- **Logbook view:** To look at earlier tracking dates.
- **Messaging:** Possibility of messaging physician or other medical personnel or providing contact information.
- **Colour coding:** Considering different user groups, different layouts and colours could be designed.
- **Customizable theme:** Themes can be important to highlight relevant information and relating to different age groups.

2.7 Similar Services and Products

This section covers other existing solutions in remote health monitoring and consumer services. The collected services are health-related products found in the app store and the google play store (*App Store - Apple*, no date; *Google Play*, no date). Related products are either services or applications available for free use, eHealth related and available in Norway.

2.7.1 Helse Norge

In Norway, we have helsenorge.no as an online public health care platform for information and health services. The service is provided by "Norsk helsenett" which collects different organizations in the Norwegian health sector. On Helse Norge, one can get doctor appointments and request renewal of prescribed medicine, insight in a patient journal, and information about Norway's current health situation. It does not offer real-time health information except details in an online medical journal, but the journal is updated after visiting a doctor (*Helsenorge – din helse på nett - helsenorge.no*, no date).

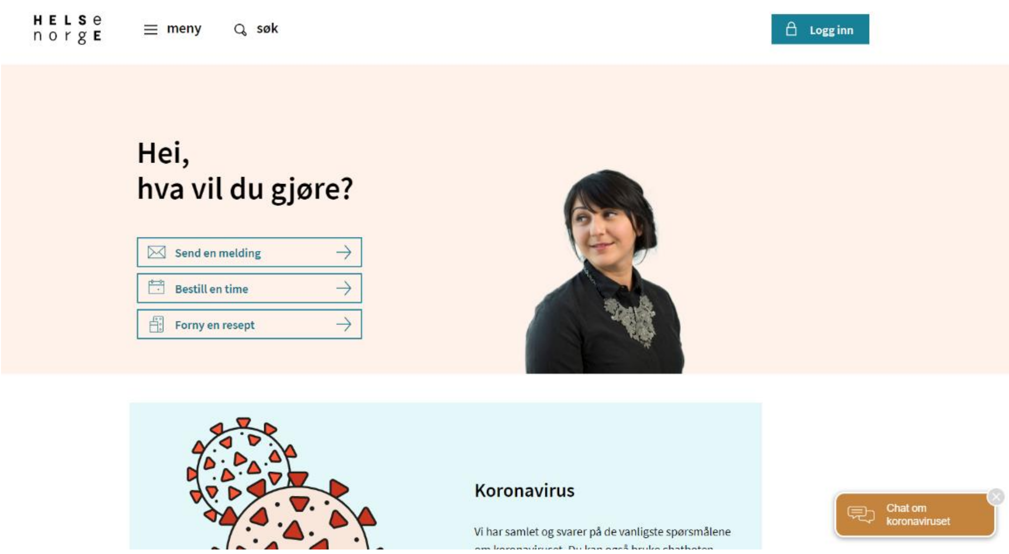

Figure 1: Frontpage of helsenorge from 30.09.20

2.7.2 Samsung Health

Samsung Health is an application available at both the app store and google play to monitor aspects of one's daily routines and contribute to physical health, diet, and sleep (*Samsung Health*, no date). It tracks movement, pulse, and allows user to register workouts and food intake. It provides a basic interface, as shown in Figure 2: Samsung Health Interface, with a view of steps and options to compete against other people using the same application. It uses the card type of interface, where all information is shown on a small card or card section. The application provides a clean and simple combination of white and gray colours and highlights the essential functions with green hues. It also provides a card-based overview of the other health routines, such as pulse, stress level, and others. The interface is easy to use for most application users. This application is aimed at improving lifestyle and less for health monitoring.

Figure 2: Samsung Health Interface

2.7.3 Glucose Buddy Diabetes Tracker

Glucose buddy diabetes tracker is an application that offers a function to help manage tracking of blood sugar, A1C, medication, blood pressure, and other health-related information (*Glucose Buddy Diabetes Tracker - Apps on Google Play*, no date). The tracker is an example of something that tracks more health-specific rather than fitness-focused. It provides a more complicated user interface than Samsung health. It has advanced health-tracking functions and uses more buttons and colours to show the difference between the available services. It seems like it has a steep learning curve from screenshots to start using it, as this might be too complicated for patients who are not familiar with mobile interfaces. It can connect to a third-party tracker of glucose levels, so one does not have to enter information manually. This application and many more serve as an inspiration for functions and design choices for apps that help remote monitoring of health.

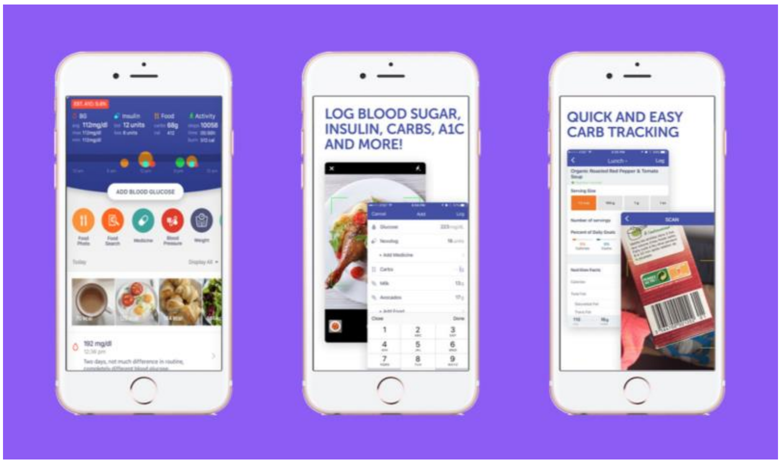

Figure 3: Glucose Buddy

2.7.4 Kardia

Kardia is a mobile application that helps to keep track of ECG - also known as electrocardiography. One can use the application for detecting atrial fibrillation, unnormal slow pulse, unnormal fast pulse, or regular pulse (*Hjem - ibeat.no*, no date). Additional to the application, there is a small trackpad electrode that one needs to buy to use the app - as seen in Figure 4. The application has few but simple functions, and the functions listed are tracking and showing ECG. The design is also effortless and clean - as seen from screenshots, but the application lacks features. This application's design choices are present to keep it clean and straightforward with no additional information a regular patient would need in a remote measuring situation. The design choices and content might be lacking vital information of interest for medical personnel.

Figure 4: KardiaMobile 1L

2.7.5 Electronic Stethoscope

Heart signals are captured by using electronic stethoscopes that are placed on measuring points on the body which are described to patients who can remote self-monitor. There are multiple options online to purchase such an equipment that has passed clinical testing and has documented technical features. Recorded signals can be sent using wireless technology. Examples of electronic stethoscopes are shown in Figure 5 (*Buy Electronic Stethoscope Model 3200 online - DocCheck Shop*, no date; *StethoMe® - Smart Stethoscope*, no date).

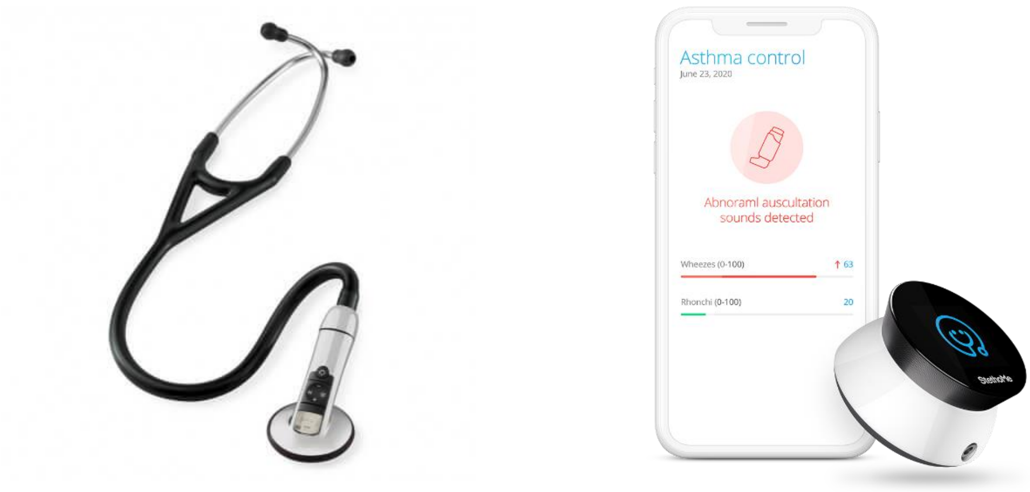

Figure 5: Electronic Stethoscope

2.8 Clinical Trials

Researchers have explored the options of using mobile phone applications to measure heart signals through multiple clinical trials. An example of this can be found in "*Cardiac auscultation using smartphones: a pilot study*" (Kang *et al.*, 2018). In this proof-of-concept study, they used Samsung and LG phones to measure heart sounds by auscultating the chest wall's skin. "*HEARt Sounds: Audio Recordings to Improve Discharge Communication for Cardiology Inpatients*" (Schott *et al.*, 2019) is another clinical trial where they measured the feasibility of audio recording to improve the discharge of cardiology patients. They showed the potential of using smartphones in clinical studies and proof of the concept of remote measuring of heart signals.

3 Research Methods and Methodologies

This section presents the different research methods and methodologies used in the thesis, consisting of research around design science research framework, data gathering, and prototype evaluation.

3.1 Design Science Research

The design science research discipline followed in this thesis is based on “Design Science in information systems research” by Hevner et al. (Hevner *et al.*, 2004), who note two different research paradigms. This thesis will follow only one of them; Design Science, that *“seeks to extend the boundaries of human and organizational capabilities by creating new and* *innovative artifacts"* (Hevner *et al.*, 2004). Hevner et al. established seven guidelines for this type of paradigm, and the following sections present those guidelines and how they apply to this thesis.

3.2 Design as an artefact

The first guideline is "design as an artefact", as Hevner et al. note, "*Design-science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation"* (Hevner *et al.*, 2004). For this thesis, the contribution will be an interactive mobile and web application created as a prototype to be tested by relevant stakeholders and user groups. The artefact goes through three design iterations ranging from low to high fidelity prototypes. The product is a semi-interactive prototype with no actual data but serves the purpose of proof of concept. Using real medical data would demand additional ethical approvals and resources, that could not be available within the timeframe of a master research project. The technical aspects of using an application to measure health data have been done before but not focusing on the understanding of data received through such services.

3.3 Problem Relevance

The second guideline is the problem relevance, which is defined as *"The objective of design-science research is to develop technology-based solutions to important and relevant business problems."* (Hevner *et al.*, 2004). This guideline should highlight the current state of the problem and address what could be solved with the artifact. In this thesis, the current state of the problem is the lack of understanding of potential remote monitoring results, and missing opportunities and advantages of remote cardiac monitoring. The artifact's goal is to show proof of concept through a prototype and show the research of remote monitoring opportunities with today's technology through research, as shown in Section 3: **Theory**. The problem relevance can also be highlighted by exploring stakeholders, creating personas, and showing scenarios, as those portray the goals and motivations.

3.3.1 Stakeholders

It is important to identify stakeholders of the prototypes, and especially primary users. Stakeholders for this thesis are health personnel who will monitor patients remotely and help them with this mobile-web application. The second stakeholders are the patients who will monitor themselves using mobile web applications. The last potential stakeholder is a family member of patients who will be helping the patient self-monitor. Additional stakeholders can be found in the form of insurance agencies, health systems and society at large.

3.3.2 Personas

In this section, the thesis presents personas to conceptualize stakeholders. Preece, Rogers, and Sharp define personas as detailed descriptions of the application's typical users (Preece, Rogers and Sharp, 2015). The personas are created in AdobeXD, and the pictures of the people are retrieved from *thispersondoesnotexist* to create randomized personas (*Adobe XD | Fast & Powerful UI/UX Design & Collaboration Tool*, no date; *This Person Does Not Exist*, no date).

The four personas in this section are a young technical nurse, an older patient, the mother of a younger patient, and an older cardiologist. The personas fulfil the list of potential stakeholders, thus presenting realistic potential users of the prototype.

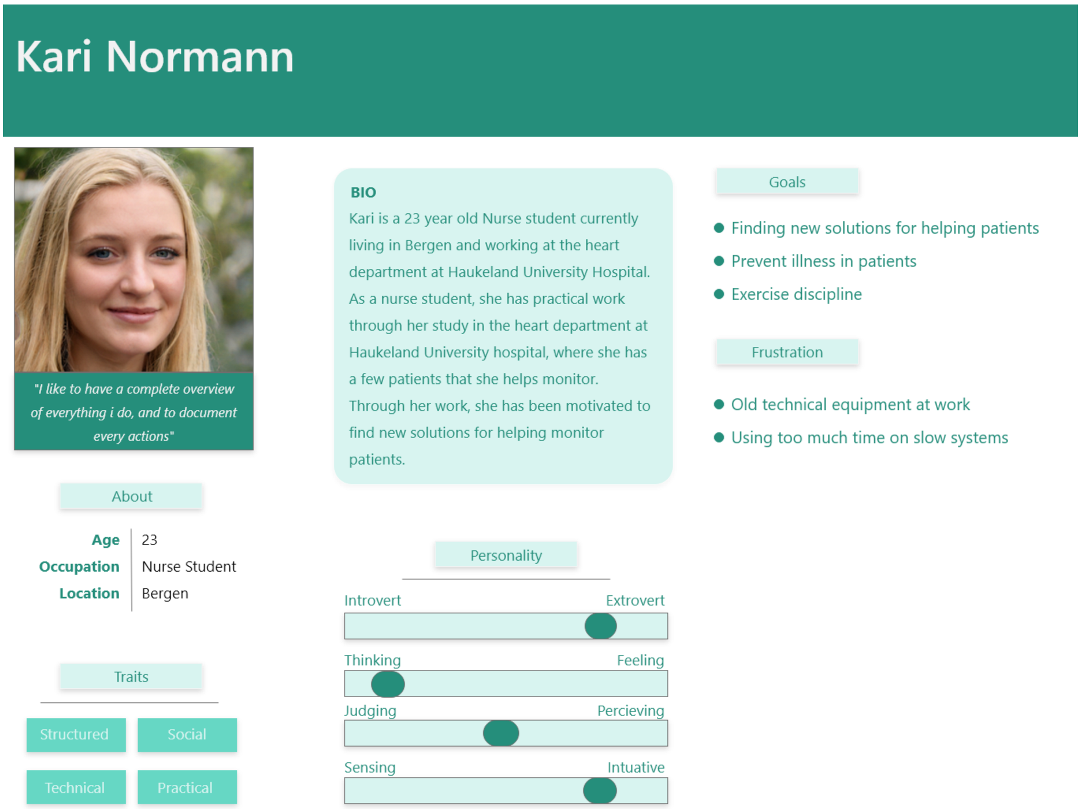

Figure 6: Persona 1, Young Nurse

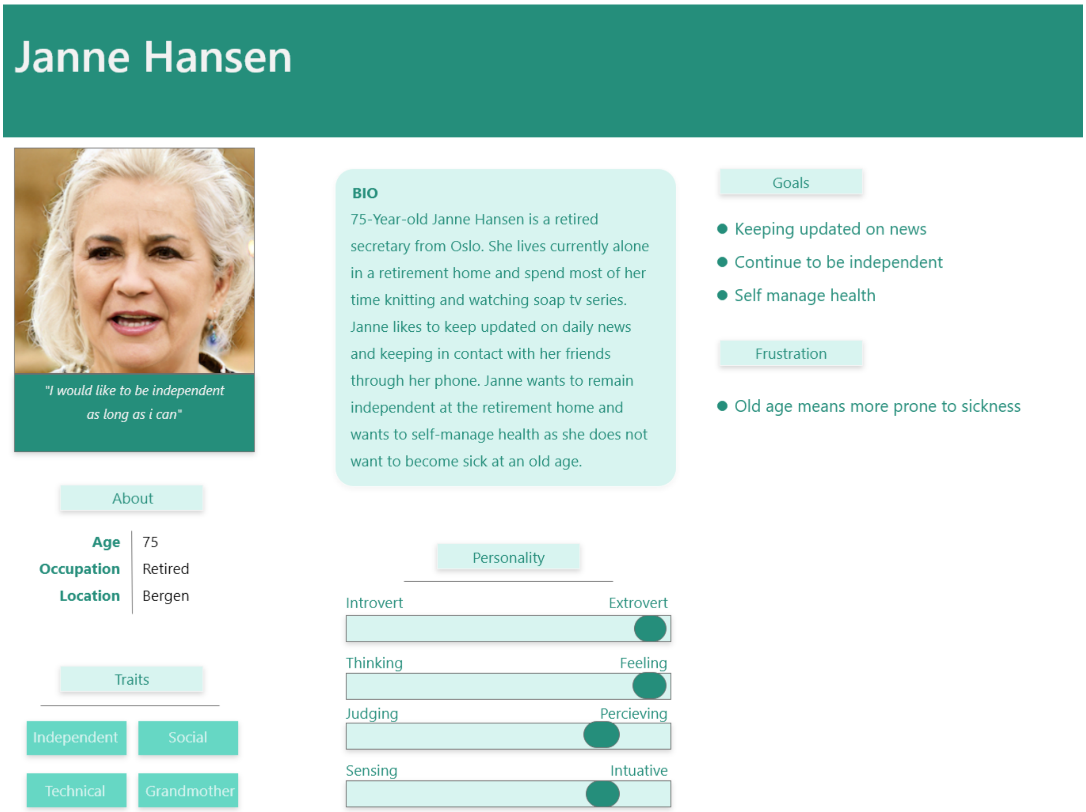

Figure 7: Persona, old patient

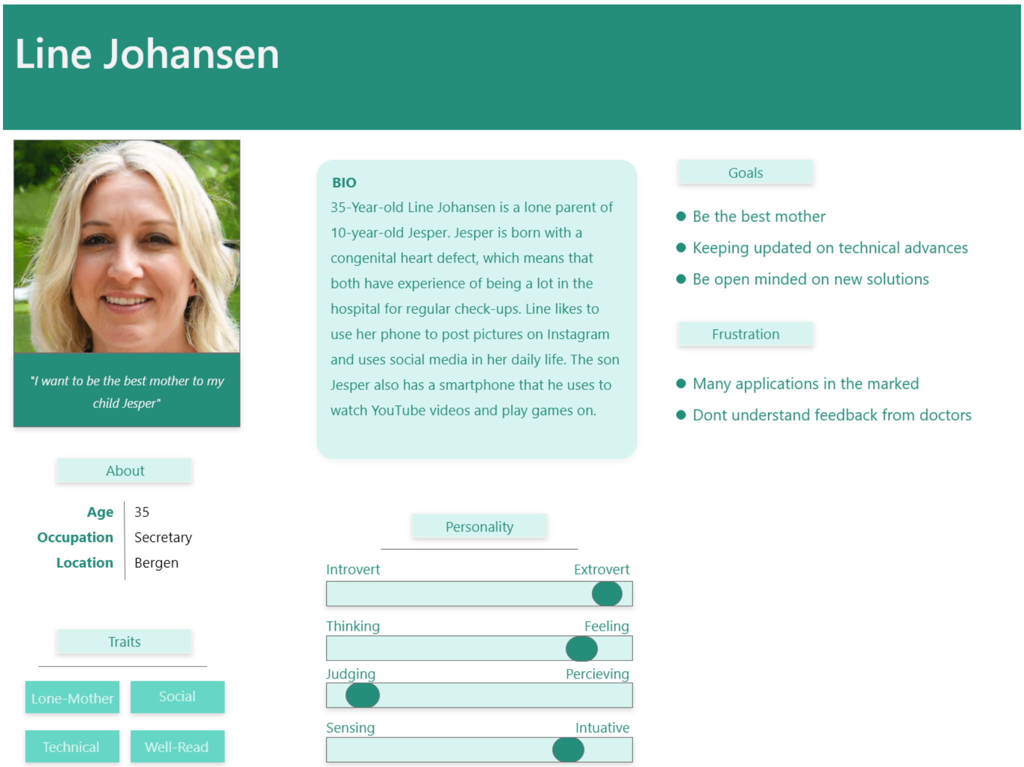

Figure 8: Persona, parent of young patient

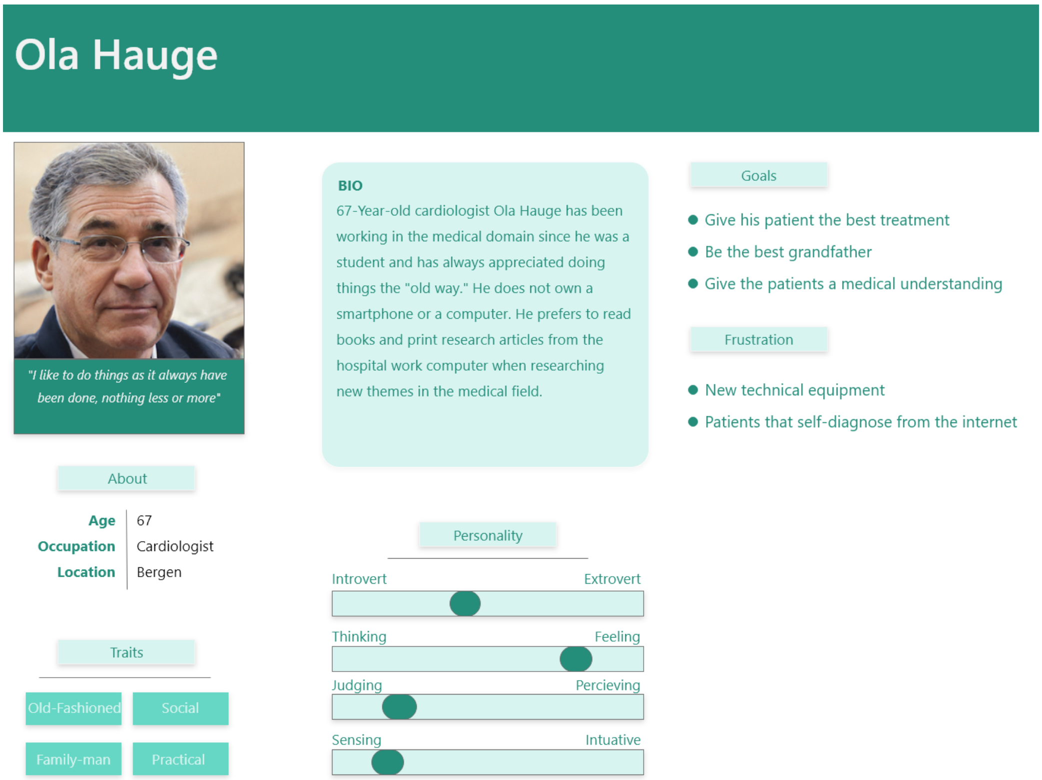

Figure 9: Persona, Old Cardiologist

3.3.3 Scenarios

In this section, the thesis uses scenarios to portray an informal story about user tasks and activity (Preece, Rogers and Sharp, 2015). Scenarios can have multiple uses depending on the need. For example, one can be incorporating scenarios in scripts for user evaluation of prototypes or the basis for storyboarding (Preece, Rogers and Sharp, 2015). In these scenarios, the people used are from the personas section—the motivation for the application presented through two different stakeholders. The first scenario is the motivation of use from the patient's perspective, and the second is from a medical personnel's perspective. The third is from a young patient with a mother who helps him/her self-monitor.

3.3.3.1 Scenario 1: Motivation for use for patients

The 75-year-old Janne has experienced complications due to her heart. She has been staying at the local hospital for observations and is ready to be discharged home. Janne is very independent, and she wishes to monitor herself remotely from her retirement home when she is discharged from the hospital. The health personnel helps her create a user profile before she is discharged and shows her the necessary instructions on registering heart signals and how to use the application. She is very independent and thrilled with this solution that allows her to leave the hospital, to enjoy life at home.

As she gets back to her retirement home and the time for monitor remotely is there. She takes the instruments needed for monitoring heart signals and connects them to her phone. She opens the application on the phone and chooses the option that she is a patient. Then she fills in the login prompt and the extra security measures. As she is logging in, it presents her with a simple dashboard with big buttons and a few technical details. She looks for a button that is called register and finds it and clicks it. The button activates her heart monitor instruments, and the web application tells her that one of the devices is not correctly placed. She places it successfully as the application tells her how to, and the signals are monitored and saved automatically in the app. As she finishes the recording session, she sees the information indicating that everything is as it should be and a time is given to her for the next recording session. It is also possible to look more into the results if she wants to. However, she removes the measurement instruments and clicks the log-off button in the application.

3.3.3.2 Scenario 2: Motivations of use for Medical Personnel

The 23-year-old nurse student Kari is in the middle of her practical work in the cardiac department at Haukeland University Hospital in Bergen. She has recently gotten a new patient to help monitor as they are discharged from the hospital after a stay due to a heart-related complications. Kari is interested in trying new IT solutions; she and the patient will try a new application to monitor her remotely after being discharged. When the patient is registering heart signals remotely to the applications, the information can be generated into a QR code. Kari can scan it next time the patient visits for a consultation.

