Patient user interface for future concept connecting data from wearables to healthcare

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Abstract

The leading causes of disability and death worldwide, are chronic diseases. They are also the costliest part of healthcare. One way to ease the pressure on healthcare and improve quality of life for patients suffering from chronic diseases, is by digitising healthcare. The Swedish government has set an ambitious goal of Sweden being the world-leading country in e-health by 2025. To contribute to digitisation of healthcare and find a way to make healthcare more accessible, not only to people suffering from chronic diseases but for all others as well, a prototype for a mobile app was created using established methods of user-centred design. The concept of the app is that data from wearables can be connected to it, and shared with healthcare. The user interface includes views for physiological data about the heart, blood pressure, sleep, body temperature, as well as a view for peak expiratory flow measurements. The high-fidelity prototype was evaluated with 11 user tests. The tests yielded a System Usability Scale score of 90.4, a completion rate of 94.7 %, and an error-free rate of 81.6 %.

Keywords: Wearables, digitisation, connected health, e-health, user-centered design

Sammanfattning

Kroniska sjukdomar är den största orsaken till funktionsnedsättning och död, och även den största kostnaden för sjukvården. Ett sätt att minska trycket på sjukvården och samtidigt höja livskvalitén för patienter som lider av kroniska sjukdomar, är genom digitalisering av sjukvården. Regeringen har satt ett ambitiöst mål att Sverige ska vara världsledande inom e-hälsa år 2025. För att bidra till detta mål och samtidigt hitta sätt att göra sjukvården med tillgänglig inte bara för kroniskt sjuka, utan även för alla andra, användes etablerade metoder inom användarcentrerad design för att skapa en prototyp för en mobilapplikation. Konceptet för mobilapplikationen är att wearables kan anslutas till den, och datan delas med sjukvården. Användargränssnittet innehåller vyer för fysiologisk data om hjärtat, blodtryck, sömn, kroppstemperatur, och även en vy för mätning av topputandningsflöde (peak expiratory flow). High-fidelity-prototypen utvärderades med 11 användartester. Testerna gav ett genomsnittligt System Usability Scale poäng på 90.4, en slutförningsgrad på 94.7 %, och en felfrihetsgrad på 81.6 %.

Nyckelord: Wearables, digitalisering, uppkopplad hälsa, e-hälsa, användarcentrerad design

Acknowledgements

Contents

List of abbreviations and acronyms

- Action bar = Title bar in Android

- AI = Artificial intelligence

- API = Application programming interface

- BP = blood pressure

- EHR = Elecronic health record

- EMR = Electronic medical record

- UX = User experience

- UI = User interface

- hi-fi = High-Fidelity

- HRV = Heart rate variability

- IDE = Integrated development environment

- LED = Light-emitting diode

- lo-fi = Low-Fidelity

- NREM sleep = Non-rapid eye movement sleep

- OS = Operative system

- PPG = Polyplethysmogram

- REM sleep = Rapid eye movement sleep

- SUS = System Usability Scale

CONTENTS

Chapter 1

Introduction

This introductory chapter will first cover some background to why this project is relevant, followed by a short section on wearable technology. Lastly presented in this chapter are the goals for this project and questions it aims on answering as well as a description of the development tools used, and the structure of the report.

1.1 Background

This section covers background information on digitisation of healthcare and chronic disease management.

1.1.1 Digitisation of healthcare

Since the year 2000, the cost of healthcare in Sweden has grown on average by 4,2 percent yearly. This is an increase of 0,9 percentage points more than the average GDP [1]. The cost of Swedish healthcare in 2013 was 415 billion SEK, and if the trend which has been ongoing since the turn of the millennium continues, this annual cost is estimated to rise to 710 billion SEK by 2025 [1]. Since healthcare as of today already is under a lot of pressure [2], this increase in costs can be assumed to have negative consequences on patient safety and quality of healthcare. By digitising healthcare to a further extent, the cost of healthcare in 2025 is estimated to being reducible to 530 billion SEK.

The report by McKinsey & Co [1], presents three main areas of how healthcare can be advantageously digitised: techniques for connectivity, techniques for automation, and techniques for data analysis.

- Techniques for connectivity:

- – Remote monitoring using sensor technology
- – Self-diagnosing and counselling
- – Remote consultations
- – Online booking
- – Digital self-care
- – Monitoring of medication
- – Preventive public health work

- Techniques for automation:
  - – Integrated journal systems
  - – Optimisation of patient flow
  - – Personnel allocation
  - – Mobile tools for home health nursing and home care
  - – Remote monitoring of intensive care

- Techniques for data analysis
  - – Uniformity in care execution
  - – Tools for clinical decision support

In a document issued by the Swedish government in 2016 [3], it is stated that Sweden shall be the world leading country in e-health by the year 2025. The three areas of focus in this vision are:

Regulations Balancing rights or interests such as protection of privacy, quality, safety, and efficiency. Regulations should handle development of technology.

More uniform use of concepts Codes, concepts, terms, and structures that are used, should be valid and usable in the work of the principals to enable the exchange of information needed for ensure quality and safety.

Standards Common national specifications and services for safe competence and processes. Also a presumption for interoperability between actors and interchangeability between components.

Conclusively can be said, that there is a definitive need for digitisation of healthcare. There is also much aspiration to do so. Apart from the government's ambitions goal, another example worth mentioning is the e-health authority (e-hälsomyndigheten, `www.ehalsomyndigheten.se`) formed in 2014, which is working on several projects related to digitising healthcare in Sweden. A lot of initiatives in e-health are related to giving the public better access to, and more information about their own health (e.g. *Hälsa för mig* `www.halsaformig.se`, and *1177 Vårdguiden* `www.1177.se`), while less initiatives are related to incorporating patient-generated data into the healthcare system.

1.1.2 Chronic disease management

The worldwide leading cause of disability and death are chronic diseases. There is no determined definition on exactly what a chronic disease is, different definitions vary from "a duration of illness exceeding 3 months", to "permanent illness" [4]. In a Swedish governmental publication, chronic disease is defined as "diseases a person has during their

lifetime or during a very long time" [5]. It is estimated that chronic diseases amount to 80-85 % of the total cost of healthcare in Sweden [6]. Some of the largest groups of chronic diseases are cardiovascular disease, diabetes, and pulmonary diseases such as asthma and chronic obstructive pulmonary disease.

In the mentioned governmental publication, an area of improvement is brought up: Patients with chronic disease should be able to partly handle follow-ups and treatment on their own (e.g. measuring blood pressure), and that innovative techniques are an important presumption for it. Demonstrably, better methods for patients to measure and manage all kinds of chronic diseases on their own, is an important part of improving the quality of life for patients suffering from chronic disease and handle the rising costs of healthcare. Blood pressure, which was mentioned in the publication, is an important parameter to manage when it comes to cardiovascular disease. Many of the other large groups of chronic diseases also require the patient to take measurements at home. Asthma, for instance, requires the patient to take peak expiratory flow PEF-measurements (see section 2.1), while diabetics are required to frequently measure their blood sugar levels.

1.2   Wearable technology

Wearable technology, wearable devices or *wearables* according to [7], are "electronic technologies or computers that are incorporated into items of clothing and accessories which can comfortably be worn on the body". This includes devices such as fitness trackers, smartwatches, smart glasses, smart contact lenses, smart earphones (so-called hearables), e-textiles, and more. Not all wearables measure bodily functions. As defined above, a wearable may also be a t-shirt with LEDs (light-emitting diodes) incorporated into it. The wearables that are of interest in this project though, are the ones that can measure either physiological or environmental parameters that are in some way health-related. The fitness tracker is likely to be the first device one thinks of, but many of the same parameters could also be measured with e.g. a hearable. Nevertheless, all of these wearables use a collection of sensors to gather the data of interest. The most common sensors will be discussed in section 1.2.1. An important note is that consumer grade fitness trackers today are not medically certified, which means that they are not used as a standard tool in healthcare. The future potential is large though, and wearables are getting better and better. For this reason, a reasonable assumption would be that some wearables will be medically certified in the future.

According to a study, less than 10 % of physicians in Sweden currently recommend the use of apps to aid with treatment and follow-up of diseases, to their patients. However, around 70 % would consider doing it in the future [8]. Studies on similar acceptance for wearables in healthcare have shown to be hard to find. One could speculate that wearables being less widespread than smartphones, this acceptance might be lower. Some studies though, indicate that the acceptance for, and usefulness of, fitness trackers among chronic disease patients is good [9]. Another survey shows that 70 % of Swedes, would not mind sharing self-collected health data to healthcare [10]. Further, a study by PwC Health Research Institute, shows that 54 % of U.S. consumers would not mind sharing their health

data to healthcare [11].

1.2.1 Sensors

Below follows brief descriptions of some of the most common sensor technology used in wearables.

Optical heart rate monitor

An optical heart rate monitor measures the pulse using light. Two LEDs using light of different wavelengths, shine light into the tissue. A light sensitive photodiode then measures the reflected light. The ratio between the amount of reflected light from the two LEDs, is dependent on the amount of blood in the tissue. Since this amount varies during a heartbeat, the pulse frequency can be derived. This measurement is called a photoplethysmogram (PPG) [12]. The principle of the method is the same that is used in a pulseoximeter, except that in a regular medical pulseoximeter, the transmittance of light through the finger is calculated instead of the reflectance of light from within the wrist. The reliability of heart rate data from fitness trackers today has been disputed. According to [13], accuracy and precision varies significantly between different fitness trackers.

A number of physiological parameters can be derived from a PPG. The low-frequency variation of the PPG baseline corresponds to respiration. Being able to measure continuous blood pressure would be very useful, but doing that using PPG presents a number of complications. Since PPG measures the change in the volume of blood in tissue, applying pressure on the tissue will change the outcome of the measurement. While this might not present difficulties on measuring heart rate, connecting the PPG-signal to blood pressure will prove significantly harder. Another problem is the fact that blood vessels behave differently depending on how fast the pressure inside them changes. The degree of this, so-called dynamic compliance, is individual which creates problems if a universal model is desired [14]. However, since the PPG-signal is a function of blood pressure, it is reasonable to think that in the future, methods to measure blood pressure using PPG might emerge.

The correlation between heart rate variability (HRV) (see section 2.1) measured using electrocardiography (ECG) and PPG, has been shown to be high [15]. Even though the study was made using a medical grade pulseoximeter, if a fitness tracker can be assumed to give reliable heart rate data, reliable HRV data could also be assumed.

Accelerometer

The accelerometer measures acceleration forces, usually in all three axes. This means that the accelerometer can be used to measure parameters such as velocity, orientation, and vibration [16, p. 137]. One important use for accelerometers in wearables, is the ability to count steps. While there are so-called pedometers, which are devices specifically for this use, all mobile devices containing an accelerometer can be used as a step counter. Accelerometers can also, in conjunction with the right algorithms, distinguish between

different types of exercise (e.g. running and cycling). The ability to detect free fall and shocks also makes the accelerometer usable for devices detecting falls and impacts. Since the accelerometer uses gravitation as its reference point, it can not detect rotation around the vertical axis.

Gyrometer

A gyrometer measures angular velocity, and can unlike an accelerometer also measure rotation around the vertical axis. A gyrometer in combination with an accelerometer, is called an inertial measurement unit (IMU) [17]. Sometimes a magnetometer is also included in the IMU.

Magnetometer

A magnetometer gives the device's orientation in relation to the magnetic north pole of the earth. Hence, it is basically a compass. Including a magnetometer in an IMU used in a wrist-based tracker, means that the position and orientation of the wrist can be determined. This can be used for many purposes. One example is analysing the movement of hands in boxing exercises, as does the Moov trackers [18, 19].

Galvanic skin response

Galvanic skin response, a.k.a. electrodermal activity or electrodermal response, is based on the fact that the impedance of the skin changes depending on the state of the autonomous nervous system. Simply put, the human body secretes sweat at different rates depending on the psychological state of the person. The secretion of sweat changes the impedance of the skin, which can me measured and analysed. One application for this, is to measure stress using a galvanic skin response sensor [20].

Skin temperature

The body uses the skin to control its core temperature. This is a reason to why measuring body temperature from the skin is not always completely reliable. However, there is correlation between core temperature and skin temperature [21]. There are wearables today (e.g. Microsoft Band) that have incorporated a skin temperature sensor.

1.2.2 Previous work

Some healthcare IT-system providers have begun to include data from wearables in their systems. One example is MyChart by Epic Systems Corporation which is a popular EHR system in the U.S. that allows for patients to connect wearables to the app, and give their doctors access to their health data [22]. Another example is MyCarolinas Tracker App by Carolinas HealthCare Systems, which allows for different wearables and connected health devices to be connected to the app [23]. In March 2016, Apple Inc. released a software development kit called CareKit [24], which allows for even easier development of patient care apps towards the iOS platform.

Hälsa för mig, except for being its own app, also provides a platform for developers to develop health apps towards. This means that the ability for patients to upload data from wearables to their health account might soon be an option in Sweden as well.

1.3 Goals and research questions

In the beginning of the project, three goals and three research questions were formulated. These goals partly acted as a guidance to make sure the project did not diverge too much from the original plan, and as a reassurance that the depth of the thesis project would be sufficient for the author to eventually obtain a scientific degree.

Goals

The goals of the project were the following:

1. Study the usefulness of, and need for, a smart phone or smart watch app that receives data from different health related wearables and smart home devices.

2. Investigate possible applications for different actors in health care for such an app.

3. Create a prototype for such an app, test it, and evaluate it.

Research questions

To achieve the goals, some basic research questions were formulated:

1. What data supplied by wearables or smart home devices can be used in health care, and how?

2. In what ways can a smartphone application that gathers data from these devices be used in healthcare?

3. How can such a smartphone application make the user experience and accessibility of health care better for people?

1.4 Development tools

During the process of this thesis, a number of software tools have been used. Below follows a short description of said.

Adobe Photoshop CC 2014
Photoshop is a raster graphics editor created by Adobe. Photoshop was used to create the graphics both in this report, and in the prototype.

Android
Android is an mobile operative system developed by Google. Over 80 % of smartphones in the world run android.

Android Studio 2.3.1
Android Studio is the official integrated development environment (IDE) for Android, developed by Google. Being specifically designed for developing Android software, it is a very useful tool.

MPAndroidChart 3.0.2
MPAndroidChart is an open-source library with tools for creating and handling graphs and charts in Android Studio [25].

MATLAB R2014b
MATLAB is a numerical computing software developed by MathWorks, that was used for certain statistics in the project .

Github
Github is a version control software, used in this project to keep track of different versions of the app.

1.5   Report structure

To comply with scientific consensus, the pronoun *we*, will be used instead of *I*, when describing actions performed by the author, even though there is only a single author of this master's thesis. The first part of the report is structured into an introduction followed by a section on basic theoretical knowledge. The introduction took up topics to motivate the usefulness and need for this project, as well as some background information on the technology. Apart from this some administrative and practical information is be included. The chapter on theory will discuss and explain some of the basic theoretical knowledge on relevant topics related to the contents of the thesis.

The methods and results for the design process will be divided into the chapters *Concept phase*, *Elaboration phase*, and *Detailing phase*. This layout is greatly inspired by the three phases of a design project described by Arvola [26] (section 2.2.5). This means that the report will follow a more chronological structure with the method and results within the chapters for each of the phases.

The final part of the report will consist of a discussion on important parts of the report, followed by a concluding chapter that will discuss to what degree the goals of the thesis project were achieved, and what conclusions can be drawn from these.

Chapter 2
Theory

Below follows a summary of important theory related to the project, beginning with relevant human physiology. After this, a walk-through of some important aspects on design theory and interview techniques.

2.1 Physiological measurements

Some of the data gathered from wearables are related to the human physiology. In the results of this project physiological terminology is also used, which is why some knowledge about the human physiology and what can be measured regarding it, is needed to seamlessly follow and comprehend this report. Below follows some theoretical knowledge about the physiology related to this project.

Heart

The maximum pulse (maxpulse) a person's heart is able to reach has been found to decrease with age. The most accurate way to find out one's actual maxpulse, is to do a cardiac stress test. There does however exist a number of methods to estimate the maxpulse. Likely to be the most famous one developed by Haskell & Fox, is $maxpulse = 220 - age$, whose accuracy since has been disputed [27]. Other studies suggest $maxpulse = 208 - 0.7 \cdot age$, or $maxpulse = 211 - 0.64 \cdot age$ [28, 29]. Whichever method one chooses, the pulse frequency can be grouped into heart rate zones, which are calculated using equation 2.1. The x-value represents the percentage ones current pulse is of the maximum pulse, which also determines the level of physical activity (see table 2.1) [30]. It is disputed whether or not there exists an optimal heart rate zone for burning fat. [31] suggests that maximal fat oxidation occurs at 60.2-80 % of maximal pulse. The "Heart zone"-column in table 2.1 is inspired by other fitness apps and exercise machines, and the same categorisation will be used in this project.

$$x = \frac{current \ pulse}{maximum \ pulse} \qquad (2.1)$$

Table 2.1: X-values (see equation 2.1) and corresponding heart rate zone.

x	Activity level	"Heart zone"
< 0.49	Low	Resting
0.50-0.69	Moderate	Fat burn
0.70-0.84	High	Cardio
>0.85	Maximum	Peak

Heart rate variability (HRV) is a measurement that has been proven to have diagnostic, and in some cases prognostic value in multiple conditions. These include myocardial infarction (commonly known as heart attack), diabetic neuropathy (nerve damage caused by diabetes mellitus), cardiac reinnervation after a heart transplant, myocardial dysfunction, sudden cardiac death, liver cirrhosis, sepsis, and many more [32, 33, 34, 35, 36]. The ability to continuously measure HRV, especially for certain patient groups, could be of great value.

Blood pressure

A measurement of blood pressure consists of two values: systolic and diastolic pressure. The systolic pressure is the pressure the blood exerts on the arterial wall when the heart is beating, the diastolic when it is resting [37]. Blood pressure is written as 120/80 mmHg, and read as 120 over 80 millimetres of mercury. Guidelines for and classification of blood pressure values [38], can be found in table 2.2. Important lifestyle risk factors to manage, to avoid hypertension (high blood pressure), are physical activity, weight, diet, smoking cessation, and alcohol intake. Hypertension is a risk factor for multiple conditions including myocardial infarction, chronic kidney disease, ischaemic and haemorrhagic stroke, heart failure and premature death [38].

Table 2.2: Classification of blood pressure. The measured value belonging to the higher category defines the class [38].

Classification	Systolic (mmHg)	Diastolic (mmHg)
Optimal	<120	<80
Normal	120-129	80-84
High-normal	130-139	85-89
Hypertension	>140	>90

Sleep

There are two main sleep stages: REM (rapid eye-movement) and NREM (non-REM), of which the latter can be further divided into stages 1,2, and 3 [39]. These have characteristic properties, and are measured using methods such as EEG (electroencephalography,

brain activity) and EOG (electrooculography, eye activity). Wearables such as the Fitbit Charge 2, estimates sleep stages using movement patterns and heart rate [40]. Fitbit groups together sleep stages into *deep, light* and *REM sleep*, and these are the stages that a developer will receive information about when programming an application using the Fitbit API (application programming interface) [41]. See table 2.3 for sleep stages and Fitbit:s grouping of them.

Table 2.3: Sleep stages. Scientific grouping, and Fitbit's grouping.

	Sleep stages	*Fitbit grouping*
REM		REM
NREM	Stage 1	Light
	Stage 2	
	Stage 3	Deep

Body temperature

Body temperature can be measured at several locations on the body: in the mouth (oral), rectum (rectal), ear (tympanic), and armpit (axillary). The range of normal temperatures varies depending on the measurement site (table 2.4) [42]. The definition of fever varies, but is commonly defined as a core body temperature exceeding 38.3 °C [43].

Table 2.4: Ranges for normal body temperature depending on measurement site.

Measurement site	*Temperature range ($°C$)*
Oral	33.2-38.2
Rectal	34.4-37.8
Tympanic	35.4-37.8
Axillary	35.5-37.0

Peak expiratory flow

Peak expiratory flow (PEF) is used to estimate the variability in airflow. To get a good estimate of the lung function, PEF measurements should be taken at least two times a day, for a period of two weeks. A PEF reading is taken three times for each measurement occasion. Often, the patient keeps a PEF diary [44], where the best of the three values along with any symptoms are noted for each measurement. PEF is used for several purposes including monitoring, controlling and diagnosing asthma and occupational asthma; and adjusting asthma medication [45].

2.2 Design theory

This section describes some of the basic theory that lies behind the design decisions made in this thesis. These principles are not restricted to the design of interfaces, but rather more general recommendations and theories that apply to several disciplines of design.

2.2.1 Fundamental design principles

Some basic terminology used in design is needed to follow the thesis unhindered. [46, pp. 72-73] describes *the seven fundamental principles of design*:

1. Discoverability
The user can determine what actions are possible in the product.

2. Feedback
The results of actions are conveyed to the user. The new state of the product, after an interaction, is easy to determine and understand.

3. Conceptual model
The product is designed, so that it conveys necessary information for the creation of a good conceptual model. A conceptual model is an, often simplified, explanation to how something works. A great example, is the conceptual model of *documents* in a computer being structured into *folders* on a *desktop*, even though none of these actually exist in the computer. These types of conceptualisations ease the use of products [46, p. 25].

4. Affordances
The product contains the necessary affordances to make the appropriate actions possible. An affordance is described as the relationship between the property of a physical object, and a person's ability to perceive its intended use [46, pp. 10-11].

