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The User Interface of LiAM: A Cardiac Rehabilitation platform

Master thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in de Toegepaste Informatica

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Abstract

Mobile is the future of health care. In a few years, every one will have at least one activity tracker, smartwatch, or an internet of things device like a Bluetooth toothbrush, scale, etc. These devices improve the understanding of our own health. Engaging in, and understanding our own health is called Patient Empowerment. It puts the patient in the heart of services.

Healthcare is a broad field, we explored a lot of possible focus points. In the field of cardiovascular diseases lays great opportunity to introduce mobile health. Cardiovascular diseases are the number one cause of death in the western world. In Belgium alone, there are more than 200.000 hospitalizations due to cardiovascular diseases every year. Most of these patients are advised to do Cardiac Rehabilitation but only a small group effectively follows it. It is proven that staying healthy and fit is very important for these patients. With the help of smartwatches we could enable Patient Empowerment to decrease hospitalizations and deaths due to inactivity or unhealthy habits.

The purpose of this thesis is to design the user interface of a mobile Android application that enables Patient Empowerment. The application is called LiAM and stands for Life Assistant Monitoring. The concept rests on three main parts: measuring, analysing, and communicating. The design and usability of the user interface is very important due to the mostly elderly population. We use a User-Centered Development Methodology to insure that it is usable for all ages and classes of society.

In the first part of this thesis research is done about available solutions and the state of the art in user interface design. This is followed by an in depth User Interface Design Analysis where we construct our user classes, user requirements, task models, user models, and style guide to formulate the specifications for the design. The prototype is developed with the help of the specifications defined in the user interface design analysis. Formative evaluations are done with our target population during and after the design of the prototype to optimally adjust the platform towards our stakeholders.

Declaration of Originality

I hereby declare that this thesis was entirely my own work and that any additional sources of information have been duly cited. I certify that, to the best of my knowledge, my thesis does not infringe upon anyone's copyright nor violate any proprietary rights and that any ideas, techniques, quotations, or any other material from the work of other people included in my thesis, published or otherwise, are fully acknowledged in accordance with the standard referencing practices. Furthermore, to the extent that I have included copyrighted material, I certify that I have obtained a written permission from the copyright owner(s) to include such material(s) in my thesis and have included copies of such copyright clearances to my appendix.

I declare that this thesis has not been submitted for a higher degree to any other University or Institution.

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1 Introduction

1.1 Context & Problem Statement

In the last decade, Mobile Health has evolved enormously (Fiordelli, Diviani, & Schulz, 2013). Mobile Health is the support of patients through mobile devices. It will evolve even more with the rise of smartwatches. These devices allow us to increase our knowledge and improve the decision-making process (Koning-Aug, 2015). Most of the popular smartwatches are already able to measure important parameters like heart rate, blood pressure, UV, skin temperature, step pace, galvanic skin response, blood data (oxygen level and bloods flow) these are all of great importance when tracking someone's health. Research shows that heart rate sensors on smartwatches are already reasonably accurate (Phan, Siong, Pathirana, & Seneviratne, 2015). Therefore, APEX Health, a company specialised into Oracle Application Express[1] (APEX), was interested to develop an innovative mobile healthcare platform. They want to anticipate on the further evolution of smartwatches and other smart devices. To explore the possibilities and potential of such a platform they formulated a couple of master thesis proposals. This thesis is the outcome of one of these proposals. The focus of this proposal was on exploring possible target area's for the platform as well as on prototyping a first appli-

[1]https://apex.oracle.com/en/

cation.

Before building a Mobile Health platform, we had to investigate for what kind of problems it could be used. Next a solution could be proposed. Therefore, a lot of research was done towards the feasibility of such a platform, both from a medically and technologically point of view. This research was done in Collaboration with AFC Leuven[2]. First of all we searched for a target audience. We concluded that the field of cardiovascular patients was most interesting for our platform. As in most industrial countries, heart diseases remain the number one cause of death in Belgium (Van de Casseye, 2016). Besides this, there are also more than 200.000 hospitalizations due to heart diseases in Belgium every year (Van Vlaenderen et al., 2010). In this context, many questions are still open, like: "How can these deaths be prevented?"; "What can we do to reduce the number of hospitalization?". This area offers opportunities for Mobile Health.

The research of KCE, Federaal Kenniscentrum voor de Gezondheidszorg[3], states that the number of hospitalizations and deaths due to cardiac events can be reduced through Cardiac Revalidation with physical exercises. This was confirmed during a meeting with dr. Van de Casseye from the Cardio Liga[4]. He called it Cardiac Rehabilitation(CR) which is a synonym for Cardiac Revalidation and will be used throughout this thesis. According to dr. Van de Casseye, only thirty-five percent of the patients that are advised to follow such a Cardiac Rehabilitation program actually do so. The standard programs are for a period of four to six months. After these four to six months, the rehabilitation caregiver stops following them. This often leads them back to their unhealthy and inactive old habits. He stated that it is important that cardiac patients stay active throughout their entire future life. A way to achieve this is by trying to make patients aware of their health and by activating them, this is described by a term that is called Patient Empowerment (Enope, 2016). It puts the patient in the heart of services and enables patients to take control of their health care needs.

How can we put wearables or smartwatches in action to reduce this number of deaths and hospitalisations related to heart diseases? To answer this, further research was done on the solutions available on the consumers market. We visited many physicians, hospitals, patient organisations, and searched

[2]http://www.afcleuven.be
[3]https://kce.fgov.be/nl
[4]https://liguecardioliga.be/?lang=nl

for related research projects. Two related projects were found, PATHway (Buys, 2016) and Picasso-TX (Dobbels & Vandenberghe, 2015). Besides these research projects we did not find a finished product similar to our specific purpose. Our specific purpose is to encourage and help patients who suffered from a heart disease to live healthier. This could help to reduce the number of deaths and hospitalisations of those patients.

Due that most of the cardiac patients are elderly people it is very important to include them in the design process of the user interface of such a platform. *Software should be designed neither for users nor by them, but rather with them* (Johnson, 2000). Besides elderly people, the user base will include doctors, nurses, physiotherapists, etc. which will all be categorised as "caregivers". Due to this broad user base, which includes all classes of society, the usability of the application will be very important. Good usability is needed to guarantee that all users will be able to use the system optimally. The popularity of our platform may very much depend on the usability. Nobody due to age or knowledge should be excluded from using the platform.