Kari wants to log in and scan the QR code as the patient is back for a consultation. As Kari is a health personnel, she chooses that option and continues to a login page that prompts her to use her login credentials. As this is a safe application, there are extra security measures when Kari logs in, a dashboard greets her with a basic overview of different information. There is a button called the register QR code. When she clicks this, her camera starts and gets the patient to generate the QR code, and then she scans it. She can see the vital heart signal information that the patient has remotely tracked and uploaded to the application. She understands that everything looks good, or else she would have gotten a notification that her data would need to be checked out. As nothing is wrong, she locates the log-off button and leaves the website.

3.3.3.3 Scenario 3: Parent who helps a young patient measure heart signals

The 35-year-old Line and 10-year-old Jesper are at a routine check at Jesper’s cardiologist Ola. Ola is in a group of doctors who will test out remote measuring of heart signals with their patients to reduce time spent at the hospital which is specifically difficult for patients with long term illness. Line and Jesper are familiar with using mobile phones in their daily lives, and they agree to join the testing of the mobile measurement tool. Jesper is too young to have a user due to the security of the data, and they will create a parent user for Jesper, so Line has the application on her phone. When they are at home to test out the new measurement tool, Line logs in with her credentials. She logs in with a parent user, as she is the parent and not the one who is measured. Greeting her with the dashboard, she decides to register data. Then she helps Jesper to connect with the measurement device to the phone and starts to log data. When the recording is completed and the results are processed, they are displayed. They are both familiar with medical expressions through years of routine checks, and Line chooses to see an advanced version of the results. When she is done looking at the results, she logs off the application.

3.4 Design Evaluation

The following guideline is design evaluation, defined as *“The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods.”* (Hevner *et al.*, 2004). The prototype development will follow multiple iterations and needs to take principles and goals into consideration. The prototype follows a set of design principles, as well as a set of usability goals. Using these principles when developing prototypes ensures the best user experience and catering to the stakeholders' best usability.

3.4.1 Design Principles

The thesis follows the design principles when creating the prototype as written in *Interaction Design: Beyond human-computer interaction* (Preece, Rogers and Sharp, 2015). Using the principles helps create the prototype, to secure the best design for a better user experience. The principles are listed as following:

Visibility: Health literacy is a strong theme in the master thesis, it follows the visibility principle, as it is essential to give instructions through design. For example, the function required to start measuring heart signals should be easy to find for the users and highlight essential tasks for users to complete when measuring, e.g., providing measuring instructions.

Feedback: The second principle followed is feedback, as it is essential to give the user feedback when interacting with the prototype. For example, if they do something wrong when measuring, they will get feedback on how to correct errors. After measuring, they will receive feedback on what to do next either through messages or visual cues.

Constraints: The third principle is constraints. It is essential to implement constraints in the design when there are multiple stakeholders from different age groups. They should only have access to the functions they should be able to do. For example, when they are registering and measuring, there is a submit button with colour which should be grey to indicate that data is not ready for submission yet.

Consistency: The fourth principle is fundamental when it comes to applications with semi-advanced functions such as this. It is essential to keep the design choice consistent as it can be difficult to navigate new applications. Colours should repeat themselves, as well as button functions should be the same throughout the application. Windows that are highlighted are essential, and if something is red, it should mean the same through the whole application.
Affordance: Fifth and final principle is about how a function or an attribute that the design suggests to users what could be done. A button invites clicking, the x button should exit an action, and the floppy disk symbol gives the user possibility of saving progress.

3.4.2 Usability Goals

Usability is a large part of the research questions, making it important to incorporate it when working through the prototype iterations. The goals pursued are from the book *Interaction Design: Beyond human-computer interaction* (Preece, Rogers and Sharp, 2015). The goals are to ensure that the interactive prototype is easy to learn, effective to use, and enjoyable from the user's perspective (Preece, Rogers and Sharp, 2015). The goals are as followed:

- Effective to use
- Efficient to use
- Safe to use
- Having good utility
- Easy to learn
- Easy to remember how to use

3.5 Research Contributions

The definition of research contributions is as follows: *“Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.”* (Hevner *et al.*, 2004). This guideline concerns what kind of contribution this thesis will create, and it will be in the form of a design artifact and data gathered from the interviews, observation, and evaluation.

3.6 Research Rigor

The definition of research rigor guideline is *“Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.”* (Hevner *et al.*, 2004). The thesis used multiple data gathering methods and followed the design evaluation considerations for creating the prototype. The thesis conducted multiple methods of evaluation to evaluate the design of the artefact.

3.6.1 Data Gathering

The thesis utilized different methods of data gathering. The data gathering methods used in this thesis are semi-structured interviews, observation, and evaluation.

3.6.1.1 Semi-structured interviews

In the interview part of the data gathering, the main goal is to be interviewing relevant stakeholders to gather the information for developing the mobile and web application. One of the motivations for conducting the interviews is to map how a patient is familiar with medical concepts that concern them and their health and to what degree they understand their usual go-to medical personnel contact. This motivation was not possible to complete in this thesis and is elaborated in Section 7.4. The second motivation for conducting interviews with patients is to gather information about health applications they might use and their technical knowledge. From the physician’s side of the interview, the primary motivation is to gather functional suggestions from their side and ask about medical and technical limitations and application suggestions. The third motivation is to get feedback from technical experts regarding the different goals presented in the previous section.

3.6.1.2 Observation

Observation is the second primary data gathering method during this thesis and conducting observation on technical and medical experts. The observation was conducted through Zoom due to limitations of the coronavirus at the time of this project. The purpose of the observation is to get an insight into what kind of medical equipment physicians use to monitor heart signals and the data the equipment produces. Observing physicians will help gain an overview of existing equipment and functions. Observing technical experts shows how they are using the application iterations following simple instructions.

3.6.2 Evaluation

Through the course of the thesis, variations of evaluations of the prototype were conducted using experts. Usability testing was conducted on all the prototypes and heuristic evaluations on the high-fidelity and fully functional prototype. System Usability Scale (SUS) was used to check the user-friendliness of the prototype.

3.6.2.1 Usability testing

Usability testing involves representative users performing tasks in relevant environments on prototypes (Lazar, Feng and Hochheiser, 2017). The usability test aims to improve the usability of a prototype or evaluate the interface's quality by finding flaws. For this thesis, a usability test would look at how stakeholders interact with the web-mobile application and look for features to improve. Usability testing usually consists of a controlled setting involving users (Preece, Rogers and Sharp, 2015). The thesis defines questions and tasks to be completed by the participants in order to conduct usability testing.

3.6.2.2 Heuristic Evaluation

Heuristic evaluation is a type of usability testing by Nielsen (Preece, Rogers and Sharp, 2015). The group of experts is guided by a set of usability principles that are also known as heuristics. The experts, in this case, would be stakeholders who will be using the system in a routine practice, in addition there are also experts in usability testing. Each stakeholder conducted heuristic evaluation after interacting with the artefact.

The set of heuristics are defined as Nielsen's Heuristics and contains the following principles (‘Heuristic Evaluations and Expert Reviews’):

Visibility of system status: The expert evaluates the system on how good it is to keep users informed about what is going on through feedback. The user receives feedback when interacting with the prototype with visual cues. If a measurement was conducted incorrectly, the system should inform the user about the reason.

Match between system and the real world is about how well the system speaks the user's language in a way that the user should recognize real-world elements in the system and can use the system based on those elements. Icons should represent the real-world counterpart, thus making it easier to learn.

User control and freedom: a user should be given the support to redo and undo mistakes. User control and freedom can be completed through navigational freedom or to abandon a measuring session when needed.

Consistency and standards: the application must have a consistent design and follow specific rules as other apps do. For example, a hamburger menu should always reveal more menu elements.

Error prevention*:* if the user is doing something wrong, a feedback should be given to prevent the error from occurring in the first place. For example, if a sensor placement is incorrect, they should get information on how to fix it.

Recognition rather than recall*:* This heuristic is one of the most important ones in this project, as most of the user group of the prototype could be older people. This principle is about having functions visible and making them easy to navigate. The instructions should be visible and easy to remember.

Flexibility and efficiency of use*:* This heuristic is about creating less unnecessary processes in the prototype. Allow users to tailor frequent actions and operations can be shown with a dashboard, where most used functions are visible and in front.

Aesthetic and minimalist design: The design should not contain much unnecessary clutter and non-essential functions. Keep the design clean and straightforward, thus making it understandable for all age groups within the prototype user group.

Help users recognize, diagnose, and recover from errors*:* If the user has managed to find a non-functional part of the application, it should provide an easily readable error message and recover from the page.

Help and documentation*:* The app should also have a place to get help and read about frequently asked questions. This also means specific functions in the app, not only general solutions.

3.6.2.3 System Usability Scale

System Usability Scale is also known as the SUS tool, a reliable tool for measuring a system's usability (‘System Usability Scale (SUS)’, 2013). The usability test consists of 10 questions, with five answer options ranging from strongly agree to disagree and is given to users who have explored or used the system. The score ranges from 0 to 4, where all scores are summed and multiplied by 2.5 (Brooke, no date). The more extensive scale goes from 0 to 100. A score from 0-50 is deemed “not acceptable” with a too low usability score to be fully functional. A score between 50-60 is marginally low, and 60 to 70 is marginally high. All scores above 70 are classified as acceptable, where 100 is the best imaginable.

3.7 Design as a search Process

The sixth guideline is "design as a search process" and is defined as *"The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment."* (Hevner *et al.*, 2004). To develop a health application, one must consider legal considerations, as Norway has already established strict health laws. In this section, the thesis presents a collection of Norwegian laws that one must consider when creating a prototype such as this. Many technical solutions could be considered, but following the law is essential, as developing functionality that can be deemed problematic by law is of no value.

3.7.1 Act on health registers and processing of health information

Act on health registers and processing of health information (Lov om helseregistre og behandling av helseopplysninger (helseregisterloven)) (Helseregisterloven, 1999). This law covers how one can gather and use health information to improve health services, as the processing of the data must preserve privacy policies. The law is relevant to the prototype as the law covers the domain of processing health information for statistics, research, and quality improvement.

3.7.2 Act on the processing of personal data and GDPR

Act on the processing of personal data (Lov om behandling av personopplysninger (personopplysningsloven)) (Personopplysningsloven, 2000). This law covers the principles of processing personal data regarding collecting, processing, and storing personal data, thus following the GDPR, also known as the European Data Protection Regulation (GDPR, 2016). The GDPR notes the following principles (*The EU General Data Protection Regulation | IT Governance Ireland Ireland*, no date):

1. Processed lawfully, fairly and transparently.
2. Collected only for specific legitimate purposes.
3. Adequate, relevant and limited to what is necessary.
4. Accurate and, where necessary, kept up to date.
5. Stored only as long as is necessary.
6. Processed in a manner that ensures appropriate security.

3.7.3 Patient and User Rights Act

Patient and User Rights Act (Lov om pasient- og brukerrettigheter (pasient- og brukerrettighetsloven)) (pasient- og brukerrettighetsloven, 2001) covers the patients' rights concerning health services. It is relevant to the thesis as it covers consent of health care for all ages, both adults and children under 18, and the right of medical journal access.

3.8 Communication of Research

The last guideline created by Hevner et al. is the communication of research and is defined as *"Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences."* (Hevner *et al.*, 2004). The thesis will be made available via University of Bergen open-source website (bora.uib.no). The thesis also covers all audiences, as well as children as patients in the next section.

3.8.1 Children as patients

In Norway, the legal age concerning health services is 16, which means that children under 16 need parental supervision if there is treatment or decision making (*Healthcare rights for children and adolescents in Norway - helsenorge.no*, no date). In case of hearth-related diseases, the child needs parents, or guardians to take decision, which also reflects on the prototype developed within this thesis. As one usually has a regular user profile for patients, one must also have a profile for the parents to help the child monitor themselves. Even though the parents might have direct access to the profile for their child, it is also essential to keep the child active regarding the results, as shown in the article by Wassmer et al. (Wassmer *et al.*, 2007). Wassmer et al. explored how paediatricians communicate with children and parents and concluded that the child needs to be more encouraged to be a part of the doctor-patient communication. Introducing a child-friendly profile of the prototype and a more detailed and manageable parent version would increase this communication and the understanding of their own health information. To have a child version of the prototype can also be supported by the article written by Lewis et al., who concluded "*a brief educational intervention administered during waiting room time can positively impact physician-child rapport and children's preference for an active role in health and their acquisition of medical information."* (Lewis, Pantell and Sharp, 1991).

How can the doctor and medical personnel adapt to communicate better with a child patient with a supervising parent to give the child comprehensive information regarding their health? According to Konstantynowicz et al., pediatric patients' parents feel that doctors deflect questions, avoid providing them with sufficient information, and use medical jargon that decreases their understanding of the illness (Konstantynowicz *et al.*, 2016). Creating a service that can answer all relevant questions and using simple language to answer those questions will battle those problems Konstantynowicz et al. considers the main issues.

4 Establishing Requirements

In this section, the thesis establishes the requirements for the prototypes in the different iteration phases. Preece, Rogers, and Sharp note in “Interaction Design: Beyond human-computer interaction” that “*Establishing requirements is not simply writing a wish list of features*” (Preece Jennifer, Yvonne Rogers, 2017) but it is instead “*a statement about an intended product that specifies what it should do or how it should perform*” (Preece Jennifer, Yvonne Rogers, 2017). It is essential to create requirements before one creates prototypes as it has two goals to achieve. Firstly the project aims to “*understand as much as possible about the users, their activities and the context of that activity*” (Preece Jennifer, Yvonne Rogers, 2017). The first goal is to understand how patients or people with close relationships with patients who experience heart problems need heart monitoring and how they manage their lives. It is also interesting to explore how they could change their lifestyle with the help of digital tools. The second goal is “*to produce a set of stable requirements that form a sound basis to start designing*” (Preece Jennifer, Yvonne Rogers, 2017). One cannot simply just jump into creating a prototype without having some basic understanding of what one should develop and why.

The requirements established in this section are described in Section 2 - **Theory**, which includes articles gathered and understanding of existing health services. After conducting the interviews, more requirements were added, and old ones were redefined.

4.1 Interview

To validate established requirements there were conducted semi-structured interviews with the different relevant stakeholders. The first stakeholder is a physician who is an expert within the heart domain. He helped the project to gain insight into existing solutions for remote monitoring of patients and kind of applications patients use to monitor themselves. The second motivation was to gain medical insight into what kind of equipment they use to monitor heart signals as well as technical and legal limitations regarding remote monitoring.

4.2 Functional Requirements

Functional requirements are defined as “*what the system should do*” (Preece Jennifer, Yvonne Rogers, 2017), and the functional requirements so far in the thesis are as follows:

1	The user should be able to register heart signals,
2	The users should be able to see earlier registered heart signals,
3	The user should be able to register current mood after registering heart signals (emojis),
4	The user should be able to communicate with health personnel,
5	The user should be able to read up on heart related symptoms and other key definitions,
6	The user should be able to register medication if they are taking any,
7	The user should be receiving feedback if the recording conditions are not met,
8	The user should be given a notice when the recording results are out of limits, and a physician should be contacted for a consultation.

Table 1: Functional Requirements

4.3 Non-functional Requirements

Non-functional requirements are defined as “*what constraints there are on the system and its development*” (Preece Jennifer, Yvonne Rogers, 2017) and concern more of the prototype's technical and development aspects. The following non-functional requirements so far in the thesis are as following:

1	The prototype must be created to be working on both phones and pc,
2	The prototype must be simple and efficient to use,
3	The prototype must be created for all age groups,
4	The prototype must do what the user expects it should do,
5	The prototype must have no bugs or faults, and offer ways to deal with errors,
6	The prototype must be easy to learn and use, and be user friendly,
7	The prototype has the possibility of saving heart recordings to patient journal.

Table 2: Non-functional requirements

5 Prototype Development

This section of the thesis will present the different iterations of the prototype and present the development tools used through the iterations.

5.1 Development Tools

5.1.1 Adobe XD

For the first and third iteration phase, the prototype was created using the design application Adobe XD, a free downloadable adobe product (*Adobe XD | Fast & Powerful UI/UX Design & Collaboration Tool*, no date). The application can be used for creating simple prototypes with simple functionalities using the prototype functionality tool.

5.1.2 Figma

For the second iteration phase, the prototype was created in Figma, a similar interface design tool, with the possibility of collaborative development (*Figma: the collaborative interface design tool.*, no date).

5.2 Iteration Overview

In this section, the thesis presents the different iteration phases and their results. A prototype was created through three iteration phases ranging from low fidelity to high fidelity and a functional prototype. The first iteration prototype was created only based on the master proposal, as it lacks in-depth functions and design choices. The second prototype was created using research from Section 2, thus lacking insight from medical personnel. The third iteration was created based on interviews from iteration two with a medical expert and technical expert. Usability evaluation was also conducted within the third iteration.

5.3 First Iteration

The first iteration of the prototype was created in the context of the proposal of the master thesis, which was informed by the literature overview. The low-fidelity prototype was created in AdobeXd to show the difference between an application that offered information to a patient and a physician.

5.3.1 Low-Fidelity Prototype

There are two views of the prototypes, one for the patient who monitors at home and one for the physician. The main functionalities are registering measurements and the motivation for this function is to register different kinds of heart signals, both electric and sound. The second function is to view results; as one can see in the prototype, it provides a simple overview of the results but with no explanation. In the patient prototype shown in Figure 10, there is a very simple but straightforward data overview of earlier monitoring results. However, on the physician's side in Figure 11, more detailed results can be found.

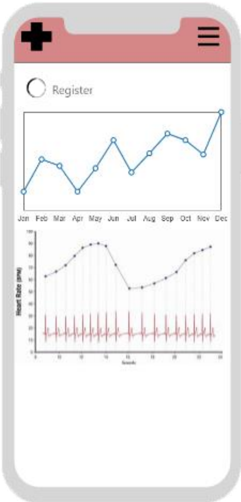

Figure 10: Patients view of the first prototype

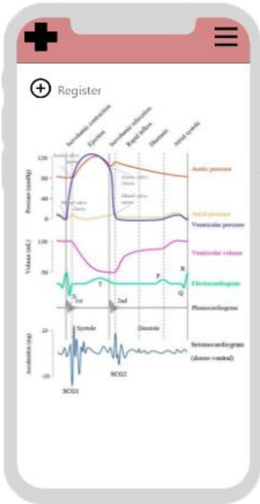

Figure 11: Physicians view of the first prototype

5.4 Second Iteration

For the second iteration, the prototype has established functional and non-functional requirements based on conducting research in section 2 - Theory and researching existing and established health-related applications and services. This iteration overlaps with the first iteration with the main functionality of registering heart signals and viewing older results but introduces more detailed functionality with research in mind. This phase aimed to get an overview of the main functions and get a basic design suitable for both physicians and patients in different age groups. This prototype was created before conducting interviews and observations, thus assuming functions and design would change through successive iterations depending on the feedback. To create this prototype, the design tool Figma was used.

5.4.1 Theoretical Background

In the theory section, the research uncovered the underlying themes of designing web mobile-based solutions for monitoring heart signals. These themes were used as a guide to aid the creation of the prototypes. Result research themes can be seen in Figure 12: Underlying themes of the thesis.

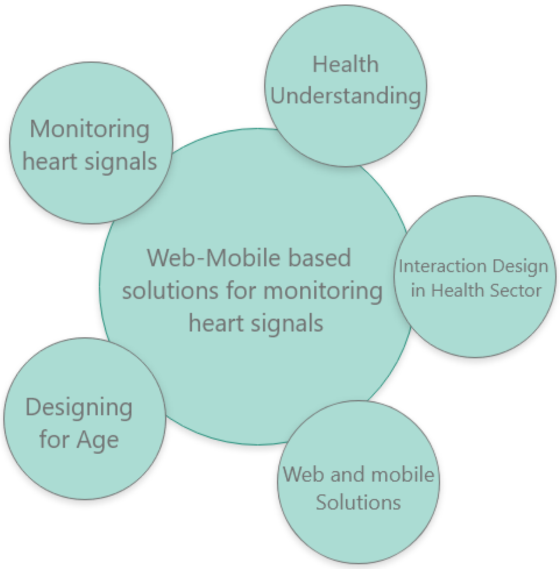

Figure 12: Underlying themes of the thesis

5.4.1.1 Health Understanding

This section covers what one must consider when creating health-related web and mobile applications with health understanding in mind. *How should one develop and design after this aspect in mind?* Choudry et al. noted that doctors' letters should be in a way that a sixth grader could understand them, so one can conclude that all text information should be short and concise (Choudhry *et al.*, 2016). The patient should get appropriate information from both the application, and medical personnel in a form that is as simple as possible. An important note about these articles is that they explored only text literacy, not text with a visual aid. A visual aid can be, for example, information such as side effects, instructions, and others designed in a more visually friendly way.

5.4.1.2 Monitoring Heart Signals

The research in the theory section uncovered how important mobile health is and should be in the future. Remote health monitoring can be digitalized and personalized to reduce the number and length of hospital visits with help of the right tools. Applications are easy to manage; they are cost-effective in the medical world, thus confirming the proof of concept and the benefits of a prototype's functionality.

5.4.1.3 Interaction Design in Health Sector

Creating prototypes to be used within the health sector is different from regular prototyping. The domain has different interaction design techniques and themes one should consider when designing for healthcare applications. There are some essential key points to consider, for example, that one should design for the person who receives the information, not for the one who delivers the information. It is essential to receive feedback both from the patient and the physician of each view of the prototype. Exploring both sides are critical regarding health information since health personnel has a different vocabulary and understanding than patients. Another point is to design after a familiar interface, in which most age groups and most cultures understand the design. There are many examples of health sector interface design that are adjusted to a broad audience by using basic colours and familiar interface.

5.4.1.4 Web-Mobile solutions

When researching web and mobile-based solutions within the health domain, the project encountered shortcomings in the articles, but this was explored through observation and prototyping. For example, in multiple articles, they created only a simple interface with little design consideration. The user interfaces found in the articles are often fundamental and serve only the function of showing data without context. Another shortcoming in the research was the lack of informing patients, even though it is essential to keep the patients informed and not only the health personnel. A more dynamic multi-layered interface with the possibility of explaining health data for patients would be a great addition to the mobile health trend.

5.4.1.5 Designing for Age

When one considers creating applications and services for all ages, it is important to consider the main demographic. On the Norwegian Cardiovascular Disease Registry's statistical database, one can gather from Figure 13: Number of patients with Heart and cardiovascular disease in Norway by year (Folkehelseinstituttet, 2020); the primary age demographic is between 70–89-year-old. According to Pew Research Institute, 73% of people over the age of 64 using the internet, thus showing the most significant part of this thesis's demographic. The most significant part is using internet, which should be taken into account when creating a prototype. ('Demographics of Internet and Home Broadband Usage in the United States | Pew Research Center', 2019) There are design choices that can cause problems for older patients, such as (Kane, 2019):

- **Small font sizes and small targets:** Websites and phones tend to have small font sizes, thus making it inconsiderate for older users with bad eyesight. Also, elements such as buttons, links, and other clickable elements are created at a small size, making them difficult to interact with. Most modern phones have the opportunity of changing both font sizes and clickable targets to accommodate this usability challenge.

- **Inflexible and unforgiving interfaces:** This challenge is that websites and services give bad feedback when making a mistake or giving bad hints at what to do in certain situations. For example, if one should fill out a form, the form does not specify what it expects from the user. Unforgiving interfaces also confuse with misplaced or miswritten error messages which can be very confusing to elderly patients.

- **Exclusion from online content**: According to Kane, seniors feel that websites and apps are not designed with elderly considerations and interest, thus making them feel left out of the online world, as it was created by and for a younger audience (Kane, 2019).

Children under 18 are not in the majority of patients who suffer from heart-related problems, but as they are present, the prototype will consider this age group.