5. Signifiers
Signifiers are used in an effective way to ensure discoverability and intelligibly communicated feedback. A signifier signals what actions are possible and how the actions should be performed. One could say that a signifier signifies the presence of an affordance [46, p. 12].

6. Mappings
Proper spatial layout and temporal contiguity is used, so that the relationship between controls and their actions follows good (i.e. natural) mapping.

7. Constraints
Actions are guided by physical, semantic, cultural, and logical constraints.

2.2.2 Usability and User Experience

Usability is a collective term for certain properties of a product or interface [47, p. 30]. These include:

Effectiveness How good the product is at doing what it is supposed to to.

Efficiency How well does the product support the user in carrying out the tasks that it is designed for.

Safety Can be divided into two categories. The first is regarding physical safety: a product should be designed in a way, so that it does not put the user in any risk of physical harm or at least minimises this risk. The second category, more related to interaction design, is about minimising the risk that the user carries out unintended actions. An example of this type of safety is not placing an exit button next to the save button in a text editor.

Utility Does the product provide the right tools and functionality to allow the user to use it for the intended purpose?

Learnability How easy is it to learn how to use the product? How intuitive is the product?

Memorability How easy is it to remember how to use the product once the functionality has already been learned?

These properties of a product can be used to evaluate its usability. While usability criteria is more quantifiable, user experience (UX) covers a more emotional set of criteria that describe how the product is experienced and how it feels [47, pp. 30-33]. These UX goals can be divided into desirable (satisfying, helpful, motivating, engaging, etc.) and undesirable (boring, unpleasant, frustrating, childish, etc.) aspects. The UX aspects of a product are more subjective than the, in comparison, rather objective usability criteria. Usability and UX are, one could say, two sides of the same coin. A bad user experience, e.g. an aesthetically unpleasing interface, might negatively affect the usability of the product, while on the other hand an interface with low usability will affect the experience it provides the user.

2.2.3   User-centred design

User-centred design is the quite simple idea, that the intended end-user should be involved during the entire design process. The role of the designer is merely to take the users' needs, and translate it to a product. The three main principles of achieving this are [47, p. 268]:

1. Early focus on users and tasks
2. Empirical measurement
3. Iterative design

Early focus on users and tasks

The main driving force behind the development of the product should be the users' needs and goals. Understanding these needs and goals can be hard, which is why the users' behaviour has to be understood. Apart from the users' behaviour in certain contexts, the cognitive abilities and limitations of the human mind also have to be taken into consideration. These include aspects like memory, attention, and perception [47, p. 269]. User characteristics might also vary depending on the intended target group, physical disabilities, and conditions such as colour-blindness. These may also have to be taken into consideration.

Most importantly: users should be consulted throughout the entire design process, and all design decisions should be made with the users in mind. Different levels of user involvement might be appropriate depending on the circumstances of the project. In some cases, users might even be included in the design team, while in others only present to influence the project during workshops, evaluations, etc [47, p. 266].

Empirical measurement

Identifying usability and UX goals at the beginning of the project, will allow for the product to be evaluated with these goals as a basis. When making decisions on the design, e.g. choosing between different prototypes, the prototypes can be measured in how well they meet the initial goals [47, p. 268].

Iterative design

By iterating through the so called design lifecycle (figure 2.1) several times, allowing for evaluation by users during each cycle, the feedback from the users can then be fed into the next cycle, continuously improving the product. Iterative design is a very prominent characteristic of user-centred design. The design cycle can be divided into four stages: Establishing requirements, designing alternatives, prototyping, and evaluation [47, p. 270].

Establishing requirements
The first step involves understanding the users and their needs. This can be done by observation, interviews, and other similar data gathering techniques.

Designing alternatives
With the requirements as a basis, different concepts for a potential final product are taken forth. There are usually many different ways to design a product to meet the expectations and goals of the users. This stage involves designing the concept, sort of an outline of what the product can do and how it can be interacted with. More concrete design choices are also made, with more detailed specifications of the product such as colours, images, icons, and menus.

Prototyping
Creating prototypes by translating the concepts and concrete design decisions made in the previous stage, allows for the product to be evaluated by the users. There are different stages and types of prototyping, discussed further in section 2.2.4.

Evaluation
Evaluating the product in terms of its usability and character of user experience, will reveal possible flaws and problems with the design. Naturally, the involvement of users is imperative in the evaluation stage.

2.2.4   Prototyping

A prototype is a materialisation of the conceptual and concrete design decisions. The prototype is both a clear visual manifestation of the product, as well as allows for interaction
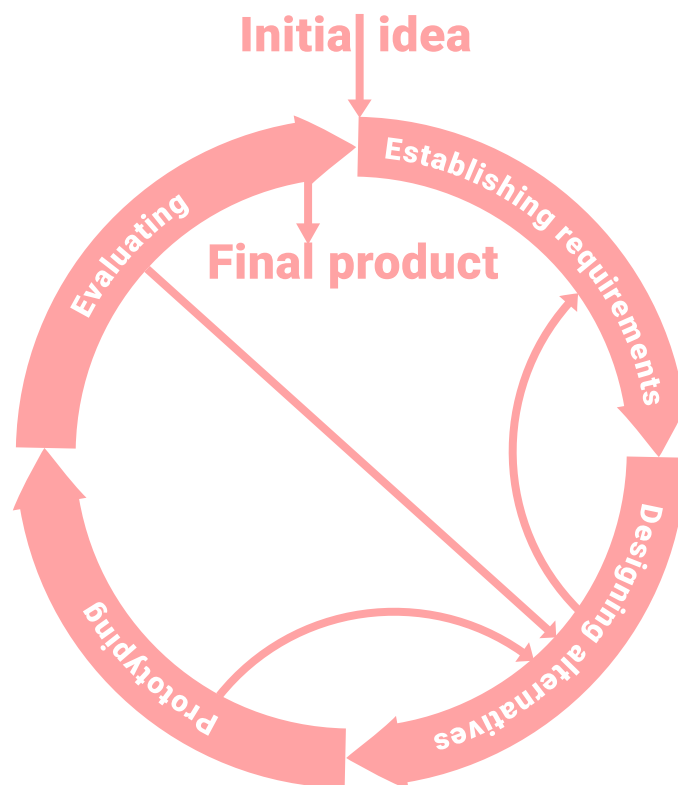
Figure 2.1: The design lifecycle

with it. Often a prototype is not fully implemented, and may have functionality limited to certain areas of interest. Hence, prototypes are quite useful when exploring ideas and evaluating design alternatives together with stakeholders [47, p. 316]. There are several different kinds of prototypes, catering to different purposes.

Low-fidelity prototypes

A low-fidelity (lo-fi) prototype is a very simplified model of the product. It does not have the same functionality or look, but is instead a simple way to explore the ideas created in the earlier stages of the process. Pen and paper are very useful tools, since they due to the simplicity and cheapness of the materials are the natural way to start creating the first prototypes of a product. Having quite a rough paper prototype can actually be of advantage, since this encourages the users to give more critique during evaluation. Sketches can also be made to simulate interaction in an interface by sketching several screens that are changed upon touch, foldable menus that drop down, or notifications that pop up. The method of having an operator simulating the interface in a lo-fi prototype depending on how the user is manipulating it, is called *Wizard of Oz* [47, p. 320].

A way of simulating how a product can be used and interacted with is by creating *storyboards*. In this method, a scenario is depicted in a series of sketches (cf. cartoons), that

demonstrate use of the product in different ways [47, p. 318].

High-fidelity prototypes

A high-fidelity (hi-fi) prototype is more sophisticated than its lo-fi predecessor. A hi-fi prototype often looks very similar to how the end product would look, but might not offer the complete set of functionality [47, p. 320]. These prototypes, when designing interfaces, are often created using prototyping software. This type of software allows for a certain degree of interaction, as well as fairly complex layouts and graphics. Hi-fi prototypes, e.g. of an app, may also be programmed in the intended coding language, but lack some of the functionality.

2.2.5 Three phases of a design project

Arvola [26, p. 7] describes the progress in a design project as three phases with at least one iteration each of the cycle described in section 2.2.3. These three phases he calls *the concept phase, the elaboration phase*, and *the detailing phase*. Further descriptions of these phases will follow later in the report.
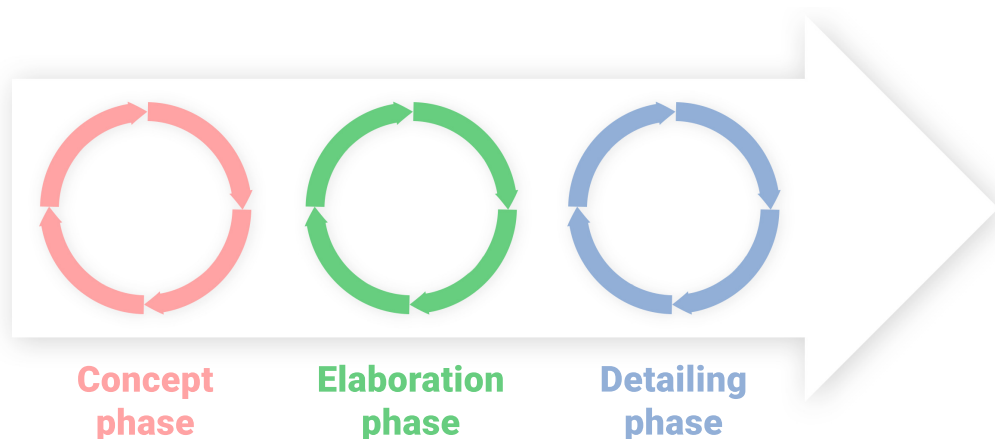
Figure 2.2: The three phases of a design project as described by Arvola [26, p. 7].

2.2.6 System Usability Scale

The System Usability Scale (SUS) is a questionnaire with ten questions, that the user fills in subsequent to the testing of a prototype or product [48]. The questions in SUS can be seen below.

1. I think that I would like to use this system frequently
2. I found the system unnecessarily complex
3. I thought the system was easy to use.

4. I think I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought this system was too inconsistent.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

The questions are graded from 1 (strongly disagree) to 5 (strongly agree) by the user. The scores for odd and even questions are treated differently. The end score for odd numbers is calculated as $score - 1$, whereas the end score for even numbers as $5 - score$. The calculated scores for all the even and odd questions are them summed and multiplied by 2.5, ending up in a score in the interval 0-100. The score should be treated as an overall score for the product in its entirety, without attempts to analyse individual questions [48]. [49] analysed nearly 3500 SUS surveys, and found the average score to be 69.5. They also paired 959 SUS surveys with a seven-point adjective scale, and placed adjectives on the SUS, as a reference (figure 2.3).
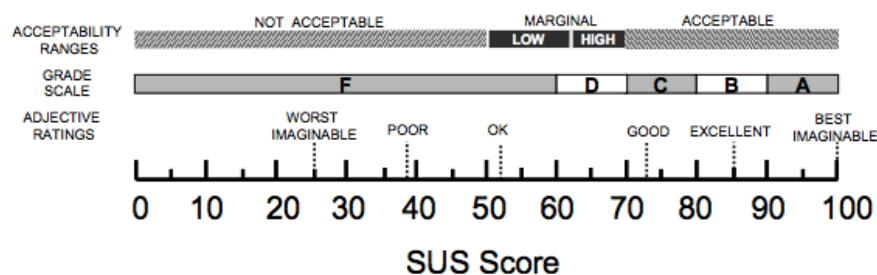

Figure 2.3: SUS paired with seven point adjective scale and school grades [49].

2.2.7 Designing for healthcare

Today's IT-systems in healthcare are often out-dated and complicated to use. Only 37 % of Swedish physicians in primary care are satisfied with the IT-systems used. One possible explanation is that Sweden was a pioneer in digitising healthcare, implementing some of the early systems. The early systems were mainly designed to *aid* the work processes, while a modern IT-system in healthcare is expected to cover the entire chain of care. Still having the same outdated systems in place, simply does not satisfy today's expected technological level [50].

Healthcare is a very complex issue to design systems for due to several reasons. Healthcare professionals are of all age ranges with varying technology skills. IT-systems used in different parts of the healthcare system may require completely different functions, and all parts of these systems should be interoperable and be able to communicate with each other. In other lines of business a design flaw might cause something to break or increase the costs, in healthcare lives are at stake. Designing the IT-systems in close cooperation with the intended users is critical.

2.3 Interviews

Interviews are used as a method for data collection in this project, therefore some theoretical knowledge on this topic is needed. There are three main ways an interview can be constructed. The difference between these are in how much control the interviewer has in the progression of the conversation [47, p. 197].

An *unstructured* interview can be described as exploratory conversations around specific topics [47, p. 197]. The interviewer might ask an introductory question and then freely come up with follow-up questions to dig deeper into the subject and gain new insights. The set of questions consists mainly of open questions. A *semi-structured* interview is in the middle of the spectrum of interview types. Here the interviewer has specific questions to ask, while then probing the interviewee to give more specific answers. The set of questions may include both open and closed questions. Semi-structured interviews were used in this project. The last of the three structures of interviews is called a *structured* interview, which can be compared to an orally collected questionnaire, where the interviewee is asked questions and given a predetermined set of answers to choose from [47, p. 197].

The balance between qualitative and quantitative information that an interview will give the interviewer differs depending on the type. The more structured the interview, the more quantitative data, easily interpreted and analysed statistically, one will get. The more unstructured the interview, the more qualitative and difficult to interpret the data will be.

A fourth type of interview often used is a *focus group*. A focus group is an interview conducted with a group of interviewees, instead of having just one interviewee. The interviewer, or facilitator in this context, leads the conversation. An advantage of using a focus group is that instead of having a two-way conversation as in a regular interview, the participants can have a discussion together and, in a way, probe each other. The method assumes that the social context of a focus group encourages the participants to develop ideas and opinions, and express them [47, pp. 199-200].

Chapter 3
Concept phase

The concept phase is the first step in the design process of a product. The task in this phase, is to create a vision of what is to be designed, and why.

3.1   Method

The design brief for this project consisted of the title: *Create an application for smartphones by collecting data from wearables*. As an initiation of the process, we started by working in a problem driven way. This means leading off by investigating the users' goals and needs. Another way one could start, is by working in a solution driven way. In this case, one starts by sketching on ideas. Whether a design team starts with one way or the other, they will sooner or later have to switch focus. Since the two go hand in hand, it is rather indifferent in which end the group begins [26, p. 39].

The concept phase was divided into the following steps:

1. Gain insights with user studies
2. Formulate intentions and set goals
3. Create ideas and conceptual sketches
4. Evaluation

In the first stage, we needed to gain some insights by studies with users and shareholders. Getting this information can be done in many ways using different methods for data gathering. Often several methods are used in parallel, which is called *triangulation*. By triangulating, if receiving similar data from several sources, the credibility of the data is strengthened [26, p. 76]. In this project, interviews with physicians were conducted. Prior to the interviews, literature was also studied resulting in the information in the background-section. The researched topics included wearables and digital healthcare. Having been gathered, the data had to be structured and analysed. This was done by to creating an

affinity diagram. Other ways to structure and analyse the data, could have been to portray insights using personas, scenarios, and storyboards.

Having analysed the data and gained insights on users' current behaviour and knowledge, it became interesting to consider the future behaviour and knowledge of the the users. Using the insights gained in the literature study and the interviews, ideas on how to meet these were generated. The process of finding the optimal idea is not linear, and often a design group initially works in a divergent way, generating multiple ideas. One good tool to use for this is brainstorming. Brainstorming is a way to generate a large amount of ideas in a short period of time. In summary, the participants take ten minutes to individually write down as many ideas as they can come up with, after which the ideas are read out one by one. The other participants then say out loud other ideas that they come up with, related to the one read up from the note [26, p. 94]. The fact that the design team in this project consisted of one person, meant that a few steps in the generalised process for brainstorming had to be skipped. Instead, possible solutions were written down and reflected on.

Having generated multiple ideas, the ideas were evaluated in how well they corresponded to the insights from the data gathering stage. A multitude of possible concept ideas had been created, which had to be narrowed down to a single idea to start working further on. This resulted in a requirements specification for the concept to be developed further. Below follows more in-depth descriptions of the different stages and results obtained from them.

3.2 Data gathering

Background data was first gathered in literature. This was complemented by interviews with physicians.

3.2.1 Interviews

Six interviews were conducted for this project: one pilot interview with a medical student, and five interviews with practising physicians, all specialising in Occupational and Environmental Medicine. The pilot interview was used to evaluate the questions and test the interviewing process. With the acquired insights from this, the questions were slightly modified. The remaining five interviews were conducted with the aim to gain information about a number of questions:

- What medical conditions today require the patient to take physiological measurements in their homes, and how is this data processed?
- To what extent is data from wearables and health apps used as a tool in healthcare today?
- Assuming wearables will be medically classified in the future, what data will be of interest for medical professionals?
- How should this data be presented, and what platforms should such a system use?
- What issues put most pressure on healthcare today, and how can e-health help solve these issues?

The semi-structured interviews were sound recorded, and parts of interest were transcribed. The data from the interviews was used to design the overall concept of the system, and to create a requirements specification for the prototype. The interview questions can be found in appendix A.

3.2.2 Results from data gathering

The interviews provided a lot of interesting insights from a physicians perspective, into how an app could be integrated with healthcare. Below follows a summary of the interviewees thoughts on different topics during the interviews, connected to some of the information gathered in the literature study.

Diseases that require patients to take measurements at home include the following:

- Diabetes (blood sugar)
- Long-term fever/infections (temperature)
- Sleep disorders (sleep data)
- Cardiovascular diseases (blood pressure, ECG)
- Asthma (PEF)
- Physical activity (time, steps)
- Vibrations as a result of labour

The chronic diseases discussed in section 1.1.2, are all mentioned by the interviewed physicians as well. Included in this list are also other diseases that are not necessarily chronic, such as infections and sleep disorders. When experiencing abnormal sleep, a patient can be asked to keep a sleep diary on the quality and quantity of sleep. In some cases the patient may be taken to a sleep centre for further testing. When seeking care for an infection, information on duration and severeness of fever is of importance. Physical activity is also a parameter that often is of interest to healthcare professionals, especially in cardiovascular diseases. ECG, which can be measured at home (often for a time-period of 24 hours), is also relevant for several heart conditions.

None of the interviewees were aware of any ability to upload data to a digital system. No such system could be found during the literature research either. Most data collected at home is brought in analogically, usually on paper. Neither had any of the interviewees experienced a patient bringing digital data of their own, i.e. from fitness tracker, to a meeting. There is also a lot of hesitation on using data from wearables, unless it would be certified by the hospital administration. Provided that data from fitness trackers is certified for medical use, data of interest would be PEF, sleep, blood pressure, heart rhythm, heart rate variability, stress, and blood sugar levels. This data should be uploaded into the EHR. The interviewees did not see any advantages to having a separate interface.

Both raw data, graphs, and statistical measurements were desired. The data representation depends vastly on the type of measurement. The ability to observe data in the same ways as corresponding in-hospital measurements was seen as an advantage, but new types of data representation being made available by the use of wearables should be utilised if

advantageous. Artificial intelligence (AI) in healthcare divided the opinions of the interviewees. Some were positive to the fact that AI could be used as a supportive tool, while others saw a physicians ability to assess nuances as too important of an advantage to risk by using AI. Complete trust in technology to diagnose patients was not present, the physician making an assessment of their own was still seen as an important part of diagnosing. Scepticism on how well AI actually works was also present.

Matters that put most pressure on healthcare are many, and diverse. Rising mental illness and stress levels in society were one factor brought up. Higher survival rates from serious diseases was another, which leads to more people needing long-term care. Higher survival rates are, obviously, one of the very core objectives with improving healthcare; nonetheless, it does also lead to more resources being demanded from healthcare. Another often mentioned cause was the limitation of resources, both too little capacity to house in-patients, and a deficit of healthcare professionals. One interviewee speculated on it not being attractive enough to work in healthcare. Causes for this could be rough work-hours or economic reasons. IT-related causes were also mentioned a lot. Since the introduction of IT into healthcare, the administrative work is perceived as having risen. One interviewee also commented on that quality controls need to be made and updated often, which takes up a lot of resources. Poor design on IT-systems does also seem to be a big factor. The systems are old, and not designed with the primary users, which are healthcare professionals, in mind. The guidance and coaching in how to use IT-systems is also insufficient.

Other possible uses for the type of concept this thesis project was presented as, were quite a few. Monitoring patients remotely was seen as a possibility, taking people in if values are abnormal. This would also allow for more preventive care. Support groups (communities) for helping people keep up physical activity is a possibility (which is already becoming more popular in fitness-related consumer grade apps). Continuous automatic data analysis on blood sugar to follow how a person's diabetes develops was mentioned. Linking together different types of data was also seen as an opportunity. One application could be algorithms that identify risks for mental illness using physiological data (e.g. connecting sleep and physical activity). Elderly persons could be monitored remotely using data from fitness trackers, both for physiological parameters and other situations such as detecting falls. The ability to show patients more precisely what happens in their bodies, as a form of patient empowerment was also mentioned.

Lastly are a few thoughts on whether or not this type of a concept could save time, relieving the healthcare professionals. Time could be saved on anamnesis interviews, since physicians could review patients' exact data prior to a meeting instead of risking receiving vague, inexact answers. Digital data would also be easier to analyse using computer software instead of by hand. This kind of concept was perceived as having the ability to leading to more qualitative care, but it could on the other hand also end up being more time consuming. It does in many ways depend on the design of the product.