Therefore the main purpose of this thesis was to perform an in depth user interface analysis and design for the Mobile Health platform that we want to create. This platform was named LiAM (Life Assistant Monitoring), and is to be realised as a Mobile Android Application. During and after this analysis and design, it will be evaluated by a broad and diverse user base and will be adjusted according to their feedback. In this way, APEX Health will be able to build a system which is adapted according to the needs of the users instead of building a system where the user needs to adapt to the system. This way of working is called a User-Centered Development Methodology (Mandel, 1997).

1.2 Research Questions

According to the context & problem statement we constructed the following research questions. These research questions are formulated according to the guidelines formulated in (Wieringa, 2009). According to Wieringa there are two sort of problems, practical problems and knowledge problems. A practical problem calls for a change of the world, while a knowledge problem calls for a change of our knowledge about the world. Our main research question is a practical problem which calls for a change of the world by building a platform. Our sub questions are all knowledge problems to ensure that we are able to solve our main research question.

1.2.1 Main Practical Problem

Design an optimal User Interface for a mobile Android application where Cardiac patients are monitored and activated

This practical problem is our main concern. Including every type of user in the design process will be essential to reach this goal. We need to know the user's requirements to make sure that we build an application that they will use and hopefully helps them to stay more active.

1.2.2 Knowledge Questions

First we need to solve some specified knowledge questions formulated in this subsection before we are able to solve the above main problem.

RQ1: What are the available applications which perform a similar task as formulated in our practical problem and what are their (design) strengths and weaknesses?

Answering this knowledge question is important to make sure that we do not make the same design mistakes. It is also a good indication to estimate whether we have an innovative idea and not just another application of that sort.

RQ2: How can we activate and motivate patients in a durable way?

Changing behaviour is a very difficult task. What makes this knowledge question even more difficult is the fact that humans easily fall back into their old habits. It is necessary to find a good way to activate patients in a durable manner and for the long term.

RQ3: What are the requirements of our stakeholders for such a platform?

The knowledge about the requirements of our stakeholders is essential to realise our practical problem. Without this knowledge we may fail to convince patients to use our application.

1.3 Research Method

We worked according to the Design Science Research Methodology (DSRM) (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) to answer the above questions and to solve the practical problem. Design Science is a methodology for creating things that serve a purpose to the user. It consists of a system of principles, practice rules, and procedures. The DSRM process has six activities in a nominal sequence: Problem identification and motivation, objectives for a solution, design and development, demonstration, evaluation, and communication. These six activities should help to produce and present high quality design science research in Information Systems that is accepted as valuable, rigorous, and publishable.

We discuss the different phases briefly.

1.3.1 Problem identification and motivation

We have covered the problem identification and motivation in section 1.1, "Context & Problem Statement", and section 1.2, "Research Questions". The solution to these problems could lead to a reduction of the number of deaths and hospitalisations. This is both economically and socially a good thing.

1.3.2 Define the Objectives for a Solution

The objectives for a solution are constructed based on the results of the research questions RQ1, RQ2 and RQ3. We need to fullfil these to reach our optimal solution to the problem. We will try to solve these knowledge questions as detailed as possible and let them result in an optimal design that immediately provides a solution for the main practical problem.

1.3.3 Design and Development

The mobile application will first be build for the Android mobile platform. Later on an iOS version will be made together with the web dashboard but this is not in the scope of this thesis. The focus of this master thesis is on the design and development of the user interface for the Android application. The main reason why we focus on Android is to explore our user base and find the right solutions to the problems stated before we start developing on the other platforms. By doing this we can experiment with the Android version and this insures that we do not need to adjust the user interface on three different applications.

1.3.4 Demonstration

The prototype has been used in an evaluation with end-users.

1.3.5 Evaluation

There have been two formative evaluations so far. Both where executed in corporation with a patient club, called Harpa VZW[5]. Future evaluations will also be done through a feedback system when we launch the first beta version through the Google Play Store.

1.3.6 Communication

The application will be launched in the Google Play Store in the summer of 2016. The website of APEX Health will also be released around that time with a page dedicated to the LiAM platform. We have also submitted our project idea to the Bayer's "Grants4Apps"[6] competition and the "LifeTech-Valley goes live & Call for start-up pitches in aging" event. Besides these, we will try to pitch our project further on other events to find funds for realising the project as start-up.

[5] http://www.harpa.be

[6] https://www.grants4apps.com

1.4 Thesis structure

This section describes the structure of this thesis.

In the next chapter, *"Related Applications & Related Work"*, we report on a broad study done about related applications and research. The Chapter *"State of the Art in User Interface Design"* gives the evolution in the field of user interface design and the impact of mobile devices on this field.

The chapter *"User Interface Design"* is the core of this thesis. In this chapter we explain the design approach, starting with defining our users and requirements gathering, over task analysis and user object modelling, to the definition of the style guide. This chapter describes the basis for the prototyping phase which is described in the next chapter *"Prototyping"*. This chapter discusses the prototype screens.

In chapter *"Evaluation"* we describe how the prototype was evaluated and the conclusions.

In chapter *"Conclusion & Future Work*, general conclusions are made and we reflect on the answers provided for the original research problem and questions. In section 7.2, we describe how we plan to continue with the project and the research that still has to be done.

2

Related Applications & Related Work

This chapter will provide an answer to two of our research questions:

- RQ1: "What are the available applications which perform a similar task as formulated in our practical problem and what are their (design) strengths and weaknesses?"
- RQ2: "How can we activate and motivate patients in a durable way?"

Section 2.1 will give an overview of similar applications that are already available. In section 2.2 we will give an overview about related research in the field of Wireless Monitoring.

2.1 Cardio Health Applications on Mobile Devices

We have evaluated applications that are similar to what we aim to build. Although these applications do not use the same methods for measuring heart rates, they can be considered as possible competition, i.e. they can easily expand their platform to include smartwatches. The interesting thing about these similar applications is that we can learn from both their shortcomings and their good features. They gave us some insights on how we could do better.

In this section we only cover the most important applications that are similar to our initial Cardiac Medical platform goal and the later formed Cardiac Rehabilitation goal. We found a lot of fitness trackers that work together with smartwatches to track your health while exercising but we did not include them in this research. This because our goal goes beyond building yet another sports tracker. We want our application to be more supportive in the sense that we will advise and motivate patients to use these sports trackers and give them the opportunity to include these activities in our platform to provide them a good overview. The collected data from the sensors and the sports tracker application can be combined to give an all round graphical overview of the sports activities.

