UNIVERSITY OF BERGEN

Smartwatch in healthcare

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Department of Information Science and Media Studies
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Abstract

With an aging population it is important to have good systems and solutions that can deliver on the challenges we as a society meet. We believe we can offer a product and service that can deliver on some of those challenges. Through our health monitor system for senior citizens we can offer security, accessibility and efficiency in the health sector.

Contents

1 Introduction

1.1 Problemspace

The problem space our idea seeks to fill exists in the intersection between health monitoring, and senior citizens. Trough wearable technology, we believe we can improve the health monitoring of elderly people at risk to health issues. The monitoring would offer safety and efficiency for both the user, and health professionals [8].

It is a well-known fact that elderly people have an increased risk of suffering from conditions like heart attack and cardiovascular diseases [11]. Our product seeks to provide a reliable and comforting solution for both health patients at risk, and the professionals who rely on information about patients to make the right decisions.

By beginning at the start of the double diamond of design we found our problem space and needed to narrow our area to focus upon. At first, we envisioned a product that could exist in both the private and professional market. But during our process and refinement of our vision we decided to exclusively focus on the professional market. As stated above seek to provide reliable and professional wearable technology to the professional health industry.

1.2 Vision

We envision a product that would ease the process of collecting vital information on elderly patients in for instance a retirement home. We wanted the product to have the shape of a watch and look like a modern smartwatch. We really wanted our product to function as a professional and reliable product, while also looking as discrete and fashionable as possible. The advantages of this form are many. The placement is very good for data collection, the shape of the product mimics a watch which many users are familiar with and ease the transition to using it.

Through sensors in a smart watch worn on the wrist, we wanted to collect vital information about a person's heart, stress and even oxygen concentration in the blood. Modern smart watches are already capable of collecting vast amount of data and providing users with information about their own bodies. Step counter, pulse monitor, stress monitoring, breath detection and exercise evaluation are already functional features available on the market. We want our device to collect similar information through such sensors, and be able to present the relevant information in a simplistic and easy to understand way to the user [7]. While for medical practitioners (expert users) monitoring a patient, a more in-depth presentation would be suiting.

1.2.1 Target group

The intended target group of our idea is senior citizens, specifically within the age group 60- 70 years old, at risk of developing heart problem or with a pre consisting heart problem. The product would be suitable for senior citizens of all ages; however, we are focusing on a narrow target audience in order to better meet the needs of the consumer. The reason we choose this age group is twofold. Firstly, we are taking into consideration willingness to learn how to navigate, read and use new technology. Secondly, we aim at the youngest section of senior citizens, hoping that learning and making a habit of using and wearing this technology before an age-related heart problem surfaces will increase the probability of actual use. The connection between actual use and exploration of a given technology had proven to increase the ease of learning, and thus the chance of "actual use" [9].

The target group could also include senior citizens with an additional wish to track exercise, as the technology that will be used in our product is similar, if not the same, as technology used in other exercise and smartwatches. Exercise tracking would be closely linked to health improvement, thus being relevant information for a possible health practitioner reviewing the user data.

1.3 Similar designs

Our idea would fall under the smartwatch and fitness tracker category. This is already a very well-established market. In 2019, an estimated 20.1 million smartwatches were sold in the United States. Between 2016 and 2020 annual smartwatch sales are forecast to grow from 9 million units to over 22 million as these devices continue to grow in popularity. [4]

Since our idea is intended as a smartwatch for the elderly it will have to incorporate ideas from both the smartwatch and the fitness tracker. The "traditional" smartwatch such as the Apple Watch and Samsung Gear usually look like a normal watch but instead of the normal watch face you have a small LCD or OLED touch display. The housing generally contains the rechargeable lithium-ion battery used to power the device. Usually the number of peripheral devices varies depending on pricing, but the common ones include digital cameras, thermometers, accelerometers, pedometers, heart rate monitors, altimeters, barometers, compasses, GPS receivers, tiny speakers, and microSD cards. Software may include maps, calendars, and various digital watch faces. It supports wireless such as Bluetooth, Wi-Fi and GPS. In many ways the smartwatch serves as a front-end system for a remote system, usually a smartphone.

Fitness trackers such as the Fitbit and Polar watches focuses mainly on the wearer's health. Physically they are usually smaller than the smartwatch, looking more like a bracelet with a screen than a clock. Inside the housing we typically find heartrate monitors, pedometers, altimeters, barometers, compasses, GPS receivers and Bluetooth. Where they differ most from the smartwatch is the software side. They do not work in tandem with your phone in the same way that a smartwatch does. Usually the fitness tracker syncs to an app on your phone.

1.4 Summary

To conclude we wanted to create a professional monitoring device based, on the already existing design and functionality of smartwatches and fitness trackers. Creating a safe, comfortable and dependable piece of wearable technology to improve and ease the monitoring of senior citizens for both user/patient and healthcare professionals.

2 Requirements

2.1 Data gathering

2.1.1 Goals and technique

When we started with our discussions on data gathering and analysis, we first looked for inspiration in the textbook [7]. We understood the importance of setting a clear goal for our data gathering to steer the rest of the process in the right direction. We quickly decided on two goals that the three of us were happy with, and that would set the tone for the rest of process. Due to the nature of our product there will be two different segments to collect data from, so we wanted to extract different information from the different groups.

The first group of people where the direct users themselves, the ones that potentially wear this device themselves. From this group we wanted to tell them about the functionality of our product and the problem spaces we think it could fill. We then wanted to see if our assumptions about the products ability to fill these problem spaces was shared with the target group. The main goal was formulated as such "Presented with the capabilities, does the target audience see this as a useful and wearable device that would bring a comforting feeling of safety?".

For the second group (the healthcare professionals), we had the same general idea in mind. We wanted to present the abilities of our product and hear if these features could fit into a professional work setting. What did they think of the features we had come up with, and where some features missing? We came up with the following goal. "Given the presented features, is this something that could be used and fill an existing problem space in a professional healthcare environment?".

Identifying participants

Naturally we knew we were searching for participants from two segments, potential users and healthcare professionals who would administer and potentially implement such a solution in their everyday work environment. Luckily, we all had potential participants in our pre-existing network eligible to participate. We ended up with a total of 4 healthcare workers and 2 elderly people in a possible user segment. Due to the current pandemic and the situation in Bergen now the interviews where all conducted over the phone and there were some participants whom we knew personally. We will return to the restrictions in the data gathering process later.

Technique

As we wanted to ask open questions to the participants and hear their thoughts, we decided to conduct interviews in our data collection. With our predetermined goals in mind we chose to conduct semi-structured interviews as they combine features of structured and unstructured interviews. This combination would allow us to have a basic format for all of us to work out from, and at the same time open up for the interviews to all capture their own distinct data (book p.269). This allowed us to gather a lot of qualitative data and what we felt was a good indicator of the thoughts from both sides.

Restrictions

As previously mentioned, we our method of collecting information was through conducting virtual semi constructed interviews. We initially wanted to conduct in person. Interviews, but as the city is currently on lockdown we were limited to a digital format. This could have influenced the quality of information as speaking with someone through the phone limits the communication to just voice. We decided to use our pre-existing network to gather information as it eased the collection of information and offered us a quick solution in a time limited process. This does however offer issues regarding the credibility of the data gathering. For instance, in collection of information from users of the product, grandparents where used. In 2 of 3 cases in collecting information from healthcare-professionals individuals acquainted with members of the group where the source.

It should also be noted that though all interviews where based of a pre decided document of questions, we allowed the interviews to drift in different directions to discover some unique pieces of information. The interviews were also conducted by different people in the group, which slightly altered the approach of each interview session. Bellow the results from two of the total six interviews are presented, as we feel they convey our overall findings nicely.

2.1.2 Results presented through personas

Personas

Anne – works in home care

Anne is in her early thirties and has worked on home care for five years. She has lived with her partner for a couple of years and has a dog but no kids. She is a driven, caring and patient woman. Anne is good at her job and can often tell how the patient is doing by a quick conversation and look in their home, but proper statistics would be helpful. Her workdays are long, but the hours are short and go by too quickly. Her patients have varying needs, some need medicine, transport help or wound care, others struggle with everyday life skills such as eating and showering, and some use medical care equipment such as IV-drips, pacemakers, urine bag, might have colostomy, etc.

Goals

Anne wants to know whether her patients are in need of urgent help. Anne would like to know whether her patients are being active or sitting around all day. Some patients are already wearing alarms, but either lose them or simply don't activate them when something happens. She needs to plan out the order of which patients to visit on a given day and would like to know if the health of any of her patients have worsened, or if they are in need of immediate help in case of a fall. In her job, Anne is a part of the everyday life of her patients and her patients to be comfortable and feel safe around her while doing her best to not be intrusive.