As a conclusion, the observation that healthcare is not working in the forefront of technology can definitely be made. Pen and paper are still used to a surprising extent, for tasks

that could easily be facilitated using simple technology. A task like analysing PEF-results, is often done by drawing graphs on paper of the obtained values, and calculating the statistics on this by hand, a task that could be easily automated using simple software. Another important observation is that the IT-systems used by healthcare do not seem to be very well received by the healthcare professionals. Whether this is due to insufficient opportunity for training in the systems, poorly designed systems, or a combinations of both is not fully clear. However, the results of the interviews seem to suggest the last alternative.

3.3   Concept generation

The data from the interviews and literature study was structured using an affinity diagram, and a final concept idea was decided upon.

Affinity diagram

An affinity diagram is a simple way to categorise data. Since the data from the interviews was highly qualitative, this was a good way to structure the data [26, pp. 52-54]. Key points taken from the interviews were written down on so-called post-it notes, and then assembled into groups, so that the contents of each note related in some way to the other notes in the same group. The entire step-by-step procedure used for this affinity diagram was (inspired by [26, p. 53]):

1. Relevant and interesting quotes from the interviews were transcribed.

2. Important passages from these were written down on post-it notes.

3. All notes were spread out on the floor for categorisation.

4. The notes were categorised into meaningful groups, by identifying which observations or ideas that were similar or in some way related to each other. Upon adding more and more notes into the categorisation system, the notes were continuously reorganised into improved categorisations.

5. Upon completion of the categorisation, the categories were named.

Results from affinity diagram

The resulting categories and contents from the created affinity diagram were the following:

Systems

- Data from app into EHR
- Big difference in understanding of IT-systems between buyers, designers, and users
- Open external files in EHR?

Data presentation - patient

- Amount of data presented to patient?

- Upload pictures (e.g. skin lesions)
- Measure temperature at home using wearable

Data presentation - healthcare

- Connect different types of data
- Data/devices have to be validated/certified
- Might need novel types of data presentation to fully utilise potential of wearables
- ECG → deviations
- Long term (Holter) ECG is analysed after recording, no real-time view or alarm

Data presentation - both

- AI → patient/physician (empowerment/concern)
- Stress - Sleep
- Sleep → variation during different periods of time
- Irregular pulse → atrial fibrillation
- Digitising analogue measurements
- Data/graphs in same time-scale above eachother
- Digital sleep diary
- Connect physical activity to mental illness

Help/change healthcare

- Save time on anamnesis interview
- Save money on home care
- Ability to save more lives → shift hospitals away from dealing with minor diseases, and towards dealing with more serious diseases
- Personnel have limited resources → forced to prioritise patients → bad

Help patients better

- People exercise less than they think → help people achieve goals
- Self-awareness/physial activity

Help both

- Notice things that would otherwise be missed (using continuous data from wearables) → fewer medical examinations
- Start data collection immediately when someone has symptoms
- Take patient in for examination if values don't get better → preventive care

Final concept idea

After considering the alternatives and ideas that had arisen, we decided to start working on and refining a particular idea. The decision was made based on the user studies, which indicated that this type of concept could be both very useful, and well received. This concept would be an app that collects data from patients using wearables (i.e. fitness tracker). The system would have a smartphone interface, possibly with an accompanying smartwatch
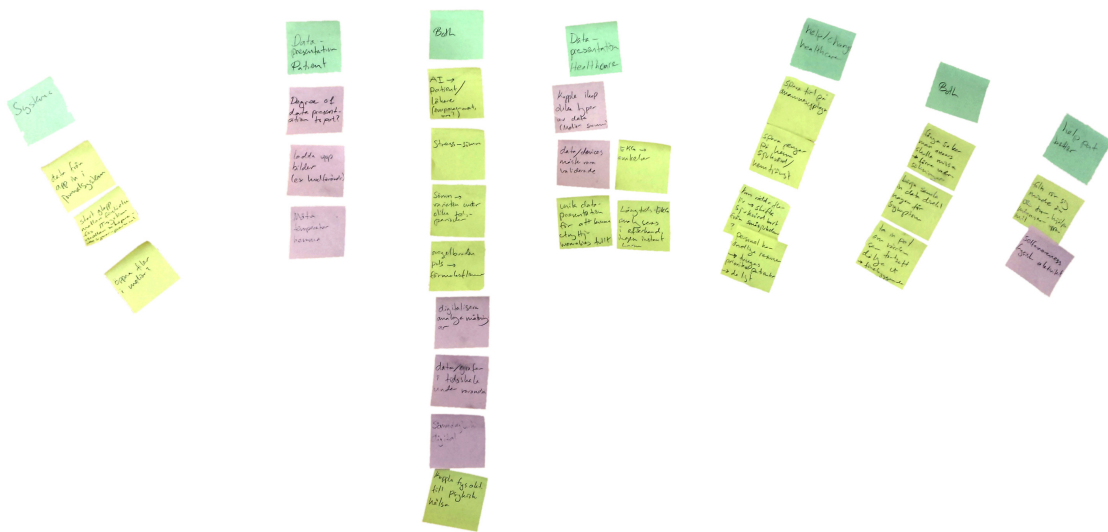
Figure 3.1: The affinity diagram created with the data from the interviews.

interface, and a separate computer interface to be used by healthcare. The computer interface, or at least parts of it, could also be accessed by the patients to enable more statistical tools for them as well. Data from the wearable comes in two types, inter-/intraday data, and real-time data. Real-time data is transmitted to the smartphone interface using bluetooth, which is a common way to transmit data over short distances. Data from the wearable is uploaded to a server, from which requests can be made by the smartphone app. See sketch of entire concept in figure 3.2. To narrow down the scope of this thesis, the decision was made to focus on the smartphone UI for the patient. Designing the computer UI would have been equally relevant, but this decision was made in accordance with the initial design brief.

The pool of possible concepts to go forward with were the following:

- Using wearable to detect falls among elderly people.

- Artificial intelligence home hub (cf. Amazon Echo, Google Home), that uses data from wearables to monitor physiological changes in patients and helps them manage chronic illnesses.

- A smartphone and smartwatch app that allows patients to queue to healthcare centres from home, instead of sitting in a waiting room for prolonged periods of time.

- Concept for system that predicts and tracks emotions/monitors mental illness using heart rate, galvanic skin response, and physical activity.

- **App that gathers health data from wearables, analyses it, and connects it to healthcare.**

- A fitness app for mental health instead of physical health.

Requirements specification

Having set the limitation of focusing on only the user interface for the patient, the following was determined to be the specification of requirements on the product at this stage.

- Connect wearable to app.
- Receive data on:
    - Heart rate
    - Blood pressure
    - Body temperature
    - Sleep

- Be able to add own data on:
    - Peak expiratory flow (PEF)
    - Blood sugar
    - Images

- Receive notifications if values show negative results (e.g. fever).
- Data should be synchronised with healthcare.
- Healthcare can adjust settings and limits in the app.
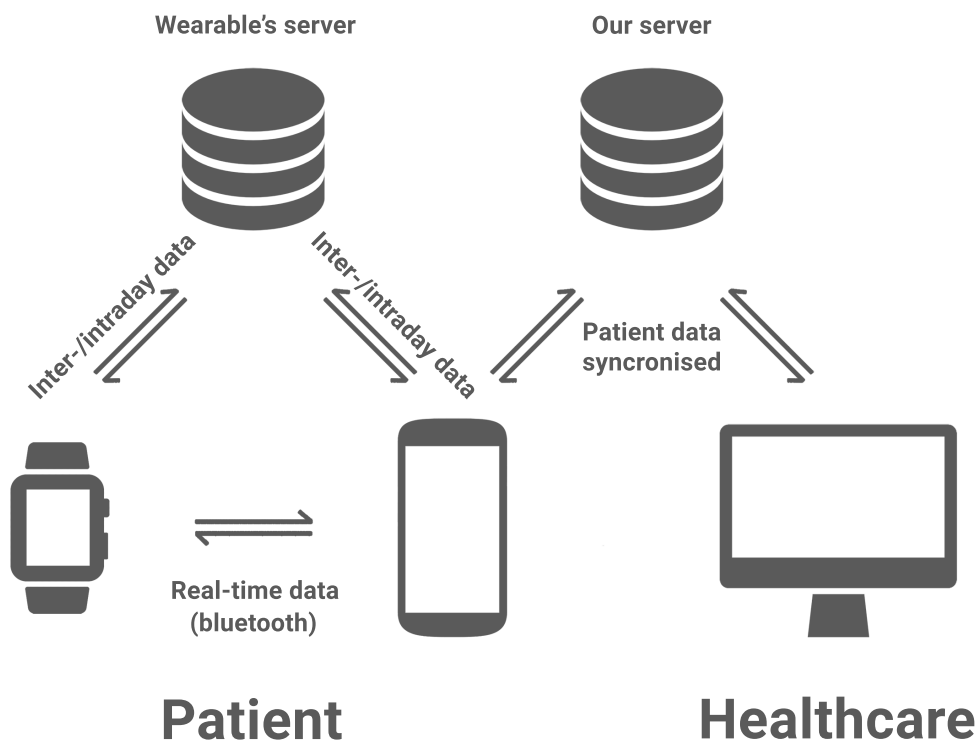- Few levels of depth in the interface, to prevent getting lost.

Figure 3.2: Sketch of the entire concept.

Chapter 4

Elaboration phase

The purpose of the elaboration phase is to translate the final concept of the concept phase into actual functionality and content. This means creating and evaluating a prototype describing how the user can interact with the product, and how the interface should be designed.

4.1   Method

The elaboration phase was divided into four steps [26, p. 104]:

1. Insights on functionality, content, and shape
2. Intentions in scenarios and abstract requirements
3. Ideas on interfaces in sketches and paper prototypes
4. Evaluation by formative testing

Having decided on a final concept, some further information was needed to accompany the insights gained during the data gathering stage of the concept phase. Knowing by now, that the product very likely would manifest as an Android application, the innate functions and layout possibilities of said operative system were studied, as inspiration for the lo-fi prototype.

After this, more detailed requirements on functionality was determined. A useful tool for doing this is a task-flow chart, which is a way to structure the tasks the user needs to perform in order to complete a certain scenario. The tasks can also be structured into sequences of actions that need to be executed to complete the tasks [26, p. 105]. In our case, no actual task-flow chart was created. Instead, we found it easier to work on creating initial sketches of the interface and develop a task-flow chart simultaneously. For this reason, the task-flow chart is instead incorporated into the initial sketches as descriptive comments. A close-up of one of the initial sketches can be found in figure 4.1.
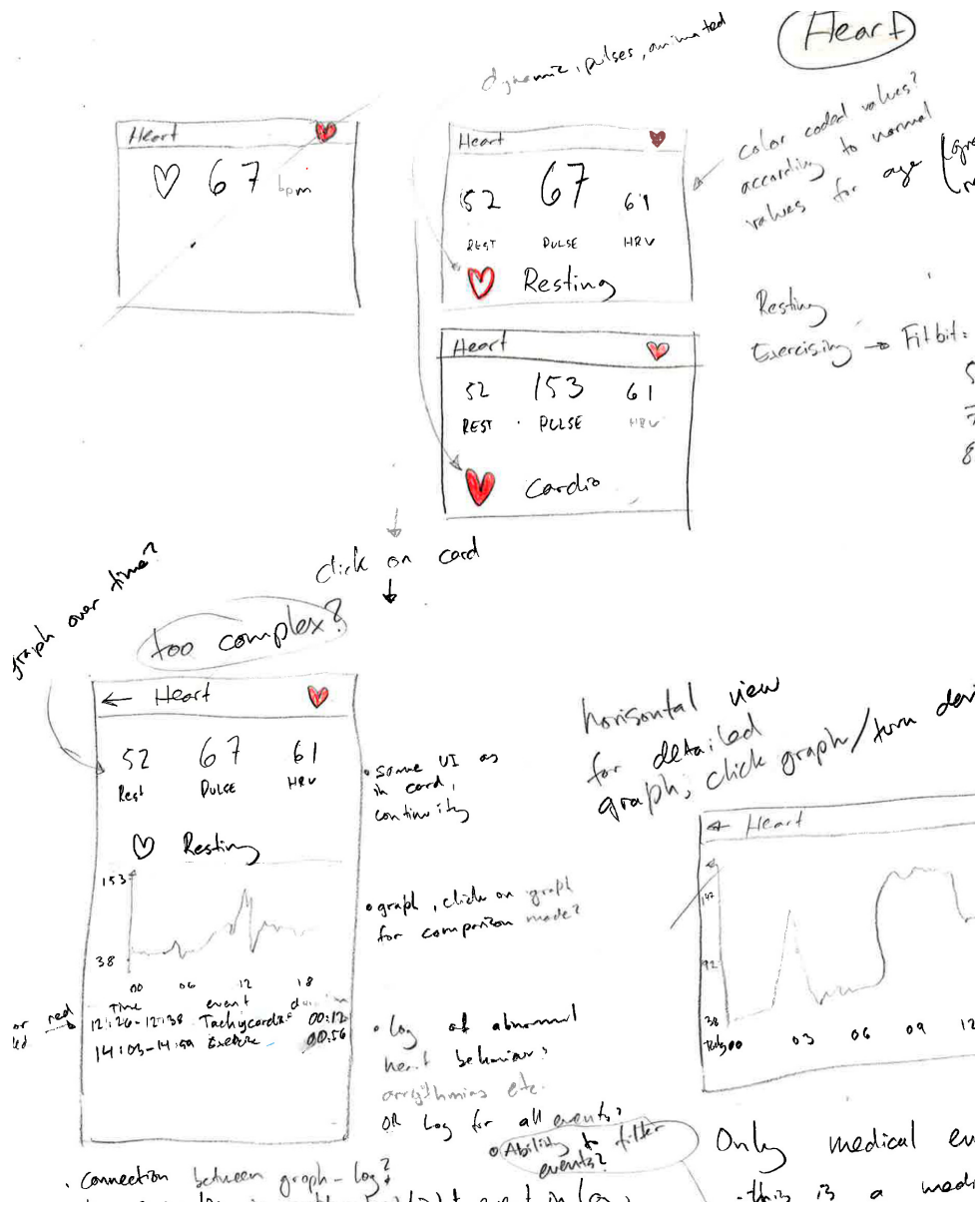
Figure 4.1: Closeup of one of the sketches from figure 4.3.

Having declared the requirements for the functionality, the task of figuring out how to design the interface in a way that meets them began. Linking functions together to see which functions and interactions are connected, was a good way to get some structure prior to designing the prototype. This was done using a *sitemap* (figure 4.2) [26, p. 110]. The sitemap described the layers of the interface. The first step in designing the interface, is usually to rely on pen and paper. The initial sketches examined different possibilities for the layouts of all parts of the interface. Arrows were drawn between actions, and descriptive comments on the functionality were stated (figures 4.1 and 4.3). Keeping in mind the design theory covered in section 2.2, a lo-fi prototype was created. Evaluation of the lo-fi prototype was done using a type of heuristic evaluation, in which the interface was analysed by two focus groups. These processes are described in more detail below.
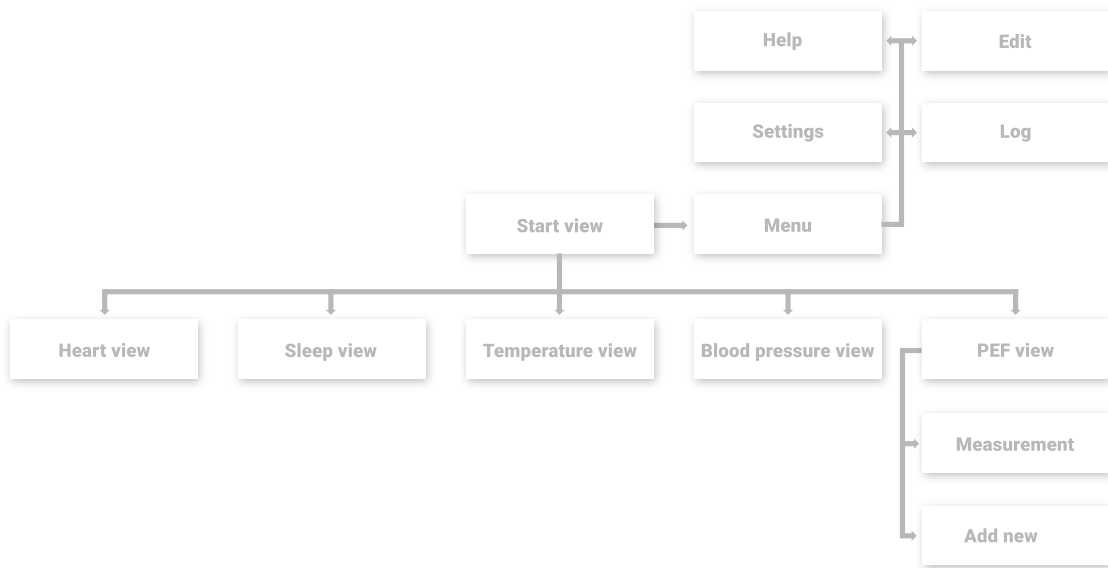
Figure 4.2: Sitemap for the interface.

Figure 4.3: Pre-prototype sketches of the interface.

4.2   Creating lo-fi prototype

As seen in the sitemap in figure 4.2, the start view is the central point of the map, and continues down into the separate views. The start view should also have a menu, where matters such as settings and help can be reached. None of these views, except the PEF view, contain any levels further down. This design is made with the clear goal of creating an interface as simple as possible. Some further aspects, apart from the ones discussed in section 2.2, are important when structuring the layout of a user interface. The elements of the interface should be structured in a way, that supports the cognitive capabilities of the human brain. Grouping related elements together, and separating them from other groups of elements, helps with focusing attention to the right place [26, p. 143].

Establishing a hierarchy between the elements in the interface is very useful. This way more important elements get more attention and are more easily perceivable. A hierarchy can be established by having contrasts in terms of size, position, shape, colour, and saturation. In our case the most important elements, the values also seen in the cards in the start view, were placed at the top of the interface in the middle. These were also grouped together, separating them from the graphs below. The lo-fi prototype consisted of sketches of the different parts of the interface. Simplicity and cleanness were the key-words when starting to design the layout and style of the interface. To ease the process and achieve the correct proportions of an actual phone screen, a template was made. Below follows a in-detail description of the different parts of the interface.

Start view

Because of its simplicity and aesthetic appeal, a card based interface [51] was chosen for the start view (figure 4.4 a-b). Cards chosen to be included was a heart card, blood pressure card, temperature card, sleep card, and a peak expiratory flow (PEF) card. The first four being measurements of physiological data, the colour of the header of the card was chosen to be a peach-pink colour, while the PEF card got its own light blue colour, being related to a specific condition (asthma). Being able to distinguish the basic physiological data from other disease specific data was considered to be important for the possibility of adding a larger amount of cards to the design in the future.

The layout of the cards was kept simple, with a title clearly stating the measured parameter in both text, and using an icon. The same information, using the same layout as seen in the card, is also seen in the detailed view when a card is clicked. This allows the user to better relate to the layout, and not get lost in the interface. This layout being the same for both the card and the upper part of the detailed view, a further description of this follows below in the separate sections for the different views. Horizontal layouts were also created for the views containing graphs (all except PEF). The different proportions of the screen, being in a horizontal state, resulted in the fact that a separate layout of the elements in the interface was needed.

The title-bar (also known as the action bar) in the start view, was chosen to be red. Being more saturated, this red colour signifies a higher hierarchy than the title bars of the cards.

Seeing the red colour also clearly signifies that the user is in the start view, and cannot go upwards in the interface. On the left side of the action bar, a menu symbol is present. This menu symbol consists of three stacked horizontal lines called a hamburger menu. When clicked the menu turns into an arrow, signifying that the menu can be closed, returning the user back to the start view. The menu contains the elements *Log, Edit, Settings,* and *Help* (figure 4.4 c).

The *log* is a function for viewing events and notable changes in the physiology, such as getting a fever or having a period of abnormal heart function or arrhythmia. The *edit-*option will bring the user back to the start view, but now allowing the order of the cards to be changed. Cards can also be added or removed using this function. The same function is also reachable by simply pressing and holding any card in the start view. *Settings* brings up a view where the basic values such as height and weight can be changed. All device-related settings should also be modifiable from here. Setting limits for the different physiological values, and modifying the usage of notifications could also be done here. If more functionality is added to the app, the possibility for adding more functions to the settings-view is good. Finally a help function, explaining abbreviations and functions is available in the menu.
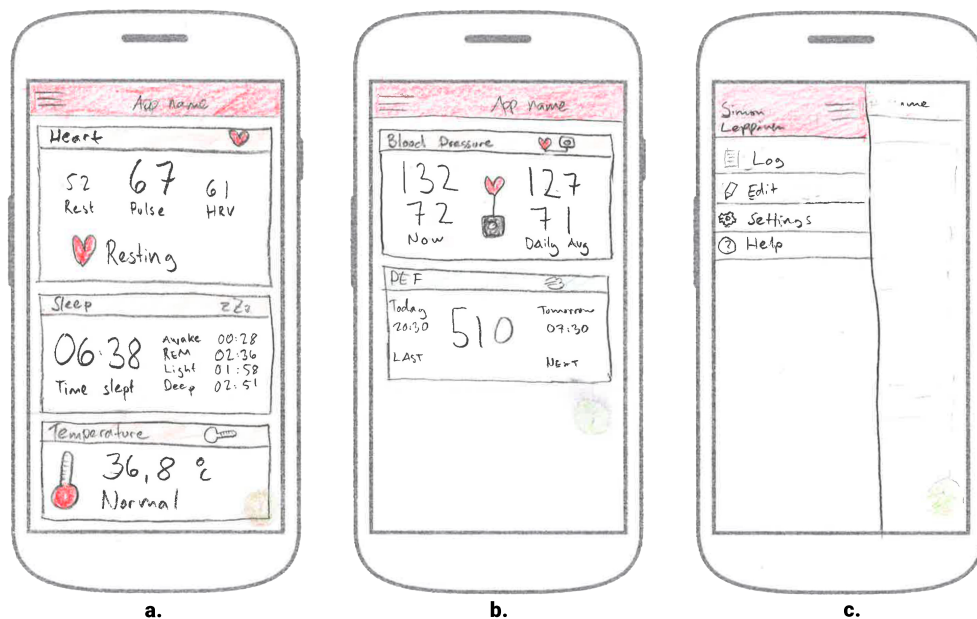

Figure 4.4: Lo-fi prototype: Start view.