1. **FibriCheck**[1]
   One of our biggest competitors is Qompium with their FibriCheck application. It is a Belgian start-up located at the Corda Campus in Hasselt. Their FibriCheck application detects irregular heart rhythms with the help of a smartphone camera and your fingertip. By placing your fingertip on the camera, the application can detect irregular heart rhythms within only sixty seconds. These irregular heart rhythms are measured through the changing color in your fingertip. On the web dashboard which is connected to the application, doctors can easily consult the measurements and quickly start a treatment when necessary. We were not able to evaluate the usability of the application since the platform is not yet released. At the moment they are still in the process of getting a Medical Validation of their application. This Medical Validation would be a big obstacle when we would decide to go on with a Medical Approved application.

Figure 2.1: Qompium

[1] http://www.qompium.com

2. **Kardia**[2]
   Kardia is a platform which uses a small handheld ECG Recording Device to monitor heart patients. The ECG Recording Device obtains ECG traces through sensing plates as shown in figure 2.2. A patient has to place the plates on his fingers or chest to execute a scan. The scan only takes thirty seconds to complete. Every scan can be supplemented with notes to indicate how they felt prior to the scan. This gives the doctor a better view on how to interpret the collected data. Their clinical studies have proved that the AliveCor Mobile ECG recordings are comparable to readings from Lead 1 of standard ECG machines. The doctor has a dashboard to easily follow his patient's scans. We can not say much about the user interface because the application and ECG device are not yet available in Belgium.

Figure 2.2: AliveECG

[2] http://www.alivecor.com

3. **SecuraFone Health**[3]
   SecuraFone Health consist of a Mobile Application and a Vital Monitoring Patch called SecuraPatch. The application includes heart rate monitoring, position of the body (standing, laying down), an SOS button, etc. It is also possible to give caregivers, doctors, or others access to monitor a patient from a distance through the application. It is not possible to test this application because it is only available in the US. The screen shot of the application shown in figure 2.3 indicates that the application has put a high priority on the SOS functionality.

Figure 2.3: SecuraFone Health

[3]http://www.securafone.com/subpages/health.php

4. **Cardiio**[4]
   Cardiio is an application which measures your heart beat through the camera of your smart phone. Compared to Qompium's FibriCheck application, the Cardiio Application can also measure your heart beat with the help of the front facing camera of your smartphone. This is possible thanks to the change of color in your face when more blood is pumped through your body. The data is mostly meant for personal use, although there is the possibility to share it with friends. The application has a nice 'how to' screen when you start the application for the first time. It is nice and intuitively designed with a menu at the bottom. When we tried the application it worked well.

Figure 2.4: Cardiio

[4]http://www.cardiio.com/#howItWorks

5. **Vitalconnect**[5]
   Vitalconnect is an American company founded in Silicon Valley. They have developed a HealthPatch MD. The patch detects the following vital signs and biometric measurements: Single-Lead ECG, Heart Rate, RR Interval, Heart Rate Variability, Respiratory Rate, Skin Temperature, Body Posture, Fall Detection, Activity including Steps. The patch works on Bluetooth LTE and has a battery span of three days. It has received an FDA clearance for sale in the US. It is not clear if they have an application, a web dashboard, or what they do with all the data from the sensors on the patch. But we will certainly need to keep an eye on their further developments.

Figure 2.5: Vitalconnect HealthPatch MD

[5]http://www.vitalconnect.com/healthpatch-md

6. **Cardiograph**[6]
   Cardiograph is yet another application which measures your pulse through the back camera and your fingertip. It has an iPhone, iPad and Mac application. The user interface seems not that comprehensive and is rather ugly. We were not able to test the application because there is no free version available.

Figure 2.6: Cardiograph

[6]http://macropinch.com/cardiograph/

7. **Pulse Point**[7]

   The Pulsepoint application is a community based application. The idea behind it is to reduce the number of deaths due to a cardiac arrest. They want to accomplish this by alerting nearby people with a CPR training when someone has a cardiac arrest. It is a totally different application as the one we intend to build, but it could be interesting to include something similar in a later version of our application. Though we will have to look out for the privacy issues that would rise with such an application.

Figure 2.7: Pulsepoint

[7]http://www.pulsepoint.org/pulsepoint-respond/

8. **Biorics**[8]
   Biorics is a Belgian company located in Heverlee. Their goal is to improve the overall wellness, health condition, mental status, and performance of people. They try to achieve this goal by developing applications which monitor stress, sleep, and pain. This they monitor by combining the application with a smartwatch. They are not yet in the same operating domain as us, but they could make that step towards our field of speciality in the near future and become a major competitor.

Figure 2.8: Biorics

[8]http://www.biorics.com/products/

2.2 Related Research in the Field of Wireless Monitoring

This section covers a study about related research work in the broad field of wireless monitoring in healthcare. It will discuss some of the aspects that are involved in the development of a platform like ours. These aspects are existing systems and their shortcomings, design principles, the Wireless Body Area Network problems, and accuracy. From the last two aspects we can conclude, like we also did after the meetings with the cardiology doctors, described in section 4.2, that there are still too much shortcomings in the wearable technologies to be usable as a medical application. That is why we shifted our focus towards an application that is less medical oriented, i.e. a Cardiac Rehabilitation (CR) application. The last two projects we describe, Picasso-TX and PATHway, are very closely related to our work. This is why they are described more extensively.

In (Baig, 2014), the authors focussed on three main concepts. Two of those concepts were wireless/remote monitoring and detection of multiple physical signs. The research about these concepts aimed at improving the current monitoring systems by evaluating them and identifying the shortfalls. After the evaluation of those monitoring systems, they developed an intelligent monitoring system combined with physiological data for patient monitoring. One of the three challenges of their research will be the primary challenge for us. It is the patients' and clinicians' usage and intentions. The acceptance of any system depends on the perception of the user. Therefore a user-centred design is essential. If the user does not fulfill the requirements such as wearing the sensor for the allocated periods of time, then the application becomes useless.

In (Greenhalgh et al., 2015), the authors sought to define quality in Telehealth and Telecare with the aim of improving the proportion of patients who receive appropriate, acceptable and workable technologies and services to support them living with illness or disability. Their study was separated into three research parts: the first part are interviews with seven technology suppliers of assistive technologies and fourteen service providers; the second part is an ethnographic case study with forty people (60 - 98 years old with multi-morbidity and assisted living needs); and the third part consists of ten co-design workshops. Their purpose was not to generate a specification list for a technology but to make a more abstract framework of design principles for both technologies and the services in which they are installed and used.