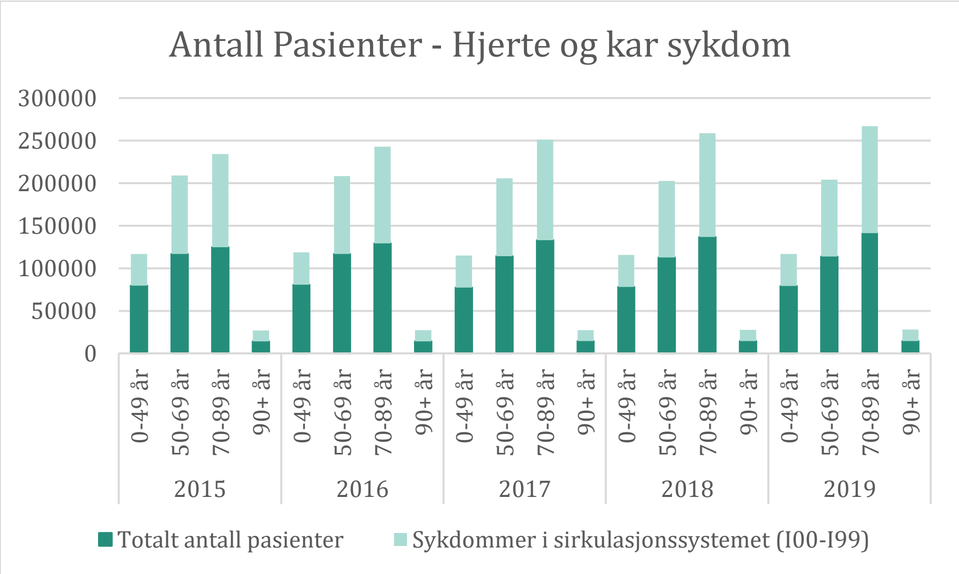

Figure 13: Number of patients with Heart and cardiovascular disease in Norway by year (Folkehelseinstituttet, 2020)

5.4.2 System Architecture

For this thesis's purpose, Figure 14 presents a simple overview of the second prototype iteration's primary key points regarding security and main functionalities. The figure presents how a patient can interact with both a phone and a computer to access the system. The figure presents security when logging in to devices and the communication from the devices to the system. It also presents how a medical staff has access to the same data as the patient using their own devices with security measures.

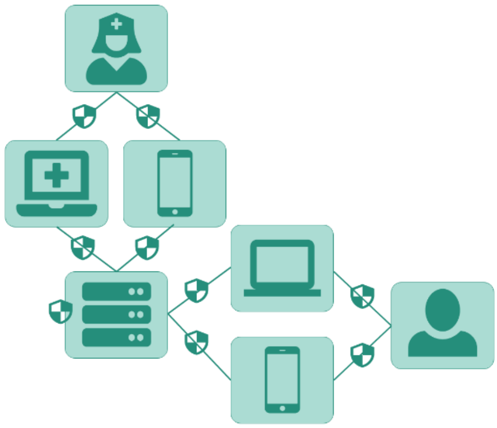

Figure 14: A potential System Architecture

Considering how easy it is to access Norwegian patient health data over the internet through services like helsenorge.no, one must consider other technical aspects when designing system architecture for a prototype such as this. Al-Sakran presents a framework architecture for improving healthcare information systems (Al-Sakran, 2015). The article uses a hybrid approach with a range of problem-solving agents, an interface agent, and a mobile agent. The problem-solving agents are doctor, EHR (that are also known in Norway as electronical medical journals) pharmacy, laboratory, radiology, other healthcare records, patient management system, remote patient. For a system developed in this project, one can discuss whether it is essential for the patient to have a direct communication line with each agent. The doctor should have communication, and the patient only has access to the information given by each agent. The other agents should be existing in the information services in this prototype. However, for this iteration, the patient can not directly contact them, only receive relevant information.

Al-Sakran brings up valid points regarding the different agents but does not review how one should take security considerations as it deals with highly detailed and important health data. Martin-Pérez, de la Torre-Díez and López-Coronado have created an overview of security and privacy recommendations for mHealth applications in regard to both American and EU regulations (Martínez-Pérez, de la Torre-Díez and López-Coronado, 2015).

The following are the recommended requirements proposed that should be of consideration for the prototype:

- **Access control:** The patients will have the opportunity of allowing or denying access to their information shared at any moment. A possibility of doing this is to create roles proposed by the authors, thus adding limitations to the different given roles.

- **Authentication:** One must log in and authenticate with a unique ID – in Norway, this can be BankID as it is a secure system already in use here, thus simple to implement.

- **Security and confidentiality:** The authors recommend Advanced Encryption Standard (AES), which uses a cryptographic key with 192 or 256 bits. This method can be used on all the secured points (lock icons) in Figure 14.

- **Integrity:** To keep the integrity of the connection and the data transferring using a public key-based signature.

- **Inform Patients:** The prototype should present a privacy policy informing the patient about the agents who will be using and have access to the data and how it is secure to use. It should be easy to understand instructions and have the policy available in the prototype.

- **Data transfer:** Transferring data between the database and between the patient and physician can use Transport Layer Security (TLS) with a 256-bit encryption method. Also, recommend having an icon showing when the data is transferred over the internet.

- **Data retention:** Following the GDPR principle, informing the patient and users of the prototype how the data will be stored, transferred, and processed.

5.4.3 Machine Learning in Health Services

If patients are going to monitor themselves at home using a prototype such as presented in this thesis, a system that processes the monitored data must exist. The data processing must happen quickly as possible, and that would be best with an automated system using machine learning to detect anomalies in the data collection. If one is going to implement machine learning into diagnosing anomalies in heart data, there is a need to confirm how reliable an automatic system would be. Bazoukis et al. present in a systematic review how state-of-the-art uses machine learning in the management of heart failure patients (Bazoukis *et al.*, 2020). Through the systematic review, it showed "*better accuracy of ML algorithms compared to conventional tools has been demonstrated for the prediction of mortality in the setting of acute HF, mortality, and hospitalization for HFpEF, and hospital readmissions. Nonetheless, there is still room for improvement of ML techniques in predicting outcomes in these patients*" (Bazoukis *et al.*, 2020). The article also highlighted other potential uses of using machine learning for identifying heart failure: Identity patients who require medications or different treatment, identify patients at risk of depression, identify patients in need of specific treatments, and improving general patient prognosis (Bazoukis *et al.*, 2020).

The article shows great promise of using machine learning to help identify anomalies in heart signals. However, as they conclude that machine learning needs improvement, it only shows potential, not a final solution. For this thesis's case, the prototype iterations will be using machine learning to give the patients their heart monitoring results back instantly, instead of using physicians that need to confirm the heart signal results. It must be said that machine learning improves by learning on large amount of data, therefore it can be expected that systems will grow better with more patients remotely monitoring and collecting their data.

5.4.4 High-Fidelity Prototype

For this iteration, the prototype contains the following functions for the patients: Measure heart signals, contact physician, earlier measurements, medication overview, information, and a calendar view, and the possibility of log out and a setting option. The physician's prototype contains the following functions: an overview of new information, patient overview, patient details, contact patient, user overview, and measurement overview, and logout and a setting option.

The prototype has information and functions available through a card interface with associative colours. Using cards is an easy method of creating a simple and similar design on both phones and the web, as they are very responsive and easy to scale. The card design also considers that the patient prototype should contain simple and concise info that should not lead to information overload, thus only listing the main functions in the intro page.

5.4.4.1 Patient Prototype

Presented in Figure 16: Patient Prototype, intro page, is the high-fidelity prototype of the application's patient view. On the left, one can see the application on a standard phone, and to the right is the web interface. The colours used in the patient views presented in Figure 15 are used in both the phone view and the web view to give a better sense of familiarity and follow the design principle consistency (Preece, Rogers and Sharp, 2015). It follows the design principle of consistency as it has a concise interface with few functions that make it easier to learn and use. In terms of usability and functions, the prototype follows the usability goal of easy to remember how to use (Preece, Rogers and Sharp, 2015). It has few functions, with colours that represent the different functions. The design has also considered Falchuk's theory as the prototype has been designed for a range of novel and familiar interfaces (Falchuk, 2009).

Figure 15: Colors used in the first patient prototype

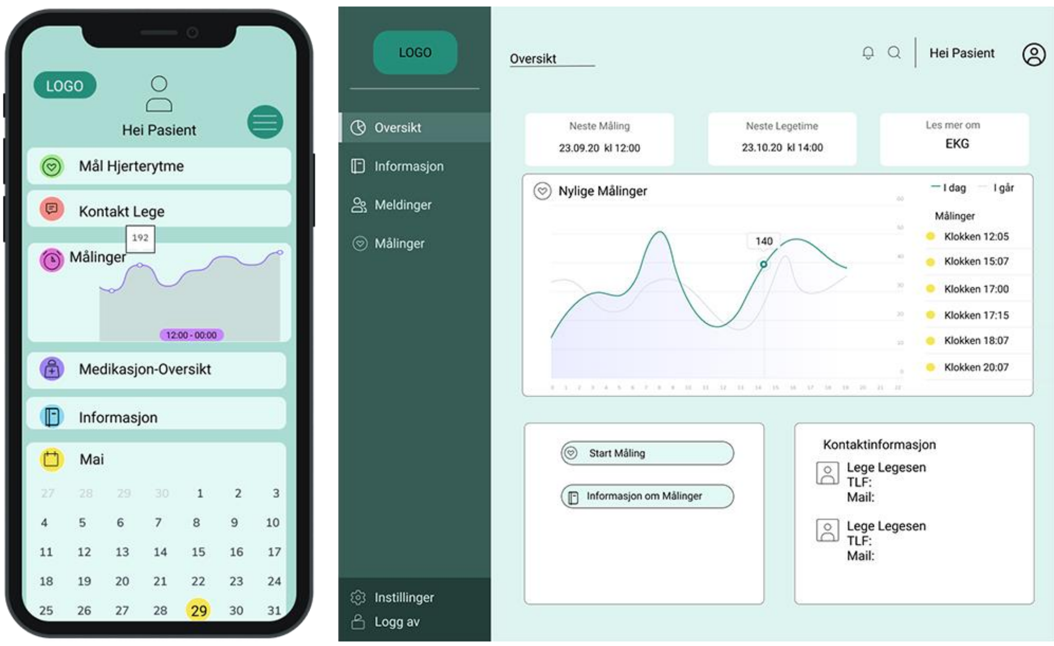

Figure 16: Patient Prototype, intro page

The first function is to measure heart signals. In this iteration, measurement can be interpreted as either measuring ECG, PCG, measuring heart rate, or using a stethoscope to measure heart signals. The colour used to indicate measuring heart signals is in this iteration green, as the colour is usually associated with nature and health, thus a good and cheerful color. The card also uses a heart symbol to indicate that it relates to the heart or the measuring of the heart, as the user of the application might not be able to read, as it is designed for all age groups. The second function is contact doctor, and it is a function that leads to the second picture on the right on Figure 18. Showing how easy it is to contact a physician and not viewed in this prototype is contacting different physicians and people in the health care domain. The phone prototype's function uses red, as it can be associated with an emergency and danger and heart and love.

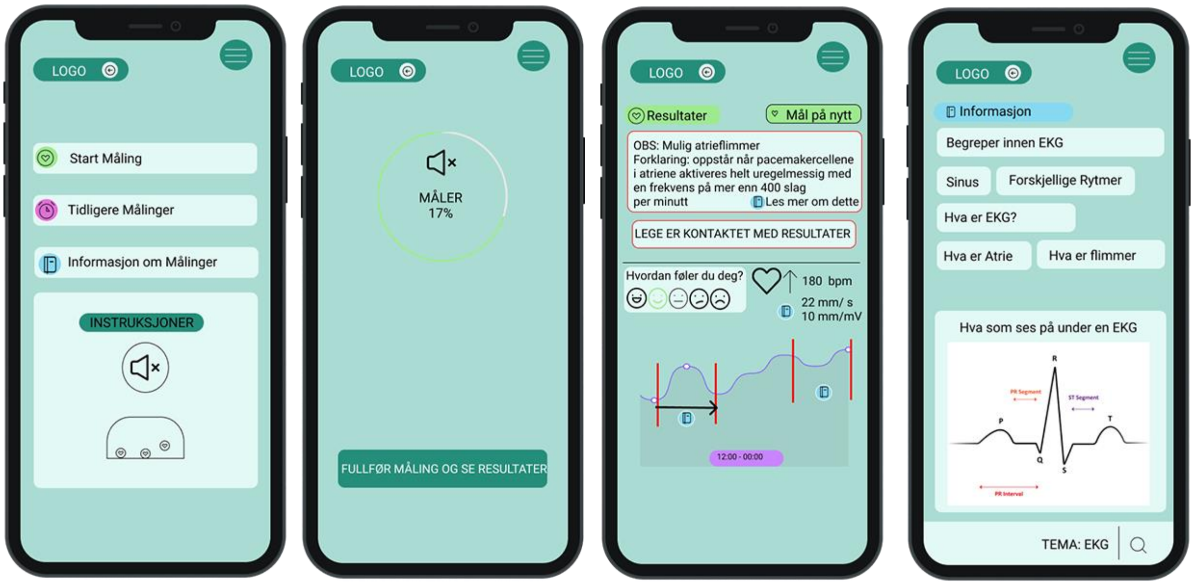

Figure 17: Patient Prototype, mobile view, measuring

In Figure 17, one can see on the phone to the left the view when one clicks the “Mål Hjerterytme” function. One can start measuring, looking up earlier recordings, and reading up on earlier recordings and relevant measurement instructions. The instructions are not detailed, as it depends on what kind of measurement of the heart one conducts. When one clicks the start measurement function, one comes to the second picture on the phone view, where the measurement starts – depending on the patient measurements and if the patient has placed the measurement device correctly. When the measurement is completed, the prototype presents the third picture, the results. Firstly, the results show whether the results were expected or not, and if not – what was not expected. The results also notify the patient that the physician was alerted with the results if the recording was abnormal, indicating that the physician will be researching the findings. The prototype also asks the patient to rate their current mood and present the result of the recording in a linear form and indicate what the abnormalities were. The mobile prototype's web view can be seen in Figure 19.

Figure 18: Patient Prototype, mobile view, measuring and physician dialog

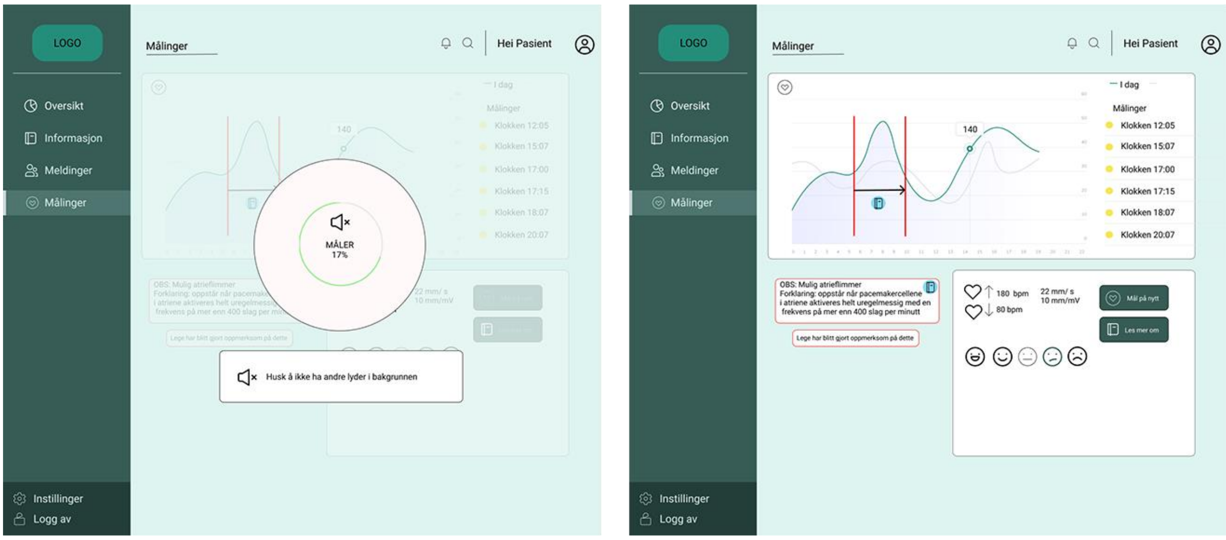

Figure 19: Patient Prototype, web view, measuring

In Figure 18, one can see on the left the chosen days previous recordings with the possibility of clicking on each recording to view the findings. The same collection of results can also be seen on the right side of Figure 19. On the right side of Figure 18, one can see an example of the dialog screen between a patient and physician. In Figure 20, one can see on the left side the web version of the information and theory function. The purpose of the information function is to give patients the possibility to learn more about medical theory and get simple and straight forward information regarding critical key points.

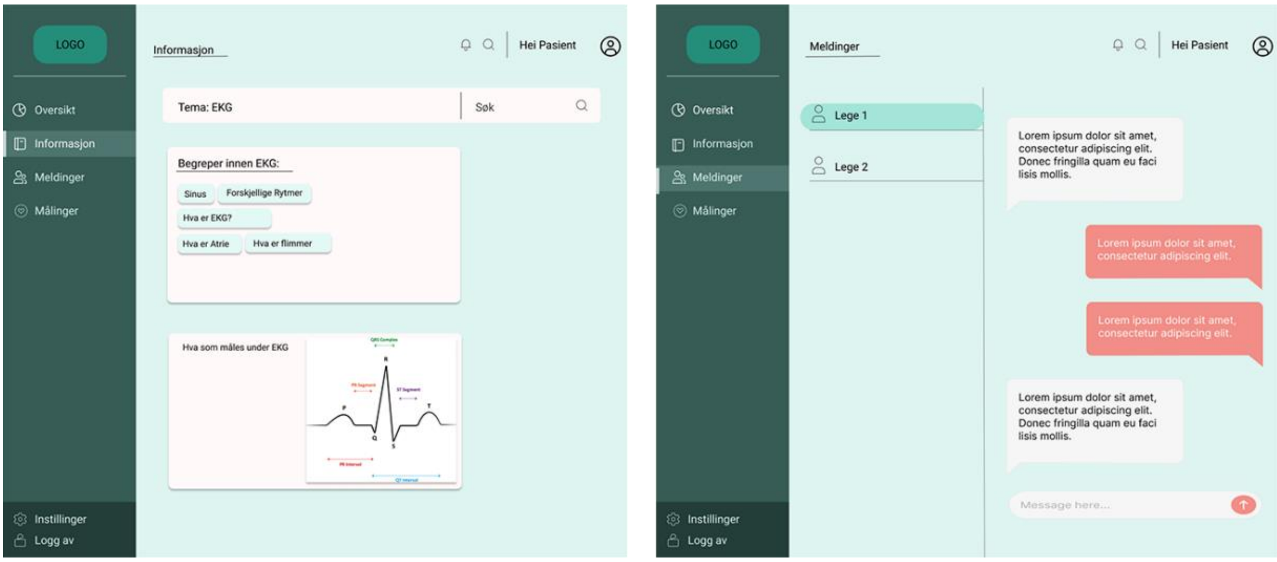

Figure 20: Patient Prototype, web view, information and physician dialog

5.4.4.1.1 Different Colour choices

When one is creating prototypes for the health care domain, one must consider different colour choices, as the health domain considers all ages and people. In this iteration of the prototype, the thesis presents a colour range of green pastel, ranging in intensity and hue. The colours presented are inspired by different health services and organizations in Norway, with the second iteration prototype on the right.

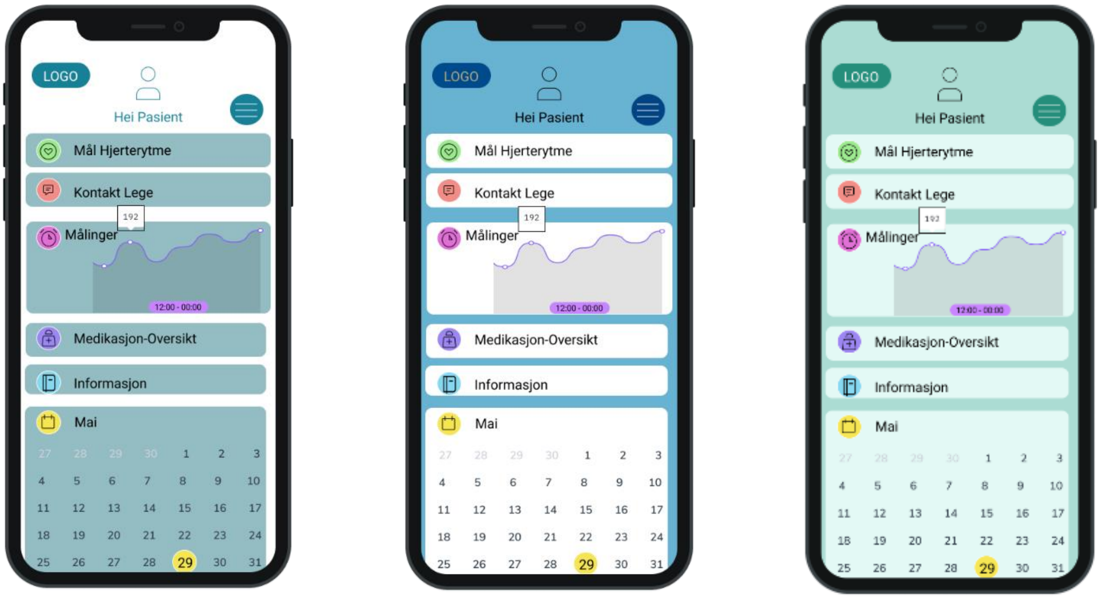

Figure 21: Different color choices; helsenorge, rikshospitalet in Oslo, and the second prototype iteration

5.4.4.1.2 Different versions of the result view

To what degree does user experience design affect a patient's understanding of heart monitoring results?

The prototype has different versions of the heart monitoring results view with the consideration of the patient’s understanding. The different views can be seen in Figure 22. The motivation for creating different versions is to present them during interviews to explore how they perceive the different views of the heat monitoring results. In the first view, the essential information is at the top and highlighted with a red border to indicate something important or dangerous for the patient’s health. The following information on the screen is that the physician is contacted to reassure the patient that the recordings will be reviewed. The patients have the possibility of giving feedback on how they are feeling during that measurement. The data results are shown on a line graph, with indicators pointing out abnormalities in the data.

The second view has limited information about the measurement results, with the possibility of clicking on it and getting a more detailed view of the recording information. This view is for the patients who are not interested in detailed reading of each measurement but would rather choose to have the possibility to request more information, thus removing cluttering from the result screen. Following comes the actual result of the measurement, the same graph as seen in the first view. This view has moved the patient's feedback from the top to the bottom as it is less important than other results, however it can be found in a place reachable by thumb.

The third view utilizes another type of heart data result, as it brings attention to a change or a difference in the results from previous or typical measures. The recording utilities a recommended technique for line graphs to give an indicator of attention and context (Reese *et al.*, 2020). Reese et al. have explored the different methods of portraying graphic displays with clinical domain experts. They have concluded that line graphs are best compared to spike graphs when depicting data over time and that the flow of data should be portrayed from left to right. The time should be a 12-hour timeframe, as most care decisions are based on those hours. Reese et al. also explored that showing the highest and lowest measures are good indicators for the patient (Reese *et al.*, 2020).

The fourth view contains only the critical parts of the results, without the actual data itself. This is to explore whether patients want to see the actual results or want to know the information they collected and processed.

Figure 22: Different version of heart monitoring results

5.4.4.2 Physician Prototype

There are fewer coloured objects for the physician prototype, as it looks more professional with clean and simple colours. In Figure 23, one can see similarities from the patient's view, but with more focus on the physician and the possibility of looking at multiple patients. The landing page shows the last measured recording from a patient, and one can choose another patient to look at from a pull-down menu. The main functionalities in this iteration are the patient overview, messaging and communication between patient and physician, and looking at earlier recordings.