The detailed views

When inside the detailed view of a card, the action bar changes to the same colour as the title bar of the card. At the very left of the action bar is an arrow facing left. Upon click, the arrow will take the user back to the start view. At the top of all detailed views below the action bar, there is a date changer consisting of two arrows surrounding a text box stating the selected date. When clicking the left arrow, the date is switched backwards, while

when clicking the right arrow the date is switched forward until the current day is reached. Clicking the text box will bring forth a calendar, to allow the user to conveniently reach data from dates further back in time. Apart from this element, the detailed views differ in content and layout.

Some of the detailed views (sleep and blood pressure) contain both a line graph and a bar graph, while the others (heart and temperature) contain only a line graph. The line graphs contain hourly data, while the bars in the bar graphs contain compiled data for an entire day. The graphs are interactive. When clicking on a line graph, a cursor appears. This allows for the user to scroll through the data, and see values specific for different points in time during the day. Activating the cursor changes the colours of the affected values, so that they are the same colour as the cursor. Clicking a bar in the bar graphs will highlight the bar, and change the colour of the affected values accordingly. Switching days using the arrows at the top also highlights the bar corresponding to the selected date. The labels below the bars contain an abbreviation for the day (e.g. WED), and the date (e.g. 24/7).

Heart view

The top section of the heart view (figure 4.5) contains the same information as the heart card. Three values are presented: *resting pulse, pulse, and heart rate variability*. The resting pulse, a value with a text saying *REST* below it, is a daily average of the resting pulse for the selected date. This value is the leftmost one of the three values. The right-most value, heart rate variability, has the text *HRV* below it. The pulse is located in the middle, with the text *PULSE* below it. To consolidate a hierarchy among the three values, the pulse has a notably larger font size on its value than the other two. The pulse is displayed in real-time, while the other two values are calculated using data from the entire day.

Below the three values, an icon picturing a heart together with a text can be found. The text changes depending on the pulse, and its four different states are *RESTING, FAT BURN, CARDIO,* and *PEAK*. When showing the pulse in real-time, the heart-icon is animated to simulate a beating heart. The requirements for real-time data are naturally that the interface is set to today, and that the cursor is inactive. When this is not the case, the heart remains unanimated.

Below the top section, is a graph depicting the user's pulse frequency from 00:00-23:59 for the selected day. The colours chosen for the graph range from beige, through yellow and orange, to red, as the pulse rises. The colour scheme for the graph was chosen because of its perceived rise in intensity. The left axis of the graph represents the pulse frequency, while the right axis represents the heart rate zone, written out in text. A purple colour was chosen to represent abnormal behaviour in the heart (e.g. arrhythmias). These abnormal behaviours are also listed in a log at the bottom of the interface.
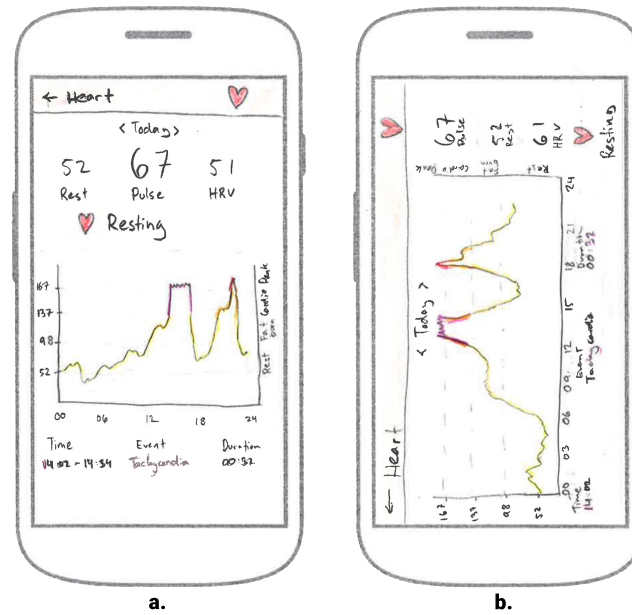
Figure 4.5: Lo-fi prototype: Heart view.

Sleep view

The top section of the sleep view layout (figure 4.6) contains information on the amount of time spent in the different stages of sleep. These stages are *deep sleep, light sleep*, and *REM sleep* (see section 2.1). Apart from these, information on the amount of time being awake during the night is also shown. This information is shown on the right side of the top part of the interface. On the left side the total amount of time slept can be found. Below are a line graph and a bar graph. The line graph shows chronological information on the sleep stages. The y-axis has four fixed alternatives, which are the three sleep stages, and being awake. The x-axis shows time from when one fell asleep until woken. The bars in the bar graph are partitioned according to the percentages of the night spent in the different sleep stages of the total time slept, and thus gives a proportional picture to the user on this matter. The bars show seven days at once, and so gives the user an oversight of the past week's sleep patterns.

Temperature view

The view for temperature (figure 4.7) clearly shows the temperature in the centre of the top section. Right below this is a text shifting between *Normal* and *Fever*, depending on the temperature. On the left side is an icon depicting a thermometer. This thermometer is filled on the bottom part when the temperature is normal, and fills up completely when the user has a fever. A line graph can be found below the top section. This shows temperature over time, with the graph being yellow for normal temperature and red for fever. At the bottom is a log that lists fever events.
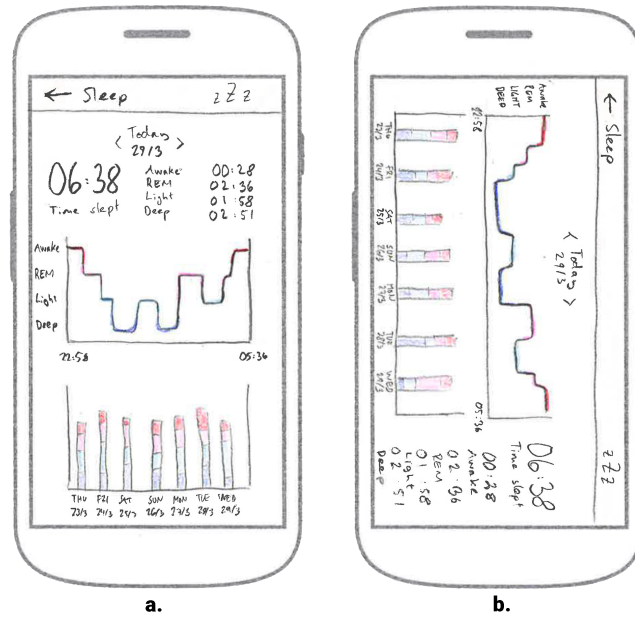
Figure 4.6: Lo-fi prototype: Sleep view.
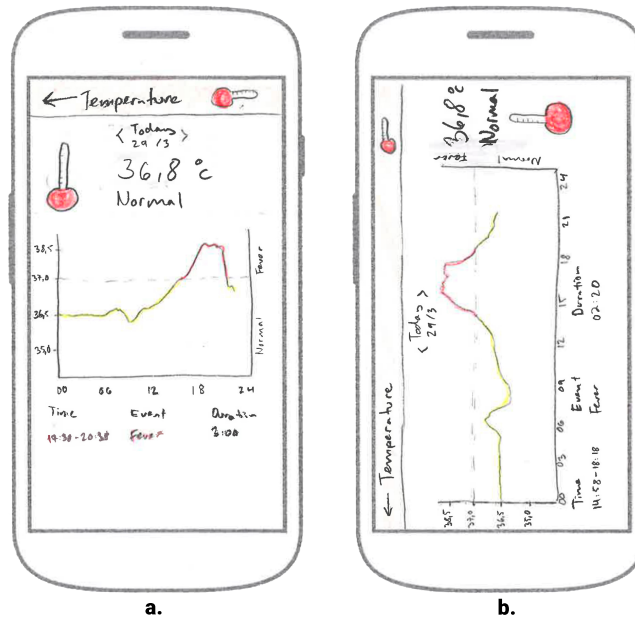
Figure 4.7: Lo-fi prototype: Temperature view.

Blood pressure view

The top part of the view contains the current blood pressure to the left, and the daily average of the blood pressure to the right. Below the value for the current blood pressure is the text *NOW*, and below the other value the text *DAILY AVG*. Between these is an icon depicting a heart connected to a measuring device. When real-time data is shown the icon is animated (figure 4.8 c), otherwise it is unanimated and semi-transparent (figure 4.8 a-b). Below the top section is a line graph. This graph contains two lines, one for systolic (above, yellow)

and one for diastolic (below, blue) pressure. The bar graph at the bottom of the interface shows the average blood pressures for the past week.
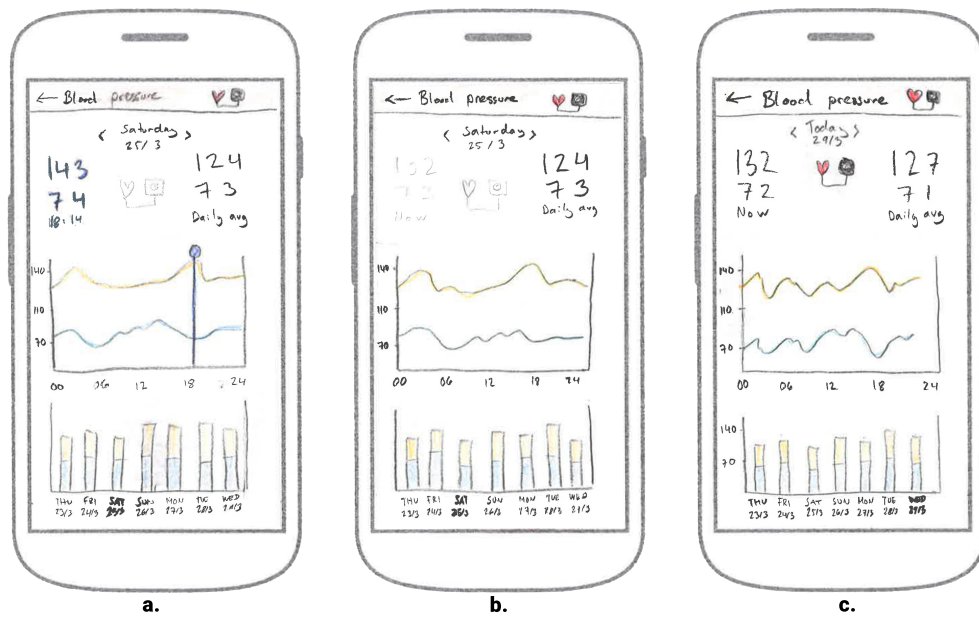
Figure 4.8: Lo-fi prototype: Blood pressure view, vertical.
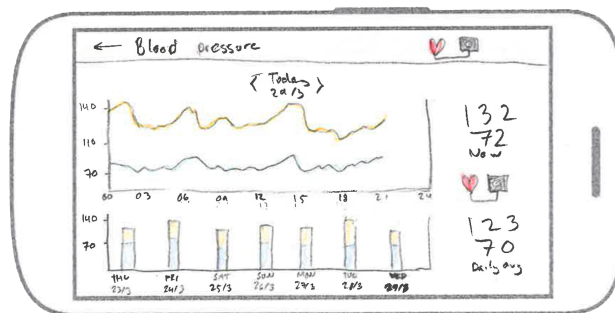
Figure 4.9: Lo-fi prototype: Blood pressure view, horizontal.

PEF view

The view for PEF-measurements does not contain continuous data on physiological parameters as the other views, hence the differently coloured action bar. The value of the latest taken measurement is displayed in the middle of the top section (figure 4.10 a). On the left side, the time for the latest measurement (above) together with the text *LAST* (below) is displayed. On the right side on the other hand, the next measurement is shown with the time for it placed above the text *NEXT*. Below this one can find a button depicting a plus-sign, with the function of adding a new measurement. Below the plus-button there is a log of past measurements, starting with the most recent measurement on the

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top. Placing the most recent measurement in close proximity to the button for adding new measurements, was considered to be more logical for the user.

When a measurement from the list is clicked, a new view showing more information about it is shown (figure 4.10 b). Here the date and time are shown in the top of the view, together with the value of the measurement. Below is the location of where the measurement was taken, and potential symptoms experienced in temporal proximity to the measurement. Clicking the back arrow in the action bar of this view takes the user back to the first state of the PEF view described above.

Clicking the plus-button opens a new view for adding a measurement (figure 4.10 c). Below the list is one text box for filling in the location, and one for describing symptoms. The last element in the interface is a green button at the bottom reading *ADD*. When one step of the list is completed, the number ahead of it changes to a *checked*-icon (figure 4.11). Thus the user gets a clear indication that he/she can move on to the next step of the sequence.
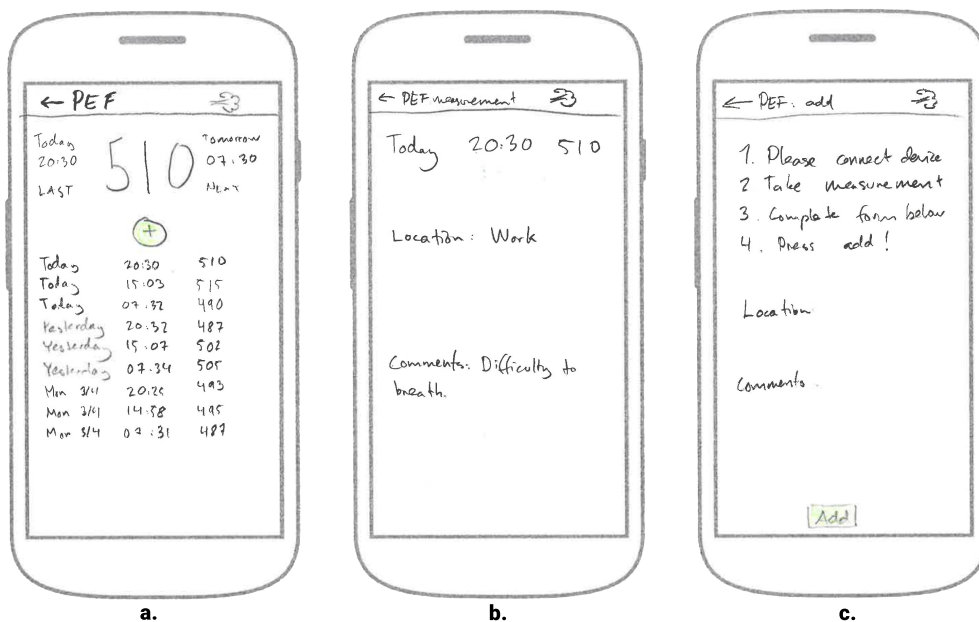
Figure 4.10: Lo-fi prototype: PEF view 1/2.

4.3   Evaluation of lo-fi prototype

To evaluate the lo-fi prototype two focus groups with 5 and 4 participants, representing potential users of the patient UI, were held. The structure of the focus group meetings were to study each part of the interface, try to understand what the intended use was, and come with feedback on the easiness to understand the intended use. If the group misunderstood the intended use of some part of the interface this was noted, as well as any suggestions for improvement. Having two separate focus groups allowed for comparison and more robust analysis; different group dynamics might affect the discussion in different ways. The focus groups were sound recorded, and the recordings analysed after the focus group meetings.

Figure 4.11: Lo-fi prototype: PEF view 2/2.

4.3.1   Results from evaluation

The discussions during the focus groups yielded a number of interesting observations and comments. Below follows a summary of these for each part of the interface.

Start view

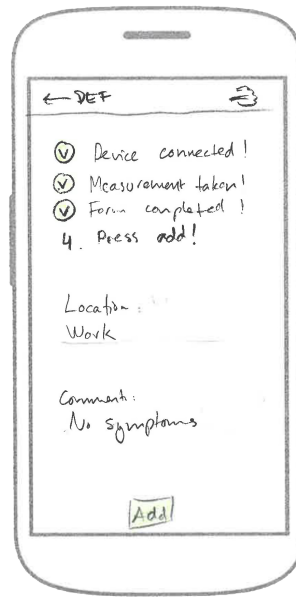The cards were overall perceived as a very good way to structure the start view. Clicking on a card was seen as a very intuitive way of reaching the detailed view. Using cards also allows for customisation, which is seen as an advantage. Disease-specific sets of cards was proposed. Taking it even further, each user could get a tailored set of cards by filling in a form regarding their conditions.

"So the PEF-card is blue because its added by the user?", which is the case, was asked. This possible confusion of having separate colours on the title bars of the cards, was noted as a possible issue prior to the focus groups, but seemed to be fairly well understood. The physiological (pink) cards, were also seen as a standard package of measurements. One interesting question arose, which was what happens if the user has several wearables that can measure the same things? Is there a way to decide which wearable the data comes from in that case? This is a very good point that we had not thought about, this matter could be handled in the settings in the menu.

The questions of notifications also arose. Notifications were not described in the lo-fi prototype. The ability to receive notifications is seen as advantageous, but the user should have the ability to turn them off and modify their behaviour as well. Whether or not, and in what way the user should be notified about abnormal values *inside* the UI was also discussed. Should the colours on the title bars of the cards change e.g. if you get a fever?

Perhaps there should be some kind of warning flag, like a "new mail"-icon? Should the colour of the numbers on the cards be changed upon abnormal values? Changing the colour of the card title bar to red, was seen as too drastic and alarming-looking. The groups preferred a more subtle way of having small notification-icons in the header-bar of the cards instead.

Overall detailed views

Having a calendar for switching dates would be very good in each detailed view. The ability to switch dates by swiping left or right in the interface was also wondered upon. Having a cursor to get more detailed information for specific points in time, was seen as very advantageous. Since some physiological definitions and abbreviations were hard to understand, some kind of help-function in every view was requested. It is also good to have the exact same information in both the horizontal and vertical modes. No information should be missed because the user does not turn the phone.

How the bar charts behave was also wondered upon. Do the bars shift sideways each time the date is changed, or are they static for each 7-day period? Regarding the overall time period of presented data, having tabs in the bottom of the interface was suggested. This would allow to see line graphs of time periods of different length. This would have to be very clear in that case. One test person having used an app for a fitness tracker, had gotten lost in that app too often. The more advanced statistics and graphing options could also be accessed in a computer interface instead.

Heart view

The log in the heart view was debated upon quite a bit in both of the focus groups. It could have both positive and negative effects, much depending on the user. On one hand, it feels a bit scary. Perhaps the log should only be visible if the user has a pre-existing heart condition? It is perceived as being very stressful to receive information on having a possible heart condition via a notification from an app, though very useful if you know you have a condition. Perhaps the log should be activated by a doctor? Many of the participants would not want to see abnormal heart events before they have been checked by a doctor. Having the data automatically uploaded and checked by doctors, and them calling the user in for a meeting if something is wrong, was proposed.

Another matter that caused some discussion, that we had not put much detailed thought on prior to the focus groups, were the colours in the graphs. For example, both high pulse and fever are represented by the colour red in the graphs. Since one is good and the other bad, this sends conflicting messages to the user. It would be good to change this so that the colour red only represents bad things, and other states being neither good nor bad, would have neutral colours.

Sleep view

Comparing the two views containing a bar graph resulted in some discussion. The bars are structured differently for sleep and blood pressure, where one is cumulative while the other

is partitioned, which might cause confusion. One participant also speculated on whether a bar could be interpreted as a chronological summary of the different sleep stages of the night. The question of which night a bar represents also arose. Does the bar for e.g. Tuesday represent the day the user fell asleep on, or the one the user woke up on. Designing this part of the interface, we thought that having the last bar representing "today", this would make it easy enough to understand that the bar represents the day one awoke. Though going further back in time might still confuse the user enough for this problem to need a better solution. Anyhow, the interface should use the same consensus as other sleep apps, since this is what users might be used to if they have used such apps before.

One participant asked about what happens if the user sleeps during the day. Should this also be registered? How would this manifest in the interface? The colouring of the graph in the sleep view was well received. The colours were seen as quite neutral, red representing restlessness while blue represents calmness. The colour red was not seen as alarming as in the heart view.

Temperature view

The same doubtfulness as with the log in the heart view, did not arise for the temperature view. The log for fever events was perceived as advantageous by everyone in the focus groups. The colouring here did present some hesitancy though. Having yellow represent normal temperature was not seen as neutral enough, perceiving yellow is a bit of a worrying colour. Making the parts of the graph representing normal temperature blue instead, was suggested. One person in the focus group speculated on whether blue could be perceived as representing hypothermia.