The ARCHIE framework that came out of the research stands for: Anchored, Realistic, Co-created, Human, Integrated, and Evaluation. One of the advantages of this study is the interdisciplinary nature of it. The research team consisted of a medical doctor, an occupational therapist, a psychologist, a computer scientist, and a sociologist. In our project we will try to follow this framework, as we want to achieve a High Quality Telecare Application.

In (Singh & Jain, 2014), the authors discuss the current Wireless Body Area Network (WBAN) prototypes and the problems related to them. These problems are related to hardware, software, wireless communication protocols, etc. Two of the big problems that keep popping up are the battery life of these devices and the fact that the sensors implemented in the devices are obtrusive. In our case, the battery life will be a big issue. We will need to find a way to make it a habit for the patients to charge the wearables frequently.

When we measure data with a wearable device it is important to know how accurate the measurement is. Eliminating false measurements and the corresponding false notifications is important to reduce the ballast for the doctor. In (Rainmaker, 2016), the authors investigated the heart rate sensor of the Microsoft band 2 smartwatch[9] and compared it to Garmins' Forerunner 630 with HR chest strap[10]. The conclusion was that the heart rate measurements of the Microsoft Band 2 were not good. The measurements were not often enough and inaccurate with intensive activity compared to the Garmin. When we search further for reviews about the Microsoft Band 2 we got confirmation about its accurateness. In (Tosy, 2015), the authors noticed that the heart rate was especially inaccurate when doing intense short workouts like sprinting.
In (Torfs et al., 2014), the authors investigated the comparison of a novel miniaturized three-channel ECG (Electrocardiography) monitoring patch versus a 24-h Holter system. The research was done with a group of ten people and gave good results. The alignment of the raw data from both devices had a correlation up to 85 percent. The RR-interval (R wave to R wave interval) analysis even had a correlations of 99 percent and higher. Out of these results, the authors concluded that the ECG patch could provide a suitable tool for long-term monitoring applications. It could be a future possibility to use such wearables in our system due their better accuracy compared to a normal smartwatch.

[9]https://www.microsoft.com/microsoft-band/en-us
[10]http://explore.garmin.com/nl-NL/forerunner/

Picasso-TX (Dobbels & Vandenberghe, 2015) is a research project from the KULeuven. The project consist of building a self-management web application for organ transplant patients. With this web application they aim at finding a better way of keeping their patients active, supporting them with medication adherence, and controlling their weight.
In the first step of their development process the authors aimed at gaining insights on transplant patients' use and appreciation of modern technology, and their attitude towards technology to support their health. They performed a diary study with twenty patients to map their current habits and the tools or solutions they use towards self-management of physical activity, medication adherence, and healthy eating. Through iterative prototyping they have build a web application adjusted to the patients' requirements.
Important for us is that they came to the conclusion that it is not motivating to use gamification with patients who's abilities are decreasing. At least not in the way of increasing the goals every time one goal is achieved or building a social game around it. This because those patients do not want to be confronted with the fact that they are becoming more and more limited in their activities; it is just too demotivating. It is better to highlight accumulated data. Therefore, they developed something that they call the pilgrimage. With this, patients set as goal to reach a destination far away, like Compostella, and when they have reached the amount of steps to get there, they virtually reached their goal. They claim that this will be much more effective in stimulating the patients. From the meeting we had with the usability expert of this project, we came to the conclusion that we should not try to simplify things too much; we should not treat them as small kids. He also said that we have to look out with using fake data when evaluating the application's usability. This could confuse the user, e.g. when the user is around 55 kg and the data representation displays random weights around 80 kg it will confuse the patient and this could influence the evaluation of the usability.

The PATHway project (Buys, 2016) is a collaboration of eight European countries and is part of the European Horizon 2020 research and innovation program. The project aims at building a web application to keep on activating Cardiac Rehabilitation (CR) patients. The authors target patients who are in the third phase of the CR process, the self-management rehabilitation phase. These patients are chosen because only approximately eleven percent goes for a long-term community-based CR program. With community-based CR programs they mean initiatives like the Harpa VZW[11] does by organiz-

[11]http://www.harpa.be

ing group sport sessions for CR patients. The PATHway web application is build to try and activate CR patients in a home setting. This by setting up a computer equipped with sensors to track their exercises. In figure 2.9, you can view the typical process a CR patient goes through when he would use PATHway.
Before the authors started developing their applications, they did an extensive User Requirements Gathering with patients (N =310) in Leuven and Dublin. On the basis of these surveys and interviews they constructed a functional requirements list and a usability requirements list. These requirements can also be used for our project due to the same user classes. Some of the results from the surveys and interviews were quite interesting, like for instance the patients do not want to be seen as ill, e.g. *"I would hate to think someone in my job thinks I'm wearing them because of a medical condition" (Patient 25 out of the PATHway research (Buys, 2016))*. Different from the Picasso-TX research, some of these patients want to improve their performance. Thus they want to be able to set new goals and like the idea of a reward systems, e.g. *"You need to have an objective" (Patient 25 out of the PATHway research (Buys, 2016))*. Besides the User Requirements Gathering with patients, they also did a smaller study with the caregivers that are involved. Positive reinforcement and personalisation of the application were the most important results from this study.

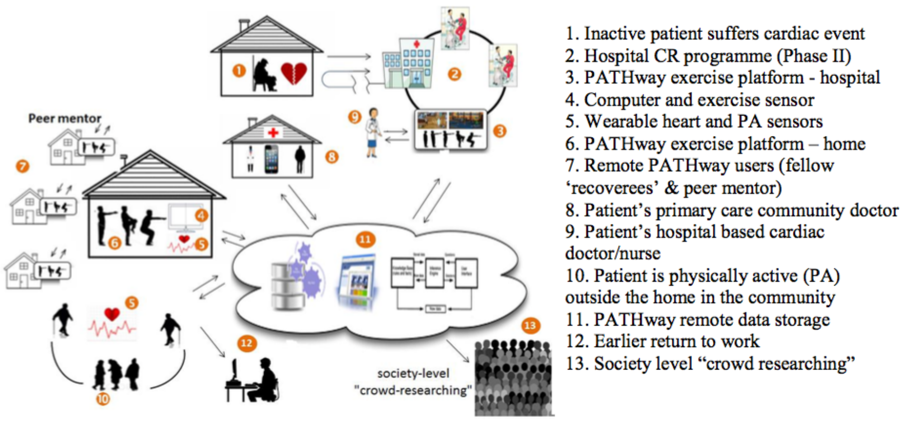

Figure 2.9: The picture depicts the typical Cardiac Rehabilitation process a patient should go through when using PATHway, taken from (Buys, 2016).