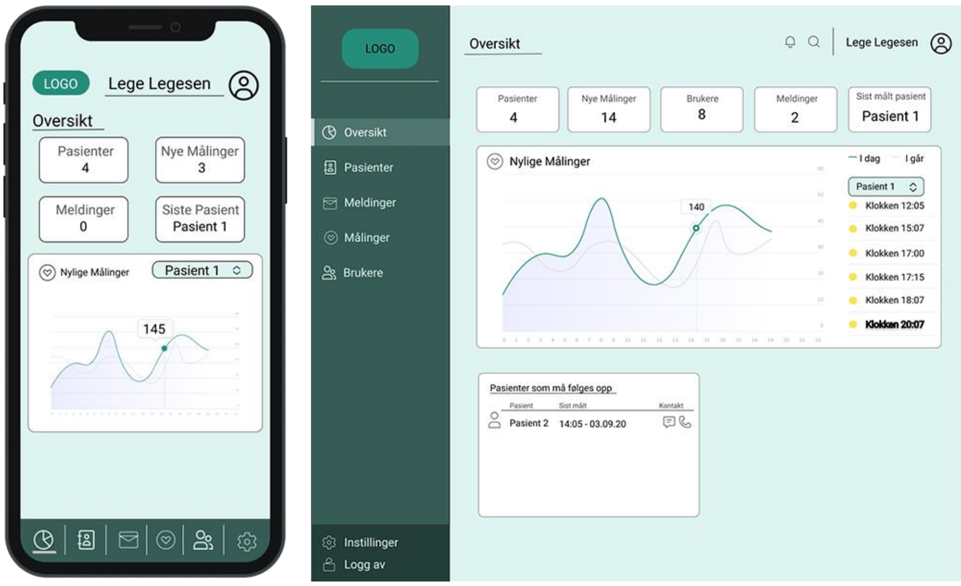

Figure 23: Physician Prototype, Intro page, mobile and web

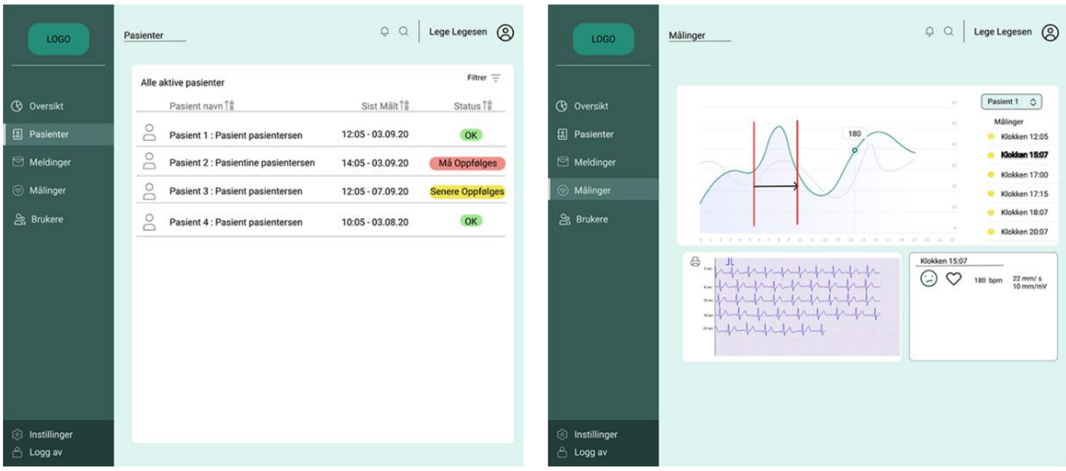

Figure 24: Physicians view, patients, and measurement page

In Figure 24, one can view all active patients, as well as the last measured time. Suppose the last measurement has shown potential problems or other health indicators. In that case, it shows either an “må oppfølges” or “senere oppfølges” to indicate that it needs to be followed up in the immediate future. On the measurement page, one can see ECG results and how the patient was feeling at the time, with a highlighted box to show where the potential abnormal results were in the recording. In Figure 25, one can see the number of registered users on that patient. This function's purpose is to show family members or a legal guardian who has access to the data. The messaging view has the possibility of contacting each patient, as well as other physicians, this can be seen in Figure 26.

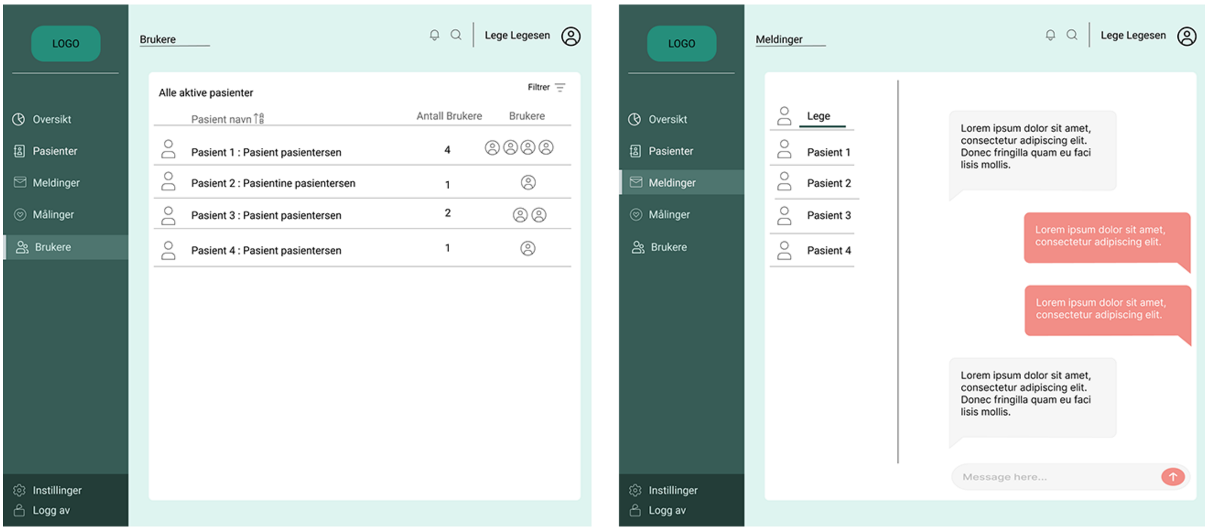

Figure 25: Physicians view, users and messaging

Figure 26: Physicians view, phone view

5.5 Interviews – Second Iteration

The interviews were conducted after approval from Norwegian Center for Research Data (NSD) as seen in Appendix A 1: Approval from NSD. The interview follows interview guides from Appendix B 3: Interview Guide – Expert and Appendix B 5: Interview Guide – Physician.

5.5.1 Interview with Paediatrician

To better understand the medical domain of cardiovascular diseases related to the thesis, an interview was conducted with a children’s cardiologist and paediatrician. This physician, referred to as Physician 1, has 30 years’ work experience within the domain. The interview was sectioned into four parts, starting with a brief overview of the project’s motivations and goals presented to the physician. In the following section, the physician introduced his work within the medical domain, being both a cardiologist and paediatrician, with comprehensive expertise in invasive procedures, procedures with a catheter, and being a paediatric professor and working at a major children’s clinic as well as in the children’s cardiologist research group.

Questions were related to the kind of work the physicians performed routinely and whether some functions could be implemented in the physician's functionality belonging within the third iteration.

The third section was focused on questions related to the physicians' work, what kind of data physicians collect when they got a patient visit, and what kind of equipment they use. Some questions regarded what kind of tools and procedures that are used during a regular workweek. The physician’s primary tool is ultrasound, to look at the anatomy of children heart’s and to calculate the bloodstream to a certain degree of precision. During polyclinical hours, there are more tools used, such as stethoscopes and other diagnostic equipment.

The data collected from the different check-ups and procedures are usually two folded, there is the patient journal, with written health information, for which there is no visual interface. The journal is updated after every consultation, where notes are made with references to measurements taken during the consultation. Weight and height are registered into a digital schema that is also graphicly presented, showing all previous measurements. Ultrasound measurements are saved on a picture server in a special program, and to review older ultrasounds, one needs to look at them manually. Further, there was a question related to how the program looked visually and about the main functions. The physician explained that they upgraded three years ago but lost some functions that they still have not received in the new program. The functions lacking in the current version are some reporting functions that help retrieve a graph of changes in a part of the heart. In addition to the lack of functions, the physician noted that it is not user-friendly, and one needs to remember many unusual functions that are not intuitive.

The following question was about how patients receive information when being discharged from a hospital or physician visit. The physician explained that they recently got approved an application called HOBS that will soon undergo a feasibility study. The application has structured information available for patients and family, and the motivations are for families who had trouble following information after consultation. The most important part of this application is that it should give the patient peace of mind at home with easy instructions in the form of a checklist and schema with instructions on whom to call and when to call in different scenarios personalized for each patient. This application is an illustration on how of the prototype can be utilized to benefit patients through such informative functions.

The fourth and final section was about the physician's technical skills and whether he was aware of patient’s level of technical knowledge. The physician is also presented the second iteration of the prototype to review design and functions. In the technical section, the physician explained that he prefers using computers over the phone but does not mind using the phone. Regarding the physician’s knowledge, when it comes to technical knowledge of patients, the physician noted it was natural for younger generations to use technical devices. However, older patients might struggle and might need to brute force through things.

Another question asked was about how the parents with younger patients work during consultations; how much they were involved in the consultation, and if they ask many questions. The physician explained a problem in global paediatrics, where one knows the child's family after the birth and often before that. What happens then is that the physician talks with the parents and continues to communicate with them even though the children are older and seem to be overlooked during the consultation. This scenario is a problem worldwide, where for example, children are watching movies during ultrasounds, and the physicians talk with the parents instead of the children. On a positive note, there has been a wave of change where one tends to involve youths more, mainly at the age of 16 and as low as 12 here in Norway. This change correlates with the article by Wassmer et al.. If they involve the youths during a consultation, they see an increase of understanding and interest in their health history (Wassmer *et al.*, 2007).

The paediatrician was shown the second prototype from iteration two regarding functions and design in the last section. The physician had some feedback that the thesis took into consideration for the third iteration. Firstly, one should be working outside the patient model, but one can test and discuss it, but not with actual patient data to avoid problems due to privacy. Due to today’s legal problems, one cannot use the second iteration solution according to strict Norwegian privacy laws and long and tedious processes of applying for Ethical Committee (EC) approval for the medical equipment. EC approval is needed when there is medical, technical equipment, such as something that measures heart signals. This means that if the prototype were made into a product, approval from the EC would be needed, even though it is a tedious process to obtain the approval.

From this interview, one can conclude a few points one can consider for the third iteration. Firstly, considering the physician's view of the prototype and review what the primary purpose of this view was going to be. The second point is exploring single and multifunctional applications to discover the best use of the prototype. According to the physician, an application should solve one problem and not too many at the same time.

5.5.2 Interview with Expert

Between creating the second prototype and creating the third prototype, the project conducted an interview with a biomedical engineering expert and an occupant researcher within the area of analysing heart sounds using AI and machine learning methods. His expertise within the domain of ten plus years of experience provided a broader view and more insight regarding how the third iteration should be created. The purpose of this interview was to take a broader look at the functions of the prototype from a technical expert's point of view. During the interview, he is presented with the second prototype and the third prototype while it was still under development in order to show the significant that took place during these two iterations.

The first thing the expert noted about both prototypes was the lack of a query function. By query, he clarified that it lacks the possibility of searching for specific patients, a patient's symptoms, age, gender, and other information. A physician can have hundreds of patients within few years of work. He noted that physicians might forget the patients' names but might remember symptoms or other factors that one can use to create a query system. Therefore, the third iteration was updated to include queries on the physician side of the prototype and multiple possibilities of filtering, sorting, and presenting the collected patients' statistics. Having a query function also adds the functionality of having active and non-active patients. Patients might not be needing remote monitoring for a period or the rest of their lives, so only the active patients are listed in the patient's overview in the physician's prototype. The physician will have the possibility of enabling and disabling the patients' access.

The second function the expert commented on was the lack of functionality from the calendar as it could be seen in both second prototype and under the development phase of the third iteration. The calendar at the time served no other purposes, and the function was reworked in the third iteration of the prototype to serve as a reminder for the next medication, doctor's appointment, with the possibility of querying earlier recordings – this is, of course, for the patient's view. For the physician's view, this was replaced by the statistical view of former patients.

The third functionality that was in question was what the prototype should be measuring and not. Instructions on the measurement page list things such as "stay quiet" and "do not move", which correlates with measuring heart sound – PCG or phonocardiogram. However, a different solution was selected for ECG measurement, where the result page was not updated. The expert noted during the interview that for PCG, the patient might want to have more feedback as the results are different from an ECG. He also mentioned that PCG is more challenging to measure without proper training with the PCG equipment, as it is very sensitive and can give false positives and other wrong results. Suppose an untrained individual measures the signals on their child, and it gives a false positive. In that case, it could lead to more people contacting health personnel and hospitals more often than they would have otherwise, thus creating a possible constraint on the hospital. If one should develop for PCG, the expert mentioned that it should include feedback if the signal has bad quality, medium quality, or signal has been measured from the wrong place, or if segmentation is not conducted correctly.

For PCG to be appropriately done, the thesis will propose the following key points and present a design choice in iteration three with these considerations:

- Good training for the individuals who are going to use the application,
- Good, but simple results view of heart sounds,
- Good feedback to the user regarding the quality of the signal,
- Statistical feedback regarding measurement. The results also should indicate the probability of having these types of symptoms and an explanation about those symptoms.

5.6 Third Iteration

In the third iteration of the prototype, changes of functions and design choices are based on the feedback gathered from the interviews from both the medical expert and the physician. This iteration was evaluated using System Usability Testing, Heuristic Evaluation, and System Usability Scale by experts and physicians as described in Section 6.

5.6.1 Physicians and mobile technology

Through the interview with Physician 1, there was noted that the thesis and development should focus more on the physician's view of the prototype due to lack of functions and background information before developing the second iteration. For the third iteration, the thesis explored articles related to physicians and mobile technology to map what kind of functions and designs such a view should have in the medical domain. Ozdalga and Ahuja conducted a review of smartphones' current and potential use among physicians and students (Ozdalga and Ahuja, 2012). There were primarily applications related to medical reference, news, social networking for physicians, and other reference manuals in the list and description of popular applications among physicians and students. Ventola finds similar medical applications and showing a lack of communication between patients and physicians (Lee Ventola, 2014). Ozdalga and Ahuja, and Ventola present communication and consulting as a category, but only as a way of networking between physicians and not directly communicating to the patients. Ventola has patient management and monitoring as a category, but that only lists application that is either diagnosis app, reference for either lab, medical calculator or screening, and prevention tool. All categories have no communication integrated (Lee Ventola, 2014). Thus, showing that functions for a physician side of an application would be a referencing manual or an overview of patients, or a combination of both as presented in this iteration.

In the article “*The uses of the smartphone for doctors: and empirical study from Samsung medical center*” by Choi et al., they developed an application for a physician to access patient information, thus providing valuable information regarding the functionality and popularity of the mentioned application (Choi *et al.*, 2011). Functions implemented in the Dr. SMART applications are the following: vital signs, orders, examination results, images, and electronic patient journal. The order function is to review examination, drug, and treatment orders. The frequently used function was examination results, as doctors were satisfied in the possibility of retrieving information of their patients, thus showing great promise for the function in the application for this thesis. A topic discussed in the article was that the application should not be used outside the hospital area due to legal restrictions; this is also something to consider when developing a new health application to be used by medical personnel in the future (Choi *et al.*, 2011).

Ozdalga, Ahuja, Ventola, and Choi et al. present a valid list of functions that one could implement in a medical application, but without mentioning how it impacts clinical outcomes. Divall, Camosso-Stefinovic, and Baker conducted a systematic review to investigate digital assistants' usefulness in a clinical setting (Divall, Camosso-Stefinovic and Baker, 2013). The review covered controlled trials that used digital devices for diagnosis or treatment and showed an increase in data quality and appropriateness of diagnosis and treatment decisions was improved. On a final note, they also concluded that further research is required, but an indication of no major concerns found.

5.6.2 Single vs. multifunctional applications

In the interview from iteration two with physician 1, the physician noted that applications in the health domain are, to a large extent, problem-oriented to solve a specific problem that one wants to tackle. Problem-oriented applications open the discussion on single vs. multiple function applications concerning development, preferences, and efficiency. The second iteration of the prototype has multiple functions, ranging from registering, diagnosing, and analyzing results and communication with doctors. Rios explores the pros and cons of using both options; it is not a scientific article but provides valid points that can be considered (Rios, 2017). One of the main advantages of Rios list is how a single-purpose app can have fewer functions. However, the user will have the full knowledge of their use, compared to a multipurpose app where some functions might be hidden due to the application's size. When an application has fewer functions, it also presents a more streamlined interaction for the user due to its simplicity. When creating a multi-purpose application, one has the advantage of multiple modules, data, and resources that can be shared across the application, which can be tedious in a single-purpose app. Additionality, in a multi-purpose application, there is only a single environment to interact with, instead of multiple applications and modules, thus simplifying everything into one place (Rios, 2017).

Considering Rio's article, the third iteration of the prototype focuses on a single-purpose application with fewer functions. In the patient prototype, the main functionality is measuring PCG signals, but with the possibility of reading more details about the results. In the physician's prototype, the main functionality is the patient overview, with the possibility of querying through old patient data to consult newer patients.

Figure 27: Proposed Single-Purpose Application

5.6.3 System Architecture: Updated

To have such a function of querying, as the biomedical expert suggested during the interview, one needs to explore how it should be connected and retrieved from a database. The database would be excluded from the patient's view and only to query former patients and statistics. In Figure 28, the database is separated from both the patient and the physician. There is an advanced medical reference on the physician's side, where it contains everything needed basing on keywords retrieved from the patient database, with the main domain being cardiology. The patient database contains information gathered from the patient consultation and retrieved from scanning a QR code during those consultations. There is a simplified medical reference on the patient's side that retrieves information regarding their health but in a simplified format. There is also a health database that saves all the data collected since the last consultation.

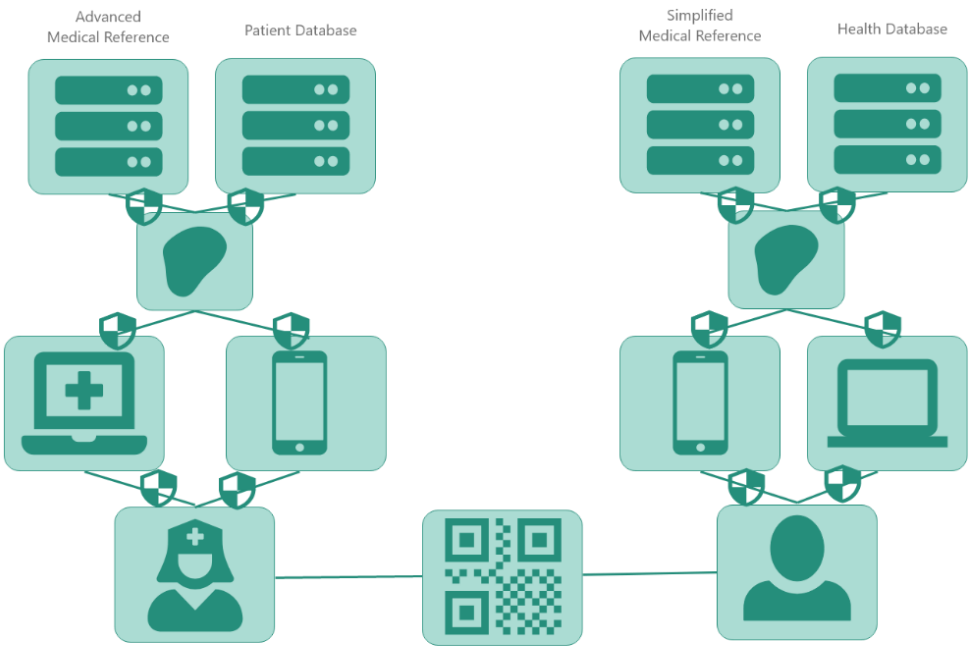

Figure 28: System Architecture: Updated

5.6.4 High-Fidelity Prototype

This section presents the third iteration high fidelity prototype of the project with updated functionality. Functions found in the patient prototype are measure PCG signals remotely, with the possibility of generating a QR code with the recorded data. Other functions are contact information of health personnel instead of direct communication due to feedback received in iteration two. Functions such as earlier recordings, medication overview with alerts, and calendar views are still present in this iteration. Functionality on the physician's prototype has been updated as they had no clear purpose in the second iteration. The functionalities are in detail under the

Physician Prototype section. Colour choices for both the patient views and the physician's view are similar in this iteration to keep a more simplified design. The mobile version menu is moved to the bottom to allow easy accessibility on all the pages. There is also added a setting and a log-out screen if one clicks on the profile icon.

5.6.4.1 Patient Prototype

For the patient prototype, the cards for the functionality have been updated with sharper edges to create a bigger distinguishability between buttons and information. Each functionality has received its own icon, and the icons are larger to make it easier to navigate for people with bad eyesight. This iteration contains many mini cards, cards within cards that give quick information regarding the functionality. The measurement card was updated with actual feedback when the last measurement was taken and a quick link to more information regarding the recording. The medication overview gained a quick info mini card regarding when the next medication is supposed to be taken – the type of medication can be found if one clicks on the mini card.

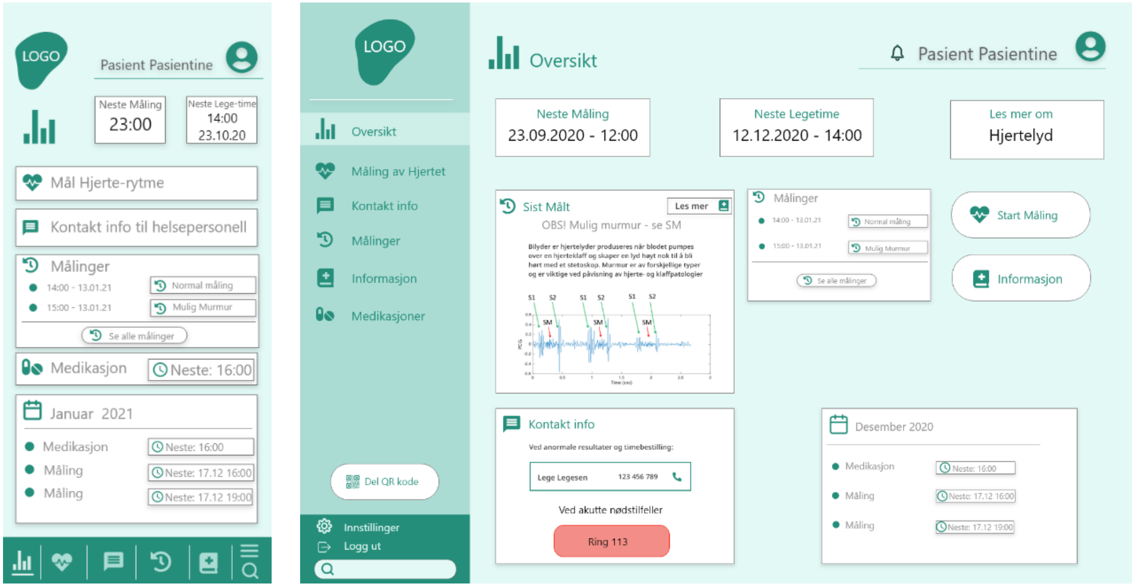

Figure 29: Iteration 3, patients view, overview page

There were added some concept instructions for the measurement page as this iteration focuses on PCG measurement instead of ECG. For this, changes to the instructions had to be made based on the feedback from the interviews. Firstly, instructions regarding how to place the nodes or sensors on the person's body—giving instructions in the form of a video indicated with the play button or a picture of a person with sensors placed on them. There needs to be feedback regarding whether the sensors are placed correctly, either through a check sensor button or other feedback. Thirdly, there needs to be feedback regarding what kind of environment the person needs to be in, as PCG measurement can easily be "corrupted" due to its nature of sounds. Other similar applications in the market alerts the user that there is too much noise in the background. On the web version of the prototype, there is information regarding the last recording.

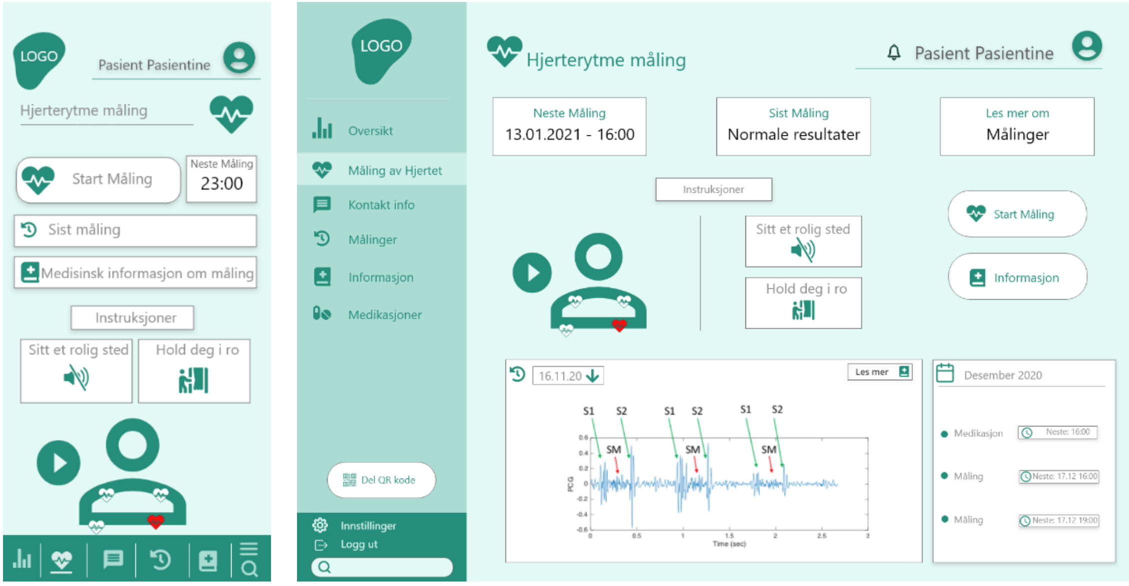

Figure 30: Iteration 3, patients view, measurement page

As seen in Figure 32 has been updated with significant cosmetic changes. The measure again button is more prominent, and a QR code icon generates a QR code containing the recording. The red lines around the information box have been removed and replaced with all caps as it serves a similar purpose and seems less alarming. The mood of the moment has fewer emojis, as fewer serves the same purpose and seem less cluttered. The results page also includes information regarding the probability of the results and the sensors' accuracy as they could have been affected by wrong placement and sounds. As seen in Figure 32, the web version has merged results and earlier recording, including the possibility of choosing dates of earlier recordings.