- **24h monitoring. Give data that helps plan the day and what to prioritize.**
- **Deliver daily reports on activity and vital signs.**
- **Provide health statistic so Anne can see patient's condition and recovery, and whether the patient is following recommended activity or not.**
- **Immediate detection and alerting Anne or other colleges in case of fall/vital signs showing a possible stroke happening etc...**

Marie and Sverre – Potential users

Marie and Sverre are healthy people 76 and 80 years old. They live on their own and are independent in their everyday life, meaning they do not require any help in their daily tasks. Though their health is in good condition, they are still in the segment of what we would consider to be potential users. They both use smart phones and computers and would be open to wearing a smart watch.

Goals

Marie and Sverre both want to be able to monitor their health as they are in an age group that are more prone to health issues. They want to feel a sense of security and to detect any possible issues as soon as possible.

- **Provide a reliable and around the clock monitoring**
- **Allow them to see data about their own health on their personal devices.**
- **Reduce the number of doctor check-ups**

2.2 Generating requirements

2.2.1 Functional

Our product will track various aspects of the patient's health. It will gather information on the patient's blood pressure, heart frequency, temperature, stress level and breathing frequency. All this will lead to a NEWS score value that will be visible to the user and others with approved access to the data. It will also gather information on the patients sleep quality and activity log. The information gathered by the watch will be accessible to the user via an app and a website, depending on their preferred technology. Health care practitioners will gain access to the information via a site like Helse Norge, if the given practitioner has been approved access to the patient journal by the patient or a legal guardian. Given an emergency, the patient can use voice activation to call for help. This is done by prelisted numbers and commands set by the user to make sure the right person or service is contacted.

- **Measurements**
  - Blood pressure
  - Heart rate
  - Temperature
  - Stress
  - Breath frequency
- **Sleep tracking**
- **Activity tracking**
- **Data analysis available through app and website**

2.2.2 Non-functional

As we want our product to be implemented in a professional healthcare solution it is essential that it is safe and reliable. We aim to achieve this through a high build quality and state of the art sensors. We want our product to be able to be worn at all times, therefore it needs to be water and dust proof, able to withstand a hard fall and have a long-lasting battery. Comfort is also a very important keep in mind as the device will simply not be worn if the device is a pain to wear. Thus, we want our product to be as sleek and light as possible to offer maximum comfort. The device needs to be easy to interact with and able to perform many operations with little user input. Therefore, the watch will have a touchscreen to increase the number of available buttons, and make it look as close to a regular watch as possible.

- **Sensors**
- **Water and dust proof**
- **Sturdy, shock resilient**
- **Long battery duration, rapid charging**
- **Sleek and light design for ease of wear and comfort**

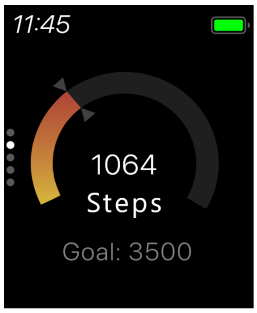
3 The health watch: Finished prototype

The finished prototype is in two parts; the smartwatch for healthcare (figure 3.1-3.2), and the corresponding website for health personnel (figure 3.3-3.4). The difference between these prototypes is intentional, as they are made for two different user groups. However, their main purpose is the same. This purpose is to collect and display as much relevant data as possible to the user in order to benefit the health and well being of elderly citizens.

Data which the smartwatch is able to collect and display to the user includes heart rate, temperature, stress level and in addition fall detection. If the smartwatch detects a fall, it will be displayed on the website (Figure.3.3) for health personnel to see, along with other relevant data such as heart rate and location. Additionally, it will automatically trigger emergency response, which establishes communication with the same health personnel. We will get into the specifics of the prototypes in the later sections of this report, such as our design rationale and evaluations.

The images below is a selection of the finished prototypes, the remaining can be viewed in full in Appendix B.

(a) Front Page



(b) Step counter 2

Figure 3.1: Two data slides from the smart watch

Figure 3.2: Prototpe of the physical model

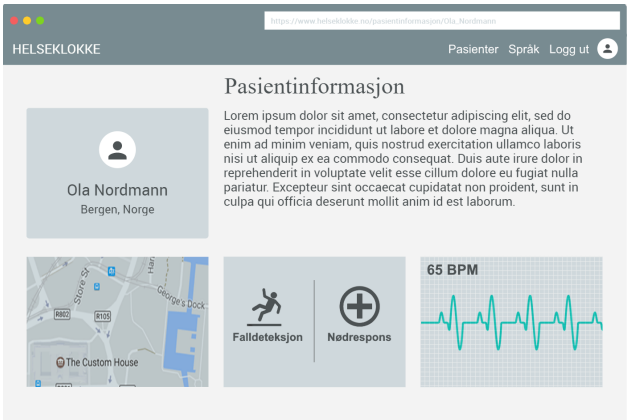


Figure 3.3: Patient information

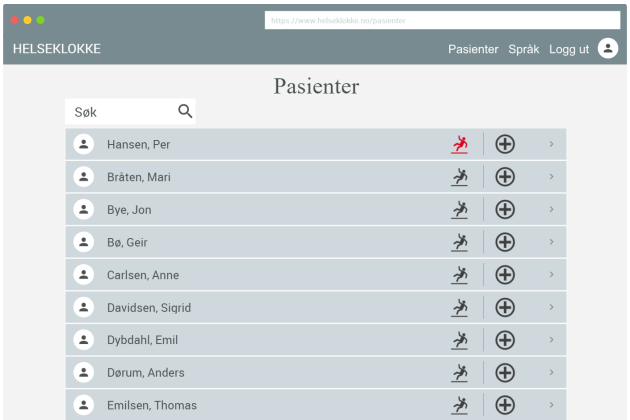


Figure 3.4: Patient list overview

4 Prototype iterations

4.1 First iteration

4.1.1 Design rationale of website

The first page we designed for the website, which also is the first page shown to the user, is the login page, figure 4.1.1. The absence of a sign up page is intended, as the website contains confidential information and should be accessed by employees only. The colour palette is chosen due to its common use in hospitals and familiarity to health workers. It is clinical, clean, and professional.

The design showed in figure 4.1.2 is a page with the list of the patients. On this page, the user can see a list of all their patients using the smartwatch. Every list item is shaped as a button, indicating that they can be clicked by the user. The patients have a small profile picture next to them for them for easier identification. Each list item has two symbols next to it. The left symbol is for the fall sensor. This symbol will turn red if the patient falls, as red is the most eye-catching colour, and known to indicate danger. The symbol next to it can be clicked to communicate with the patient.

When clicking on one of the list items, the website opens the page of the given patient information, as shown in figure 4.1.3. The point of this page is to provide the user with as much relevant information as possible. Firstly, the user will see a picture of the patient, along with their name and city. Under this, their exact location is shown in Google Maps, a map service most users are familiar with. The symbols for fall detection and emergency response are also shown due to their importance. To the bottom right, a heartbeat chart is shown to inform the user of the patient's heart rate. Lastly, the paragraph of text is there to inform the user of important information about the patient, such as their pre-existing conditions and medication.

4.1.2 Design rationale of smartwatch

It was important for the main screen to not have too much information at once, and for the clock to be clearly visible. The decision to use black as the main screen are twofold. It makes the white text easier to see and it saves on battery life as you do not have to light up the entire screen at once. The battery icon in the corner is quite small, and changes colour as the battery depletes. From the main screen it is possible to swipe up, represented by the arrow at the bottom, revealing the notification screen. The notification screen is pretty straight forward. We wanted a background that contrasts well with most smartphone icons. The text will tell what app the notification is coming from, as well as the subject or information to let you know what the notification is about.

4.2 Second iteration

4.2.1 Design rationale of website

After last evaluation of our project, we discovered how to improve our designs for future iterations. Budiu argues that login walls are beneficial when the site contains highly personal information, which is very much the case for our website [1]. The input fields are labelled with "brukernavn" and "password" because input fields without labels are useless [3]. Changing the input label from real name in the first iteration to username in this second iteration is an elaborate choice, as every bit of personal information we request increases the chance of things going wrong [5]. According to Nielsen's heuristics [6], the user should always be informed about what is going on. Thus, we improved the site by providing an error message to the user if they enter a wrong username or password.