2.3 Chapter summary

The related applications section answers RQ1. The applications that we found were no direct competitors but some could become one in the near future. We were not able to draw any advantages out of their structural design or specific functionality except from the Pulse Point application. It had some functionality that could be interesting for the future.

Out of section 2.2 we could draw some conclusions. First we discovered that the acceptance of an application depends on the users perception. Therefore we will use a user-centred design and keep the ARCHIE framework in mind. Another thing that can influence the overall working of our application is the accurateness and battery life of smartwatches.

The last two research projects were very closely related to our cause. We were able to partially answer our RQ1. One of the results concluded that gamification or social interaction with patients with decreasing abilities is not a good way to achieve Patient Empowerment. Although they nuance it by saying that you should not do it in a way that you increase their goals every time they reach one. An accumulation of their achievements would be a smarter way to solve it. Patients also indicated that there needs to be an objective. Setting goals and rewards when reaching such a goal could be a good idea. The caregivers in these studies mentioned that the personalisation of such an application is very important.

3

State of the Art in User Interface Design

In this chapter we will first do a study about user interface design for web applications and mobile devices in general. We will narrow it down to the use of mobile devices by elderly. This because a major part of our user base will be over the age of fifty.

3.1 State of the Art

User interface design guidelines were already present in the early days of computing. In 1971, Hansen already described some user interface principles, two of them were *know your user* and *minimize the memorization* (Hansen, 1971). These two principles will be used extensively throughout this thesis. After all, they are still part of the main principles of the user interface design process. These early design guidelines were expanded bit by bit by different researchers. In 1987, Shneiderman formulated the *Eight Golden Rules of Interface Design* which are still applicable today (Shneiderman, 1987). Later on, Nielson defined *10 Usability Heuristics for User Interface Design* which are broad general rules of thumbs instead of specific usability requirements (Nielsen & Molich, 1990). These usability heuristic can be used as an evaluation method for finding usability problems in a user interface.

Though there are a lot of extensions to the initial design guidelines of Hansen, the most important general design guidelines stay the same. In figure 3.1 you can see a comparison of the two best known lists of user interface design guidelines (Johnson, 2013).

Table I.1 The Two Best-Known Lists of User Interface Design Guidelines

Shneiderman (1987); Shneiderman and Plaisant (2009)	Nielsen and Molich (1990)
• Strive for consistency • Cater to universal usability • Offer informative feedback • Design task flows to yield closure • Prevent errors • Permit easy reversal of actions • Make users feel *they* are in control • Minimize short-term memory load	• Consistency and standards • Visibility of system status • Match between system and real world • User control and freedom • Error prevention • Recognition rather than recall • Flexibility and efficiency of use • Aesthetic and minimalist design • Help users recognize, diagnose, and recover from errors • Provide online documentation and help

Figure 3.1: User Interface Design Guidelines, taken from (Johnson, 2013)

As expected, they contain the same principles but described in a different way. This is not because the authors copied each other, but the reason for the underlying similarities is that these design rules are based on human psychology, i.e. how people perceive, learn, reason, remember, and convert intentions into actions (Johnson, 2013). These principles are still very important and we will have take them into consideration in our application to ensure usability.

When we focus more towards the development of a user interface for mobile applications, we can notice that the ground principles stay the same but there are some important differences. Some principles are not applicable for mobile applications, while some new ones have to be added. In particular, the impact the application has on the mobility of the user needs to be limited (Harrison et al., 2013).

In (Harrison et al., 2013), the authors state that some attributes, such as cognitive load, tend to be overlooked in the former usability models and therefore introduced a new usability model called PACMAD (People At the Center Application Development). In this model they try to address the limitations of existing usability models when applied to mobile devices. The model is mostly build on the models introduced by ISO (International Organization for Standardization) (Witold et al., 2003) and Nielsen (Nielsen, 1994), further it also includes the attribute of cognitive load which is important for mobile applications. In figure 3.2 you can see a comparison between ISO, Nielsen and PACMAD.

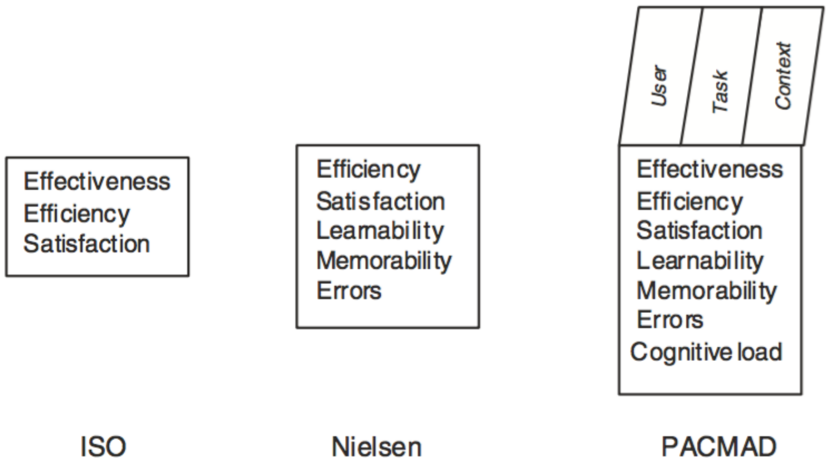

Figure 3.2: Comparison of usability models, taken from (Harrison et al., 2013)

In (Baharuddin et al., 2013), the authors also propose a model to guide the design of a usable mobile application. They based their work on reviews of previous related studies. It considers four contextual factors: user, environment, technology and task/activity, as shown in figure 3.3. When comparing this model with the PACMAD model, we can conclude that they are basically the same except that the usability dimensions are more comprehensive than in the PACMAD model.

Now narrowing this down to the usability of mobile applications used by elderly results in yet a more specialised model of user interface design principles.
As you any other type of user, it is important to involve the elderly early in the design and development process. Involving them too late in the design cycle may result into troubles which could otherwise have been avoided (Essén & Östlund, 2011). This is also concluded in (Lee, 2014) where they did an extensive literature study.