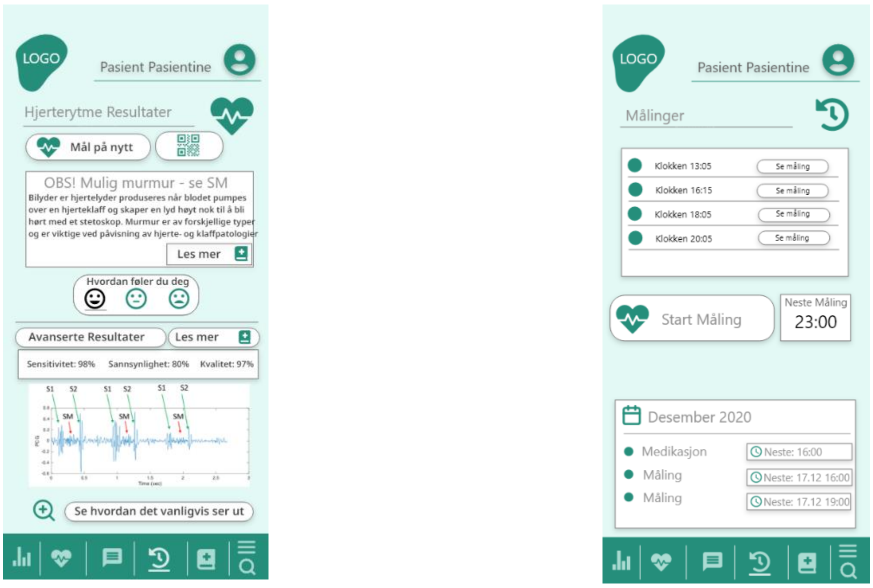

Figure 31: Iteration 3, patients view, Results page on phone

Figure 32: Iteration 3, patients view, Results page

Figure 33 presents the medical information and theory page with more query functionality than iteration two. These functionalities include favourite subjects to give easy access to things one might often read or visit. The other functionality is adding the last visited to a list of favourite pages.

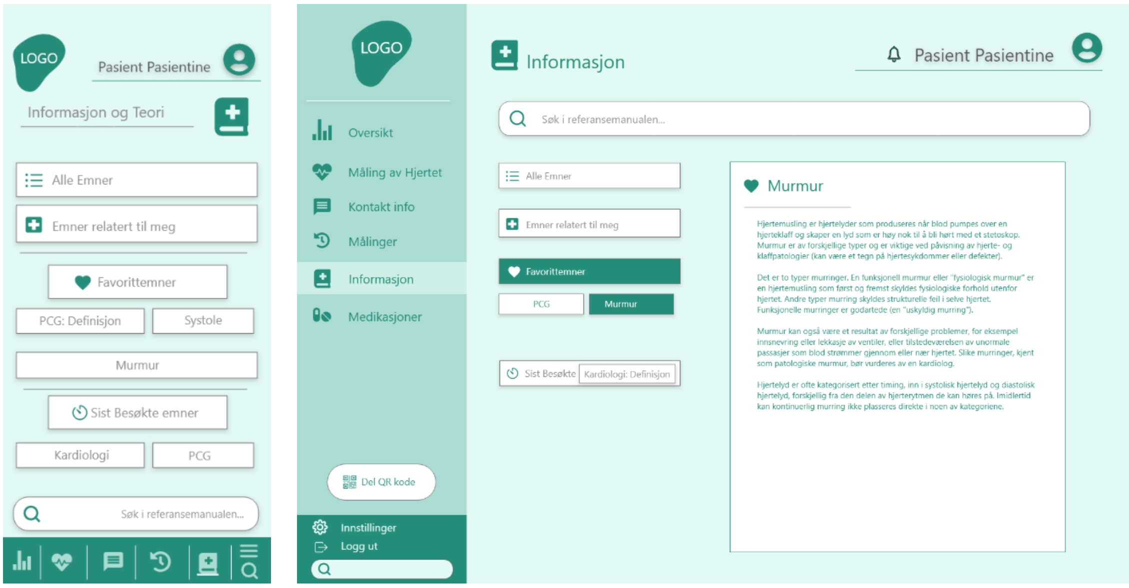

Figure 33: Iteration 3, patients view, Information page

As the communication between physician and patient has been removed in this iteration, Figure 34Figure 34: Iteration 3, patients view, contact info page presents quick call functions and contact information for different vital staff to contact regarding different scenarios, as well as 113 for cases of emergency.

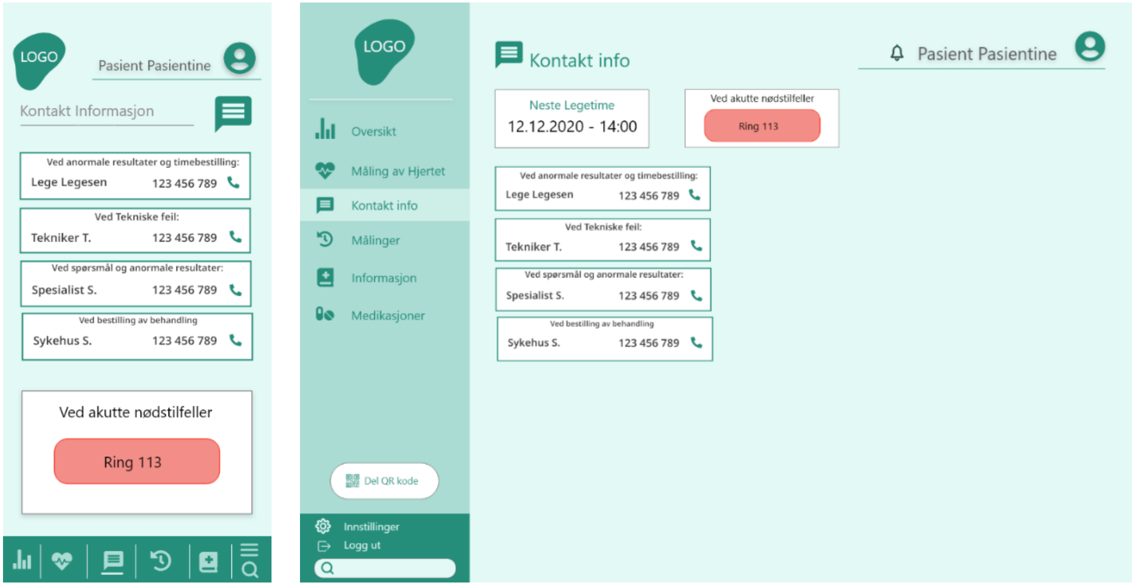

Figure 34: Iteration 3, patients view, contact info page

5.6.4.2 Physician Prototype

In this iteration, the physician prototype includes a register QR code button that opens the camera and gives the physician the possibility of registering PCG recording from a patient's phone instead of directly linking them. This choice of functionality was to confront the strict laws regarding Norwegian health data as discussed in the Section 5.5.1, Interview with a paediatrician. Restrictions were made by having a work phone that one can only use when on duty within the hospital network, making it unavailable otherwise. Restricting the application's use makes the data's integrity kept in place, as the data will not leave the hospital. Other functionality added on Figure 35, is statistics of earlier according to a suggestion from the expert interview. The primary purpose for the physician view of the prototype is registering patient data, looking up active patients and their recording, querying for earlier patients based on specific criteria, medical encyclopaedia, and statistics.

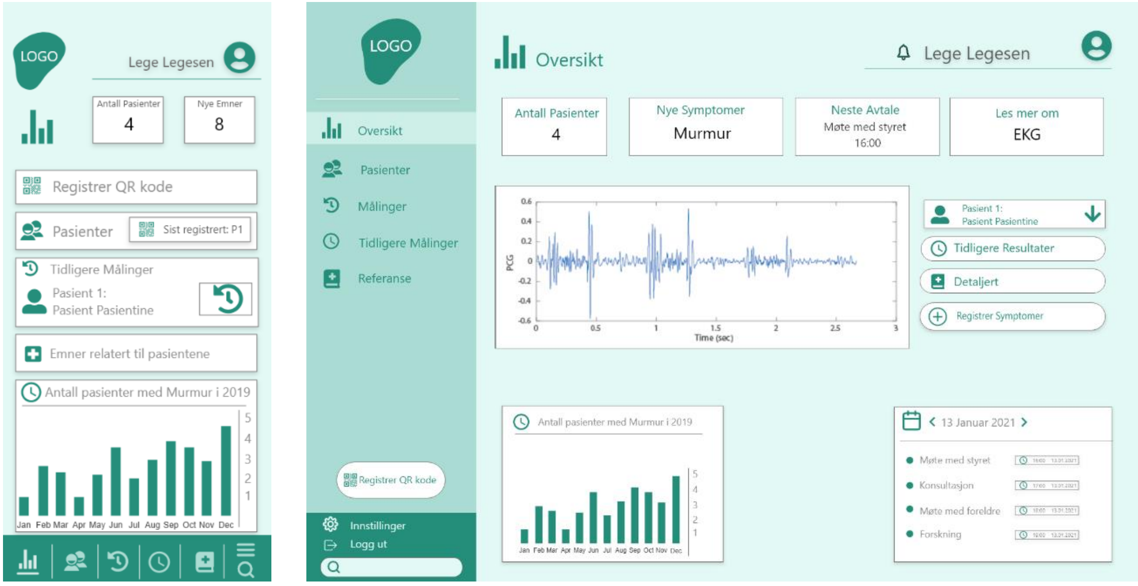

Figure 35: Iteration 3, physician view, overview page

The prototype's measurement page contains earlier measurements of patients, with a more detailed view compared to the patient's version, as physicians do not need the same simplified feedback as seen in Figure 36. This page also has a start consultation button to give the physician possibility of registering new health data from the patient directly with their own device and registering symptoms and other information in the patient's health journal.

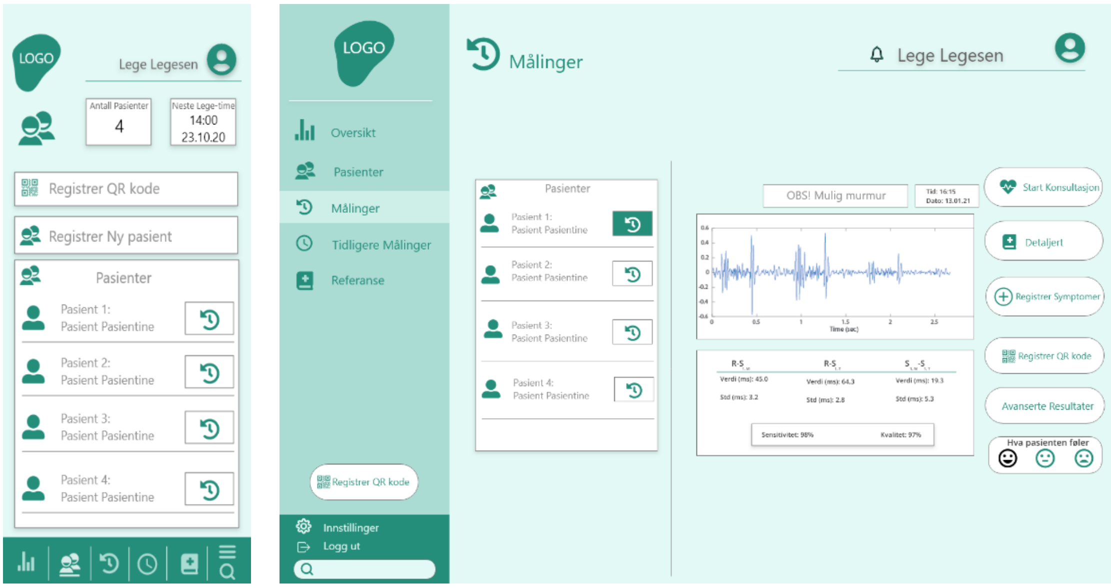

Figure 36: Iteration 3, physician view, measurement page

On the patient overview page, one can look up earlier measurements, register new symptoms, register QR codes, and browse all the current active patients.

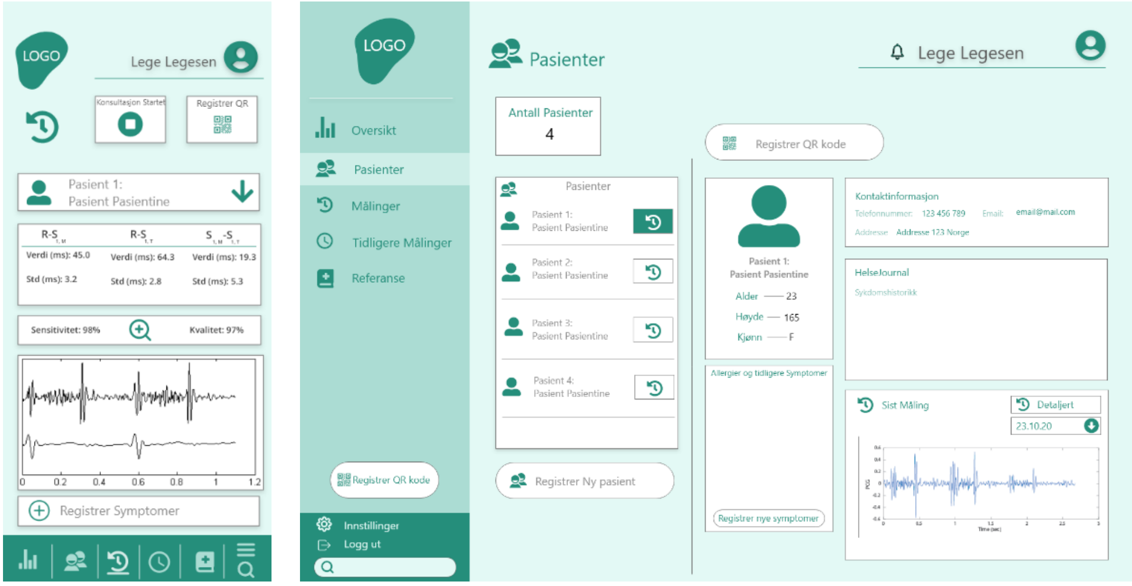

Figure 37: Iteration 3, physician view, patient overview page

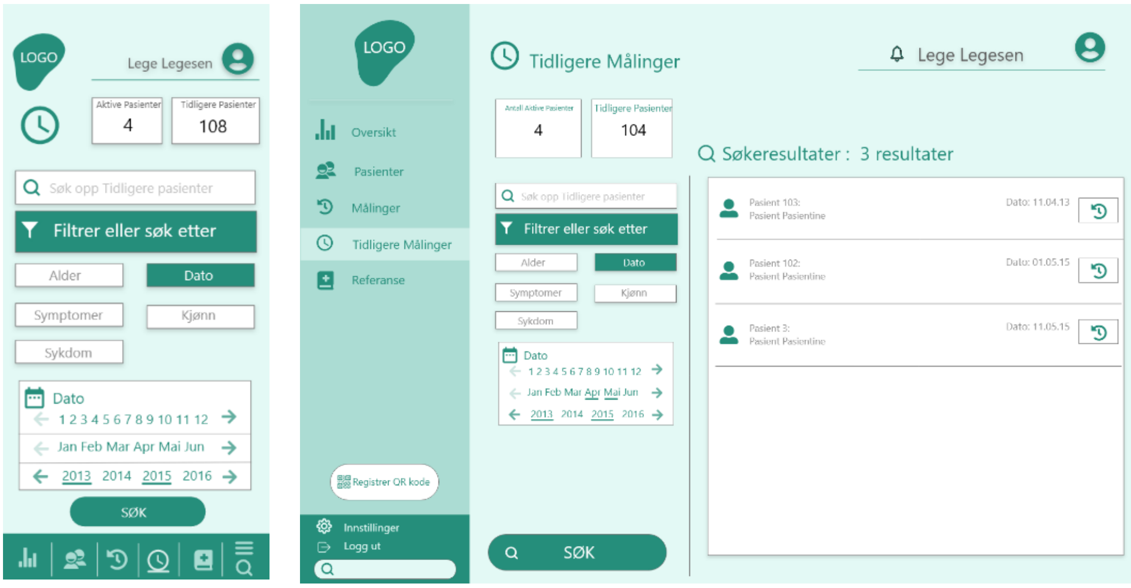

Figure 38: Iteration 3, physician view, patient Query page

In Figure 38, the physician can query through earlier patients based on specific filtering keywords such as age, gender, symptoms, illness, and others. This function is created for physicians who want to review a former patient but cannot remember their name but remembers the year or symptoms. Figure 39 has not changed since the last iteration, except for updated design.

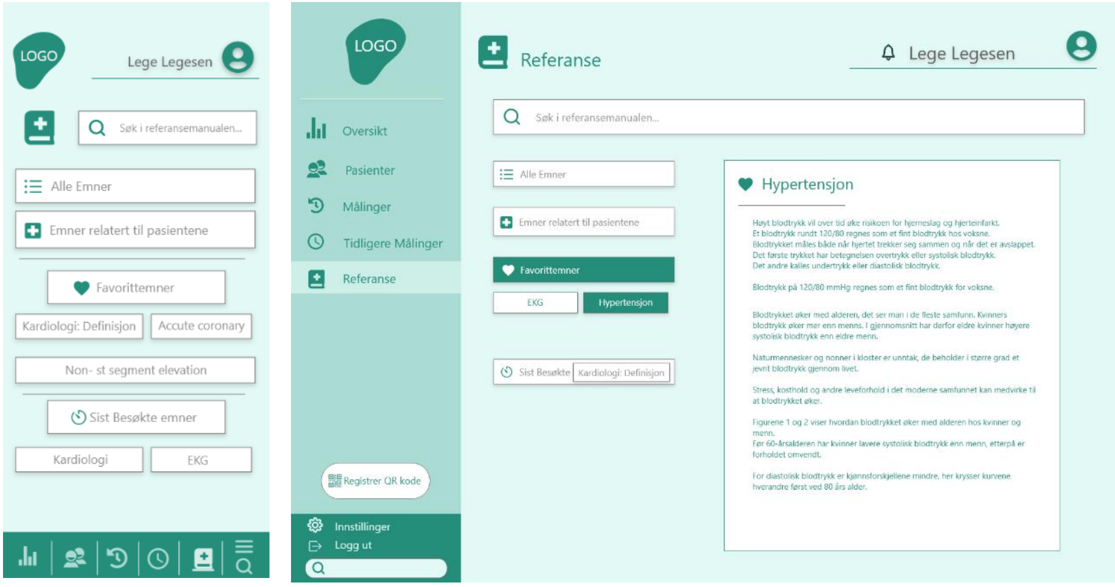

Figure 39: Iteration 3, physician view, medical reference page

5.6.4.3 Different Results Version 2

The different versions of the results screen have the same setup as the last iteration, but with the new design choices for this iteration.

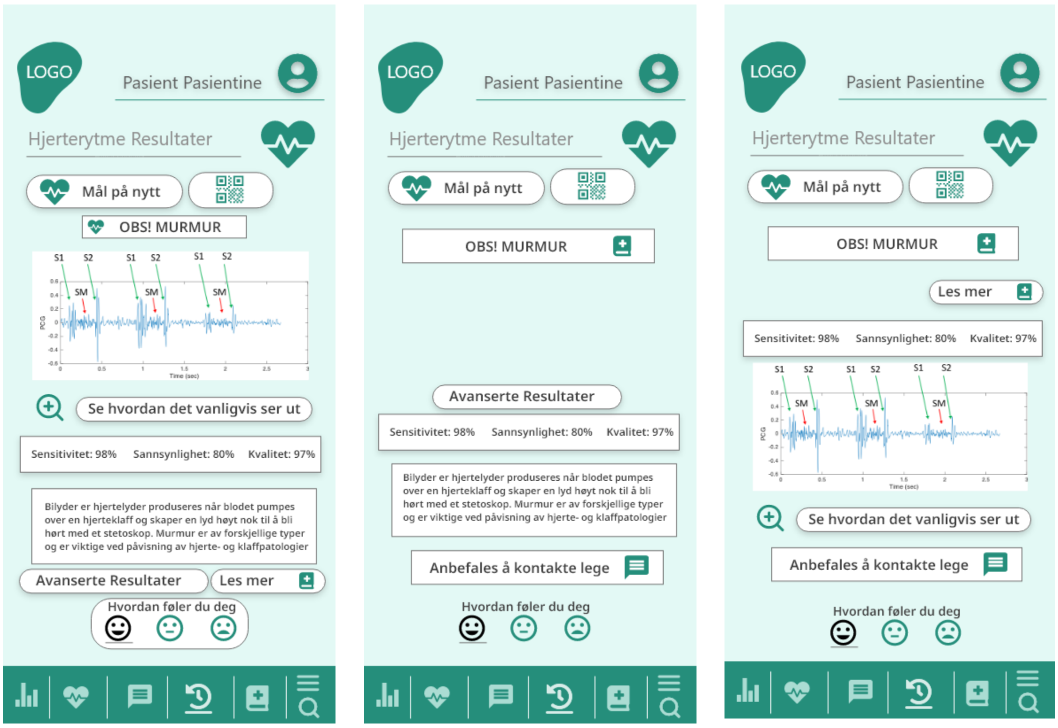

Figure 40: Iteration 3, patient view, different version of results page

5.7 Final Design Choices

5.7.1 Name Choice

For the final iteration, the prototype gained its name "IntelliCor" inspired by the Latin word for understand, Intelligo, and the Latin name for heart, cor. The logo, as seen in Figure 41, was created using the Google font Roboto Condensed and the heartbeat icon from the metro iconset using AdobeXD (Google, no date; Pimenov, 2020).

Figure 41: Logo

5.7.2 Icons

The icons used in the third iteration of the prototype were retrieved through AdobeXd using a collection of icons as seen in Figure 42. The libraries used were: Ionic, feather, metro, material, and awesome (*feathericons*, 2020; Google, 2020; Pimenov, 2020; Awesome, 2021; Team, 2121). The collection of icons has a simplistic design but represents critical functions in the prototype.

Figure 42: Icons used in the final iteration

5.7.3 Colours

The colour choice for the final iteration has fewer colours than the two first prototypes, as to not confuse the user with more colours and keep it simple. The final colour palette can be found in Figure 43. Hues of green, blue, and pink are all present in the medical world and are not intense for the eyes. Jane and Nigel Coad explore colour preference in a health care setting. They gathered views of 180 children and their preferences of thematic colours. They found that overall the most popular colour preference was the mid blue and green colours (Coad and Coad, 2008). Nevertheless, the colour choices might be wrong for people of old age, as Bosch notes in her report about the application of colour in health care settings as: "*Rousing, bright colors are more appropriate in environments for the aged than pastels, which are barely visible to those with failing eyesight"* (Bosch and Ki Jain Malkin Inc, 2012). To design for this predicament, one can add a contrast mode for the application to increase the contrast between functions, making them more easily distinguishable.

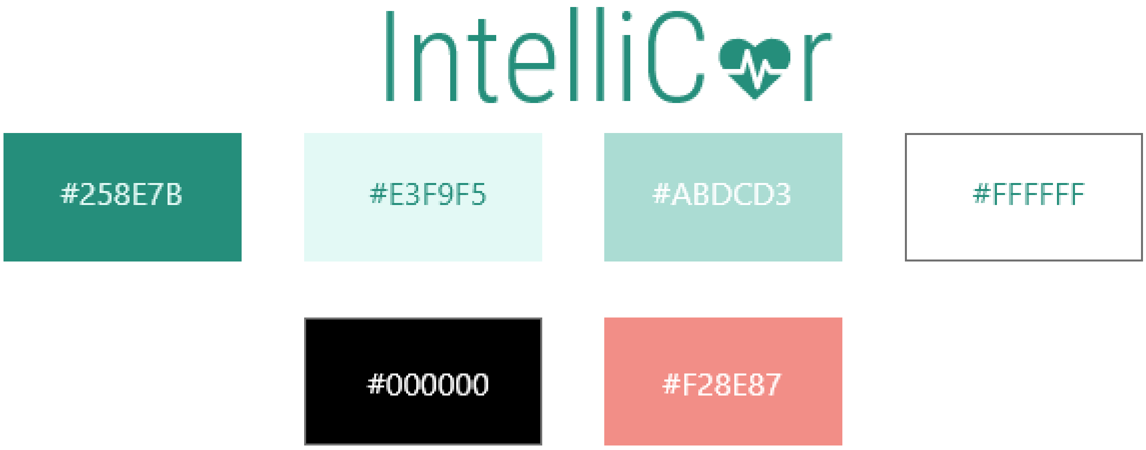

Figure 43:Colors used in the prototype

6 Evaluation

In this Section, the thesis presents results from the evaluation conducted on the third iteration. The evaluators evaluated the project through observable and quantifiable metrics discussed in the evaluation section, System Usability testing, System Usability Scale (SUS), Heuristic evaluation, and an evaluation of the variations of the results screen.