4.2.2 Design rationale of smartwatch

For the new iteration we have created a sketch of a physical model to give a better idea of the button layout and overall design. In figure 4.2.5 the parallel lines above and below represent the wrist-straps keeping the watch in place. The casing is designed to be thin and slim, surrounding the rectangular screen. We intend for the watch to be as discrete and fashionable as possible, functioning as a device to be worn as a normal watch. The two buttons on the right side are used to vertically navigate the data pages. The red button on the left side represents the SOS button. This button is exclusively used to call for assistance and triggers an emergency call if pressed for 5 seconds.

Additionally we have updated several software elements in the new iteration. The first one is in figure 4.2.6, we made the numbers bolder, so they are easier to see. The notifications figure 4.2.7 has remained untouched as we were quite happy with it. Figure 4.2.8 has a few updates in it. The first change is the placement of the 5 dots, moved from bottom to the left side to show that we have altered the scrolling direction from horizontal to vertical. The second change is the updated font.

Figure 4.2.9 shows a new data page implemented in the new prototype. It gives the user a visual representation of how close the user is to reaching the daily goal for steps, encouraging movement. Figure 4.2.10 is also a new page, showing the oxygen saturation in the patient's blood. The watch is also designed to alert staff if the measurement drops far below a set safety limit. Figure 4.2.11 shows the previously missing settings page. A settings page allows the users to customize their smartwatch if they wish to, and can, do so themselves.

Common for most data pages on the watch is the use of icons. We have implemented icons as they are frequently used in other similar products, they quickly and simply tell the user what kind of information they are looking at. The use of icons gives the benefit that even if the user has not seen the given image before, they can quite easily assume what information it's trying to convey. By giving the user a visual representation like this, we wanted to make the overall experience more inviting, emotionally appealing, memorable, and distinctive. [7]

5 Design Evaluation

5.1 Evaluation method

Due to the situation with COVID-19 it is hard, given our target group to do any form of evaluation including the user without risking the health to the people involved. Therefore, we decided to use evaluation methods that could be carried out without involving the user. We ended up using cognitive walkthrough [10] and heuristic evaluation [6]. The reasoning behind using two different evaluation methods is to prevent blind spots that could occur if we where to use only one type of evaluation. This way we feel we can perform a decently comprehensive evaluation even without involving the user.

5.1.1 Cognitive walkthrough

The cognitive walkthrough is an evaluation of usability. One or more evaluators sets up a series of tasks and ask a set of questions from the perspective of the user. The focus of the cognitive walkthrough is to try to understand a given systems learn-ability for new users. It was originally designed as a tool to evaluate systems like postal kiosks and ATMs where users would have little or no training. However, the cognitive walkthrough has later been employed with more complex systems with successful results.[10]

- **Will the correct action be sufficiently evident to the user?**
- **Will the user notice that the correct action is available?**
- **Will the user associate and interpret the response from the action correctly?**

5.1.2 Heuristic evaluation

Heuristic evaluations main goal is to spot problems associated with the design of user interfaces It involves an evaluator examining the interface and judging how usable it is. Because it does not need users to be present during the evaluation this method is ideal when evaluating at an early stage. It is guided by a set of principles called heuristics. In our evaluation we used the heuristics derived from Jacob Nielsen.[6]
They are as follows:

- **Visibility of system status**
- **Match between system and the real world**
- **User control and freedom**
- **Consistency and standards**
- **Error prevention**
- **Recognition rather than recall**
- **Flexibility and efficiency of use**
- **Aesthetic and minimalist design**
- **Help users recognize, diagnose, and recover from errors**
- **Help and documentation**

A heuristic evaluation will not find all usability problems with only one evaluator. It has been shown from experience across different projects that different people find different usability problems. Therefore, involving multiple evaluators significantly the evaluation. In this evaluation we ended up with two evaluators per system. Two for the smartwatch and two for the web page. [6]

5.2 Low fidelity

5.2.1 Cognitive walkthrough of smartwatch

The data set we created by performing the steps in this model can be found in appendix A. The lessons learned from this exercise where many. When visualizing the actions, it forced us to notice the areas that were not yet fully developed and needed more attention. Although we knew our prototype was basic, this model made it easy to visualize the next steps in taking it closer to our goal.

To highlight the most pressing findings, we found the simple process of scrolling between pages of information to create some debate about the process to do so. The current design was based in the idea of two scrolling directions and all based on touch. After some discussion we decided we wanted to reduce the alternative scrolling direction to only horizontal. Further, incorporating two buttons on the side to open up to more possibilities for navigation. Another important element was the absence of a way to trigger the emergency alarm, a crucial to implementation in the next iteration of the prototype. This first iteration was only showing interface of the prototype. The need for an illustration of the physical elements of the product became apparent through this process.

5.2.2 Heuristic evaluation of smartwatch

Through the Heuristic evaluation of our smartwatch we found that we are lacking in a lot of areas. Running through the most significant findings. On one hand, there is a complete lack of flexibility due to lack of a settings menu. Furthermore, the user is not able to perform any meaningful inputs, he can just choose what to observe. On the other hand, it is safe to assume that the user will be able to understand the information given to him on screen even if he has not used the watch before. Ex, when using the heart rate monitor. We have also adhered to known standards when it comes to touchscreens and how to navigate it.

5.2.3 Cognitive walkthrough of website

We have found several flaws about our project when conducting the cognitive walkthrough. The login page should include an error message when the user is providing a wrong password or username. For the list of patients, several improvements can be made. Firstly, the list should be alphabetical for easier navigation. However, patients who have fallen should be placed on top regardless of their name. A search engine could also prove to be beneficial for the user to find a specific patient more easily.

On the last page, the heart rate chart should be labelled, and the BPM should be written explicitly in text. To increase accessibility, the website should also be available in English. Lastly, the colours have not been tested to be accessible to colour blind people. This should be tested for the next design iteration.

5.2.4 Heuristic evaluation of website

Looking at the heuristic evaluation of the website we have found that the page has some flaws that we had not immediately thought to incorporate. For one we have found that the website lacks a help centre and error messages, thus the user must already know what to do and how to perform an action in order to successfully navigate the website.

At the moment the site only available in Norwegian, so only healthcare practitioner who understand this will be able to use. We also found that the only current ways to navigate the site is by the three-option menu, or by the patient list. A back button would be necessary for easier navigation, it would also be necessary to add some button styling so that the user knows if a button is responding or not.

5.3 High fidelity

5.3.1 Cognitive walkthrough of smartwatch

When conducting the cognitive walkthrough of the second iteration (8.1-8.7) we found that we had added some functionality and wanted to include this in the evaluation. The more confusing way of navigating the watch with two different swiping directions is gone. In its place is the page navigation one swipe direction, up and down. This also makes it possible for the user to navigate using two of the buttons on the side if they should prefer it to touchscreen navigation.

With the inclusion of a prototype of the physical watch we can also say that the ability to call for emergency help has been implemented. This iteration also includes the settings menu. It can be a bit hard to find the first time, but it is difficult to say how severe it is without user testing.

5.3.2 Heuristic evaluation of smartwatch

In the heuristic evaluation of the second iteration(8.1-8.7) we found that not a lot had changed from the first iteration. Since the changes from the first to the second iteration mainly focused on functionality and adding more sensor screens the heuristic evaluation looks very much the same as it did in the first iteration. We are still lacking when it comes to error prevention and help and documentation but given that those topics has not been the focus it is not surprising.

5.3.3 Cognitive walkthrough of website

Conducting the cognitive walkthrough(8.8-8.11) of the second iteration of the website we found it to have improved in a bunch of areas. The patient list is now ordered alphabetically unless there is an emergency, then the patient is placed at the top. Pulse (BPM) is now given as a number instead of just a graph. Furthermore, the user now has the ability to change the language between Norwegian and English depending on the users preference.

5.3.4 Heuristic evaluation of website

We have improved quite some aspects since the previous version. The navigation has been improved by adding more options to the menu bar, and by making the site accessible in English. The aesthetics have also been improved, keeping the colour scheme, but changing the saturation and contrast between the colours, decreasing the chance of the site being problematic for visually impaired users. "The influence of contrast in reading is important not only because text of wide range of contrasts is encountered in the environment but also because many ocular conditions lower the effective contrast of the reading stimulus". [2]

It would be wrong to assume that any user of the site has perfect vision no matter their age, so we have tried to make the site so that anyone, no matter if their colour vision is perfect or not, can successfully read and navigate the text. Lastly, an error message has been added to the site, letting the user know when a faulty input has been made.