In (Silva, Holden, & Jordan, 2015), the authors discuss the importance of making mobile applications usable for elderly and provide a list of 35

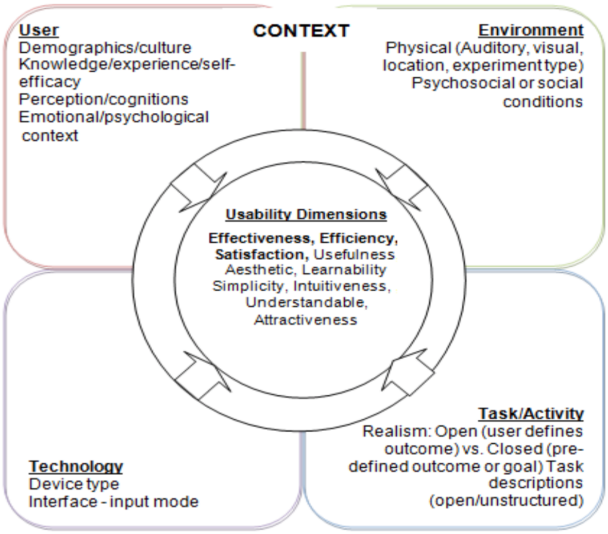

Figure 3.3: Model of usability dimensions based on four context factors, taken from (Baharuddin et al., 2013)

heuristics to evaluate mobile applications on their usability for elderly. This list was conducted by combining existing lists. They grouped the list in six categories: perception, cognition, dexterity, navigation, content, and visual design. We only focussed on eight of the most important heuristics from the list because 35 heuristics would make us lose focus. These eight are the most important once for our elderly population. These are: cognition (H1, H5), content (all, H7 - H10), navigation (H14), visual design (H33). These can be found in the complete list in appendix A.1.

3.2 Chapter summary

Out of this research we can conclude that the overall idea and concept of making an application usable almost stayed the same. There are some changes noticeable due to the evolution from the personal pc to the mobile devices. This evolution made it necessary to adjust some of the early heuristics to more specific heuristics for the mobile environment. In our case we have even further optimised these heuristics to our elderly audience.

4 User Interface Design

In the first stage of the project we want to develop a good reliable platform offering the basic functionalities that our stakeholders require. Later on, it should be possible to add new features and further adjust the platform.

As explained in the introduction, the focus of our work is on the user interface of the LiAM application. In this chapter we will focus on the different steps performed in the context of the design of this user interface and we will solve RQ3. We have followed a user-centered design methodology. In the first step we investigated the user classes and formulated the requirements for the application. This required a lot of research: meetings with important people in the medical field, attending conferences, talking to patients, and searching for related work. When this research was done, we started with a task analysis and user object modelling, and we defined a style guide for the application based on the requirements of our stakeholders. Based on all these results, we constructed prototypes. As last we evaluated the prototypes by means of a field study and adjusted it according to the outcomes of the evaluation. While it is recommended to iterate through this process at least 3 times, we were only able to do two iteration due to time limitations.

The chapter is organized as follows. First there is the elevator pitch of the LiAM platform. After this short description we describe the requirements gathering process. It gave us a better insight on the users and their needs. Out of this requirement gathering we constructed our User Classes, (Non-)Functional Requirements, and Usability Requirements. These requirements were used as starting point for the modelling of the Concurrent Task Trees (i.e. task modelling) and ORM (i.e. user object modelling). The last part describes the style guide of the mobile application.

4.1 LiAM Cardiac

LiAM Cardiac or Life Assistance Monitoring for Cardiological patients will be a platform consisting of a Mobile Application and a Web Dashboard. The base of the application consist of three main core functionalities: measuring, analyzing, and communicating. This should all be combined in a highly usable interface.

First of all, certain parameters of patients will be measured by using smartwatches/wearables in combination with a smartphone. The collected data on the smartwatch will be transmitted via Bluetooth to the smartphone. The smartphone at its turn will send the measured data securely to the cloud. The mobile application will show an overview of the live sensor data. The patient and the caregiver can view the measurements at any time.

Furthermore, the collected data will be analyzed and presented graphically for each sensor. The data analysis is open for research and development. We should make it easy to include external data analysis plugins. We aim to do this to achieve a social base as broad as possible and to provide caregivers with an optimal support for the decision making process. We will also use HL7[1] or Health Level 7 which is a standard for the exchange, integration, sharing, and retrieval of electronic health information.

Last but not least, we will try to improve the communication between the caregiver and the patient. The communication will be partly automatic and partly personalized. The communication will consist of automatic advice, as well as personal manual advice, motivational messages, reminders when inactive, etc. This way of communicating and the frequency of it can be adjusted in the settings according to the user's requirements.

[1] http://www.hl7.org/implement/standards/

4.2 Target Users and Requirements Gathering

First, we performed an in-depth exploration about the possibilities and functionalities of the platform we had in mind. This investigation started with different meetings with important cardiovascular doctors from UZ Gasthuisberg Leuven[2] and OLV Aalst[3]. From these meetings we had to conclude that a medical platform as we had in mind would not yet improve anything from a medical point of view, although the physicians all were very interested. There were three major problems that kept returning. Firstly, there was the extra workload issue. There were concerns about the fact that someone would have extra work, i.e. controlling the collected data. Secondly, they asked the question "What are the benefits of such a platform with the current state of the art wearables?". Before the meetings, we were rather convinced that these sensors would be sufficient to improve treatments or avoid deaths but apparently the physicians had a different opinion and would not really benefit from using the currently available sensors in wearables. Thirdly, the accurateness of the sensors on the wearables is not yet sufficiently high to be approved as a medical device. It would be very difficult to get such a platform medically validated.

We also visited the Belgian Cardio Liga[4]. The Cardio Liga is a non profit organization with the goal to create awareness around cardiovascular diseases. By discussing our plans for the platform with dr. Van de Casseye we adjusted the goal of the platform as well as the target audience. Every year there are 15.000 people with a heart attack, 23.000 people with a coronary stent, and 6.000 people with a heart valve surgery. These people should follow cardiac rehabilitation after such an event. According to dr. Van de Casseye, only thirty-five percent of these patients follow a cardiac rehabilitation program for a period of four to six months. After these four to six months the rehabilitation caregiver stops following them. This could lead them back to their unhealthy old habits. After this meeting we concluded that our goal should be to increase the number of people that do cardiac rehabilitation and to motivate them to keep a healthy and active lifestyle after the rehabilitation. We would like to achieve this by Patient Empowerment (Enope, 2016). This means stimulating and enabling patients to manage their own health. This by making sure they understand their health condition, know the different possible treatments, take responsibility for their own health and only reach out when necessary, etc.