6.1 Evaluators

To obtain more varied feedback for the evaluation of the third iteration of the prototype, two different user groups evaluated the prototype. The first group was six students from the master's in information science line at the University of Bergen. The second group consisted of a medical student in their 6th semester and a children's cardiologist. The total number of participants is eight. According to Nielsen, the ratio between benefits and costs using a number of heuristic evaluators for finding problems during usability evaluation methods is around five evaluators – as exceeding, the benefits and costs are not as high as payoff (Nielsen and Landauer, 1993). Thus, this project using six usability experts and two medical experts is within that range.

6.1.1 Usability Experts

The group of master students in the evaluation were considered IT usability experts. They have knowledge and experience in evaluating prototypes by participating in subjects such as Human-Computer Interaction, User Design, or Interaction Design. All the participants evaluated the prototype through the four evaluation methods. Table 3 presents the demographics of the IT experts.

Participant ID	Age	Gender	Education Level
P1	25	M	Master Student, 4th semester
P2	34	M	Master Student, 4th semester
P3	26	M	Master Student, 4th semester
P4	24	F	Master Student, 4th semester
P5	24	F	Master Student, 4th semester
P6	25	F	Master Student, 4th semester

Table 3: Usability experts

6.1.2 Medical Experts

The medical expert's group consists of two people: a younger physician student who provides a younger perspective and is new to the medical world. The second participant is an experienced medical children's cardiologist who has worked in different parts of Europe and is considered a medical expert with long experience. Presented in Table 4 summarized the demographics of the medical experts.

Participant ID	Age	Gender	Profession
P7	25	F	Medical Student, 6th semester
P8	44	F	Cardiologist and paediatrician

Table 4: Medical experts

6.2 System Usability Testing

The system usability testing conducted with all participants was done over the internet through Zoom or other internet communication program due to the coronavirus. During the evaluation, the person had to share their screen and use a computer when completing the task as one could not share screens using a phone in the same effective way.

6.2.1 Usability Metrics

The usability metrics used in the system usability testing are inspired by a collection listed by Justin Mifsud (*Success Rate: The Simplest Usability Metric*, no date):

- Effectiveness: How the users achieve specific goals, and if they can complete them
- Efficiency: How fast the users achieve specific goals
- Satisfaction: Comfort and the acceptability of using the prototype is presented through the System Usability Scale.

6.2.2 Tasks

The evaluators were presented with the task in Figure 44. The tasks were divided into two categories: patient and physician, as well as tasks for the mobile version and the web version. The mobile version is represented by the phone icon on the left of the tasks, and a computer icon represents the web version. Before the evaluation, the evaluators received information regarding the prototypes' main functionality, as they had not interacted with it before. The participants were presented a use case for each prototype to get them immersed in the evaluating. They did not receive any instructions on completing the tasks, only clarification of the tasks if needed.

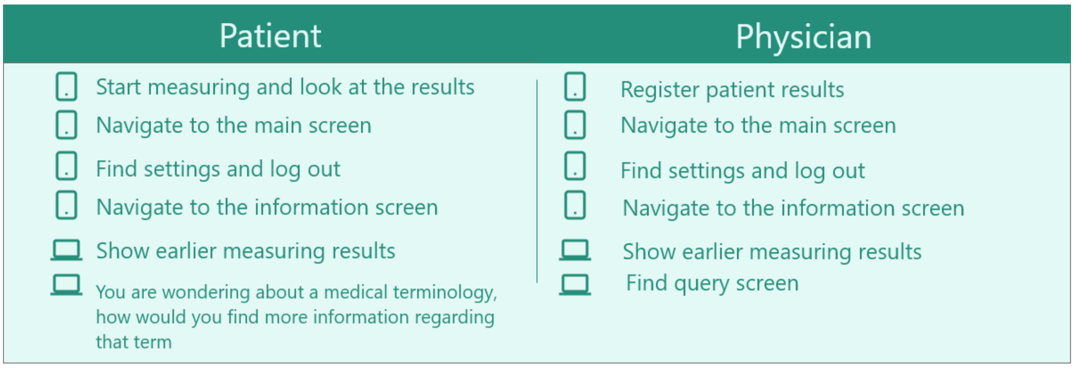

Figure 44: System Usability Testing Tasks

6.2.3 Evaluation Results

6.2.3.1 Patient Version

For task one, the evaluators got to view the phone version of the prototype for the patient version, and they were given the task "start measuring and look at the results." To give them more context to the task, they were given the scenario of being a patient who is going to measure remotely from their home; they have had received instructions on how to do it from their physician. They were not given any further instructions, and the main purpose is to see if the functions, names of functions, and icons are correctly placed and named so they can navigate without prior instructions. As seen in Figure 45, task 1, P8 did not complete the task as they were too similar to the physicians' tasks and therefore the tasks were not given to the participant to complete. P1 and P4 used more time than the rest on task one, as there is a static loading screen that one needs to click away manually; these numbers would have been lower if they were auto directed from that page.

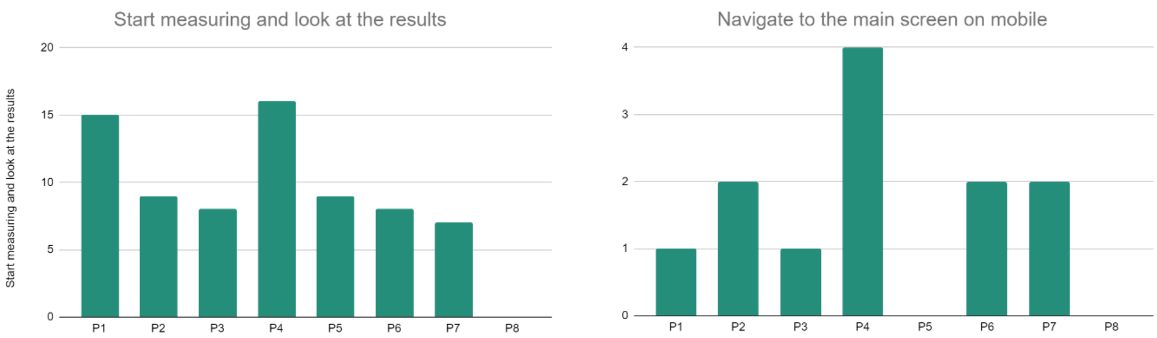

Figure 45: Task one and two represented by time of completion in seconds

In task two, results can be seen in Figure 45, P5 managed to navigate back at 0.5 seconds, which is why the bar is not shown. For P4, there was some uncertainty about what the definition of the main screen was. There were three ways of navigating back to the main screen, either through the logo, which three of them used, through the menu bar, which three of them used, and through the expanded menu, which none of them used. In task three, as seen in Figure 46, the participants were supposed to find settings and log out on the mobile version. The function was in the profile icon, and most of them found it within seconds except for participant four. The participant four had some complications with finding it and clicking at every function to navigate to the correct task.

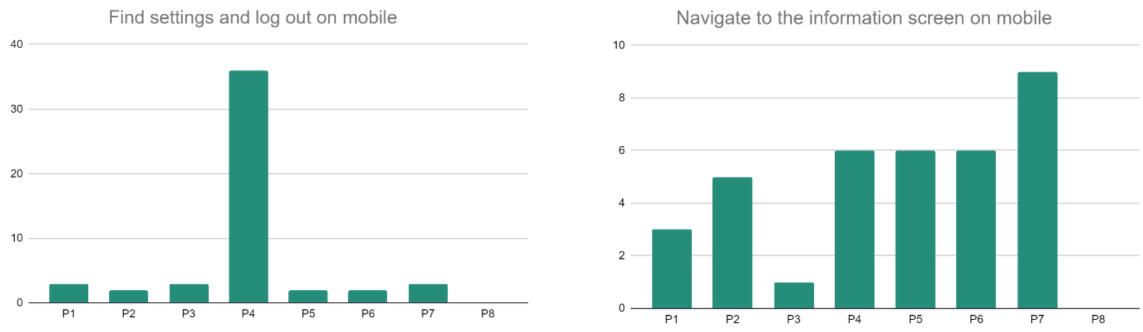

Figure 46: Task three and four represented by time of completion in seconds

In task four found in Figure 46, the participants were supposed to navigate to the information screen (called information and theory in the Norwegian version). There are multiple ways of navigating to that function; most of them used the menu, except for P3, who used one of the main screen shortcuts, thus saving much time. P7 was unsure about what icons represented that function and needed to get extra clarification and context. Task five was using the web version of the prototype, and the results of this can be seen in Figure 47. In task five, the participants were supposed to find earlier recordings results on the web version. There were also multiple ways of navigating to that function, through the menu or through the main screen of clicking the earlier results icon, which appears twice. Participants with the quickest time navigated there through one of the buttons on the main screen, P3 and P6 navigated there through the menu; after clarification, one can use the menu to navigate. P5 was unsure and found it by manually clicking through all functions.

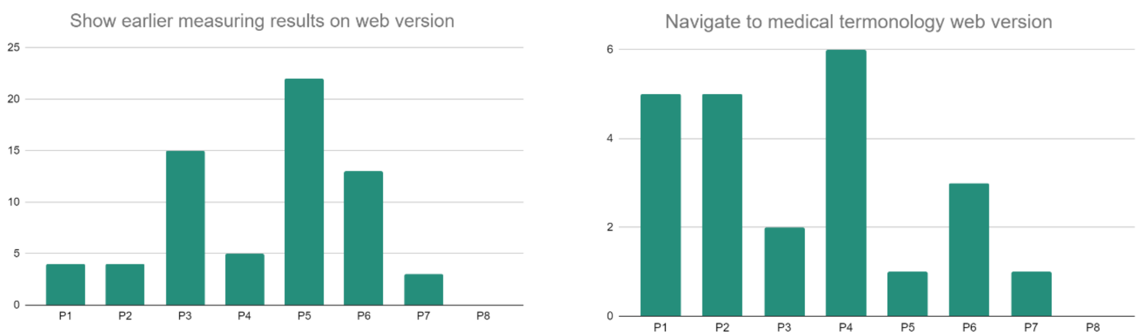

Figure 47: Task five and six represented by time of completion in seconds

In task six, the participants navigated to the medical theory section in the web version. There was some confusion about what to navigate to, so most needed a context of “you have recently measured something, and you were unsure about the wording in the recording, where would you navigate to, to explore this further.” They were initially on the measuring results page, and they could navigate via the menu or directly in the information box in the measuring results screen. Half of them navigated through the menu, while the rest used the link in the information box. The participants who used 3 seconds or more navigated through the menu but was unsure about where to find the function.

6.2.3.2 Physician Version

The usability experts (P1-P6) were not given the first four tasks for the physician version, as they were too similar to the patient version. Instead, the medical experts P7 and P8 evaluated through tasks. For task one on the mobile version of the physician’s prototype, the task was to register patient results using a mobile. The participants were given the context, “you are a physician who has a patient in for a consultation, they have presented you with a QR code with their recording in, and you are going to scan it and look at the results.” Both the participants found the function within one second, as it is one of the first functions located on the main screen.

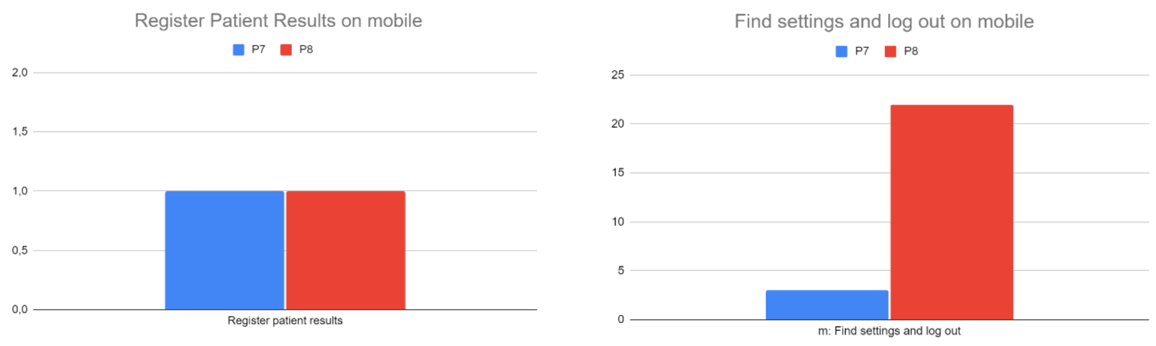

Figure 48: Task one and two, physician version represented by time of completion in seconds

In task two, P7 and P8, were given the same task as the usability experts in the prototype's patient version. P7 found the function within the profile icon within seconds, implying that this is familiar due to similar functions in other applications. P8 did not know that the profile icon would lead to the logout and settings. P8 commented that if the profile icon contained a picture of the physician and/or the person's name that it would help the participant find the function quicker.

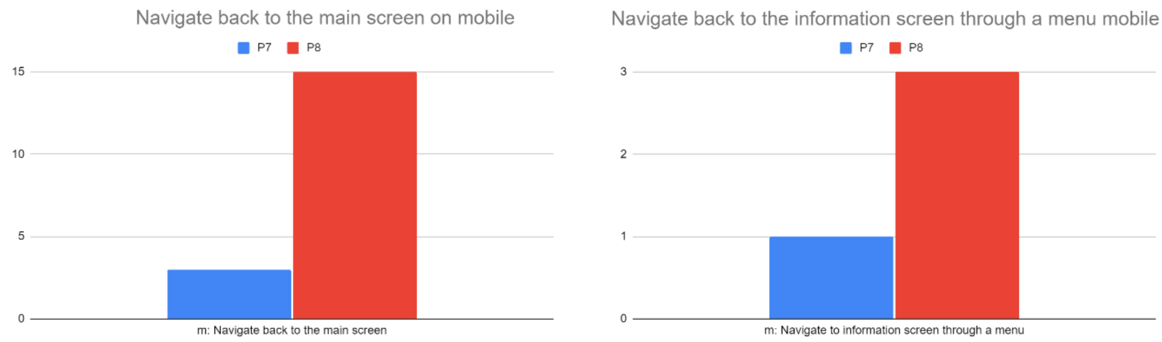

Figure 49: Task three and four, physician version represented by time of completion in seconds

In Figure 49, they completed task four before task three, as they needed to navigate to somewhere before they could try to find their way back. When the participants were asked to navigate to the information screen, they were given the context of: “you are a physician who wants to read quickly upon a medical term.” Both participants understood where to navigate; P7 navigated through the main screen using the cards' functions, while P8 used the expanded menu. For navigating back to the main screen, P7 used the logo, but P8 was unsure what the definition of the main screen was and was confused using the icon for the main screen, thus taking longer for explaining and defining the main screen.

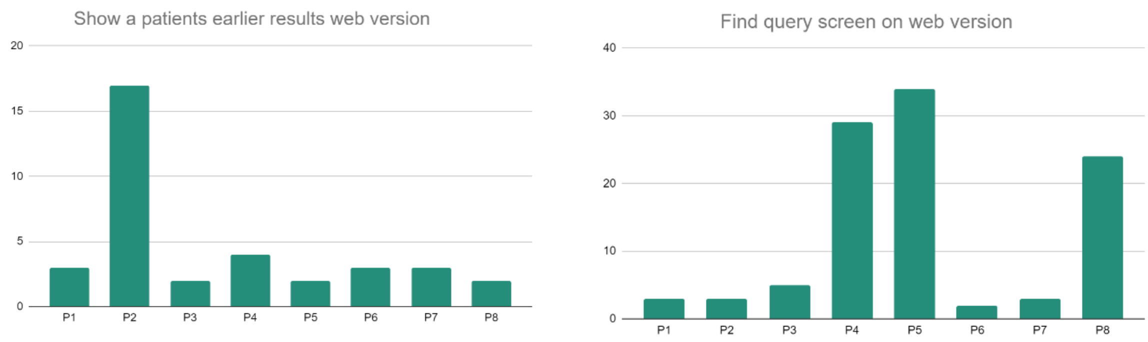

Figure 50: Task five and six, physician version represented by time of completion in seconds

For tasks five and six, all participants received the same tasks. In task five, all participants found the function within 3 seconds except for P2. P2 was unsure about the task and needed further explanation and indicated that the icons and names for functions were confusing. In task six, the participants received the following context: “you are a physician who has a new patient with symptoms that reminds you of an earlier patient, but only remembers the year and symptom. Where does one go to query this, to find that former patient”? P8 commented that the function was too similar for the list of earlier measurements and active patients, there was some confusion in where to find the query function. P4 and P5 had some confusion around what the query function was. Multiple participants suggested to either rename the function or rename the function's title for more straightforward navigation.

6.3 System Usability Scale

The evaluators provided feedback on the third iteration through a system usability scale sheet. The sheet can be found in Appendix C 1: System Usability Scale. The sheet was filled out by the participants on their own time after completing the task. When completing the form, they had access to the prototype through AdobeXd links to refer to any functions. Most of the participants responded positively to the prototype, while P4 and P5 had some problems. P4 and P5 both expressed how they felt they lacked the prototype's context through the heuristic evaluation comments, indicating that more context and explanation should have been received beforehand. The average results from the system usability scale evaluation were 90 points, which is the rating of excellent as it is above 80.3 points.

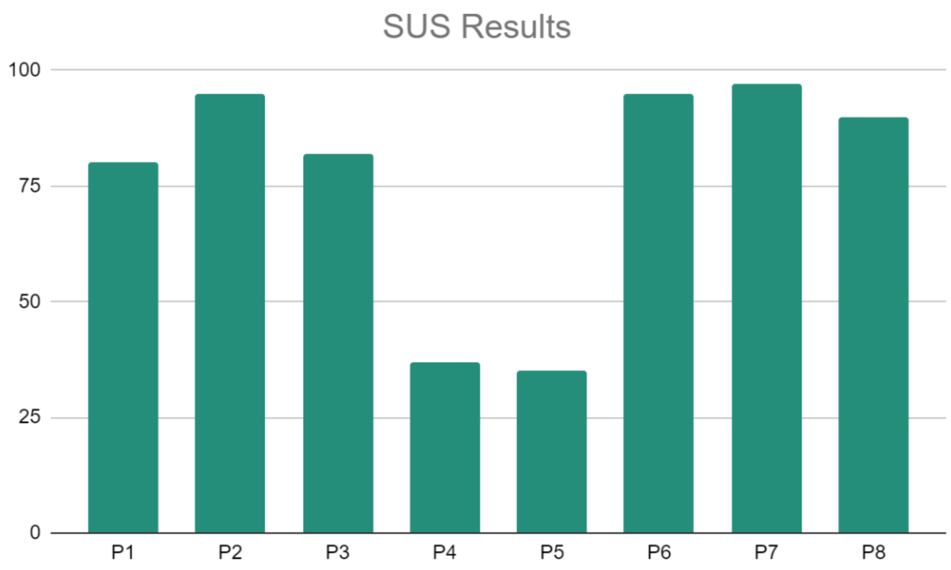

Figure 51: System Usability Scale Results

6.4 Heuristic Evaluation

The third type of evaluation the participants used was filling out a heuristic evaluation sheet based on Nielsen’s heuristic after completing the tasks on their own time (Nielsen and Landauer, 1993). The sheet can be found in Appendix C 2: Heuristic Evaluation Sheet. They were asked to rate each heuristic severity from 0 (I do not agree that this is a usability problem) to 4 (usability catastrophe, imperative to fix this before the product can be released).

The average results from each heuristic can be seen in Table 5. The participants gave written feedback regarding each heuristic issue and recommendations to mend those issues (if they had any); these are presented under each heuristic in the following sections.

Heuristics	Average on a scale from 0-4
1) Visibility of system status	1,25
2) Match between system and the real world	0,25
3) User control and freedom	0,625
4) Consistency and standards	0,75
5) Error Prevention	0
6) Recognition rather than recall	1
7) Flexibility and efficiency of use	0,75
8) Aesthetic and minimalistic design	1,125
9) Help users recognize, diagnose, and recover from errors	0
10) Help and documentation	0,625

Table 5: Average results of heuristic evaluation

6.4.1 Visibility of system status

As the application lacked some functions, it also lacked some key points to the visibility of system status. The lack of features is reflected in the participants' feedback that they are unsure whether they would get feedback from the application. Other feedback from the participants was that visibility was somewhat good, few of them felt that each site's heading was not clear enough and might need a rework, and the menu items were not highlighted enough. Suggestions for the issues were increasing the text and icon size to make the page heading clearer. There were suggestions about making the icons bigger and more contrast for the menu bar to make them stand out.

6.4.2 Match between system and the real world

The participants seemed pleased with how the prototype matched the system with the real world with an average of 0.25. Some participants commented that the icon for keeping still in the measuring screen might not be intuitive and that another icon might be a better fit. One could replace that icon with a person sitting on a chair or something similar. A participant commented that symbols should have text above when hovering over them on the web version to indicate what they lead to. In the mobile version, one could press and hold the button, and a small text could appear above it. Other than that, the participants found the prototype not too advanced and gave the user good information while they used it.

6.4.3 User control and freedom

User control and freedom is where the prototype received the most critical feedback due to its importance. Multiple participants noted a lack of a return to the last page button and needed to navigate to the main page, then to the previous visited function. Another feedback was that the earlier measurement button is not as intuitive as possible. One should either merge the active patient with the earlier recordings or make the icon more intuitive. One participant commented on the recommendations that the focus should be on the individual patient. One could implement a search function within a tab in the active patient list, thus merging them would create a better navigational experience.

6.4.4 Consistency and standard

The feedback retrieved from consistency and standard was that the consistency was mainly great, but that the button shapes should be consistent. Varied shaped buttons might lead to confusion. The same feedback can be applied to the information and theory, as the boxes are sorted in different shapes and sizes. The participants were happy that the icons match functions, as one can recognize functions based on the icons, thus providing consistency and a standard for this prototype. An issue that one of the participants have reported was that a lot of the buttons navigate to the same function. This was implemented to keep the design unique and simple and secure an effortless navigation, nevertheless it seems to be confusing for some which has to be addressed in the design.

6.4.5 Error Prevention

As the prototype lacked fully implemented functions, it had consequence on reporting of errors; hence the participants had no feedback regarding the error prevention in the prototype. This can be found in many student projects, due to the lack of time to implement more functionality and corresponding error reporting.

6.4.6 Recognition rather than recall

Most of the participants were pleased with the recognition but commented again that the buttons should be of consistent shapes, as one should recognize the buttons as buttons. Another suggestion was to have all the buttons in another colour or have them all in the standard oval button shape.

6.4.7 Flexibility and efficiency of use

The average of this heuristic was 0.75; the participants felt that the prototype was efficient to use, with great flexibility except for the lack of a go back button. As adobeXd prototypes are manually connected by the person who creates the prototype (developer), some human errors occurred during the evaluation. Some functions or smaller links were not correctly connected, thus creating some navigation problems, but the participants were clarified of this problem before starting to evaluate the prototype. Other comments were that two of the participants felt that it was difficult to navigate to the settings button through the profile icon located on each page; a possible recommendation from both participants is to place it above the profile icon or in the expanded menu.

6.4.8 Aesthetic and minimalistic design

For aesthetic and minimalistic design, the participants felt that the information and theory page was cluttered due to the different sizes of the boxes. A recommendation for fixing this is to change the boxes' size and list the user's favourite definitions and articles instead of already showing them when entering the page. This recommendation also fixes how some of the participants felt that the information and theory page felt cluttered. Some participants were unsure about the importance of the share QR code button that is prominently displayed in several places in the prototype. However, as this is an essential function, it needs to be present, but maybe less prominent as earlier planned. Two participants commented that they felt the main page had too much information and that the user might feel overwhelmed.

6.4.9 Help users recognize, diagnose, and recover from errors

Like the error prevention recognition, there is a low average score on this heuristic as they had no errors, thus not needing to recognize, diagnose and recover from them.

6.4.10 Help and documentation

One of the participants commented that elderly patients need additional help to use the prototype. One needs to implement a help page to explain them in both pictures and familiar words. Another participant commented that they found no visible help button in the prototype, but this might be a misunderstanding from the participant. This function was clarified in the tasks, as the help functions would be placed within each profile icon. Another view on this is that the help function might be more visible than inside the profile icon.

6.5 Variations of the Results Screen Content

The evaluators were also provided a google form with questions and pictures of the different versions of the results screen as presented in Different Results Version 2 in Chapter 5: Iteration 3. The results screen presented to the evaluators can be seen in Figure 53. The idea of presenting results differently was to gain an insight into what would be a preferred way of presenting health information and why.