For the next iteration it could be an idea to add a "help" page where you could register problems you experience with the site. We also realized that some of the measures taken by the watch does not show up on the patient's information page on the website, such as temperature. Luckily, this information is not critical in the way that BPM and fall detection is, but it is very relevant for the healthcare practitioner, and would be necessary to add in the future.

6 Discussion

6.1 Biases

There are some biases with our project that needs to be addressed. The interviewees were all relevant and gave good, insightful feedback and answers to our questions. However, in every interview, the given interviewer and interviewee had a personal relation to each other. In some cases that were longtime friends, in others it was family members, and also previous colleges. This did most likely have an effect on the answers we got for the better and worse. On one it made it possible for the interviewer to better analyze the answers and come with follow up questions. On the other hand, it may have influenced the way the interviewee formulated and angled their answers, interpreting the question and giving an answer that they think or assume we are looking for.

Another bias is that all evaluations were done by us. Thus, we knew what to expect and which actions to make, which may have influenced the accuracy, especially of the Cognitive Walkthroughs. When it comes to the Heuristic evaluations it could be argued that it is an advantage that they were performed by us, as Heuristic evaluations are done by experts within a given field or topic, and as the creators, we are the experts of our own product. However, we are only experts on our own product, not on the type of system, or hardware, making it possible that we missed certain elements, as we do not have enough firsthand experience with evaluations yet.

Building on these biases, no possible users have been involved in the design process, evaluations or iterations. The only information we have from the users is what we learned in the interviews. It would be valuable to get feedback from the users while designing, to know whether we meet their needs and expectations or not. At least, it would be preferable if the users were involved between the first and second iteration to make sure we catch the things they don't understand, or feel are missing.

6.2 Changes

Throughout the design and planning process we made a couple of changes to our initial plan. First, we ended up narrowing our area of intended use. We initially planned on the watch being available within both the public and private sector. While working on the project and performing out interviews we realized that need for such a product was more urgent in the public sector, specifically within home care. We therefor decided to take distance from the private sector in order to better meet the needs of the public sector and home care workers.

We also ended up scrapping some of the elements we wanted to track. One of the things we scrapped was tracking blood pressure. We realized that it would be very difficult for a smart watch to give reliant numbers. Additionally, we found during our interviews and research that the most critical factor that leads to further health related problems in home care patients is that they fall and do not get help for an extended amount of time. We therefor prioritized the fall detection, and scrapping blood pressure, to avoid the risk of trusting inaccurate numbers causing further problems for the patient.

Finally, we changed two last measures. First, the watch does not measure breath frequency as first stated, rather we made it measure oxygen saturation instead. Second, there is no dedicated interface on the watch that shows measures of stress. Stress measurements are found by looking at the current bpm and looking at variability in bpm based on personal user data. Thus, the watch does track it, but we have not implemented it into the design part of our project

Biases with our project include personal relations to between interviewer and interviewee, in all interviews, and that our evaluations where not performed by anyone outside of the development team. Throughout the project changes were made to the intended target group, narrowing it to better meet the needs of home care workers. Changes were also made regarding exactly what the watch would measure, namely blood pressure, breath frequency and stress.

6.3 Ethical dilemmas

The smartwatch is designed to track a lot of data. With this comes a lot of issues regarding privacy. This violation of privacy may be uncomfortable for some. However, data collection is absolutely necessary for the purpose of our project. The General Data Protection Regulation (GDPR) sets a high standard for consent. This means that the data subject has to explicitly consent to their data being collected in order for us to comply with GDPR. We think that the benefits really outweigh the privacy concerns, especially for our target audience.

6.4 Future work

There will be made two changes to the website for the next iteration. First, we will add a help page, and secondly, we will make sure that all the measurements taken by the watch is available and visible to the healthcare practitioner on the patient page. There can always be made improvements to a site, and as the needs and demands of the users change the site will change to meet these. The current state of the site satisfies the most pressing issues and needs of the users, it is easy to navigate, user friendly, and aesthetically pleasing.

It is also hard to know exactly which impairments a user may have, however, we have had this in mind while designing and tried our best to make the site usable, by having good color contrast, and a simple font that would be easy to read. As of now we are we can not find any glaring issues with the watch interface. Therefore, for future work we are thinking about prototyping a phone app that integrates with the watch. However, for this to work we would also need to expand the watch interface further to accommodate some sort of first time setup. On the phone app should be possible to see the same information as on the watch as well as a log for the different sensors.