Blood pressure view

"I don't know what is normal and abnormal", was said rather quickly. Should some type of limit lines be added, that would divide the graph vertically into different zones depending on the normalcy of the blood pressure? Should these zones also be coloured-in differently? How much does blood pressure vary during a day, can you even have general limits? Does a healthy person even need to see the limits? Questions also emerged on whether or not the line graph should be zoomable?

The scale on the pressure-axis was also discussed, in terms of whether or not it should be static. An advantage would be that if two users were to compare graphs, they would likely be less confused or mislead if the scales on both users' graphs are the same. A disadvantage with a static scale would be that the graph could go above or below the scale. This means that extreme blood pressures would have to be accounted for, pushing the actual line of the graph into a smaller vertical space, making it harder to read.

Some test persons were used to seeing systolic and diastolic values next to each other horizontally, since this is usually how blood pressure is presented, which caused some confusion. Should the colours in the graph be connected to the values above (e.g. colouring the values accordingly to some degree), to make it cleared which line belongs to which

value? Having a blue cursor as well as a blue graph also caused some minor confusion.

In the first focus group, not all participants agreed with the structure of the bars as they were. One participant would have preferred having the systolic and diastolic pressures next to each other instead of stacked. Another wanted them semi-super-positioned so that half the bar is behind the other. Most of the persons in the first group though, as well as all in the second, liked them they as they were.

Some discussion arose on whether there is too much information crammed into the view? In the design of the interface, this was seen as a secondary concern compared to splitting the interface into several views, thus risking users getting lost. Should there be a possibility of incorporating medication for high blood pressure in the interface? Since this will affect the blood pressure, should it be handled in the blood pressure view in some way?

PEF view

The individual measurements shown in the first view of the PEF interface, should be made to look clickable, i.e. by adding button-like features like dividers between the bars, and shadowing. It is seen as a good feature, to have the newest measurement on the top in the list. Whether or not one wants to see graphically how the values progress over time was also taken up. There could be tabs at the bottom of the interface to shift between the log and the graph. When designing the PEF view, inspiration was taken from PEF-diaries [44]. On the other hand, utilising the available technology does encourage improvements to be made, and a graph could also possibly be added.

Regarding the view for adding a new measurement, having constant feedback is seen as very good. This way, the user always knows how far in the process he/she has come. Functionality allowing the user to instantly see which value was measured should be added. In case a user often has the same symptoms, the participants wondered whether it would be easier to have checkboxes so you don't have to write the same thing every time.

No classification of PEF-results have been added to the interface at this stage, which was commented by the participants: "Do you get any indication on whether or not the measured value is normal? The value could be coloured depending on how good the result is".

Miscellaneous

The possibility of having an overall comparison mode is seen as having the possibility of being useful. This way several physiological parameters could be viewed below each other and compared. Whether or not this could be done without the interface getting too messy, was also discussed. The ability of having a general timeline, so the user could see all values for a certain time was also deemed interesting by some participants. This could for example mean that pulse, temperature and blood pressure could be seen in the same view when analysing exercise. At this stage of the process, these types of adaptions are not seen as necessary, already having planned on a computer interface for these types of

functions. However, in future development this could definitely be an option to investigate.

4.3.2 Changes to be made in hi-fi prototype

There was a lot of discussion about the interface. A lot of the design was seen as positive. A lot of possibilities for additional functionality was also discussed. However some immediate problems could be identified during the evaluation. Other matters had been completely overlooked during the design process. Below follows a suggestion on things to be changed or added in the interface.

- Remove log in standard settings for heart view

- Change colours in heart graph to more neutral ones

- Change yellow colour to more neutral in temperature view

- Change colour of cursors to orange

- Add help function in every view

- Design notifications/alerts sent to the user from the different views upon abnormal values, when user is not actively using the app.

- Design notification system notifying the user upon abnormal values within the UI (e.g. "new mail"-type small static notifications on the title-bars of the cards).

- Investigate in what way the bars should move and behave when switching dates.

- Add information to the sleep interface clarifying which bar belongs to which night.

- Add possibility for normalcy-zones to blood pressure graph.

- Design the list of previous measurements in the PEF view, so that the individual measurements are perceived as clickable.

- In the PEF view: Change text-boxes to checkboxes with predetermined symptoms, and one with "Other" containing a single empty text line.

- Investigate normalcy indications for PEF measurements.

Looking at the list of changes above, the importance of evaluating the prototype continuously with the users, certainly is highlighted.

Chapter 5

Detailing phase

The detailing phase is the last phase in the model. Here, the prototype from the elaboration phase, together with insights from the evaluation and possible further data gathering, will result in a refined hi-fi prototype.

5.1   Method

The cycle of the detailing phase was divided into three steps:

1. Intentions in specific requirements
2. Ideas in digital prototypes and design specifications
3. Final evaluation

The original sequence of steps in [26, p. 141], includes an initial step on gathering further data on users. This was not deemed necessary in our case, having gotten a large amount of new data from the recently performed focus group meetings.

The evaluation was chosen to be in the form of individual user tests, where users complete tasks. The specific goals for these tests were set prior to the evaluation, after completion of the prototype. One goal that was set at this stage though, was a target SUS score. Revisiting figure 2.3, we decided that it would be desirable to place at least between good, and excellent on the adjective scale. Hence, the goal of an average SUS score of $SUS_{AVG} = 80$ was set.

Having already specified most of the structure and functionality of the interface in the previous phase, designing the actual layout and style of the interface in greater detail was the main task from now on. A more detailed description of how the hi-fi prototype was implemented follows further below. Before the final step of handing over the complete

prototype and specifications to the developers, the prototype has to be tested and evaluated. The test was divided into tasks, with a clear beginning and end, easing the analysis of the results. Further description on how the user tests were conducted, and how the results were analysed, follows.

5.2   Creating hi-fi prototype

When creating a hi-fi prototype (section 2.2.4), the completeness of the prototype may vary. The prototype does not have to be fully implemented, as long as it can be evaluated and tested in a representative way. This means that certain parts of the interface can be faked. With the limited time-frame of this project, and us being rather satisfied with the layout in the lo-fi prototype, the decision was made to first implement the same layout in the hi-fi prototype. The decided upon changes regarding this layout were also included. More functions would be implemented in case of having a sufficient amount of time to do so.

The hi-fi prototype was developed directly in Android Studio (see section 1.4). The reason for this was that the end product of this project was decided to be an Android app, and thus the intermediary step of creating a hi-fi prototype in prototyping software was deemed unnecessary. The development of an Android application consists of two dimensions. The layouts of the elements in the different views are programmed in XML, while the functionality is programmed using Java. The app was programmed in Android Studio, the official integrated development environment (IDE) specifically designed to develop Android applications. This environment allows for a visual view of the layout, changing in real-time when structuring the XML-files, which is very useful. With the interface containing a fair amount of graphs, Android's inherent functions for creating graphs were not considered advanced and easy enough to work with, which is why an external package (MPAndroidChart [25]) was used for this purpose. While this package also has certain limitations, the possibilities were far greater than those of the intrinsic one.

The data used for the graphs was faked. The possibility to draw data from a fitness tracker was investigated, and found possible. This was the original plan for the final product (as in figure 3.2). However, with the limited temporal resources of this project, this plan was eventually discarded. The interface of the application would not be notably affected by the realness of the data used in the graphs. Being a prototype, faking certain parts of it is something that is often done [26, p. 147]. The feedback from interacting with the prototype was developed to behave the way it would in the final product. Below follows figures in the form of screen shots from the developed hi-fi prototype, together with describing sections. The descriptions of the different views are fairly comprehensive in the section describing the lo-fi prototype. For this reason the descriptions of the views in this section will mostly review changes made, and further functionality implemented.

Pre-start view

One addition to the hi-fi prototype is the pre-start view. This view is only shown when the user starts the application the first time. On the top, the text *Welcome!* is shown. Below are four relevant pieces of information that are used for functions within the application: Gender, date of birth, weight, and height. Clicking on the box saying *Select gender:*, opens up a dialog box where the user selects gender from the alternatives *Female, Male,* or *Other*. Clicking the box with the text *Birthday:*, opens up a date picker where the user chooses her/his date of birth. Clicking *OK* on the bottom of the date picker closes it, and automatically sets the cursor to the text box for *Weight* bringing up the virtual keyboard. The bottom-right button on the keyboard, when filling in the weight, is a right-pointing arrow. When clicked upon, the cursor shifts to the text box for height. When shifted, the arrow turns into an "enter"-arrow, signifying that clicking this closes the keyboard. The user can not proceed to the next step in the interface without filling in the four pieces of information required in this view. Having filled in everything correctly, upon click on the *OK*-button, the start view opens.

Start view

The layout of the start view has not changed notably since the lo-fi prototype. The icons inside the heart and blood pressure cards are animated. In this prototype they pulsate with a static pulse frequency, but in the final product they should pulsate with the current frequency of the heart. Clicking anywhere on a card, takes the user to the detailed view for that card. The buttons in the menu have not been implemented in this prototype.

Heart view

The heart view has gone through a few changes since the lo-fi prototype. The colours have been revised, ranging from light blue at the bottom (rest), through dark blue (fatburn) and purple (cardio) to pink (peak). These colours are all more neutral compared to those used in the lo-fi prototype. Lines separating the different heart zones were also added. In the finished product using real data, the heart rate zones are to be calculated and set automatically using the formulas for this (see section 2.1).

When the interface is showing data for the current day (figure 5.3 a) the heart-icon is pulsating. The text next to the icon shows the current heart rate zone that the pulse is located in. The value and text in the middle representing the current pulse are also at full opacity. When another date than the current one is selected using the arrows, the animation of the heart-icon stops and the value and text for the current pulse, together with the icon and adjacent text are set to a lower opacity (figure 5.3 b).

The cursor is activated by clicking the line graph. When this is done, the value and text change colour into the same orange colour as the cursor. The text *PULSE* changes to *CURSOR*, and a text saying which point in time is selected by the cursor is added below it, changing as the cursor is moved (figure 5.3 c). The icon is set back to full opacity, but remains unanimated. The text next to the icon changes accordingly depending on which

heart rate zone the selected pulse is within. The cursor is deactivated either by clicking the cursor itself, or the value of the pulse. When the date is shifted forward to the current date, the opacity of the pulse value and -text are set back to full opacity and the animation of the heart-icon is started.
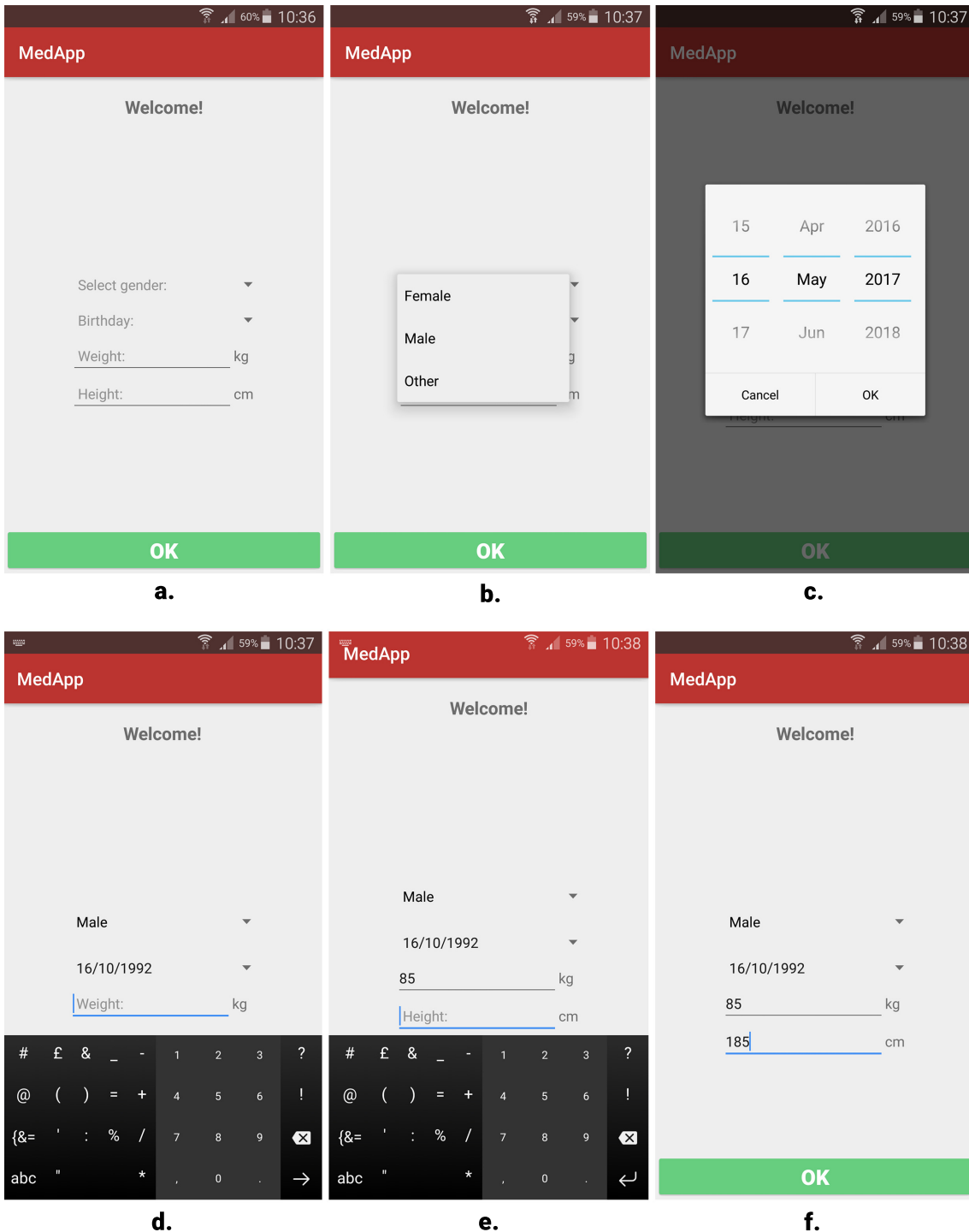

Figure 5.1: Pre-start view: **a.** First screen. **b.** Selecting gender. **c.** Selecting date of birth. **d.** Specifying weight. **e.** Specifying height. **f.** Everything filled in.
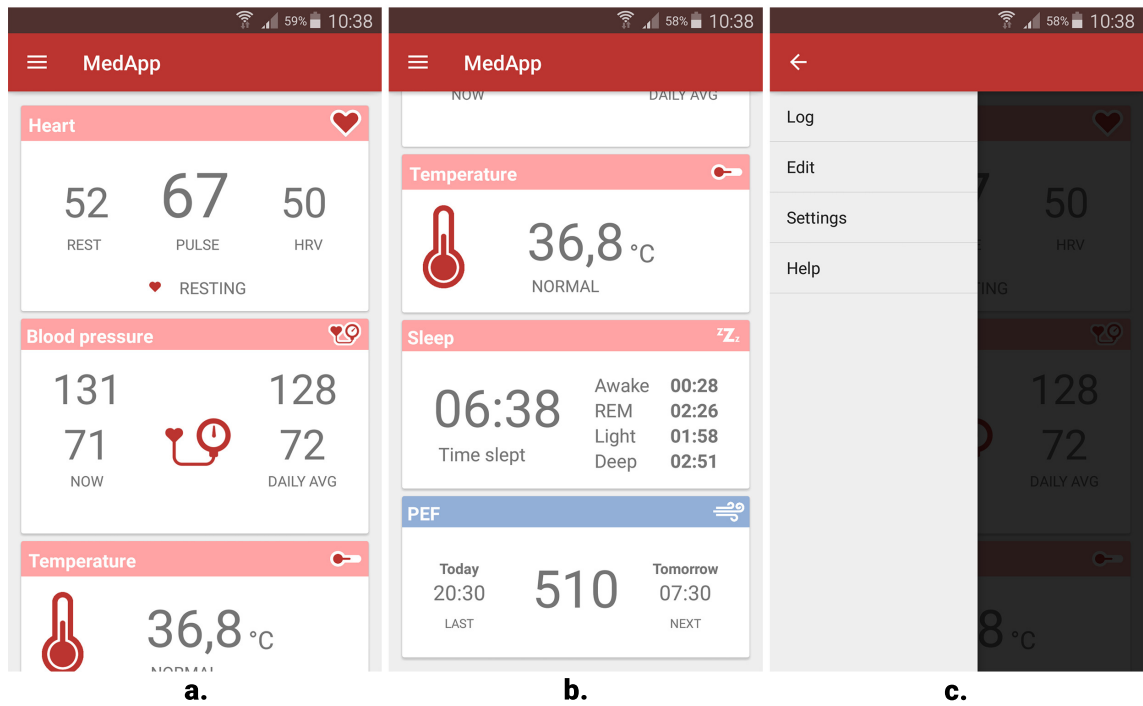
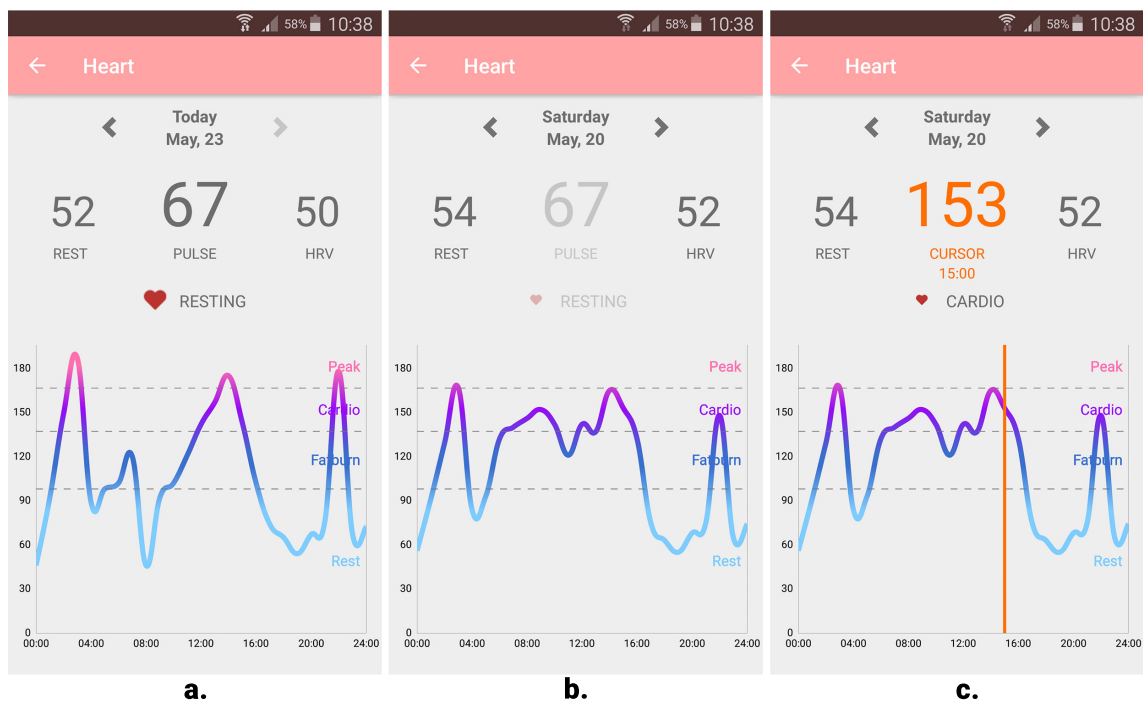**Figure 5.2:** Start view: **a.** Cards. **b.** Cards. **c.** Menu.

Figure 5.3: Heart view: **a.** Date set to today. **b.** Date set to past date. **c.** Cursor active.

Sleep view

When the date is shifted backwards, the bar in the bar chart corresponding to the selected date is highlighted with a dark blue colour. To change date, either the arrows at the top, or the bars can be used. When the interface is set to the current date, all numbers are the same grey colour as the text (figure 5.4 a). When the date is shifted away from the current date, the colour of the numbers turns into the same blue colour as the colour of the highlighted bar (figure 5.4 b). By clicking any blue number, the interface returns to the current date. Using the same colour for the highlighted bar and the numbers, should convey this function to the user.

The bars are sectioned into the amount of time spent in all the different sleep stages. The labels of the y-axis show time in hours. This will not give the user any direct perception of the exact times in different sleep stages, but rather a rough overview. The exact times are found to the left above the line graph. The line graph show time spent in the sleep stages over time during the night. The graph is divided into four sections representing the sleep stages, and awakeness. The colouring of the line graph corresponds to that of the bar graph: dark blue for deep sleep, light blue for light sleep, pink for REM sleep, and red for being awake.
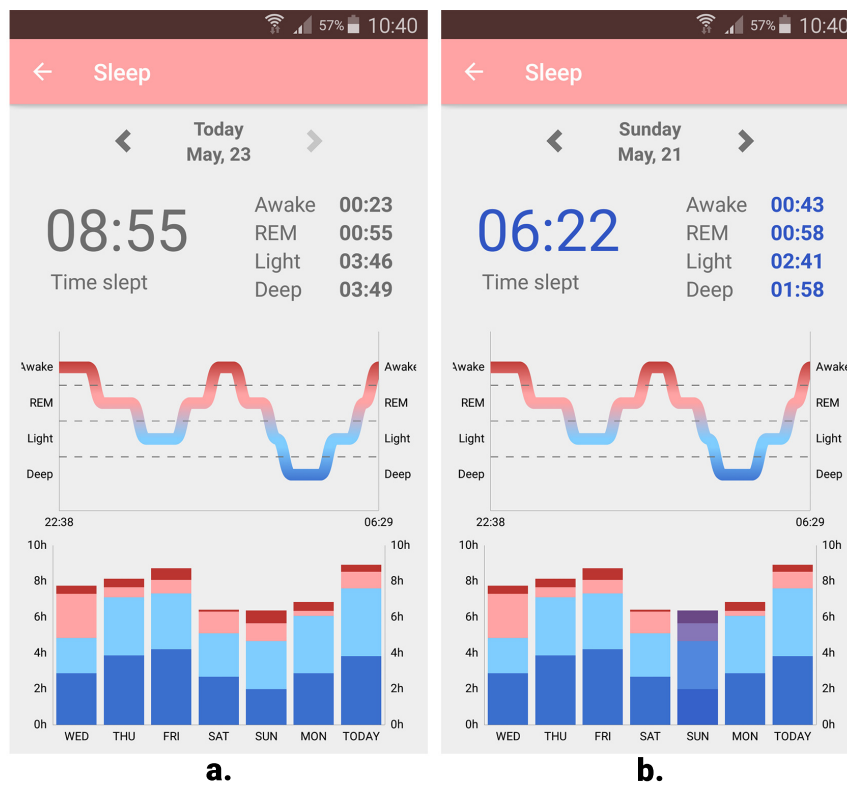

Figure 5.4: Sleep view: **a.** Date set to today. **b.** Date set to past date.