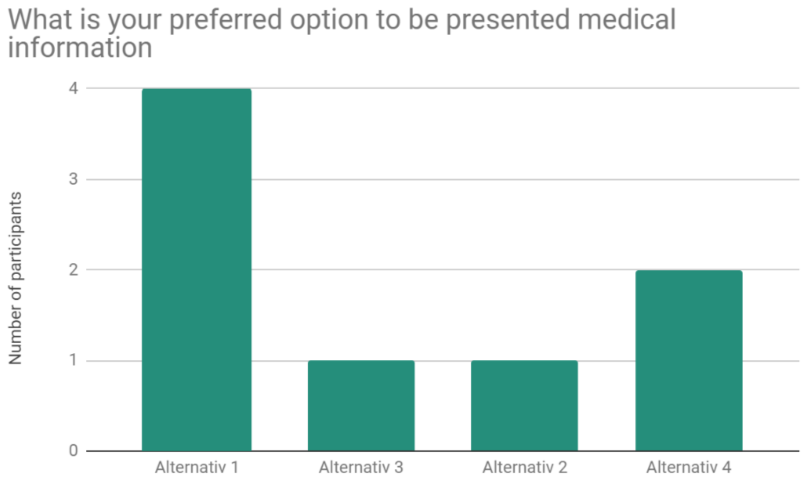

Figure 52: User preference regarding presentation of health information

Half of the evaluators preferred alternative one, which is the original design choice for the result screen. The information about the results was presented first, then the visual representation of the measurement. The evaluators liked that one could read up on the results before showing the visual measurement, as first text is presented first, followed by visuals. They felt that this way of sorting the information was better flow in the design, and it presents a more logical progression of information than the other versions.

One participant preferred version two, where the visual is presented first, then the text information are followed. The most critical data comes first (the visual measurement), and additional information that might not be as interesting or relevant for the patient came afterwards. The evaluator who liked version three – which is the no graph version of the prototype, argued that this version was less “noisy” due to the lack of the visual. The two evaluators on alternative four commented that the amount of information (or the lack of it) was preferable, as it could otherwise give the patient information overload. Other general feedback from the results screen was some felt the smile icons should be more precise and available as they became too hidden or small.

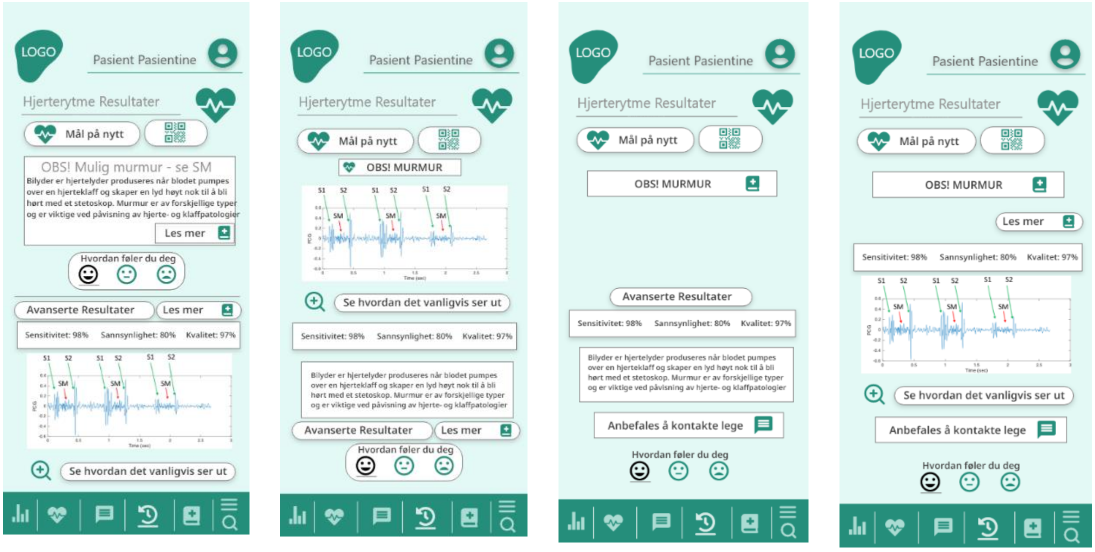

Figure 53: Four variations in presenting results as given to the participants in the google form.

7 Discussion

In this section, the thesis addresses methods and methodologies, the final prototype, data acquired during the research, and discussing the research questions that were stated in the beginning.

7.1 Research Methods and Methodologies

There have been multiple research methods and methodologies were applied during this study. The thesis followed the design science research discipline based on Design Science information systems research by Hevner (Hevner *et al.*, 2004), as explored in Section 3: Design Science Research. The thesis followed the seven guidelines; the primary methods and methodologies that are presented in Section 3, the following section presents how they were used in the project.

7.1.1 Design Principles

The design principles presented in Section 3.4.1 were applied and used throughout the prototype iteration development. The principles correlate with the evaluation in Section 6.4, Heuristic Evaluation. The design principle *Visibility* can be compared with the results from the heuristic evaluation of the heuristic *visibility of system status*. The participants found the prototype had rather good visibility but commented regarding navigational indications, stating that the prototype complies with the design principle *visibility.* The second design principle is *feedback;* one can compare the principle to the heuristic *help the user recognize, diagnose and recover from errors* and *user control and freedom*. One can say that those heuristics do not necessarily describe feedback but all of them in some parts correspond with the feedback principle. In *help the user recognize, diagnose and recover from errors*, one can argue that using feedback, one can help the user use visual feedback to recognize, diagnose and recover from errors. The participants rated this heuristic as 0, as there was no error to recover from in the final iteration. The following heuristic is *user control and freedom*. The users can get information regarding where to navigate through visual feedback, either through hovering or pressing a function instead of clicking it. The participants rated this heuristic low, feeling that they could navigate freely through the prototype. Combining those principles, one might say that the prototype has good *feedback* integrated but needs to add more clues and indications in the future development.

The third principal *Constraint* concerns how to create a functionality that does not negatively impact the workflow. For this, one can also include the heuristic *help user recognize, diagnose, and recover from errors*, as well as *help and documentation* and *error prevention*. Constraints concerns how the application's developer creates functionalities that should help the user recognize, diagnose, and recover from errors, either via the functionality or through feedback. If the user has received an error, they should consult a help and documentation function. All the heuristics received a low score, as it is impossible to receive errors during this part of the iteration. However, the participants reported the desire for error handling functionality through documentation and visual feedback.

The design principle *Consistency* represents how the design and functionalities should be consistent through the application and make it easier for the user to navigate and recognize functionalities; thus, the heuristics of *consistency and standards* and *aesthetic and minimalistic design* can be applied to this principle. The participants had more feedback on these two compared to the other heuristics. The feedback was generally about the button design and how it should be kept consistent through the prototype.

The final principle is *Affordance,* which is an essential principle. It deals with understanding functionalities and design so that the user can recognize certain functionality, colours, or icons. For this principle, one can compare it to the heuristic of *match between system and the real world, recognition rather than recall*, and *flexibility and efficiency of use*. For the first heuristic, the prototype has icons that represent the real-world counterpart, e.g., heart with a pulse, means monitoring heart. By observing the evaluation of the prototype, it could be noted that some participants were confused with some of the icons, thus indicating that they need to be modified. For the heuristic *recognition rather than recall*, there were some similar comments about the confusion regarding the icons; some menu icons were found to be too similar and should have been more contrasting. Other than that, the participant found that the functionalities were easy to recognize and navigate. For the last heuristic, *flexibility and efficiency of use*, the participants felt that the prototype was easy to use and navigate through. On the other hand, two of the participants still found the navigation somewhat confusing and suggested additional instructions for use.

7.1.2 Usability Goals

For the development through the different iterations, the usability goals established in Section 3.4.2 were used. To explore whether those goals were utilized in a good way and efficient, one can look at the System Usability Scale evaluation results from Section 6.3. The goals of *Effective to use* and *Efficient to use* have been confirmed through the high mean value of the SUS score of 90 points, which is classified as the excellent score. With the high score, one can argue that the goals are fulfilled according to the participants. The third usability goal is asking if the prototype is *Safe to use*, which is very important in the medical domain, both in the way of recovering from errors for the user and protecting the user's information and data (Pastel, no date). The prototype exhibits *Having good utility* through having essential and powerful functionalities. For future work, one might incorporate more support functions.

For the goal of *learnability,* the user must also be instructed in how to operate the application and place the sensors correctly when measuring. From the feedback in the interviews and the evaluation, the participants provided positive feedback, suggesting that this prototype is both easy to learn and *easy to remember how to use.*

7.2 Development and Prototyping

The prototype created for this thesis was developed through three design iterations. The final artifact and prototype were a high-fidelity prototype called IntelliCor created in AdobeXd with implemented functionality through AdobeXds own prototype view. The first prototype was created in AdobeXd and served as a proof of concept when creating the proposal for this thesis. The second prototype was created in Figma and was presented to a medical expert and the technical expert and had some navigational functionalities. The third prototype was presented for evaluation by usability experts, as well as by medical experts.

7.2.1 Functionality

The functionalities changed from iteration two to three, as advised from the interview's feedback in Section 5.5. Iteration two had fewer functions on the physician side of the prototype. Direct communication between the patient and physician that needed to be removed and updated as it is not allowed in Norway due to strict privacy laws. The final functionalities in the final iteration are presented in the next section.

7.2.1.1 Patient Prototype

The patient prototype's main functionality is the *Measure and see results of measuring of PCG signals* function*.* This function starts with giving the patient instructions on how to place the sensors or the piece of equipment (e.g., stethoscope) to measure the PCG signals. The instructions are given either through a video or in simple words during training with medical staff to learn how to use equipment to record heart signals correctly. When the patient has completed the measurement, they are presented with the results as it has been processed through a machine learning program running in the health domain network. The results are presented in an understandable layout to the patient; these results include detailed explanations, and a PCG picture of the actual recording. The application has the functionality of a *QR code generator* to save recordings*,* which physicians can scan with their application at any later point in time. The patient also has the possibility to *explore earlier recordings.* If they are wondering about wording of the recording, they can read upon *Medical information on PCG and heart.* Suppose they receive results they are unsure about. In that case, they can navigate to the *contact information of medical personnel* to find relevant medical personnel for explanation. Additional important information regards cases of emergency and whom to contact.

7.2.1.2 Physician Prototype

The physician can use the functionality of *scanning QR code for retrieving patient data from patient prototype* during a consultation, as this needs to be done manually when the patient is present. The physician can use these results to help consult the patient and use earlier patients' results to help consult by *Viewing patients and their earlier recordings* when needed*.* If the patient has similar symptoms as an earlier patient, but the physician cannot remember the name, they can go to the *querying for patient data* function, created after feedback from the interview in Section 5.5.

Research presented in Section 5.6.1 suggests that most applications used by physicians are medical journal or medical lookup, which is implemented in this application with dedicated functions for heart and PCG.

7.2.2 Design choices

The final design choices are presented in Chapter 5.7, with the final iteration being the third. The prototype received positive feedback regarding the design choices, except for some of the icons and certain functions' names. Suppose one is to implement this for a health domain. In that case, one needs to create icons from scratch to secure best representation of functions, which might be difficult to achieve using only free to use and limited copyright icons. As for the function names, it would be best to involve more representatives of the physician group as well as patients, who would come with their familiar terms.

7.3 Data Gathering

The data was gathered in iterations two and three as explored in Section 3.6.1. The data gathered from the different methods explored are presented in Sections 5 and 6, which includes interviews with experts, and the participants' evaluation. The data gathering focused on improving functionality in both prototypes and improving the design by gaining insight into the medical domain and usability.

7.3.1 NSD

Before gathering the data, the project has obtained NSD approval for the processing of personal data. The approval for the request can be found in Appendix A 1: Approval from NSD. The project requested to gather data from three selections, firstly for patients with heart problems or parents to patients with heart problems. Collecting data from patients was not possible to conduct in this thesis as elaborated on in Section 7.4. However, there was a consent forms for the patient, as well as interview guides found in Appendix B 1: Informed Consent Form – Patient over 18, Appendix B 2: Informed Consent Form – Parent and child, and Appendix B 4: Interview Guide – Patient.

The second selection was physicians who treat patients with heart problems or other related conditions. Interview guides for this can be found in Appendix B 5: Interview Guide – Physician.

The third was experts within the field of interaction design, preferably within the health domain. The interview guide for this group can be found in Appendix B 3: Interview Guide – Expert.

7.3.2 Interview

The prototype was evaluated through semi-structured interviews as presented in Section 3.6.1.1; the interview was conducted with a medical expert and a technical expert who evaluated the second iteration of the prototype and gave valuable feedback that was used in the third iteration. The experts answered questions regarding three main areas. Both experts got similar basic information questions regarding their occupation, age, and what is their field of expertise.

The second area contained questions regarding medical check-ups and information gathered from them; this was aimed at the medical expert. The technical expert received questions regarding their experience of evaluating health-related applications instead of medical field-related questions.

The third and final area was divided into two parts: questions regarding their technical preference and information regarding applications in the health sector. The second part was questioning regarding the application's design and functions to map knowledge to the research questions. Firstly, the intention was to find out what was preferred, web or mobile applications and why. It was important to gain insight into already accepted health applications or programs that are already in use in the Norwegian health sector, as well as to understand the level of technical knowledge in patients and their preferences. Additional to this, both experts were asked to evaluate the second iteration of the prototype. The interviews' main feedback created the basis to update the functionalities in both the patient view and physician's view of the prototype. The updated functionalities can be found in Section 7.2.1.

7.3.3 Evaluation

A total of eight participants evaluated the third and final prototype using methods such as heuristic evaluation, System Usability Scale, and system usability testing. Six of the participants were usability experts, additional to two medical experts with little experience in evaluating a prototype using heuristic evaluation and system usability scale. It might have been better to provide them with a tailored version of the evaluation tools to suit better to their medical background. Even though they had limited experience evaluating such a system, the participants were pleased with the application which is reflected in evaluation scores, comments, and observation.

The heuristic evaluation was conducted on the basis discussed in Section 3.6.2.2. The heuristic evaluation results show that the project has an excellent basis, but the participants uncovered some issues that need to be improved when it comes to user interface and design; these issues are discussed both in Sections 6.4 and 7.1.1.

For the system usability scale, the prototype received a score of 90 points of possible 100 points, which is an excellent result to achieve for such a project. Two of the participants scored the prototype a very low score; there can be multiple reasons for this. Firstly, one can have multiple issues navigating the prototype due to lack of instructions during the evaluation, thus having a bad user experience and rate it low. On the other hand, being unfamiliar with a clinical area might make it difficult and therefore less appealing. It could be hard to engage in the application which demands imagining the real functionality behind it.

In the system usability testing, each participant was observed and timed when completing specific tasks. The main issues uncovered during this observation were related to confusion around the names of the functions and the representation of some icons. The completion time was low and similar to the majority of the participants, thus indicating that the prototype is easy to navigate and use.

Ideally, patients should have been a part of this evaluation as they are the primary users in such an application, but this is a limitation discussed in Section 7.4.

7.4 Limitations

During this project, the thesis encountered a significant limitation due to the ongoing Coronavirus pandemic at the time. For evaluating the prototype and gathering information, the thesis should had involved patients, but this was not feasible due to travel restrictions and strict rules regarding hospital visits. The patients' feedback would have provided valuable insight as they would be the prototype's primary users.

The second limitation is that the high-fidelity prototype should have been a fully functional one, as the evaluation would have been more accurate with a fully interactive prototype. An ideal situation would be to receive feedback using an interactive prototype evaluated by patients in a clinical setting which would secure a more realistic evaluation of the prototype.

7.5 Research Questions

In this section, the four research questions are discussed in detail, specifically how they are answered through the research described in Section 2, which involves prototyping, interviews, and evaluations.

7.5.1 To what degree does user experience design affect a patient's understanding of heart monitoring results

To the first research question, the thesis explored and reviewed research articles in Section 2 and found five major recurring themes that needs to be considered when designing for remote heart monitoring; those themes are presented in Section 5.4.1. As researched in Section 2, *Health understanding* is a critical part of how patients receive medical information. One can assume it is possible to create understanding through proper design of health applications. The recommendations to battle health understanding, or the lack of it, within the health domain is significant since lack of proper of communication between medical personnel and patients is hindering feedback and disabling deeper understanding of the patient problem. It is recommended that feedback and medical information is simple, straightforward, and written in the language understandable to a sixth-grade student. Thus, to increase health understanding through user experience design, one needs to simplify information and consider how to do *Interaction design in the health sector.*

Throughout all three development iterations efforts were made to secure better understanding of medical content, especially following interaction design in the health sector. The result screen of the prototype provides heart monitoring results for the patients, for which four design choices were presented to the evaluators, the results of this are presented in Section 6.5. The choices presented were all different variations of how data can be portrayed combining various levels of details (text only, visuals only and combination of both). Evaluators had shown different preferences of the variations of the result screen, where the most popular was variation one (text first, then visuals). This shows us that one might ask the user how they want to have their data specified, with the possibility of changing if they want another layout of the information, thus creating health understanding tailored to the needs of each patient.

Through the interviews and the evaluation with the participants, the prototype received positive feedback. It seems that the result screen combining medical information would create a better understanding of health recording and its meaning. However, to fully understand the depth of the research question, one would need to include patients. Through research, interviews, and prototyping, it seems to be safe to conclude that user experience motivated design affects a patient understanding and leads to a more profound knowledge of heart monitoring results.

7.5.2 To what degree do patients prefer web-based over mobile-based solution for monitoring heart signals

Due to the coronavirus's limitations, there was no possibility of conducting interviews and retrieving feedback regarding their preferences on web- over mobile-based solutions for monitoring heart signals. To address this question, we have to rely on the interviews with medical experts who work with patients, whose observations were described in Section 5.5. From Chapter 2, one can conclude that one should create one website that can work across multiple platforms, as it is the most cost-effective solution. Patients might find it easier to use, as one web site across multiple platforms has become a modern trend when creating new services and products. One does not need to prioritize one form over the other, as phones provide something that the web version cannot utilize. That is the phones' internal sensors, which can be used to measure additional health data. Web-version has the advantage of having a larger screen, thus providing the possibility to look at the data with more details and within the wider context. Even though the web version can have more details, it should not compromise removing some information from the mobile version. Both versions should have the possibility of showing the same amount of information but with different layouts.

One of the medical experts preferred to use the web to look at detailed data but did not mind using phones for smaller tasks and quick information. Thus, to create a practical and easy-to-use application, one needs consider creating both a mobile- and a web-version of the application. One can reasonably assume that there exists a degree of preference between web- over mobile-based solutions. However, both solutions have their benefits in different situations, and choosing one over the other would not be beneficial.

7.5.3 What are physicians’ attitudes towards patient self-monitoring using mobile-based solutions

Through interviews with the medical experts and evaluation with the medical student, the thesis gained insight into how physicians look at patients who monitor themselves using mobile-based solutions. The paediatrician from Section 5.5.1 mentioned that their hospital created an application for the scenario of sending patients home with instructions to monitor themselves. The motivation for creating the application was for the scenario of where information given to families of new-born babies is often forgotten or misunderstood. The medical staff does not have enough insight whether instructions are received and understood properly. Even though this scenario was an application about information to families, it can be applied to patients with other instructions needing to monitor themselves.

Other systems that patients use to monitor themselves are cloud-based applications that patients can use to measure insulin to control better insulin intake, which is in use in Norway today. In Section 5.5.2, the technical expert warned us that one should be careful when getting patients to monitor themselves. One must not miss the negative or false negative patients and be careful about the false positive ones. Having multiple false-positive patients creates an extra burden on the healthcare system.

One can conclude that physicians’ attitude regarding self-monitoring using mobile-based solutions is positive when it comes to applications that are carefully evaluated. It is important that an application does not create false positive findings which alerts patients and consequently burdens the healthcare system. It is essential to secure a good quality of monitoring, which includes that patients are using devices correctly and learn in good time how to follow instructions and contact personnel when they are supposed to.

7.5.4 Are there any systems developed for physicians for monitoring patients who monitor themselves?

For the final research question, one can look at the interview with the medical expert and the findings in Section 2, especially in Sections 2.7 and 2.8. Here are listed multiple services and products in the medical or remote monitoring domain. Thus, confirming that there are systems developed for physicians who monitor patients monitoring themselves out of hospital setting, so one can argue that the answer to the research question is *yes*. However, from the Norwegian health domain perspective, there are no such systems in use. From the paediatrician interview, it was clear that the Norwegian health system does not use any applications outside the hospital to communicate with patients as Norway has such strict privacy laws. The paediatrician from Section 5.5.1 informed us that most health-related applications that are in use today are tool-based with no communication.

If there are going to be systems developed for physicians to monitor patients monitoring themselves, lots of effort needs to be paid to regulatory demands which will be demanding in time and resources before it could be utilized in the Norwegian health domain.

8 Conclusion

8.1 Conclusion

The research and prototyping results presented in this thesis provide insight into the possibilities of remote monitoring of heart signals, a rather new area of research in which web and mobile solutions could be taken advantage of. User experience design can utilize to create health understanding and interaction to benefit patients and even physicians who are involved in their long-term treatment. There is an increase in the use of mobile devices due to their advantages and availability; however, there are also challenges to address, such as patient data security and safety of environments in which the data is recorded. There is also a challenge of understanding health data and correct interpretation of patients' results through proper design and sufficient information presented in a straightforward, simple manner.

This project's main contribution is a high-fidelity prototype that went through three design iterations using the basis of the research conducted through the thesis. The prototype was created using the research of significant health themes. To acquire data, interviews were conducted with a medical and technical expert to gather an understanding of the medical domain and medical technology in it. This way, the thesis could get insight into the systems medical personnel use and their standard routine in a clinic which helped establish requirements necessary for both the patient and physicians’ side of the prototype. The second contribution is a literature overview that presents five themes one needs to consider when creating an application for remote monitoring of health data.

Evaluations were conducted with usability experts and medical experts to assess usability and gather feedback on functions and design of the third and final iteration of the prototype. The evaluators gave positive feedback on the concept of creating an application that motivates heart monitoring results understanding. The medical experts gave the impression that they would welcome such as system into their work domain if developed correctly and in accordance with the formal expectations, both legal and clinical.

The thesis provides the foundation for future development of an application that promotes health understanding in remote heart monitoring; many functionalities are dedicated to patients and physicians who can prospectively gather data otherwise impossible to obtain and benefit patients and the healthcare sector.

8.2 Future Work

Future work on IntelliCor would firstly be taking feedback from the evaluators of the prototype of iteration three into consideration. The next step would be creating an actual working prototype using either the REACT framework to create a solution that works both on the phone and the web. This would be necessary to gather feedback and evaluation from actual patients who would help overcome a significant loss that thesis suffered from the lack of patient feedback. New functions might be suggested by patients that could also influence self-monitoring in a good way.

The next step would be looking further into what kind of equipment one will use to measure PCG signals, as the equipment connected to the application should have EC approval. There are also strict privacy laws to obey and need to be considered in further development. There are fewer strict laws in other countries in Europe and the world, so the application might be more suitable outside of Norway in countries that allow communication between patients and physicians using mobile technology.

A primary concern not fully addressed in this thesis is data security in remote monitoring which could be solved by strict encrypting procedures and IoT that are employed by some major health care sectors; for example, x-ray images are sometimes shared between countries. Such solutions have to be worked out for remote cardiac monitoring.

Further involving patients in creating the next version of the prototype, looking further into the measuring equipment, law reviews, and data security seem to be logical steps in the development leading to the product that would be welcome into the medical domain.

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Appendix A

Appendix A 1: Approval from NSD

NORSK SENTER FOR FORSKNINGSDATA

NSD sin vurdering

Prosjekttittel

Designing web-mobile based solutions for monitoring heart signals

Referansenummer

479112

Registrert

28.08.2020 av Malin Wist Jakobsen - Malin.Jakobsen@student.uib.no

Behandlingsansvarlig institusjon

Universitetet i Bergen / Det samfunnsvitenskapelige fakultet / Institutt for informasjons- og medievitenskap

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)

Ankica Babic , ankica.babic@uib.no, tlf: 55589139

Type prosjekt

Studentprosjekt, masterstudium

Kontaktinformasjon, student

Malin Wist Jakobsen, malin@j-j.no, tlf: 91770018

Prosjektperiode

01.10.2020 - 30.06.2021

Status

04.09.2020 - Vurdert

Vurdering (1)

04.09.2020 - Vurdert

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet den 04.09.2020 med vedlegg, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte.

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. Før du melder inn en endring, oppfordrer vi deg til å lese om hvilke type endringer det er nødvendig å melde: https://nsd.no/personvernombud/meld_prosjekt/meld_endringer.html
Du må vente på svar fra NSD før endringen gjennomføres.