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7 Appendix A

7.1 Low fidelity prototypes

Figure 7.1: Watch face

Figure 7.2: Notification

Figure 7.3: Pulse sensor

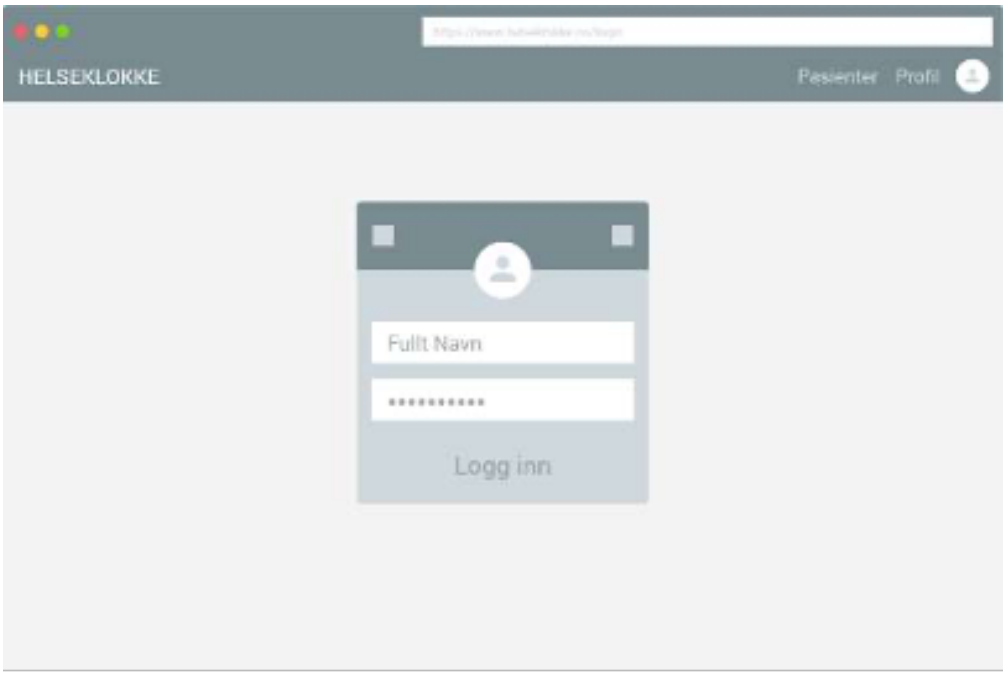

Figure 7.4: Login screen

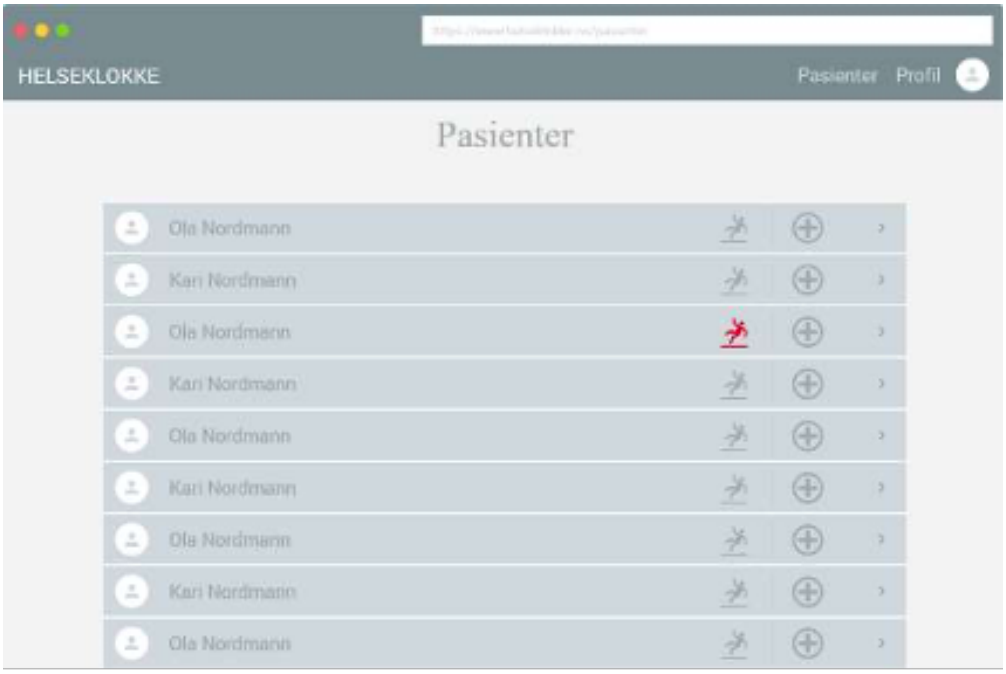

Figure 7.5: Patients list

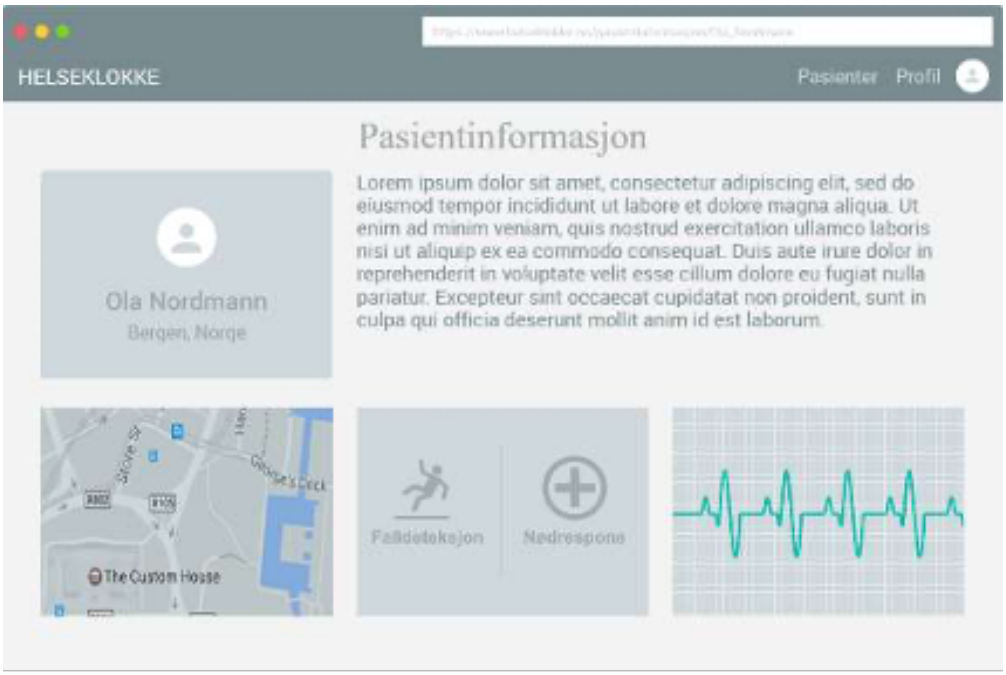

Figure 7.6: Patient info

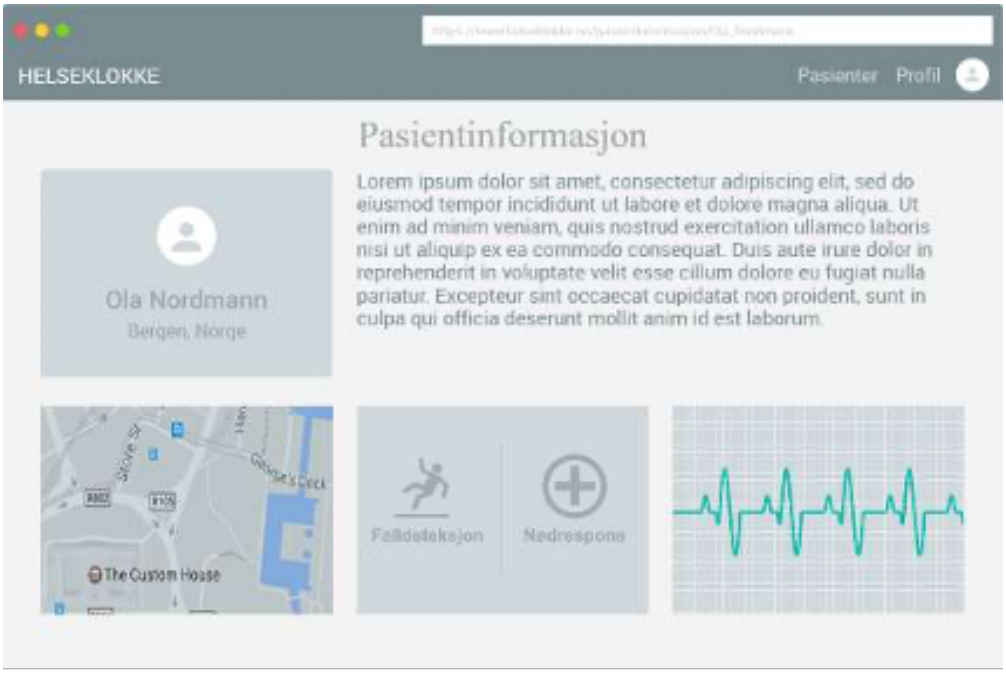

Figure 7.7: Patient info

Heuristic evaluation of Website

#	Heuristic	Notes
1	Visibility of system status	The website gives immediate feedback on the most critical aspect of the user's health, lighting up a symbol on the screen when a user falls, and by contacting the user when pushing the (+) sign.
2	Match between the system and the real world	The symbols used on the website are universal and will be recognized by anyone who have previously used a smartwatch, social media, or works in healthcare. The website is currently only in Norwegian, but universal languages would be added. This is because it is critical that the healthcare practitioner knows the exact status of the patient's health.
3	User control and freedom	There is no option for the user to undo or redo any actions. If the user has clicked on the wrong patient information, it is possible to go back by using the buttons in the menu.
4	Consistency and adherence to standards	All actions, words and symbols used are consistent and mean the same thing no matter where it appears on the site. Thus, setting a common platform standard.
5	Error prevention, specifically preventing usability-related errors	The website focuses on giving the user outputs, not on the user giving inputs. Therefore, critical mistakes or usability errors can hardly be made by the user.
6	Recognition rather than recall	All possible actions are visible to the user by buttons. All relevant information will be available when relevant. No instructions are given on how to use the system.
7	Flexibility and efficiency of use	The site only caters to healthcare practitioners. The site provides few possible actions, thus, no need for additional shortcuts.
8	Aesthetic and minimalism in design	The design is minimal and does not distract from any important information. The site is currently not compatible with multiple display use.
9	Recognition, diagnosis, and recovery from errors	There are currently no error messages on the site, so the user is not notified if their login was incorrect. There is also no "onclick" or "hover" function over the buttons, so they cannot see if the buttons are active and functional or not.
10	Help and documentation	The website does not have any help center or possibility for the user to troubleshoot.

Figure 7.8

Heuristic evaluation of smartwatch

#	Heuristic	Notes
1	Visibility of system status	The watch gives feedback through notifications and vibration when you get a notification on your phone. When the user raises his hand to check the time the screen turns on immediately letting him see the time.
2	Match between the system and the real world	No language, familiar symbols. Some may not be familiar with BPM, but it is safe to presume it will be understood with the heart symbol on screen.
3	User control and freedom	No "Home" button. Two different swipe directions
4	Consistency and adherence to standards	The arrow to swipe up is used in other touchscreen applications most notably social media. And the battery indicator is something that's been used on battery powered devices for a long time.
5	Error prevention, specifically preventing usability-related errors	As of this prototype the user does not have the capability to do any meaningful inputs apart from deciding what to look at. Therefore, it is not do anything that would create an error.
6	Recognition rather than recall	Arrow indicates swipe direction to get to the "card menu". The dots at the bottom of the heart rate monitor indicates swipe direction in the "card menu".
7	Flexibility and efficiency of use	Missing settings menu to alter user experience. No flexibility only able to observe.
8	Aesthetics and minimalism in the design	Minimalistic no more information than necessary.
9	Recognition, diagnosis and recovery from errors	No error messages Type low battery, loss of connection etc
10	Help and documentation	No way to inform the user of how to use the product apart from information the user sees on screen.

Figure 7.9

Cognitive Walkthrough of Website

Task 1: Log in to website

	Will the user try to achieve the right affect?	Will the user notice that the correct action is available?	Will the user associate the correct action with the effect that the user is trying to achieve?	Will the user see that progress is being made toward the solution of the task?
Open browser	Yes.	Yes.	Yes.	Yes.
Navigate to site	Yes.	Yes.	Yes.	Yes. The website will open as a result of the action of the user.
Click login button	Yes.	Yes.	Yes.	Yes.
Enter username in username field	Yes. The username field is labelled with "fullt navn".	Yes.	Yes.	Yes.
Enter password in password field	Yes. The password field is labelled with "passord".	Yes.	Yes.	Yes.
Click the login button	Yes.	Yes.	Yes.	Yes. The main page will open as a result of the action of the user.