Temperature view

The colours on the graph were changed to light blue for normal temperature, and red for fever. When the date is shifted away from the current date, the opacity of the entire top section is lowered, greying out the temperature value, text and icon (figure 5.5 b). Whenever the cursor is selected by clicking the graph, the value of the temperature turns into the same orange colour as the cursor (figure 5.5 c). A text stating which time is selected by the cursor is also added. If the cursor is located on a part of the graph depicting fever, the text *NORMAL* changes into *FEVER*, and turns red (figure 5.5 d). The icon depicting a thermometer also fills up. The cursor is deactivated either by clicking the cursor, or the orange temperature value. On the right side in the graph, the texts *Fever* and *Normal* can be found above and below the dotted line, respectively. Directly above the dotted line, there is a text stating which value is the limit for fever.

Blood pressure view

When having the interface set to the current date, the icon is animated so that the heart pulsates and the pointer on the "measuring device" moves (figure 5.6 a). If activating the cursor when remaining on the current date, the blood pressure value to the left turns orange like the cursor (figure 5.6 b). The text *NOW*, located below the value, changes to *CURSOR*, and a text stating which time is selected by the cursor appears. The animation of the icon stops, and the opacity is lowered. The cursor is closed either by clicking the cursor itself, or the orange values.

When selecting another date than the current one, the left values together with the text *NOW* are greyed out, and the right values and text turn blue as does the bar corresponding to the selected date. The animation of the icon is also stopped, and the icon is greyed out. If switching dates while the cursor is active, the cursor will be deactivated. Clicking the blue values, or clicking the highlighted bar will set the interface to the current date.
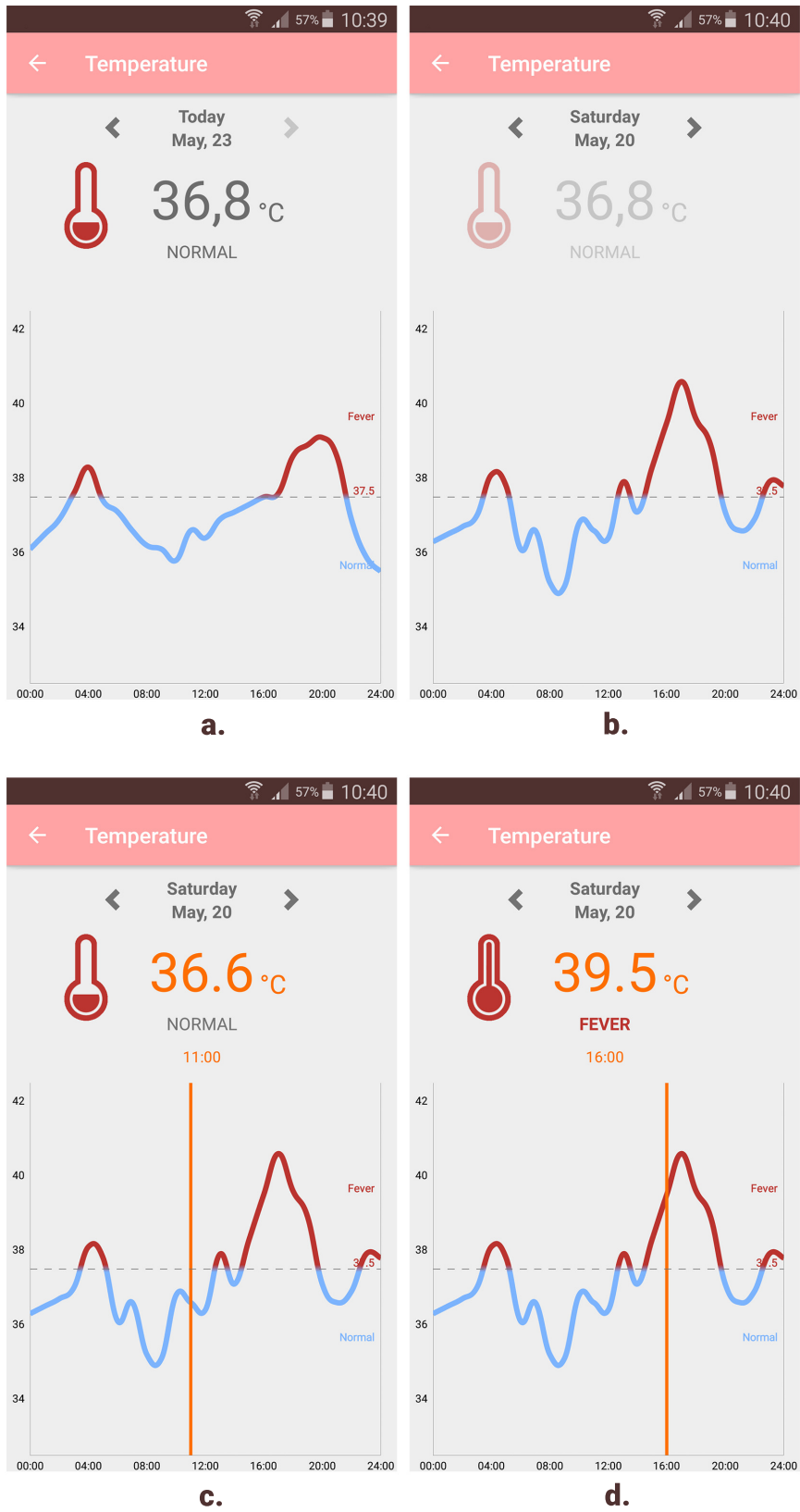
Figure 5.5: Temperature view: **a.** Date set to today. **b.** Date set to past date. **c.** Cursor active, normal temperature. **d.** Cursor active, fever.
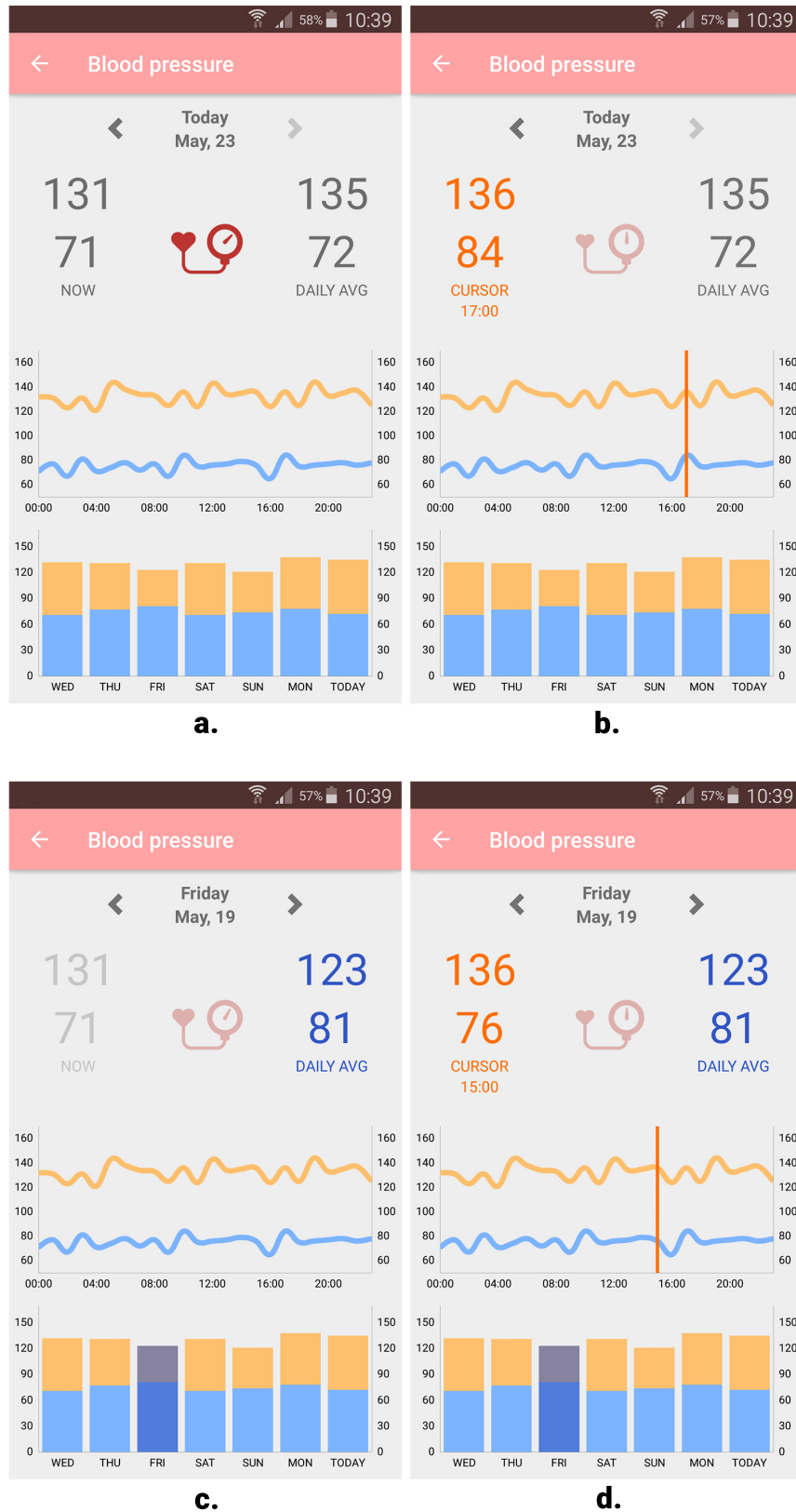
Figure 5.6: Blood pressure view: **a.** Date set to today. **b.** Date set to today, cursor active. **c.** Date set to past date. **d.** Date set to past date, cursor active.

PEF view

The first the user sees after having clicked the PEF card, is the main view (figure 5.7 a). Upon clicking one of the previously taken measurements, a detailed view about that specific measurement opens up (figure 5.7 b). This information includes the date, time, measured value, location, and symptoms for the measurement. In this first iteration of the hi-fi prototype, this view does not precisely match the alternatives available for choice in the questionnaire filled in when adding a new PEF measurement (figure 5.9). This is to be adjusted. Clicking the back-arrow in the action bar, takes the user back to the main view. These two views are rather identical to the ones in the lo-fi prototype.

When clicking the green plus-button, the process of adding a new measurement is initiated. This prototype assumes a digital PEF-measurement device is used. The ability to add PEF measurements manually could be added to the product in the future. The process of adding a PEF-measurement is completely faked in this prototype, and no actual ability to connect a PEF-measurement device exists at the this stage. In the first view of adding a PEF measurement, three steps are listed. The current step is of full opacity, while the upcoming steps are greyed out. Also greyed out in the middle of the view, are the texts *Measurement 1*, *Measurement 2*, and *Measurement 3*.

First the user is prompted to connect the device (figure 5.8 a), which is done outside of the interface of this application (presumably using the Bluetooth settings of the PEF-device and phone). When the interface recognises that the PEF-device is connected, the message *Device connected!* is shown on the screen (figure 5.8 b). The greyed out text *Measurement 1*, is brought up to full opacity, and changed to the text *Take measurement 1* (figure 5.8 c). This prompts the user to take the first measurement. Having done so, the text *Take measurement 1*, turns into the measured value, with a green text colour. Simultaneously, the text *Measurement 2* turns into *Take measurement 2* and is brought up to full opacity (figure 5.8 d). This is done one more time for the last measurement. The best measurement throughout the process always has a bold font. After all three measurements have been taken, the *next*-button at the bottom of the view is activated, and the opacity is turned up to 100 % to signify this (figure 5.8 f).

Having clicked next, the view for the second part of adding a PEF-measurement is opened (figure 5.9). The user first fills in any recently experienced symptoms. Checkboxes are used for this purpose, which means several boxes can be selected. After this, the user selects the location at which the measurement was taken. For this purpose so-called radiobuttons are used, which only allow for one alternative to be selected. This function could be implemented to use the GPS-sensor of the phone and map applications, to allow it to be automatically filled in. Having filled in possible symptoms, and the location, the user may click the *add*-button to add the taken measurement.
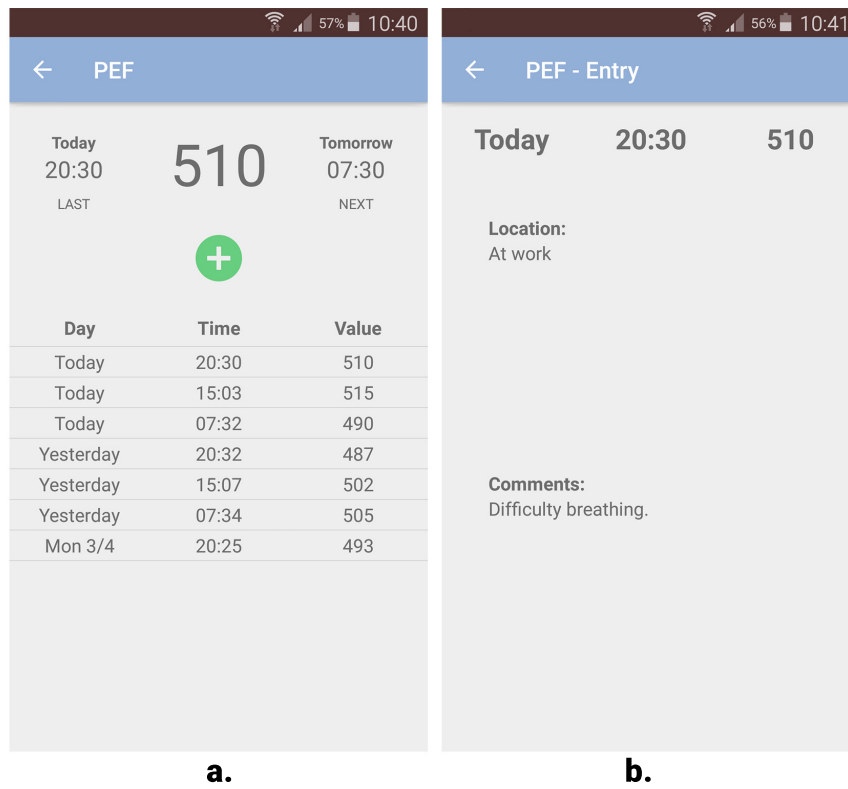
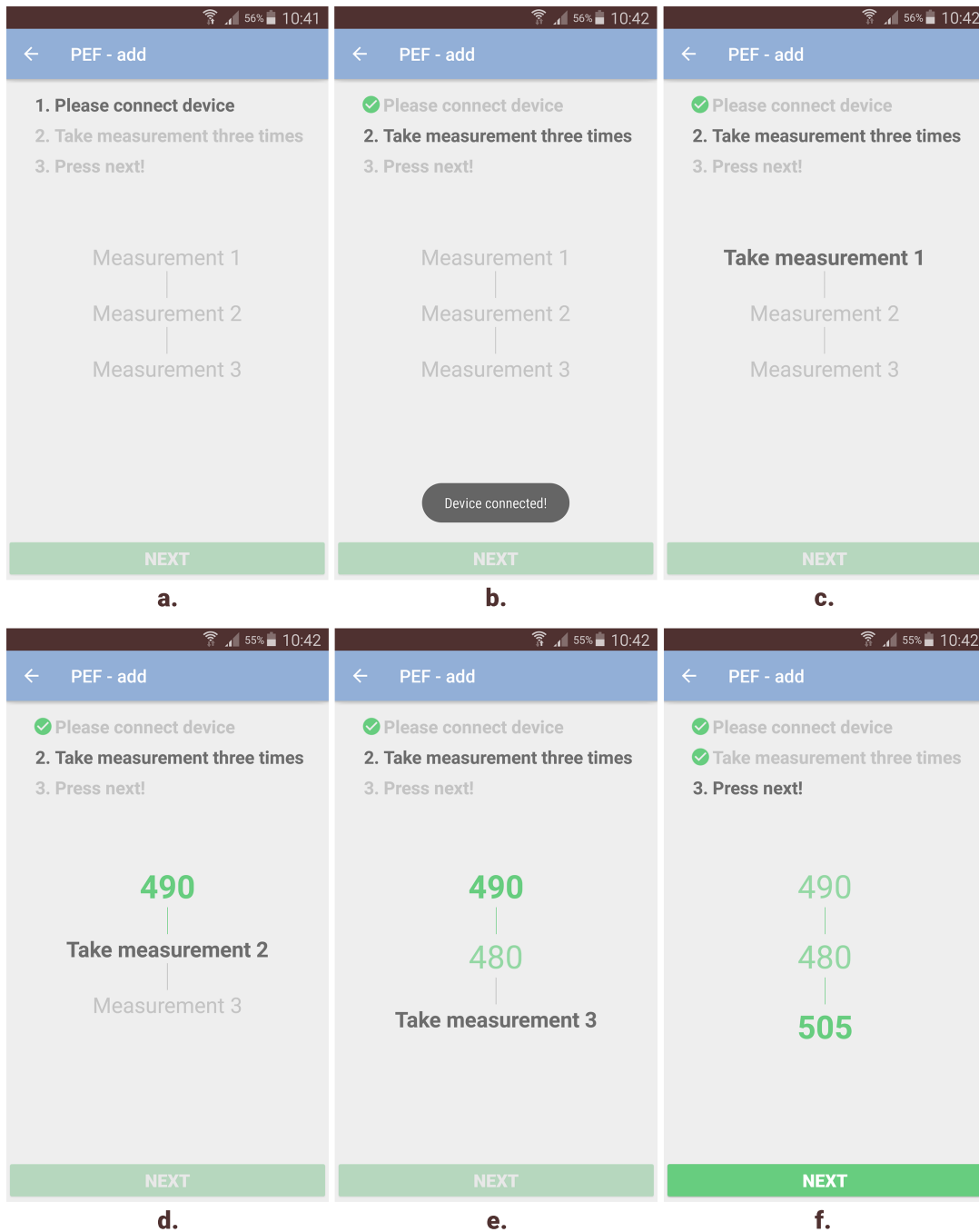**Figure 5.7:** PEF view (1/3): **a.** Main PEF view. **b.** Detailed view on entry.

Figure 5.8: PEF view (2/3): **a.** First view when adding new measurement **b.** Device connected. **c.** Measurement 1. **d.** Measurement 2. **e.** Measurement 3. **f.** Measurement done.

Figure 5.9: PEF view (3/3): **a.** Post-measurement questionnaire. **b.** Post-measurement questionnaire, filled in.

5.3 Evaluation of hi-fi prototype

Prior to beginning with the user tests, the following terminology was defined in accordance with [52]. The usability goals seen in table 5.1 were also set.

Critical error
A critical error is defined as the participant in the test not completing the attempted task, or completing the attempted task incorrectly. The participant may or may not be aware of making a critical error. An example could be that the participant is asked to find a specific value in the interface, and either not finding it or reading out the wrong value.

Non-critical error
A non-critical error is defined as performing an action that is either wrong, or not contributing to the task being completed (excessive action), with the requirement that the total sequence of actions leading to the task being completed successfully.

Usability metric
A usability metric is a quantitative measurement used to determine the usability of a product. The three following definitions are all examples of usability metrics.

Time on task
The time a participant spends on a certain task. This usability metric can also be used to calculate the average time spent by all participants.

Task completion rate
The percentage of participants completing a task without critical errors.

Error-free rate
The percentage of participants completing a task without errors (non-critical and critical).

Table 5.1: Set usability goals for the user tests.

Usability goal	Target level
Task completion rate	100 %
Error-free rate	80 %
SUS score	80

The evaluation of the prototype consisted of 11 separately conducted user tests. All test persons were students. Before the actual testing of the prototype, a questionnaire (appendix B) was filled in by the participant. To get a perception on the overall demographics of the group of participants, the data from these questionnaires were compiled in table 5.2. This data was also statistically analysed. The purpose of this was to investigate whether the time spent on tasks and the amount of errors differ, depending on which operative system the participant uses themselves. This was done using two-sample t-tests, which is a widely used method in design-related fields [47], and Wilcoxon rank-sum tests (a.k.a. Mann–Whitney U tests) [53]. The null-hypothesis was that there is no difference in the results (errors and time spent) for Android users and iOS users. The tests were done using the `ttest2`-function for the t-tests, and `ranksum`-function for the Wilcoxon rank-sum tests, in MATLAB. The two data sets containing information on either number of errors, or total amount of time spent, for Android users and iOS users respectively, were inserted into the function. This yields a p-value, which tells the probability that the effect found did not occur by chance. Usually a p-value of 0.05 is required to be able to reject the null hypothesis. This level of significance was used in this case as well.