TYPE OPPLYSNINGER OG VARIGHET

Prosjektet vil behandle særlige kategorier av personopplysninger om helseforhold og alminnelige kategorier av personopplysninger frem til 30.06.2021.

LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger og fra foresatte til barna i utvalg 1. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 nr. 11 og art. 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse, som kan dokumenteres, og som den registrerte kan trekke tilbake.

Lovlig grunnlag for behandlingen vil dermed være den registrertes uttrykkelige samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a, jf. art. 9 nr. 2 bokstav a, jf. personopplysningsloven § 10, jf. § 9 (2).

PERSONVERNPRINSIPPER
NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen om:

- lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
- formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke viderebehandles til nye uforenlige formål
- dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet
- lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet

DE REGISTRERTES RETTIGHETER
Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: åpenhet (art. 12), informasjon (art. 13), innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18), underretning (art. 19), dataportabilitet (art. 20).

NSD vurderer at informasjonen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Vi minner om at hvis en registrert/foresatt tar kontakt om sine/barnets rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER
NSD legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

For å forsikre dere om at kravene oppfylles, må dere følge interne retningslinjer og eventuelt rådføre dere med behandlingsansvarlig institusjon.

OPPFØLGING AV PROSJEKTET
NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!

Kontaktperson hos NSD: Simon Gogl
Tlf. Personverntjenester: 55 58 21 17 (tast 1)

Appendix B:

Appendix B 1: Informed Consent Form – Patient over 18

Informasjonsskriv til pasienter over 18 år

Forespørsel om deltakelse i forskningsprosjekt

Designing web-mobile based solutions for monitoring heart signals

Dette er en forespørsel om å delta i et forskningsprosjekt hvor formålet er å forske på tema innen mobil og web baserte løsninger for å måle hjerte-data hjemme, for å hjelpe personer i alle aldre å overvåke hjerte-data selvstendig hjemme uten hjelp av lege. Dette dokumentet skal oppklare bakgrunn og formål med prosjektet, i tillegg til hvordan din deltakelse vil innebære for prosjektet og deg.

Formål

Dette forskningsprosjektet er en del av masteroppgaven på mastergradsstudiet til informasjonsvitenskap ved Institutt for informasjons- og medievitenskap ved Universitetet i Bergen. Prosjektets formål er å svare på følgende spørsmål:

1. I hvilken grad påvirker bruker design pasientens forståelse av hjerte-overvåknings resultater
2. I hvilken grad foretrekker pasienter web-baserte løsning over mobilbaserte for å overvåke hjerte resultater
3. Hvordan ser leger på pasienter som overvåker seg selv med mobilbaserte løsninger
4. Finnes det eksisterende systemer som er utviklet for leger som fjernovervåker pasienter som passer på sine egne hjerte resultater hjemme.

Hva innebærer det for deg å delta i forskningsprosjektet

Deltakelse i forskningsprosjektet innebærer et intervju og evaluering av helse-relaterte applikasjoner og konsepter med hovedtema hjerteproblemer. Deltakelsen tar ca 40-60 minutter, avhengig av svar fra deltakeren(deg). Det kommer til å bli tatt opp lyd under intervjuet som kommer til å bli slettet etter prosjektslutt (ca. 1 Juni 2021) i tillegg til notater av gitt svar under intervjuet som kommer til å bli brukt i masteroppgave.

Hvis barn deltar, så har foreldre mulighet til å se spørreskjema på forhånd ved å ta kontakt.

Deres personvern

Vi vil bare bruke opplysningene om deg og barnet ditt til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket. Det er kun masterstudenten og veilederen som kommer til å ha mulighet til å se på innsamlede data og informasjon kommer til å bli anonymisert før det blir publisert. Både barn og forelder skal ikke kunne bli gjenkjent i den publiserte oppgaven med mindre annet er oppgitt direkte med de. Navn kommer til å bli fjernet fra intervju loggen og erstattet med tall eller kodenavn. Hva de ulike kodenavnene eller tallene representerer kommer til å bli oppbevart i en separat fil med begrenset tilgang. Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 1 Juni 2021.

Frivillig deltakelse

Det er frivillig å delta i prosjektet. Hvis dere velger å delta, kan dere når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle deres personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for dere hvis dere ikke vil delta eller senere velger å trekke dere.

Deres rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om dere

Vi behandler opplysninger om dere basert på foreldres samtykke.

På oppdrag fra Institutt for informasjons- og mediavitenskap har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dersom dere har noen spørsmål, ta kontakt med:

Hvis dere har spørsmål til studien, eller ønsker å benytte dere av deres rettigheter, ta kontakt med:

Student: Malin Wist Jakobsen, 91770018, malin.jakobsen@student.uib.no

Veileder: Ankica Babic, 55589139, ankica.babic@uib.no

NSD: Norsk senter for forskningsdata, 55582117, personvernombudet@nsd.no

UIB: Personvernombudet ved UIB, personvernombud@uib.no

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet Designing web-mobile based solutions for monitoring heart signals, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ❑ At jeg og mitt barn deltar i intervjuet
- ❑ At jeg og mitt barn deltar i evaluering av prototyper og lignende applikasjoner

Jeg samtykker til at våre opplysninger behandles frem til prosjektet er avsluttet

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(Signert av prosjektdeltakere, dato)

Appendix B 2: Informed Consent Form – Parent and child

Informasjonsskriv til foreldre/barn pasienter

Forespørsel om deltakelse i forskningsprosjekt

Designing web-mobile based solutions for monitoring heart signals

Dette er en forespørsel om å delta i et forskningsprosjekt hvor formålet er å forske på tema innen mobil og web baserte løsninger for å måle hjerte-data hjemme, for å hjelpe personer i alle aldre å overvåke hjerte-data selvstendig hjemme uten hjelp av lege. Vi vil bare bruke opplysningene om deg og barnet ditt til formålene vi har fortalt om i dette skrivet, i tillegg til hvordan deres deltakelse vil innebære for prosjektet og dere.

Formål

Dette forskningsprosjektet er en del av masteroppgaven på mastergradsstudiet til informasjonsvitenskap ved Institutt for informasjons- og medievitenskap ved Universitetet i Bergen. Prosjektets formål er å svare på følgende spørsmål:

1. I hvilken grad påvirker bruker design pasientens forståelse av hjerte-overvåknings resultater
2. I hvilken grad foretrekker pasienter web-baserte løsning over mobilbaserte for å overvåke hjerte resultater
3. Hvordan ser leger på pasienter som overvåker seg selv med mobilbaserte løsninger
4. Finnes det eksisterende systemer som er utviklet for leger som fjernovervåker pasienter som passer på sine egne hjerte resultater hjemme.

Hva innebærer det for deg å delta i forskningsprosjektet

Deltakelse i forskningsprosjektet innebærer et intervju og evaluering av helse-relaterte applikasjoner og konsepter med hovedtema hjerteproblemer. Deltakelsen tar ca 40-60 minutter, avhengig av svar fra deltakeren(deg). Det kommer til å bli tatt opp lyd under intervjuet som kommer til å bli slettet etter prosjektslutt (ca. 1 Juni 2021) i tillegg til notater av gitt svar under intervjuet som kommer til å bli brukt i masteroppgave.

Hvis barn deltar, så har foreldre mulighet til å se spørreskjema på forhånd ved å ta kontakt.

Deres personvern

Vi vil bare bruke opplysningene om deg og barnet ditt til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket. Det er kun masterstudenten og veilederen som kommer til å ha mulighet til å se på innsamlede data og informasjon kommer til å bli anonymisert før det blir publisert. Både barn og forelder skal ikke kunne bli gjenkjent i den publiserte oppgaven med mindre annet er oppgitt direkte med de. Navn kommer til å bli fjernet fra intervju loggen og erstattet med tall eller kodenavn. Hva de ulike kodenavnene eller tallene representerer kommer til å bli oppbevart i en separat fil med begrenset tilgang. Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 1 Juni 2021.

Frivillig deltakelse

Det er frivillig å delta i prosjektet. Hvis dere velger å delta, kan dere når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle deres personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for dere hvis dere ikke vil delta eller senere velger å trekke dere.

Deres rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om dere

Vi behandler opplysninger om dere basert på foreldres samtykke.

På oppdrag fra Institutt for informasjons- og mediavitenskap har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dersom dere har noen spørsmål, ta kontakt med:

Hvis dere har spørsmål til studien, eller ønsker å benytte dere av deres rettigheter, ta kontakt med:

Student: Malin Wist Jakobsen, 91770018, malin.jakobsen@student.uib.no

Veileder: Ankica Babic, 55589139, ankica.babic@uib.no

NSD: Norsk senter for forskningsdata, 55582117, personvernombudet@nsd.no

UIB: Personvernombudet ved UIB, personvernombud@uib.no

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet Designing web-mobile based solutions for monitoring heart signals, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ❑ At jeg og mitt barn deltar i intervjuet
- ❑ At jeg og mitt barn deltar i evaluering av prototyper og lignende applikasjoner

Jeg samtykker til at våre opplysninger behandles frem til prosjektet er avsluttet

----

(Signert av prosjektdeltakere, dato)

Appendix B 3: Interview Guide – Expert

Interview guide for expert evaluation

Designing web-mobile based solutions for monitoring heart signals

This is an interview guide for the research project designing web-mobile based solutions for monitoring heart signals. In the interview, the main focus will be on subjects such as monitoring through web-mobile based solutions, heart signals, interaction design in the health sector and personal application preferences. The interviews will be in Norwegian, but the thesis will be in English, so there will be translations made by the thesis author (me).

Information gathered from the interviews will be completely anonymized, and stored in an inaccessible method to protect the anonymity of the interview subjects. The interviews will be voice recorded to have an accurate quality control of the interview when it is rewritten in the master thesis.

Section 1

Basic information questions (5 minutes) This will be an introduction to the interview with basic information gathered from the participants

- What is your name
- What is your age
- Where do you come from
- What is your occupation
- How are you an expert
- Have you any experience of evaluating or using health-related applications

Section 2

Questions about design and functions of the application (20 minutes)
Show present prototype and ask about:

- Design feedback
- Functionality feedback

Appendix B 4: Interview Guide – Patients

Interview guide for patients who are in need of monitoring heart signals

Designing web-mobile based solutions for monitoring heart signals

This is an interview guide for the research project designing web-mobile based solutions for monitoring heart signals. In the interview, the main focus will be on subjects such as monitoring through web-mobile based solutions, heart signals, interaction design in the health sector and personal application preferences. The interviews will be in Norwegian, but the thesis will be in English, so there will be translations made by the thesis author (me).

Information gathered from the interviews will be completely anonymized, and stored in an inaccessible method to protect the anonymity of the interview subjects. The interviews will be voice recorded to have an accurate quality control of the interview when it is rewritten in the master thesis.

Section 1

Basic information questions (5 minutes) This will be an introduction to the interview with basic information gathered from the participant.

Section 1.1

- What is your name and age
- Where do you come from
- What is your occupation
- Is a patient/parent
- Where did you receive heart diagnose
- When did you receive your diagnose

Section 1.2

- What kind of information did you receive when you received your diagnoses
- Was it difficult to understand the instructions
- Was it hard to maintain the instructions received
- Is it the first time you need to follow medical instructions

Section 2

Questions about medical check-ups (20 minutes) This section is to map how often the patient is in need of a check up, and if that check up can be converted to self-checks at home with a potential application.

Section 2.1

- How often do you go in for check ups
- Do you receive information about what you should do between check ups and you when contacting the doctor for if something occurs.
- How advanced are the check ups
- Are you self-monitoring
- Have you tried mobile solutions of check-ups
- To what degree, how much info do you want from the check-ups
- Are you receiving your health information from both a specialist and a general practitioner?

Section 3

Questions about applications and design preferences(20 Minutes) In this section there will be questions regarding their preferences in health-related applications (if they are used by the participants) and the second purpose of this section is to get them to evaluate the preference of different health-related applications and their functions.

Section 3.1

- Do you use applications on the web or mobile? (How technical the person is)
    - If child and parent is present: ask both, but phrase differently
- Do you have a preference of web vs mobile solution
- Do you use any health applications on either phone or computer?
    - If child is present: ask both, phrase differently
    - If yes: Ask what kind of applications they use
    - If yes: What do you use the health applications for
- What do they like about the application in regards to functions and design
    - What functions are lacking

Section 3.2

- I present different applications through screenshots or print outs
    - Gather opinions about functions present
    - Gather opinions and ratings about design present
- Participant rate the applications by design and function

Appendix B 5: Interview Guide – Physician

Interview guide for physicians of patients who monitor heart signals

Designing web-mobile based solutions for monitoring heart signals

This is an interview guide for the research project designing web-mobile based solutions for monitoring heart signals. In the interview, the main focus will be on subjects such as monitoring through web-mobile based solutions, heart signals, interaction design in the health sector and personal application preferences. The interviews will be in Norwegian, but the thesis will be in English, so there will be translations made by the thesis author (me).

Information gathered from the interviews will be completely anonymized, and stored in an inaccessible method to protect the anonymity of the interview subjects. The interviews will be voice recorded to have an accurate quality control of the interview when it is rewritten in the master thesis.

Section 1

Basic information questions (5 minutes) This will be an introduction to the interview with basic information gathered from the participant.

Section 1.1

- What is your name and age
- Where do you come from
- What is your Position
- What is your medical field and role in treatment

Section 2

Questions about medical check-ups and information gathered from them(20 minutes)

Section 2.1

- How often do heart problem-related patients go in for a check-up
- what kind of data do you gather from a patient visit

- What kind of instructions do you give if a patient is supposed to have self-checks at home
- How many different diagnostic systems are you using
    - How visual is the results from the diagnostic procedure
    - How are the results from the diagnostic procedure presented (Report/visual/on screen/other)
        - What kind of visualisation method of the diagnostic procedure do you prefer

Section 3

Questions about applications and design preferences(20 Minutes) In this section there will be questions regarding their preferences in health-related applications (if they are used by the participants) and the second purpose of this section is to get them to evaluate the preference of different health-related applications and their functions.

Section 3.1

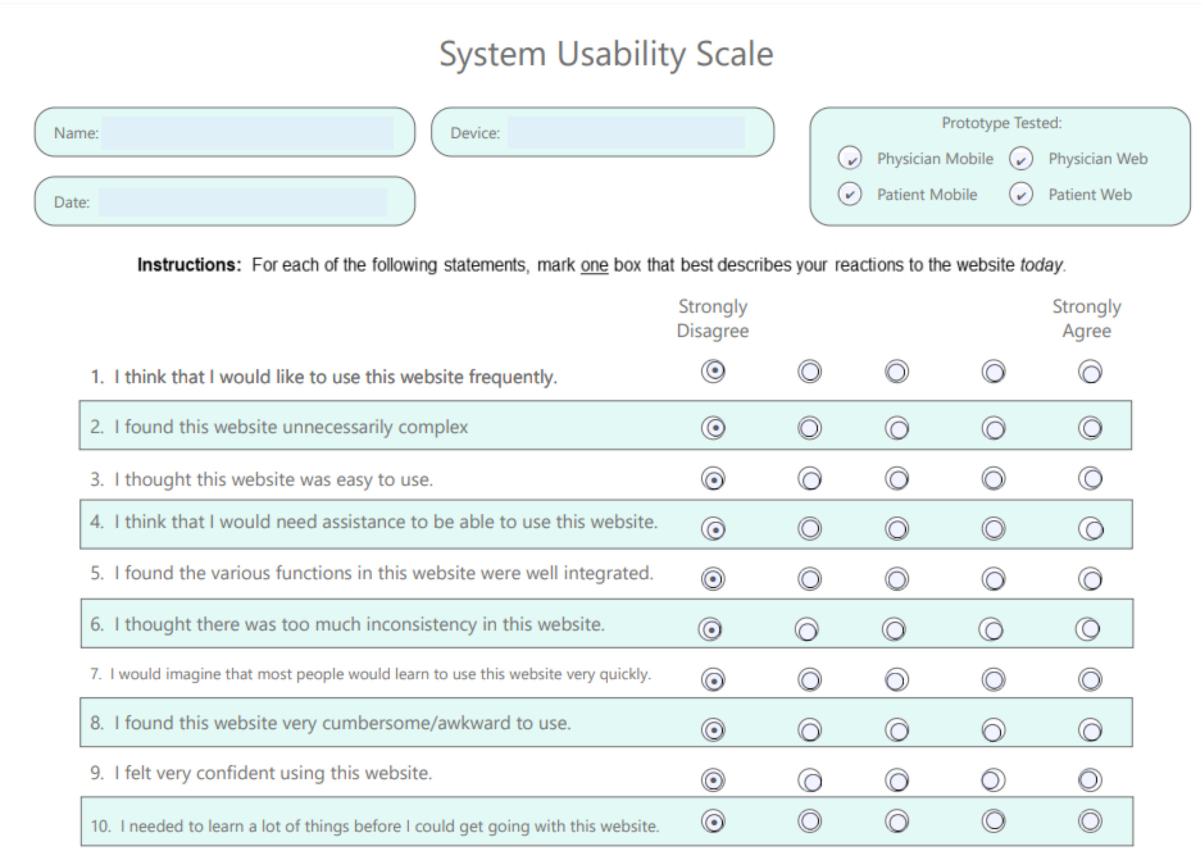
- Do you use applications on the web or mobile? (How technical the person is)
- Do you have a preference of web vs mobile solution
- Do you use any health applications on either phone or computer?
    - If yes: Ask what kind of applications they use
- Do you know of any applications your patients use in regards to health monitoring
    - And in what context
- What do they like about the application in regards to functions and design
- Do you use any application in communication with your patients

Section 3.2

- Participant rate the applications by design and function
- What kind of functionality do they prefer and why
- Suggestion for modification about the different functions and design

Appendix C:

Appendix C 1: System Usability Scale



System Usability Scale

Name:

Device:

Date:

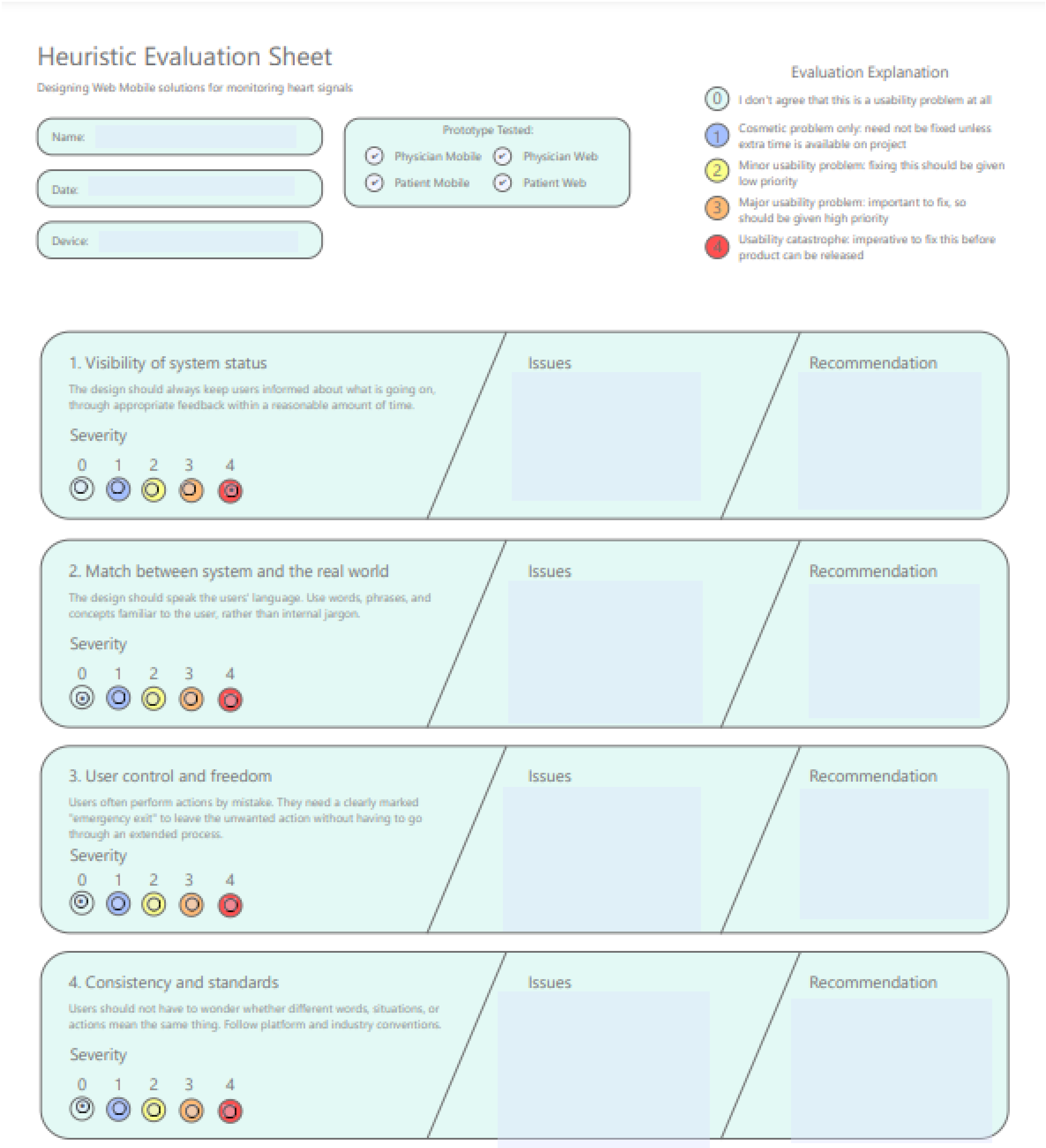
Prototype Tested:

- Physician Mobile
- Physician Web
- Patient Mobile
- Patient Web

Instructions: For each of the following statements, mark one box that best describes your reactions to the website *today*.

	Strongly Disagree				Strongly Agree
1. I think that I would like to use this website frequently.					
2. I found this website unnecessarily complex					
3. I thought this website was easy to use.					
4. I think that I would need assistance to be able to use this website.					
5. I found the various functions in this website were well integrated.					
6. I thought there was too much inconsistency in this website.					
7. I would imagine that most people would learn to use this website very quickly.					
8. I found this website very cumbersome/awkward to use.					
9. I felt very confident using this website.					
10. I needed to learn a lot of things before I could get going with this website.					

Appendix C 2: Heuristic Evaluation Sheet



Heuristic Evaluation Sheet

Designing Web Mobile solutions for monitoring heart signals

Name:

Date:

Device:

Prototype Tested:

Physician Mobile | Physician Web
Patient Mobile | Patient Web

Evaluation Explanation

0 I don't agree that this is a usability problem at all

1 Cosmetic problem only: need not be fixed unless extra time is available on project

2 Minor usability problem: fixing this should be given low priority

3 Major usability problem: important to fix, so should be given high priority

4 Usability catastrophe: imperative to fix this before product can be released

1. Visibility of system status

The design should always keep users informed about what is going on, through appropriate feedback within a reasonable amount of time.

Severity

0 1 2 3 4

Issues

Recommendation

2. Match between system and the real world

The design should speak the users' language. Use words, phrases, and concepts familiar to the user, rather than internal jargon.

Severity

0 1 2 3 4

Issues

Recommendation

3. User control and freedom

Users often perform actions by mistake. They need a clearly marked "emergency exit" to leave the unwanted action without having to go through an extended process.

Severity

0 1 2 3 4

Issues

Recommendation

4. Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform and industry conventions.

Severity

0 1 2 3 4

Issues

Recommendation

5. Error prevention

Good error messages are important, but the best designs carefully prevent problems from occurring in the first place. Either eliminate error-prone conditions, or check for them and present users with a confirmation option before they commit to the action.

Severity

0 1 2 3 4

Issues

Recommendation

6. Recognition rather than recall

Minimize the user's memory load by making elements, actions, and options visible. The user should not have to remember information from one part of the interface to another. Information required to use the design should be visible or easily retrievable when needed.

Severity

0 1 2 3 4

Issues

Recommendation

7. Flexibility and efficiency of use

Shortcuts — hidden from novice users — may speed up the interaction for the expert user such that the design can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

Severity

0 1 2 3 4

Issues

Recommendation

8. Aesthetic and minimalist design

Interfaces should not contain information which is irrelevant or rarely needed. Every extra unit of information in an interface competes with the relevant units of information and diminishes their relative visibility.

Severity

0 1 2 3 4

Issues

Recommendation

9. Help users recognize, diagnose, and recover from errors

Error messages should be expressed in plain language (no error codes), precisely indicate the problem, and constructively suggest a solution.

Severity

0 1 2 3 4

Issues

Recommendation

10. Help and documentation

It's best if the system doesn't need any additional explanation. However, it may be necessary to provide documentation to help users understand how to complete their tasks.

Severity

0 1 2 3 4

Issues

Recommendation