Figure 7.10

Task 2: Find information about patient in emergency

	Will the user try to achieve the right affect?	Will the user notice that the correct action is available?	Will the user associate the correct action with the effect that the user is trying to achieve?	Will the user see that progress is being made toward the solution of the task?
Navigate to patients	Yes. The navigation shows menu items and is placed in the website's header.	Yes. The navigation has "pasienter" on the menu.	Yes.	Yes. The "patients" page will open as a result of the action of the user.
Click the patient in emergency	Yes. The page includes a list of all patients.	Yes. A red symbol is red, symbolising danger. However, the list is unordered, and no search engine is available.	Yes.	Yes. The "pasientinformasjon" page will open as a result of the action of the user.
Check pulse (BPM)	The pulse diagram is not labelled, and the BPM is not written explicitly.	Yes.	Yes.	Yes.
Check location	Yes.	Yes.	Yes.	Yes.
Click "nødrespons" to communicate with patient in emergency	Yes. The button is labelled with "nødrespons".	Yes.	Yes.	Yes.

Figure 7.11

Cognitive Walkthrough of smartwatch

Steps	Will the user realistically be trying to do this action?	Is the control for the action visible?	Is there a strong link between the control and the action?	Is the feedback appropriate	Comments
Check the time	Yes	Depends if the screen is on or not. Screen wakes by wrist movement or buttons	Mimics normal way to check the time of a normal watch	Yes, the screen lights up to let you see the time	
Check pulse	Yes	Yes, but somewhat misleading. The scrolling direction switches	Yes, as the only action is to scroll between pages of information	Yes, you know you are on the right page because of the heart symbol.	Assumed because it's the only option.
Clear notification	Yes	The means to do so is visible but not the instructions (buttons on the side of the watch)	Not necessarily. The buttons have previously been used to scroll through the menus	Yes, the notification disappears	
Call for help	Yes, if the person needs it and has the capability	Yes, it is always the red button on the watch visible	Yes, red is a colour used for aid. Type red emergency string	Yes, the screen lights up and says, "Help Sent!"	Not implemented but will be in the next iteration