Each test was filmed using a video camera. The smartphone used for testing was placed on a table, and the camera placed on a tripod directly above the phone pointing straight down. The tests were not conducted in any kind of laboratory, but instead in various locations. After each test, the participant completed a SUS form. The procedure comprising of the pre-test questionnaire, test using prototype, and post-test evaluation including discussion and SUS form, lasted 10-20 minutes each. To be able to make a quantitative analysis, the footage was analysed for the following usability metrics:

- Number of critical errors per task per participant
- Number of non-critical errors per task per participant
- Amount of time spent per task per participant

The test was divided into 14 tasks. The facilitator of the test read out loud a task, which the participant completed according to her/his best ability. For the user tests, 14 tasks were formulated.

Table 5.2: Demographic information of user test participants.

Characteristics	Participants
Number of participants	11
Gender	
Male	4 (36 %)
Female	7 (64 %)
Median age (range)	25 (23-30)
Current operative system	
Android	7 (64 %)
iOS	4 (36 %)
Other	0 (0 %)
Has used fitness tracker	
Yes	1 (9 %)
No	10 (91 %)

Tasks:

1. You are a man/woman born today in the year 1992. You weigh 80/60 kg, and are 180 cm tall.

2. Find the view dedicated to data about the heart.

3. What average resting pulse did you have on (5 days back, e.g. Saturday 13.5)?

4. What exact pulse did you have the same day at 14:00?

5. Close the cursor.

6. Adjust the interface to that you see your pulse in real-time.

7. Find the graphs for your blood pressure.

8. What average daily systolic and diastolic pressure did you have on (3 days back, e.g. Monday 15.5)?

9. What blood pressure did you have on (2 days back, e.g. Tuesday 16.5) at 12:00?

10. Adjust the interface so that you see your blood pressure in real-time.

11. Did you have fever on (6 days back, e.g. Friday 12.5) at 21:00?

12. Close the cursor.

13. How long did you spend in REM-sleep the night preceding (3 days back, e.g. Monday 15.5)?

14. Add a PEF-measurement. You are at work and have coughed an unusual amount today.

To simulate a PEF-reading the participants were instructed to imagine blowing into a PEF-device. The hypothesised actions, that also are the correct sequence of actions to perform in order to correctly complete a task, are stated below. Some of the tasks can be completed in different ways. For example, the date can be changed either using the arrows or bars. These alternative ways to complete tasks, are also stated below. Further unexpected alternative sequences of actions tried by participants, were individually analysed on the correctness.

Hypothesis and correct sequence of actions for each task:

1. Clicks on the text *Gender:* → chooses gender → Chooses the correct date (today's date, except the year 1992) → Fills in the correct weight → Clicks the forward button on the virtual keyboard → Fills in the correct height → Closes the keyboard using the *Enter*-arrow → Clicks the *OK*-button.

2. Clicks the heart-card.

3. Clicks the arrow for selecting previous dates, until correct date is reached → Reads out the correct value.

4. Clicks the graph to activate the cursor → Selects the correct time → Reads out the correct value.

5. Clicks the cursor/clicks the orange value.

6. Uses forward-arrow to change date to the current date (today).

7. Exits the heart view by clicking the *back*-arrow in the action bar → Clicks the blood pressure-card.

8. Clicks the *back*-arrow to the correct date/clicks on the bar corresponding to the correct date → Reads out the correct values.

9. Clicks the *forward*-arrow to go one day forward/clicks the bar corresponding to the next day → Activates the cursor → Moves the cursor to the correct time → Reads out the correct values.

10. Uses *forward*-arrow to change date to current date (today)/clicks the bar corresponding to the current date (today).

11. Closes the view for blood pressure by clicking the *back*-arrow in the action bar → clicks the temperature card → Clicks *back*-arrow to get to correct date → Activates cursor by clicking the graph → selects the correct time using the cursor → Interprets the interface correctly to decide if normal temperature or fever is selected (reads out the correct decision).

12. Clicks the cursor/clicks the orange value.

13. Clicks the *back*-arrow in the action bar → Clicks on the sleep-card → Uses arrows to get to the correct date/clicks bar corresponding to correct date → Reads out the correct value.

14. Clicks the *back*-arrow in the action bar → Clicks on the PEF-card → Clicks on the *plus*-button → Simulates measurement → Clicks the *next*-button after measurements are taken → Fills in questionnaire correctly → Clicks the *OK*-button.

5.3.1 Results of evaluation

The results from the pre-test questionnaires were compiled (see table 5.2). The analysis of the user tests was divided into qualitative and quantitative results, which follow below.

Quantitative results

Table 5.3 contains the results from the analysis of the collected footage. These were also used to calculate the completion rates, error-free rates, and error frequencies, both for each individual task (table 5.4), and for an overall result (table 5.5). The overall results were calculated by looking at the total amount of errors for all tasks, completed by all participants. The overall completion rate was 94.7 %, which does not reach the goal. The overall error-free rate was 81.6, which just exceeds the goal.

The average SUS score was $SUS_{AVG} = 90.4$, with a standard deviation of $\sigma_{SUS} = 7.14$. This places quite high on the scale, in between *excellent* and *best imaginable* (figure 5.10), and exceeds the set goal of $SUS = 80$. The range of SUS scores was $72.5 - 100$.

Table 5.3: Results on errors, and average and standard deviation of times on tasks.

	Non-critical errors	*Critical errors*	*Average time on task (s)*	σ *(s)*
Task 1	11	2	27.6	6.4
Task 2	0	0	2.3	1.1
Task 3	2	1	14.0	8.1
Task 4	1	2	9.6	5.8
Task 5	8	0	5.2	5.1
Task 6	6	0	8.2	5.0
Task 7	0	0	4.2	0.9
Task 8	3	1	11.1	5.7
Task 9	1	1	9.9	6.2
Task 10	1	0	3.3	3.4
Task 11	0	0	16.0	3.6
Task 12	0	0	1.6	0.8
Task 13	1	1	21.1	8.2
Task 14	1	0	34.8	5.0

Lastly for the quantitative results, some statistical analysis was made on the demographic data. The results from these are seen in table 5.7. The data sets used for the calculations can be found in table 5.6. The average times and amounts of errors were: $Android_{err} = 3.00$, $iOS_{err} = 4.75$, $Android_{time} = 166$ s, $iOS_{time} = 173$ s. However, a statistically significant difference could not be proven. To be able to reject the hypotheses, and prove a difference

Table 5.4: Results on usability metrics from analysing footage from the user tests.

	Completion rate (%)	Error-free rate (%)	Error frequency (err/min)
Task 1	82	0	2.57
Task 2	100	100	0
Task 3	91	82	1.17
Task 4	82	82	1.70
Task 5	100	64	8.42
Task 6	100	82	4.00
Task 7	100	100	0
Task 8	91	82	1.97
Task 9	91	91	1.10
Task 10	100	90	1.82
Task 11	100	100	0
Task 12	100	100	0
Task 13	91	82	0.52
Task 14	100	91	0.16
Overall	**94.7**	**81.6**	**1.39**

Table 5.5: Results from quantitative analysis in comparison to set usability goals.

Usability goal	Target level	Result
Completion rate	100 %	94.7 %
Error-free rate	80 %	81.6 %
Average SUS score	80	90.4
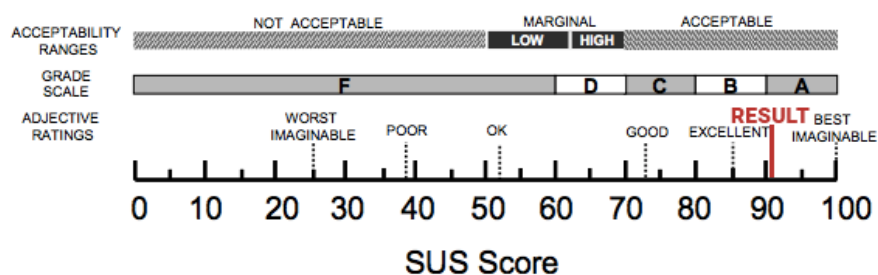
Figure 5.10: The resulting SUS score from the user tests, placed on the scale taken forth by [49] (cf. figure 2.3).

in the results, a p-value of 0.05 had been needed. The obtained p-values for the t-test were $p_{T1} = 0.19$ and $p_{T2} = 0.63$, and for the Wilcoxon rank-sum test $p_{W1} = 0.21$ and $p_{W2} = 0.89$. However, the very small sample sizes add uncertainty to the results. It is possible, had more user tests been done, that a difference in the results could have been proven.

Table 5.6: Number of errors and amount of time for Android and iOS users.

Parameter	Data set
Android-errors	1, 1, 2, 2, 4, 5, 6
Android-time	148, 154, 156, 165, 170, 170, 202
iOS-errors	2, 5, 6, 6
iOS-time	145, 167, 169, 212

Table 5.7: P-values and conclusions for the hypotheses in the statistical tests. A statistically significant difference in results could not be determined.

Null-hypothesis	T-test (p-value)	Wilcoxon (p-value)	Conclusion
The number of errors is not affected by which OS the user is used to	0.19	0.21	**Not rejected**
The total time spent is not affected by which OS the user is used to	0.63	0.89	**Not rejected**

Qualitative results

Below follows a compilation of comments made by the participants during the user tests, and observations made by the test facilitator. The compilation is divided into separate sections for each view, including suggestions for improvement.

Pre-start view
(Task 1) All subjects tried a scrolling down movement, before clicking the forward-arrow on the virtual keyboard. One person prefers to click down the keyboard using a button on the keyboard for this purpose, and manually select the next text box. This button was not available on the virtual keyboard in the interface. One person commented on the year-picker, it could take an unnecessary long time to scroll to an early year of birth, the scroll wheel is quite inert. One comment on that the layout of the virtual keyboard contains unnecessary symbols, which could be removed to display only numbers. If one has large fingers, the current small numbers could be cumbersome.

Suggestions for improvement:

- Move layout upwards so all text boxes are visible when keyboard is visible.
- Investigate different layouts for the virtual keyboard. Change if one with only numbers exists.
- Program the keyboard so it disappears when background is clicked.
- The date-picker does not scroll very many years back with one scroll. Investigate settings for inertia on the date-picker wheels.

Heart view
(Task 2) All participants found the heart card immediately and clicked on it. The heart

animation is perceived to be a bit lower quality compared to the animation for blood pressure.

(Task 3) When instructed to find the resting pulse for a few days back, some issues were identified. The text *RESTING* describing the current heart rate zone of the pulse, is the default zone using this test data. Even though greyed out, it is by a few subjects connected to the number 67 (current pulse, also greyed out in this scenario). Some test subjects believed that 67 was the resting pulse, instead of the actual resting pulse with the text *REST* beneath it. It could be assumed that once this is realised, the problem does not occur again very frequently.

(Task 4) The task was designed to test how the cursor is used, and some problems with this task was expected. Since the question was formulated with the words "exact pulse", the test subjects realised that just reading straight from the graph would not give sufficient information to give an exact answer. All subjects decided to click or move their finger on the line graph, which was intended. Two subjects simply clicked on the spot on the graph that they considered to be 14:00, did not notice the text stating the time the cursor is set on that emerges upon activating the cursor, and ended up saying the pulse for the wrong time. 9/11 of the test subjects though, ended up selecting the right time using the cursor and found the correct number.

(Task 5) The closing of the cursor proved to be quite difficult. 7/11 test subjects managed to complete the task on the first try, of which 6 pressed the cursor line. A few subjects tried to click the orange text *CURSOR* under the selected value. A number of participants tried to click on other elements in the interface.

(Task 6) Adjusting the interface so that real-time data is shown was fairly well executed by the test participants, but the interface could be improved further. Most importantly a calendar (when clicking the date at the top) should be implemented to select dates easier. One person suggested adding a second "go to today"-arrow next to the current forward-arrow. Another commented that if looking at data further back in time, the person would close the heart activity, and re-click the heart card to get to today. This would be effective but undermine the functions of the interface. The interface should be built so that an action like this is not necessary for executing the task. Another test subject actually did this exact thing when instructed to set the interface so that real time data is shown. Two subjects also tried to swipe, both did this over the line graph and thus activated the cursor. Swiping on the upper part of the interface could be implemented as a way to change dates. Swiping on the line graph should always open the cursor.

Suggestions for improvement:

- Implement ability to close cursor when clicking anything that is greyed out, the background, or the CURSOR-text.
- Add calendar activated by clicking the date at the top.
- Investigate ability to add "go to today"-button in calendar.
- Implement swiping on top of interface to change date.
- Create smoother animation of the heart.

Blood pressure view
(Task 7) No complications performing this task.

(Task 8) All test subjects found the right date, although finding the requested information proved to be a harder task. The question was formulated as "find the systolic and diastolic pressure". An overestimation of common knowledge about blood pressure seems to have been made. A majority of test subjects did not seem to have sufficient knowledge about blood pressure to be able to directly point out the systolic and diastolic blood pressures. While people suffering from blood pressure-related diseases probably have better knowledge about the meaning of these terms, the fact that the majority does not, means that the interface definitely has to include some sort of help function. Help functions were included in the requirements, but not yet implemented in this iteration.

One person suggested a frame around the bar instead of the current method of highlighting, to prevent distortion of the colours. Same person also did not make a connection between the highlighted bar and the blue text (*daily avg*), this was not evaluated on other participants, but merely a comment by this participant. On the other hand, the connection does not seem to have been made by the other participants either, since no-one clicked the blue text to return to "today". If accidentally using this function, the user might get confused as to why the interface returned to today. All but one of the participants used the arrows instead of clicking the requested day on the bar chart. This could be a result of first evaluating the heart-activity, where no bar graph is present, as one participant also speculated. One person also had the opinion that the numbers for *daily avg* and *now* should switch places, since the daily avg is more used when going back in time, which done on the left side of the screen, while the right side of the screen is more related to the current blood pressure in today, facing "forward" in the interface.

(Task 9) The task was completed by all participants except one. The cursor in these cases was used as in the corresponding task related to the heart activity. The participant not completing the task, instead of activating the cursor, tried clicking on one of the bars in the bar chart. This was found out to be because the label for 12:00 was located almost directly above one of the bars, leading to the wrong connection.

(Task 10) When instructed to set the interface so that real-time data about blood pressure is shown, 8/11 participants pressed the forward arrow until "today" was reached. The other actions included one person pressing the bar for today, one trying to press the bp animation (greyed out) but then exiting the view and re-pressing the blood pressure-card. Since the animation is animated and active during today, this connection is present. Two of the participants tried performing this action. For one test subject, the facilitator unfortunately missed this task by accident. When calculating the total time spent for individual tasks, this person was calculated as having spent the average time for the task.

Suggestions for improvement:

- Help-function in each activity.
- Decrease distance between upper/lower pressures, so they are perceived as more connected.
- Investigate having frame around selected bar instead of current highlighting.
- Better separation between the two graphs (line).
- Switch places between daily avg and now-boxes.
- Consider removing function of returning to current date by clicking blue numbers.

Temperature view

(Task 11) 9 participants completed this task correctly. The other two subjects started scrolling back in the blood pressure view, and when facilitator said "fever" once more, they realised their mistake and completed the task correctly. This mistake is considered to be inattention, and not a fault in the interface. When selecting a date further back, some of the participants were seen quite rapidly clicking the back arrow-button, which resulted in the app not registering every touch. Some of the subjects did not seem to note any information in the activity on whether or not the selected value is of fever-temperature or normal temperature. The quite subtle shift in height of the thermometer-icon might not be enough. One person noted that having some kind of signifier for the existence of the ability to activate a cursor could be good.

(Task 12) No issues with this task.

Suggestions for improvement:

- Extend touch-area for arrow-buttons to the edge of the screen (applies to all views).
- Clearer indication on fever/normal temperature might be good. Could be that the icon "flashes" a few times if fever is present. Could also be a change in colour for the icon.

Sleep view

(Task 13) Which day to select when wanting to see data from a specific night proved difficult, though with only one participant ending up choosing the wrong date. Solving this, was set as a requirement, but not prioritised in this iteration due to limitations in the graphing package used. Suggestions made by the test subject on how to solve the problem were adding dates below the time-labels for falling asleep and waking up, and adding a vertical line in the line chart separating the dates and writing the dates next to this line. One subject interpreted the numbers describing the amount of time spent in each sleep zone, as the time at which the sleep zone was entered. One suggestion was to change the current format of 00:44 to 00h44min. Currently no cursor is available in the line graph for the sleep view, since no actual numerical values are measured. However, knowing the exact times for events during the night might be interesting. Adding a cursor for this purpose, or adding dotted vertical lines in the graph and more labels to the time-axis might be a solution.

Suggestions for improvement:

- Add date/day below the time-labels for falling asleep and waking up.
- Investigate whether cursor or dotted vertical lines in the graph and more x-axis labels are good ways of seeing more exact times for events during the night.

PEF view

(Task 14) This task was highly simulated, having the entire procedure from connecting the PEF-device to having done all three measurements (blowing into the pef-device) timed with set delays in the app. This resulted in some desperate clicking in the interface before the participants realised that the procedure was timed and that they could not affect the results. One improvement however, is that the delay between the upper list changing to "Take measurements" to the first text changing to "Take measurement 1" can be deleted.

All participants pressed the *Next*-button once it was activated. All participants also filled in the form correctly and clicked the *add*-button. One person suggested to change the header (view and card) to "Peak expiratory flow (PEF)", and that the plus-button could be text instead (e.g. add new measurement/add).

Suggestions for improvement:

- Remove unnecessary delay between upper list changing, and lower procedure sequence list changing to "Take measurement 1".
- Change the header (activity and card) to Peak expiratory flow (PEF).

General comments by participants:

- Would be good with some indication that the cursor is movable
- Hard to understand what all the shortenings mean
- More statistics, interesting to know. Could add a button in each activity where one could examine and analyse chosen statistics.
- Add button to all activities that takes you back to real-time/closes cursor.
- Larger labels in all graphs
- It is nice to have everything related to one measurement on a single screen
- Explain somewhere why certain cards are pink and others blue.
- Separate colour theme for each card, easier to navigate. Ability to change colour themes manually.
- It is not clear exactly how to close the cursor.
- I navigate more using the pictures than the headers when choosing the right card to click on. Why does only certain cards have pictures and animations? Can these be added to all cards?
- Animate sleep and PEF-icons as well
- Want ability to choose the order of the cards.
- The icons are not consistently placed in the cards.
- I wanted a calendar to choose days from, especially in the activities not containing a bar graph.
- Confusing to only have bar graphs in certain activities
- Since the heart view was tested first, I automatically used the arrows to navigate even when the bar graph was present.

This will be the extent of this project. We would recommend the hi-fi prototype to undergo at least a second iteration in the detailing phase. A few things identified as problems in the evaluation of both the lo-fi and hi-fi prototypes are yet to be implemented, as well as possible further additions to the interface. Future work is discussed further in the next chapter. In addition to the suggested improvements in this chapter, a list of future changes not only related to the evaluation of the hi-fi prototype can be found in appendix D.

Chapter 6

Discussion

This chapter begins with a chronological discussion about the methods and results of the three phases of the design project. After this follows a general discussion about wearables in healthcare, and suggestions for future work. Lastly, ethical considerations related to the project are discussed.

6.1   Methods and results

The structure of the design process was to a big extent inspired by Mattias Arvola's book *Interaktionsdesign och UX* [26]. The book covers a great amount of methods, that can be of use in the different phases. However, different methods fit different types and sizes of projects and personal preferences, in different ways. In this project, the book with its methods acted more as an inspirational guide than as a book of instructions. The division of the entire design process into these three phases proved very efficient, and made the project more comprehensible. A further discussion about the three phases follows below.

6.1.1   The concept phase

An important topic to discuss in the concept phase is the interviews. The five physicians interviewed, all had the same speciality. While interviewing physicians specialising in Occupational and Environmental Medicine is relevant for the project, a more optimal solution would have been to interview physicians from several different specialities. Physicians with different specialities have different knowledge, and since the questions the interviews were intended to answer were quite broad, a broader spectrum of specialities could have been covered. Apart from physicians, other professions working within the healthcare system could have been interviewed. The weaknesses of the healthcare system, and suggestions for improvements from a nurse's perspective, would likely have been very valuable information. Conducting interviews with administrative and IT personnel would also have

been advantageous. Having a broader insight into how new equipment and systems are assessed and purchased would have been good.

The affinity diagram created, could have been even further developed. The categorisation resulted in three main groups, out of which two were split into 3 subgroups. The created categorisation is very intuitive, but perhaps different insight could have arisen had other constellations been explored. The instinct to rush forward in the project towards the prototypes, was quite strong in the beginning of the project during the concept phase. An important eventual insight was to put our trust in the methods. They have been created for a reason, and using established methods related to user-centred design has been shown to improve the decisions and the end result of a design process [47, p. 21][26, p. 22].

6.1.2   The elaboration phase

Knowing the result would turn out as an Android application, the options for layout elements and functions were studied. Our own favourite apps were also studied in terms of their layout, and inspiration drawn from them. We quite early were determined to use a card based design for the start view, which also would set the style of the entire app. Although the card based style is very intuitive, aesthetically pleasing, and simple, no alternative designs were explored. This was completely due to our own intuition and preference. Optimally, more alternative designs could have been explored. Perhaps some other design could have turned out even better, or the insights from it could have influenced the current design positively.