[2]https://www.uzleuven.be
[3]https://www.olvz.be
[4]https://liguecardioliga.be/?lang=nl

After our conversations with professionals we went further and tried to reach out to existing projects around Patient Empowerment and to the patients themselves. We found two projects that are very closely related to our project which are already discussed in section 2.2. The first project is Picasso-TX[5] project. This project focusses on three things: medication adherence, physical activity, and healthy eating. The second and most closely related project is the PATHway[6] project. This is a very large project in the European Horizon 2020[7] research and innovation program. The project is about cardiac rehabilition in a home environment using a Web Application, a Microsoft Kinect, and a Microsoft Band. In both projects they did a thorough user requirements investigation. We will use this research in combination with our own small user requirements research to define our user classes, (non-)functional requirements, and usability requirements.

4.3 User Classes

Users are the main focus in a User-Centered Design Methodology. It is very important to define them rigorously. We identified two different user classes with each other functionality.

The first user class is the *Patient*. He will need to register before he will be able to use the platform. Once he is registered, he is able to log in and use the LiAM Cardiac mobile application as well as the web dashboard. He will be able to view his sensor data, his history, answer the follow up questions, set his goals, receive notifications, etc.

The second user class is the *Caregiver*. He first has to register and indicate in the registration that he is a *Caregiver*. In this registration he has to prove that he is certified by uploading an official document. This document can show that he is a qualified fitness coach, nurse, doctor, or has another medical/sports qualification that is in the acceptance list. After he proved that he is qualified, he receives the role of *Caregiver*. With his new role, he is now able to log in on the web dashboard for *Caregivers*. Now he can send requests to follow existing *patients* as a *Caregiver*. When a *Patient* accepts his request, he is able to follow the measurements of the patient and send him motivational messages, advice, and follow up questions depending on

[5]http://soc.kuleuven.be/mintlab/blog/project/picasso-tx/
[6]http://www.pathway2health.eu
[7]https://ec.europa.eu/programmes/horizon2020/

the *Patient's* preferences. We have chosen to only allow a *Caregiver* to add a *Patient* and not the other way around because we do not want *Caregivers* to be overloaded with follow up requests from random patients.

Below you find the specification of the two user classes; the functional requirements for the mobile application and web-dashboard are described in detail in the next section.

4.3.1 Patient

Type of user: Direct

Motivation/goals: He will be able to view his sensor data, his history and progression. He will be reminded/motivated to do the exercises.

Task experience: Low

Frequency of use: Daily/Weekly (depending on their personal settings)

Task knowledge: Low

Use: Voluntarily

Computer experience: Low

Age: All possible ages

4.3.2 Caregiver

Type of user: Direct

Motivation/goals: Being able to follow up patients, sent motivations, advice, and follow up questions.

Task experience: High

Frequency of use: Daily/Weekly

Task knowledge: Medium

Use: Mandatory

Computer experience: Low-Medium

Age: 21-67

4.4 Usability Requirements

To construct the usability requirements, we first defined the basic functional requirements. We base these on existing work, the Picasso-TX and the PATHway project which are described in section 2.2. After we established the functional requirements, we verified them by the caregivers and patients by means of interviews. Accompanied with these interviews, we also did a small survey in Dutch which can be found in appendix A.2. We did this to acquire more insights in the patients profiles and their requirements. After these interviews and survey, we constructed a final list of functional requirements and associated usability requirements. We first describe the basic functional requirements, then the basic non-functional requirements and next the actual usability requirements.

4.4.1 Functional Requirements

Mobile Application

1. Visualize live sensor data form the wearable/smartwatch
2. Visualize historical sensor data graphically with the possibility to change the time span
3. Provide combined historical data visualisations, like e.g. steps with goals, heart rate where also the min and max heart rate is visualised, etc.
4. Allow to add, edit, delete, view goals and achievements
5. Allow editing the basic personal and medical information in a profile
6. Allow adjusting settings to personalize the application
7. Provide sensors/wearables instructions and explanation on how to properly wear the devices
8. provide a notification system for inactivity, questions, medication reminders, advice, and goal achievements
9. Show a caregiver's public profile
10. Provide clear and unambiguous error handling to keep inconvenience as low as possible

11. Provide adjusted feedback to actions/events like visualizing the success of an entered value with a green thumb

12. Use a clear and unambiguous language and cultural usage adjusted to the users' locality

Web-dashboard

1. Allow to add, view, edit (goals, advices, etc.), and delete a patient

2. Allow to add personal advice, questions, goals, and medication reminders for a specific or all patients.

3. Allow to print a patient's data

4. The Web-dashboard should be Implemented in an existing platform like KWS

4.4.2 Non-Functional Requirements

We have distinguishes the following non-functional requirements:

- **Scalability & Reliability**
  We require that the platform will work in all circumstances, also when there are a lot of users. The performance needs to be optimal in all situations to ensure usability. We will also need to guarantee that there is no downtime of the platform. It could be a major issue when the system goes down and a patient is not monitored.

- **Extensibility**
  Currently we target the broad field of cardiology but it should be possible to extend the application for use in different fields. therefore, it is important that the application has a solid structure that can be easily adapted and extended. It should also be easy to connect different sorts of wearables to the mobile application.

- **Performance**
  Nobody wants a slow application, it has to perform well.

- **Security**
  The privacy of patients is an important issue. It will be of major importance to ensure the security of the patients' private and medical data. Therefore we have formulated some security requirements for our platform. First of all, we define some requirements for the password of

an account. The password must contain at least 8 characters. Besides this, the transmission of the data will have to happen securely. From both the smartwatch to the smartphone as well as from the smartphone to the cloud. The smartwatch connection to the smartphone will have to use the latest version of Bluetooth Low Energy (currently 4.2). The connection between the smartphone and the cloud also needs to happen in a secure encrypted way (using https). Due to the importance and vulnerability of the data, we will have to make sure that the above items are fulfilled. This we need to achieve to be able to get the quality certificates ISO 9001[8] and ISO 13485[9]. These certificates will improve our market position compared to other platforms.

4.4.3 Usability Requirements

Based on the previously formulated requirements, we have constructed a list of 17 Usability Requirements (UR). Next, we selected the eight most important ones out of these 17 and made a more detailed specification for each in order to check later on whether they are satisfied by the application. The given measurement criteria may be adjusted in a later phase.

Usability Requirements for the Mobile Application

- Live sensor data should be showed in an easy and unambiguous way directly when starting the application.
- Monitoring the historical data of a specific sensor should be possible within 3 steps starting from the main view.
- Each sensor should have a graphical overview of its historical measurements in a clear and unambiguous way with important values highlighted.
- It should be possible within 5 steps to combine the historical data of two different sensors into one graph.
- Login should be possible within one step after registration (first login).
- Registration should be possible within 2 minutes
- Goals should be easy and flexible to set within only 45 seconds.