Figure 7.12

8 Appendix B

8.1 High fidelity prototypes

Figure 8.1: Physical design illustration

Figure 8.2: Front page

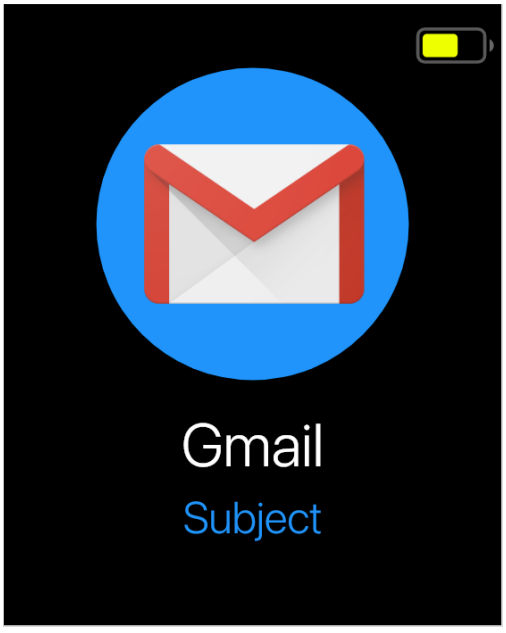

Figure 8.3: Notification

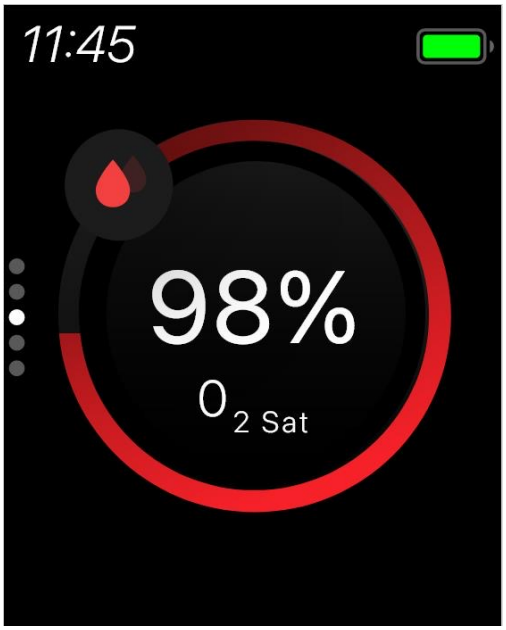

Figure 8.4: Blood saturation

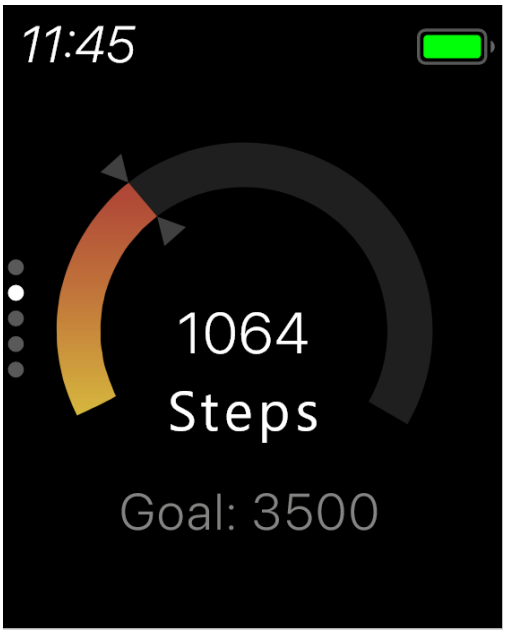

Figure 8.5: Step counter

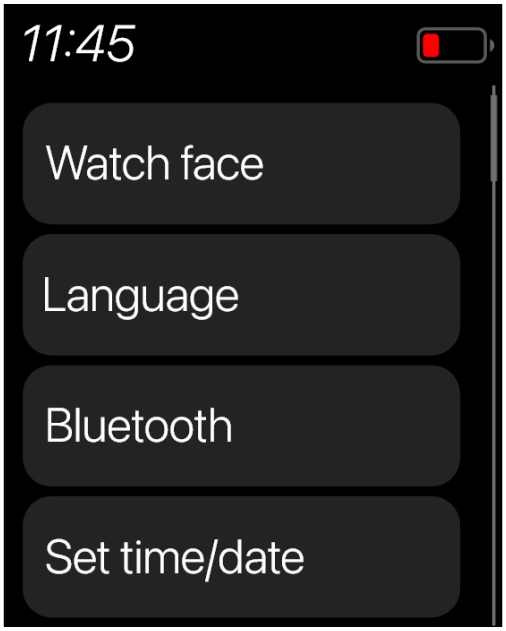

Figure 8.6: Settings

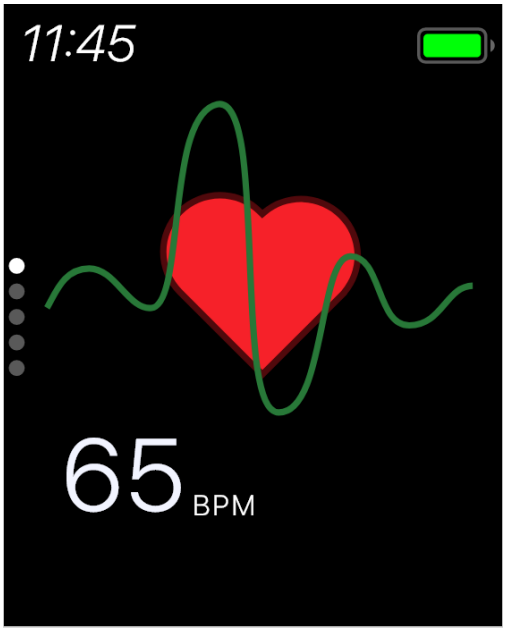

Figure 8.7: Pulse sensor

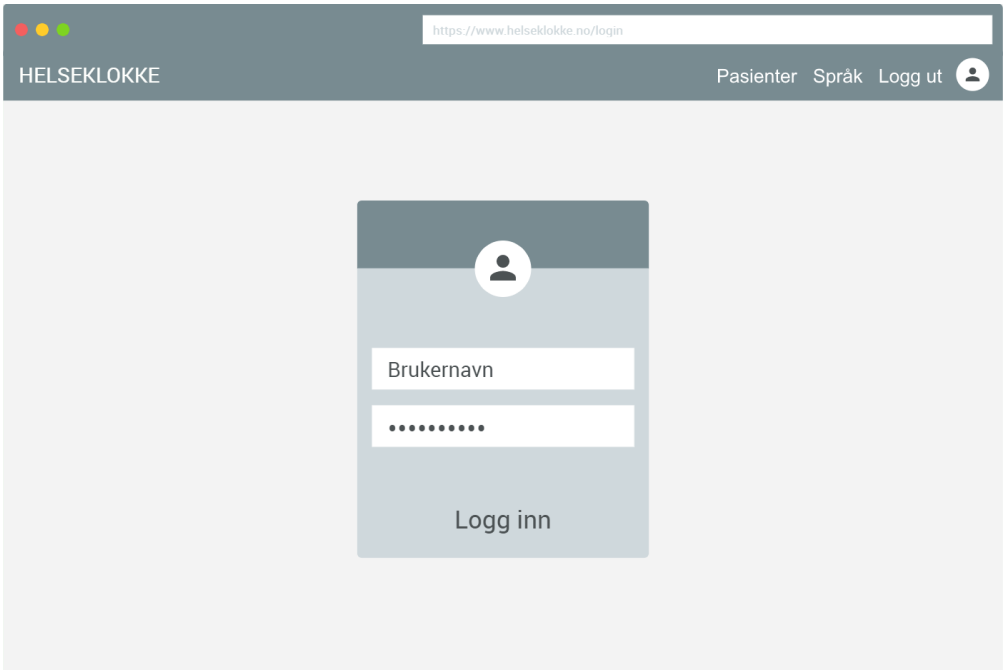

Figure 8.8: Login page

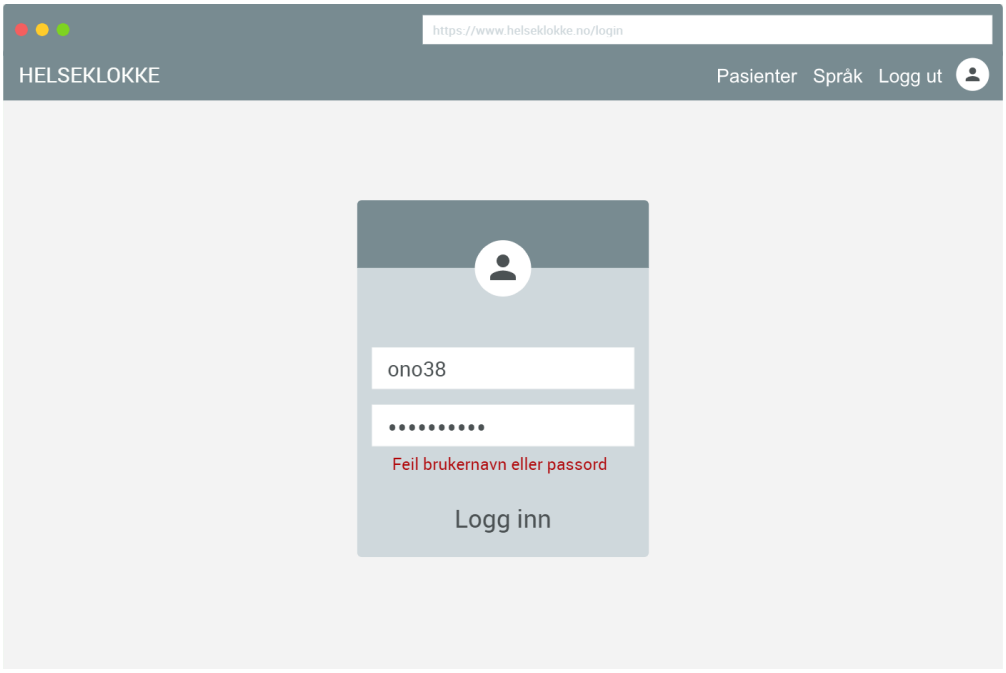

Figure 8.9: Website login feedback

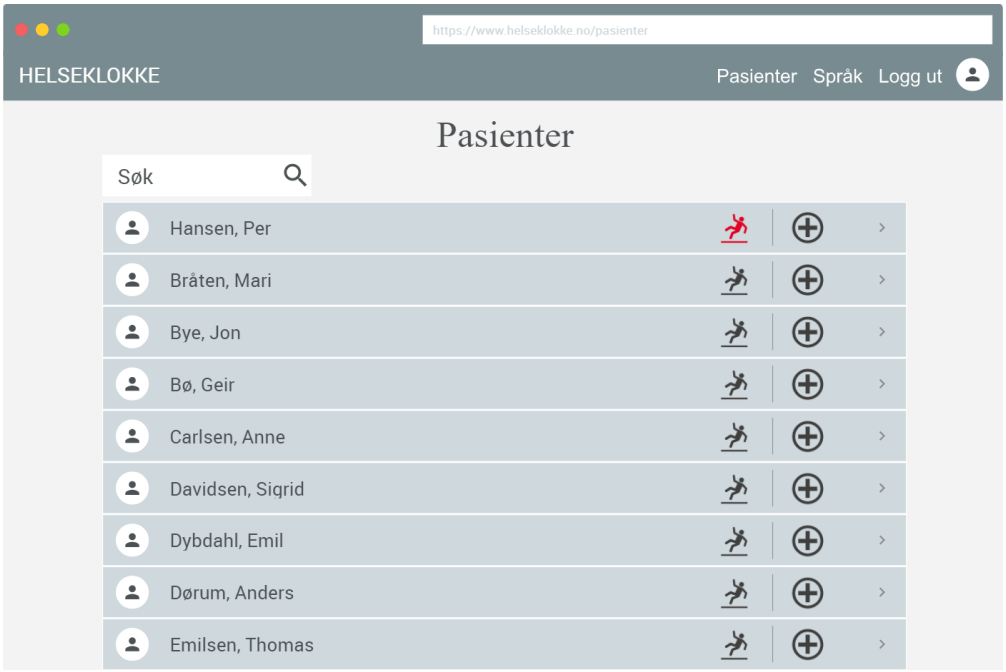

Figure 8.10: Patient list overview

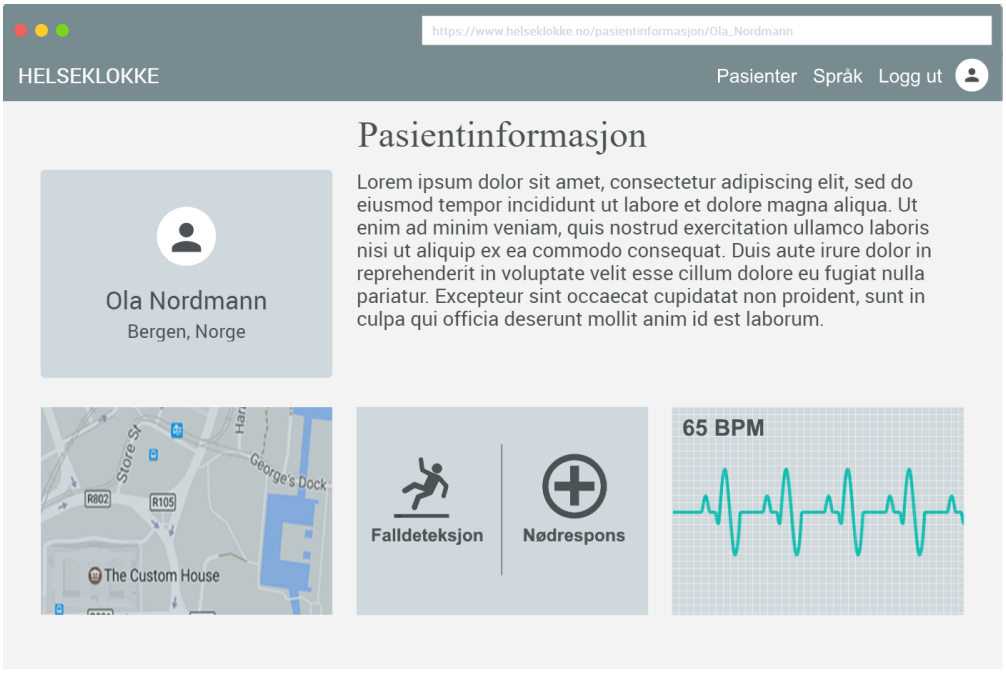

Figure 8.11: Patient detailed information overview

HEURISTIC EVALUATION OF WEBSITE

#	Heuristic	Notes
1	Visibility of system status	The website gives immediate feedback on the most critical aspect of the user's health, highlighting it in patients list, or on their profile through the bpm chart and GPS. It gives the user feedback on what is going on through error messages.
2	Match between the system and the real world	The symbols used on the website are universal recognizable (heart, fall, icon, (+) emergency response icon) , especially to those who have used a smartwatch, social media, or works in healthcare. The website is available in both Norwegian and English by clicking a button in the menu. This makes it easier to use and more secure as it decreases the likelihood of the healthcare worker reading the data wrong because it is in a second or third language. The information in the patients list is arranged by last name, making it easy to navigate.
3	User control and freedom	When a wrong input is provided, the user is able to redo it, by being alerted of the mistake and then do it again. There is otherwise only one way for the user to give input and that is by deciding which page to load. There exists no specific back arrow, but all possible navigations can be accessed by the menu bar, thus letting the user go back to any other existing page on the website.
4	Consistency and adherence to standards	Common platform standards are followed, and all actions, words and symbols are consistent across the page. Holding the same meaning no matter where they appear on the site.
5	Error prevention, specifically preventing usability-related errors	It is not possible for the user to make any serious usability errors since the page focus on giving information to the user and not receive information. The main error possible to be made by the user is to use a wrong login, though this is not considered critical as it does not change any important information or the physical state of the website.
6	Recognition rather than recall	All possible actions are visible to the user by buttons. All necessary information is available through one click on the patient in the list. Error message is given if an action is performed wrong. There is no help page, but the site is so minimal, and the actions available describe themselves.
7	Flexibility and efficiency of use	The site only caters to healthcare practitioners. Most possible actions are available through one click, so no shortcut is needed. It would be impractical to add a shortcut to any individual patient page since there would be too many shortcuts.
8	Aesthetic and minimalism in design	The design is minimal and does not distract from any important information. The site is not compatible with multiple display use. The site has improved colour contrast, decreasing the likelihood of it being problematic for visually impaired (example struggling with colour vision)
9	Recognition, diagnosis, and recovery from errors	Login error message is simply explained and precise, saying what is wrong. And since it does not specify whether it is the username or the password that is wrong, it is harder for people to hack as they will not be informed if any or which of the actions used were right.
10	Help and documentation	The website does not have any help centre or possibility for the user to troubleshoot.

Figure 8.12

Heuristic evaluation of smartwatch

#	Heuristic	Notes
1	Visibility of system status	The watch gives feedback through notifications and vibration when you get a notification on your phone. When the user raises his hand to check the time the screen turns on immediately letting him see the time.
2	Match between the system and the real world	No language, familiar symbols. Some may not be familiar with BPM, but it is safe to presume it will be understood with the heart symbol on screen.
3	User control and freedom	No "Home" button. Two different swipe directions
4	Consistency and adherence to standards	The arrow to swipe up is used in other touchscreen applications most notably social media. And the battery indicator is something that's been used on battery powered devices for a long time.
5	Error prevention, specifically preventing usability-related errors	As of this prototype the user does not have the capability to do any meaningful inputs apart from deciding what to look at. Therefore, it is not do anything that would create an error.
6	Recognition rather than recall	Arrow indicates swipe direction to get to the "card menu". The dots at the bottom of the heart rate monitor indicates swipe direction in the "card menu".