The decision was made not to implement any interactivity into the lo-fi prototype. We had already planned on programming the hi-fi prototype in Android Studio, which would make it interactive in the same ways the finished app would be. The plan to evaluate this in user tests with tasks, would also very directly evaluate the interactions and functions, such as the cursor. Since evaluating both how the interaction is perceived by the user, and how the screen layouts are structured is important in interaction design, we decided to split these two parts into the separate phases. Due to this we did not think that creating Wizard of Oz-like scenarios would be necessary, and instead focused on evaluating the layout at this stage. While this did work out, perhaps some of the problems encountered in the evaluation of the hi-fi prototype could have been noticed already here, had the interactions also been tested for the lo-fi prototype.

6.1.3   The detailing phase

Due to practical reasons, some unexpected changes can be seen between the lo-fi and hi-fi prototypes. One example is that in the hi-fi prototype, the labels for the dates in the bar charts only contain the day instead of the day and date, as designed in the lo-fi prototype. The reason for this is simply that the graphing package used, did not allow line breaks in graph labels. While this could have fixed by re-implementing some of the java-classes from the package, it was not deemed time-efficient enough to do so for the purpose of this prototype. The graph labels could not be rotated either, which is the reason for the heart

rate zones being rather clumsily placed on top of the graphs. Needless to say, some compromises had to be made on the design of the hi-fi prototype due to time constraints, and limitations in the packages used. The use of faked data, also provided some restrictions. The data not being of as high temporal resolution as the real data may have affected the looks of the graphs. This also made the cursor rather rugged to scroll.

The age range of the participants in the user tests was 23-30 years. To get a better comprehension of how the user interface would be received by the older population, the ones suffering from chronic diseases to a larger extent, older participants would have had to be included in the tests.

During the user tests, the opening and closing of the cursor provided some interesting observations. Both of these tasks were carried out on two separate occasions during the user test. The average time for opening the cursor the first time was $t = 9.64$ s, and for the second time $t = 9.91$ s. This difference is very small, which could indicate the task was intuitive to the users. Closing the cursor on the other hand, was completed on an average time of $t = 5.18$ s the first time and $t = 1.60$ s the second time. This could indicate that closing the cursor is not as intuitive as opening it, and that the knowledge on how to do this had to be acquired. The learnability seems to be quite good though, with a substantial decrease of completion time already the second time the task was performed.

The goal of achieving a completion rate of 100 percent was not reached, which was expected. Despite of this, we decided to aim for this target rate. We wanted to be able to design an interface in a way that maximised simplicity and ease of use, for all users. Setting this goal, while at the same time not aiming for a full completion rate, felt hypocritical. The results from the SUS scores were higher than expected, with an average score of $SUS_{AVG} = 90.4$. The conductor of the test knew all participants to some degree prior to the user tests, which may have elevated the SUS scores. On the other hand, reliability of the result is supported by the fact that the SUS score is quite robust for smaller test groups. A study comparing different evaluation forms, found that SUS provides very reliable results with test groups as small as 8 persons [54]. This means that there is a clear indication the usability of the prototype, at this stage, is quite good despite of the flaws identified during the evaluation.

The statistical tests, were not central to the evaluation of the prototype itself. Since this data was available, we saw an interesting opportunity to investigate whether the operative system the participant in a user test is used to, might affect the results of it. When planning and analysing user tests, if such an effect would be present, knowing about it and being able to compensate for it in some way could be of advantage. The investigated question was whether a significant statistical difference could be determined between the results (errors and total time spent) of regular Android users and iOS users. Even though the average results differed, no significant difference could be proven. Prior to performing the user tests, we also planned on trying to find a connection between whether the results are affected by previous experience and use of wearables. However, only one of the participants had used a wearable before, thus the data basis for trying to find a statistical difference was considered too inadequate.

6.2   Wearables in healthcare

The sensors used in wearables today were reviewed in the initial literature study, as well as the data made available by these. The project becoming somewhat futuristic, simulated data not yet available from wearables, such as blood pressure, was incorporated into the concept. While this decision might not have any impact on today's healthcare, at some point in the future it is likely that this type of data will become available. Having done research on the subjects arising when this happens, is likely to prove useful in the future.

The interviewed physicians had a lot of visions on the possibilities of wearables in healthcare. Anamnesis interviews take time for physicians to conduct, and the received information is often inexact. Being a necessity in healthcare, if these could be made more time efficient and exact, it would both aid the healthcare including the physicians and provide better care to the patients. Having more data about the patient available prior to a meeting would fulfil this objective. Digitising healthcare and having access to more data could also end up being more time consuming. Thus, new systems that are implemented in healthcare have to be thoroughly evaluated to maximise the benefits. Other projects and research, such as *Hälsa för mig* (`www.halsaformig.se`), have similar visions for improving healthcare using digital solutions, as this project. Access to more data, provided it is used in an effective way, is an important part of developing a more cost effective and qualitative healthcare [1, 55].

In addition to improving *healthcare*, more accessible healthcare is undoubtedly also an advantage to the patients. Remote monitoring of patients would, in a lot of cases, allow them to stay in a home environment still being cared for and looked after, taking pressure off healthcare at the same time. Patients suffering from chronic diseases, the largest cause for mortality and disability worldwide and the biggest cost for healthcare, could to a larger extent handle follow-ups and treatment independently. The concept created in this project could be of help in this, allowing patients to measure important physiological parameters at home. Having access to more physiological data, can also help people become more aware of their own health.

6.3   Future work

The product described in this thesis is still far from finished. Firstly, we would suggest implementing the ability to connect wearables to the interface. The fact that the data at this stage of the prototype is faked, to simulate the look and feel real data would bring to the app, also means that a lot of structural changes in the code has to be made when real data is available. Starting further development in this end, will likely prevent the code having to be rewritten multiple times. Having implemented this, the rest of the layout-related changes and further additions can be built around it. This second iteration of the detailing phase should also be evaluated, in the same manner as the user tests in the iteration performed in this thesis. Concrete suggestions for how the prototype could be improved in the next iteration can be found in section 5.3.1 and appendix D.

The end-result of this project is just one part of the larger concept taken forth in the concept phase. The larger concept includes connecting the data from this app to healthcare. Prior to starting development of the entire concept though, the computer interface for the patients could be implemented. Because of the larger screen size of a computer, more information can be added to the interface without jeopardising the clean and simple design. Having designed and evaluated the computer interface for the patients, the interface for healthcare could be more smoothly implemented as well. The development of a smartwatch interface for the app, would also be a good complement. At this stage of the project, the communication system between patient and healthcare has not been designed. Instead of relying on methods such as text messages, we think that more innovative and integrated methods could be come up with. Looking towards different types of communication in social media for inspiration could be an idea.

Another possibility, much like the concept of *Hälsa för mig*, would be to integrate the patients' medical health records into the app. This would also be one type of communication between healthcare and patients. Prior to this, a lot of regulatory material would have to be studied. With the vast amounts of data being created in this concept, different types of artificial intelligence could also be implemented into the system. This could act as a good tool, in the form of decision support, to healthcare. The data could be used in research to understand diseases in relation to the connection between different physiological parameters [55].

Great possibilities but also great challenges are ahead if this project is developed further in the future. Security throughout the entire system is of utmost importance, to ensure the integrity of the users. A lot of sensitive personal data will be transferred between the different parts of the system. *Hälsa för mig*, developed by the E-health authority, recently received supervision (swe. tillsyn) from the Data inspection authority, due to not meeting juridical criteria about the handling of personal information [56]. Both being governmental authorities in Sweden, this type of issues at such a high level demonstrates the tremendous requirements and challenges in the area of future healthcare.

6.4 Ethical considerations

Health data is a very wide concept, that includes everything from heart rate data, to prescribed medication, sensitive information on diagnoses, and peoples complete DNAs. Health data is very sensitive, and while it can be used for good and important purposes such as improving healthcare and contributing to research, it can also be used for more questionable purposes. An example of one such purpose is insurance. There are already insurance companies offering cheaper insurance to people with the condition that they share their health data with them. While this is a type of data collection that may be widely done to certain degrees using analogue methods such as questionnaires, the topic will become increasingly important in the future when more and more health data becomes widely available. One problem that we identify is the risk of starting to use people's DNA data to price their insurance. This could mean that people with a genetic *probability* of *maybe* being diagnosed with some certain disease at some point in their life, will be treated

differently. This opens up for a lot of inequality in societies, based on entirely new variables. Another important consideration is of course, the utmost importance of security in both storing and transferring all health data.

More specifically for this project, it is from an ethical standpoint very important that all results from interviews, focus groups, and user tests are kept anonymous as they have in this report.

Chapter 7

Conclusions

This chapter presents the conclusions drawn in the project. First, the initial research questions formulated in the introduction are addressed, after which conclusions from the methods and results are drawn.

The first research question was regarding what, and how, data supplied by wearables and smart home devices can be used in health care. The literature together with the interviews suggest data such as body temperature, sleep data, heart rate, heart rate variability, electrodermal activity, body and wrist movement, and physical activity. Although digital PEF-devices are not wearable, data from these can also be included. Healthcare having access to more digital data instead of analogue, would allow for easier analyses. The mentioned data is of relevance as is, but can also be utilised in more complex concepts such as decision support.

This leads into the second question, on which the interviewed physicians had a lot of input. In what ways can a smartphone application that gathers data from wearables be used in healthcare? Having access to patients' data, would according to the interviewees, allow for more efficient and precise anamnesis interviews. Solutions for managing chronic diseases are also a large part of the answer to this question. Patients having access to their physiological data through an appropriate interface, could help them manage conditions such as diabetes, cardiovascular disease, and asthma. Being an important factor to healthiness, concepts encouraging physical activity, such as digital support groups, were also suggested. The ability to monitor patients remotely, would possibly increase efficiency for both healthcare and patients. This increased accessibility to healthcare, together with the increased proximity to ones own health in being able to manage different types of conditions at home to a further extent, also concludes the third question regarding improvement of user experience and accessibility.

Another conclusion that can be drawn, is that there are many issues with the healthcare

system today. Digital tools are not used to the extent that they could be. The interviewed physicians were generally positive towards digitisation, provided that the changes improve conditions both for the healthcare system in general, themselves, and for their patients. IT-systems in healthcare have to be designed in a user-centred way which, taking into account the data from the interviews, is an aspect that seems to have been overlooked in the implementation of the current systems.

The end result of this project manifested as a hi-fi prototype in the form of an Android app. The evaluation of it, in the form of 11 user tests, indicated good usability. A SUS-score of 90.4, a completion rate of 94.7 %, and an error-free rate of 81.6 %, were obtained. The overall error frequency for all user tests was 1.39 errors per minute. A statistical analysis comparing demographic data on the participants in the user tests, to the results, was performed. The question this intended to answer was whether or not the results from the individual user tests were affected by which mobile operative system the participants themselves use. No significant differences between the results of Android users and iOS users could be found.

The result from this thesis is not a finished product. The hi-fi prototype should go through at least a second iteration of the detailing phase, allowing for correction of issues that arose during the evaluation. All intended functions were not implemented into the current hi-fi prototype either, which is something that should be done if continuing on this project. This thesis only handled a part of the wider concept formulated in the concept phase. Further work can be done in developing a computer interface for healthcare, and connecting it with the interface designed in this thesis.

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Appendices

Appendix A

Interview: Questions

Introduction and demographic information

- I explain my thesis
- Name? Age?
- What field have you specialised in as a physician?

Attitudes

- Do any diseases require patients to take measurements at home? What diseases? What type of data?
- Is this data written down and taken to the hospital for a meeting with a doctor like you, or is it uploaded somewhere?
- Are there any possibilities for patients to upload own data into any of your systems?
- Has it happened that a patient brought with them any data of their own, e.g. data from fitness tracker (heart-rate, calories eaten, hours of sleep, etc.), body composition scale (weight log, BMI, fat percent, muscle percent)?

    – If yes, what data? Did you use this data? In what way?

- Do you see any medical value in this data as of today? Would you use it as an aide for diagnosis?

Data

- Assuming: Data from fitness trackers is medical grade, and devices are certified for clinical use. Data is collected continuously.

- What type of data from patients, collected continuously (in home environment), would you be interested in seeing as an aide for diagnosing? Motivate answer. Examples:

    – Sleep data

- Heart rate/Heart rate variability

- Blood pressure

- Physical activity

- Stress levels

- Weight, fat percentage, muscle percentage

- Respiration

User Interface

- How would you want to receive this type of data?

    - Patient shows it to you on own phone.

    - Data continuously uploaded into EHR?

    - Separate web page?

    - Other?

- How would you prefer the data be presented?

    - Raw data

    - Simple statistical data and graphs

    - Same as corresponding examination today

    - Algorithms that compare to database and give statistical suggestions ("AI diagnosis", ex. IBM Watson)

Wrap-up

- What puts the most pressure on health care today?

- Except desicion support in diagnosing, can you think of any other uses a concept like this could have in the health care of the future?

    - Potential for monitoring chronic diseases from patient's home (e.g. instead of monthly checkups)?

    - Shift towards more preventive care in the future?

    - Other?

- Is there a potential to save time? Relief administration duties? Or will it be an additional burden?

Appendix B

User study: Pre-test questionnaire

Formulär innan studie

Namn: _____

Ålder: _____

Kön:
__ Kvinna
__ Man
__ Annat

Vilken typ av smartphone använder du?
__ Android
__ iOS
__ Windows
__ Annan: _____

Har du använt en fitness tracker inklusive medföljande app innan?
__ Ja
__ Nej

Om ja, vilken? _____

Appendix C
User study: SUS-form

System Usability Scale

Instruktioner: För varje påstående, välj <u>ett</u> alternativ som bäst beskriver din reaktion till produkten.

		Håller absolut inte med				Håller helt med
1.	Jag tror att jag skulle vilja använda produkten ofta.	☐	☐	☐	☐	☐
2.	Jag tyckte att produkten var onödigt komplex.	☐	☐	☐	☐	☐
3.	Jag tyckte att produkten var enkel att använda.	☐	☐	☐	☐	☐
4.	Jag tror att jag skulle behöva hjälp av en teknisk person för att kunna använda produkten.	☐	☐	☐	☐	☐
5.	Jag tyckte att de olika funktionerna i produkten var väl integrerade.	☐	☐	☐	☐	☐
6.	Jag tyckte att det fanns för mycket inkonsekvens i produkten.	☐	☐	☐	☐	☐
7.	Jag tror att de flesta användarna skulle lära sig produkten snabbt.	☐	☐	☐	☐	☐
8.	Jag tyckte att produkten var mycket besvärlig att använda.	☐	☐	☐	☐	☐
9.	Jag kände mig trygg i att använda produkten.	☐	☐	☐	☐	☐
10.	Jag behövde lära mig mycket för att kunna använda produkten.	☐	☐	☐	☐	☐

Appendix D
Future changes

1. Implement the ability to connect wearables and other relevant devices to the interface.

2. Build data processing functionality, to restructure the data from different wearables into a format that can be used for the graphs.

3. Adapt the graphs (labels, etc.) the the new data.

4. Change the bars in the bar charts, so that they move when the date is changed. Suggestively so that the selected date stays in the middle (when it's reached that point from "today").

5. Build notification system that alerts the user, when inactive from the app, about relevant physiological changes (such as fever, scheduled PEF measurements, etc.)

6. Build notification system inside the app as well, where changes can be seen in the headers as "new mail"-type notifications.

7. Restructure the detailed view for PEF-measurements, so it corresponds to the layout of the questionnaire better. Also explore possibilities for using e.g. Google Maps, to determine locations for home and work directly in the app.

8. Implement menu in start view.

9. Add functionality to reorganise cards, by click-and-hold and using "Edit" tab in menu.

10. Implement ability to take pictures within the app.

11. Design system for communication between patient and healthcare.

12. Implement more cards: blood sugar etc.

Appendix E
Interview: Information sheet

Information about interview

Within a reasonably near future, data from wearable technology (e.g. fitness trackers) will be medical grade, and usable as decision support in diagnosing. As of today there are apps, mostly from the companies providing the wearables themselves, presenting data from the wearables to the user. These apps though, are mainly for fitness and lifestyle purposes. This project is about creating a prototype for an app that instead focuses on connecting this data with healthcare.

The interview is about doctors' attitudes towards wearable technology (such as fitness trackers), data from these, and how this data should be processed and presented. The length of the interview is about 20-30 minutes.

Handling of data and secrecy
The interview will be sound recorded. Written notes might be taken. Presentation of results will be done in a way, so that no information can be tracked to any individual participant.

Voluntariness
Participation in the study is voluntary and you can cancel your participation at any time without stating a reason.

Contact person for the interview:
Simon Leppänen
mte12sle@student.lu.se
073 982 92 87

Responsible from Lund University:
Héctor Caltenco
hector.caltenco@certec.lth.se
046 222 08 77

Appendix F
Interview: Informed consent

Consent for participation in study

Hereby I consent to participating in the interview: Doctors' attitudes towards wearables, data from these, and presentation of this data.

I am fully in agreement with that:

- Participation is voluntary, and that I at any time can cancel my participation if I find this desirable, without stating a reason.

- I give my permission to treatment of personal data in accordance with attached information letter.

- The interview is documented in accordance with the attached information letter.

- The results can not be connected to me as a person.

- The material is stored safe in a locked archive at Lund University.

- This form is made in two copies, where I as a participant keep one, and the other is stored in a locked archive at Lund University.

Contact person for the interview:
Simon Leppänen
mte12sle@student.lu.se
073 982 92 87

Responsible from Lund University:
Héctor Caltenco
hector.caltenco@certec.lth.se
046 222 08 77

Place, Date

Signature

Clarification of signature

Appendix G

Focus group: Information sheet

Information om användarstudie i form av fokusgrupp

Inom en relativt snar framtid kommer data från wearables (aktivitetsarmband etc.) att hålla medicinsk kvalitet och bli användbar som hjälpmedel inom sjukvården. Redan nu finns appar, främst produkternas tillhörande appar, som presenterar data från wearables för användaren. Dessa appar är dock främst anpassade för fitness- och livsstilssyften. Konceptet som tagits fram fokuserar istället på att koppla samman denna data med sjukvården. Prototypen du kommer testa är patientens gränssnitt i detta koncept. Fokus gruppen beräknas ta ungefär 30 minuter.

Hantering av data och sekretess
Ljudinspelning av intervjun kommer att ske. Även skriftliga anteckningar kan komma att tas. Redovisning av resultat kommer att ske så att inga uppgifter kommer att kunna spåras till någon enskild individ.

Frivillighet
Att delta i studien är helt frivilligt och du kan avbryta din medverkan när som helst utan att ange orsak.

Kontaktperson för intervjun:
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Appendix H
Focus group: Informed consent

Samtycke för medverkan i fokusgrupp

Härmed samtycker jag att medverka i användartest i form av fokusgrupp av app-prototyp.

Jag är fullt införstådd med att:

- Medverkan är frivillig och att jag kan avbryta min medverkan närhelst jag finner detta önskvärt utan att ange orsak.

- Jag ger mitt tillstånd till behandling av personuppgifter enligt bifogat informationsblad.

- Intervjun dokumenteras enligt bifogat informationsblad.

- Resultatet inte kan knytas till min person.

- Materialet förvaras säkert i ett låst arkiv vid Lunds Universitet.

- Denna blankett upprättas i två exemplar, där jag som medverkande behåller den ena och den andra förvaras i ett låst arkiv vid Lunds Universitet.

Kontaktperson för intervjun:
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Ort, Datum

Signatur

Namnförtydligande

LUND
UNIVERSITY

Appendix I
User study: Information sheet

Information om användarstudie

Inom en relativt snar framtid kommer data från wearables (aktivitetsarmband etc.) att hålla medicinsk kvalitet och bli användbar som hjälpmedel inom sjukvården. Redan nu finns appar, främst produkternas tillhörande appar, som presenterar data från wearables för användaren. Dessa appar är dock främst anpassade för fitness- och livsstilssyften. Konceptet som tagits fram fokuserar istället på att koppla samman denna data med sjukvården. Prototypen du kommer testa är patientens gränssnitt i detta koncept. Användarstudien beräknas ta 20-30 minuter.

Hantering av data och sekretess
Ljud- och videoinspelning av intervjun kommer att ske. Även skriftliga anteckningar kan komma att tas. Redovisning av resultat kommer att ske så att inga uppgifter kommer att kunna spåras till någon enskild individ.

Frivillighet
Att delta i studien är helt frivilligt och du kan avbryta din medverkan när som helst utan att ange orsak.

Kontaktperson för intervjun:
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Appendix J
User study: Informed consent

Samtycke för medverkan i studie

Härmed samtycker jag att medverka i användartest av app-prototyp.

Jag är fullt införstådd med att:

- Medverkan är frivillig och att jag kan avbryta min medverkan närhelst jag finner detta önskvärt utan att ange orsak.

- Jag ger mitt tillstånd till behandling av personuppgifter enligt bifogat informationsblad.

- Intervjun dokumenteras enligt bifogat informationsblad.

- Resultatet inte kan knytas till min person.

- Materialet förvaras säkert i ett låst arkiv vid Lunds Universitet.

- Denna blankett upprättas i två exemplar, där jag som medverkande behåller den ena och den andra förvaras i ett låst arkiv vid Lunds Universitet.

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