7	Flexibility and efficiency of use	Missing settings menu to alter user experience. No flexibility only able to observe.
8	Aesthetics and minimalism in the design	Minimalistic no more information than necessary.
9	Recognition, diagnosis and recovery from errors	No error messages Type low battery, loss of connection etc
10	Help and documentation	No way to inform the user of how to use the product apart from information the user sees on screen.

Figure 8.13

COGNITIVE WALKTHROUGH OF WEBSITE

Task: Log in to website

	Will the user try to achieve the right affect?	Will the user notice that the correct action is available?	Will the user associate the correct action with the effect that the user is trying to achieve?	Will the user see that progress is being made toward the solution of the task?
Open browser	Yes.	Yes.	Yes.	Yes.
Navigate to site	Yes.	Yes.	Yes.	Yes. The website will open as a result of the action of the user.
Click login button	Yes.	Yes.	Yes.	Yes.
Enter username in username field	Yes. The username field is labelled with "brukernavn".	Yes.	Yes.	Yes.
Enter password in password field	Yes. The password field is labelled with "passord".	Yes.	Yes.	Yes.
Click the login button	Yes.	Yes.	Yes.	Yes. The main page will open as a result of the action of the user.

Figure 8.14

Task: Find information about patient in emergency

	Will the user try to achieve the right affect?	Will the user notice that the correct action is available?	Will the user associate the correct action with the effect that the user is trying to achieve?	Will the user see that progress is being made toward the solution of the task?
Navigate to patients	Yes. The navigation shows menu items and is placed in the website's header.	Yes. The navigation has "pasienter" on the menu.	Yes.	Yes. The "patients" page will open as a result of the action of the user.
Click the patient in emergency	Yes. The page includes a list of all patients.	Yes. The patient in emergency is placed on top of the list.	Yes.	Yes. The "pasientinformasjon" page will open as a result of the action of the user.
Check pulse (BPM)	The pulse diagram is labelled, and the BPM is written explicitly.	Yes.	Yes.	Yes.
Check location	Yes.	Yes.	Yes.	Yes.
Click "nødrespons" to communicate with patient in emergency	Yes. The button is labelled with "nødrespons".	Yes.	Yes.	Yes.

Figure 8.15

COGNITIVE WALKTHROUGH OF WATCH

Steps	Will the user realistically be trying to do this action?	Is the control for the action visible?	Is there a strong link between the control and the action?	Is the feedback appropriate?	Comments
Check the time	Yes	Depends if the screen is on or not. Screen wakes by wrist movement or buttons	Mimics normal way to check the time of a mechanical watch	Yes, the screen lights up to let you see the time	Text is altered and optimized to be easier to see.
Check pulse	Yes	Yes, improved accessibility as the scrolling direction is standardized	Yes, as the only action is to scroll between pages of information	Yes, you know you are on the right page because of the heart symbol.	The dots on the left side of the device indicates what page you are on and how many pages are accessible
Clear notification	Yes	The means to do so is visible, but not the instructions (buttons on the side of the watch)	Not necessarily. The buttons have previously been used to scroll through the menus	Yes, the notification disappears	By pressing any button on the watch, the notification goes away.
Call for help	Yes	Yes, it is always the red button on the watch visible	While pressing the button for 5 seconds a message shows that SOS alert is activated	Yes, the screen lights up and says, "Help Sent!" after being pressed for 5 seconds.	This feature is now better developed with the introduction of a physical and dedicated button
Change settings	Yes	It is always not visible, but can be found by scrolling to the bottom page. Can be hard to find	Yes	Yes, the setting page has a list of options for the user to change	There is a dedicated settings page
Navigate between pages	Yes	We have implemented two dedicated scroll buttons on the side of the watch in addition to the scroll by touch function	Yes, the two buttons are located in such a way they indicate their scroll direction	Yes, a new page appears based on the scrolling direction	

Figure 8.16

9 Appendix C

9.1 Contributions

325
Document layout and script, Abstract, problem space (1.1), goals for data collection, technique (2.1.1), Half of the interviews, non-functional requirements (2.2.2), Design rationale for smartwatch (4.2.2), cognitive walkthrough of smartwatch (5.2.1, 5.3.1), Future work (6.4), Figure (7.12),(8.16)

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Target group (1.2.1), Personas (2.1.2), Functional requirements (2.2.1), Half of the interviews, Heuristic evaluation of website (5.2.3),(5.3.3), figure (7.8, 8.12), Discussion (6.1), changes (6.2)

286
Design rationale of website (4.11), Design rationale of website(4.2.1), Cognitive walkthrough of website(4.2.1), Cognitive walkthrough of website(5.2.3), The health watch: Finished prototype(3), Ethical dilemmas(6.3), Figure (3.3, 3.4, 7.4, 7.5, 7.6, 7.7, 7.10, 7.11, 8.8, 8.9, 8.10, 8.11, 8.14, 8.15)

181
Similar design(1.3) Design rational Smartwatch(4.1.2), Design rational Smartwatch(4.2.2), Evaluation method(5.1), Cognitive walkthrough (5.1.1), Heuristic evaluation (5.1.2), Heuristic evaluation of smartwatch(5.2.2), Heuristic evaluation of smartwatch(5.3.2)