[8] http://www.iso.org/iso/home/standards/management-standards/iso$_9$000.htm

[9] http://www.iso.org/iso/catalogue$_d$$etail?csnumber$ = 36786

- Goals should be presented in a simple and graphical way that users can immediately (within 5 seconds) see how close they are to reaching their goal.
- The learning curve should be as low as possible; users should be able to understand the workings of the application within 5 minutes.
- The application should be build in such a way that every functionality is reachable within 5 steps starting from the home view. The less interaction needed to reach a functionality, the better.
- Checking notifications should be possible within 1 step from the home screen.
- The frequency that the user receives notifications should be adjustable within 4 steps starting from the home view.
- Follow up questions should be written clearly and answerable with a short predetermined answer in less than 15 seconds.
- A patient should be able to edit his profile in less than 20 seconds.
- A patient should be able to fully personalize the application in less than 2 minutes.
- The application could fail for several reasons but there should always be a clear and appropriate error message that explains why it failed and what the user has to do next.
- When entering a manual measurement, answering a question, etc. there has to be a feedback message whether the system did or did not register the input.

Usability Specification for the most important URs

1.
- **Description:** Monitoring the historical data of a specific sensor should be possible within 3 steps starting from the main view.
- **Motivation:** The historical measurements visualization is one of the core aspects of the application and it should be easy and fast to inspect them.
- **User class(es):** Patient
- **Measuring concept:** Quality of task performance
- **Measuring method:** Task scenario
  - *Result:* Amount of steps to perform the task
- **Criteria for judging:**
  - *Worst level:* 5 steps or more
  - *Planned level:* 3 steps
  - *Best level:* 1 step

2.
- **Description:** Login should be possible within one step after registration (first login).
- **Motivation:** It should be easy and quick to login and start using the application.
- **User class(es):** Patient
- **Measuring concept:** User satisfaction
- **Measuring method:** Task scenario
  - *Result:* Amount of steps to perform the task
- **Criteria for judging:**
  - *Worst level:* 4 steps when entering login credentials
  - *Planned level:* 1 step
  - *Best level:* 1 step

3.
- **Description:** Goals should be fast and flexible to set within only 45 seconds.
- **Motivation:** The system is build upon the principle of Patient Empowerment; goals are important when activating patients. That is why it is important to make it fast and flexible to set personalized goals.
- **User class(es):** Patient
- **Measuring concept:** Quality of task performance
- **Measuring method:** Task scenario
  - *Result:* Time to perform the task
- **Criteria for judging:**
  - *Worst level:* 180 seconds
  - *Planned level:* 90 seconds
  - *Best level:* 45 seconds

4.
- **Description:** Goals should be presented in a simple and graphical way that users can immediately see how close they are to reaching their goal.
- **Motivation:** Patients want as less interaction as possible with the application. They want to know their performance as fast as possible.
- **User class(es):** Patient
- **Measuring concept:** User satisfaction
- **Measuring method:** Interview
  - *Result:* satisfaction
- **Criteria for judging:**
  - *Worst level:* Do not understand the graphical representation
  - *Planned level:* Need some time to figure out the graphical representation
  - *Best level:* Instantly see it

5.
- **Description:** The learning curve should be as low as possible; users should be able to understand the working of the application within 5 minutes.
- **Motivation:** Most of the patients are elderly people, they do not like technology as much as young people do. When they can not understand the application within 5 minutes they will stop using it.
- **User class(es):** Patient
- **Measuring concept:** Learnability
- **Measuring method:** Task scenario / interview
  - *Result:* Time to perform the task
- **Criteria for judging:**
  - *Worst level:* 7 or more minutes (no smartphone experience at all)
  - *Planned level:* 4 minutes
  - *Best level:* 2 minutes

6.
- **Description:** Checking notifications should be possible within 1 step from within the home screen.
- **Motivation:** Patients should be able to see their notifications after only a small interaction with the application. Otherwise, they may not check them.
- **User class(es):** Patient
- **Measuring concept:** Quality of task performance
- **Measuring method:** Task scenario
  - *Result:* Amount of steps to perform the task
- **Criteria for judging:**
  - *Worst level:* 5 or more steps
  - *Planned level:* 2 steps
  - *Best level:* 1 step

7.
- **Description:** Follow up questions should be written clearly and should be answerable with a short predetermined answer in less than 15 seconds.
- **Motivation:** It should be easy and quick to answer these question without it being tedious.
- **User class(es):** Patient
- **Measuring concept:** Quality of task performance
- **Measuring method:** Task scenario
  - *Result:* Time to perform the task
- **Criteria for judging:**
  - *Worst level:* 45 seconds
  - *Planned level:* 30 seconds
  - *Best level:* 15 seconds

8.
- **Description:** A patient should be able to fully personalize the application in less than 2 minutes.
- **Motivation:** Most people like to personalize an application towards their needs, but they do not like to put a lot of effort in it to do so.
- **User class(es):** Patient
- **Measuring concept:** Quality of task performance
- **Measuring method:** Task scenario
  - *Result:* Time to perform the task
- **Criteria for judging:**
  - *Worst level:* 5 minutes
  - *Planned level:* 2 minutes
  - *Best level:* 1 minute

4.5 Task Analysis

This section presents the results of the Task Analysis. The tasks that the users need to perform with the application are modelled by means of the Concurrent Task Trees technique (CTT). Each task is described in a different sub-section.

4.5.1 Login

When opening the LiAM Cardiac application for the first time, the user is directed to the *login* page. On this page he can either create an account or login when he already has an account. After a login, it will not be shown again unless you explicitly log out. When you open the application and you are still logged in, it automatically loads the *home view* page. In figure 4.1 and 4.2 you can see the model for these tasks.

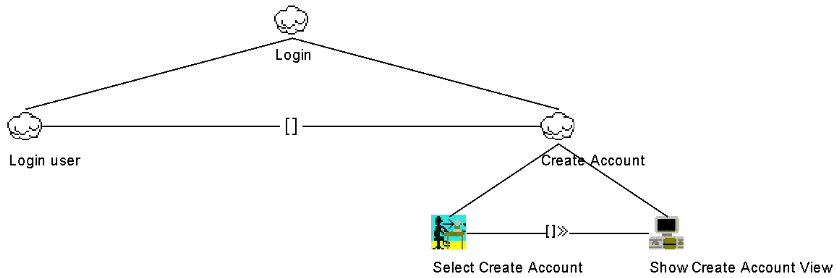

Figure 4.1: The Login Overview CTT

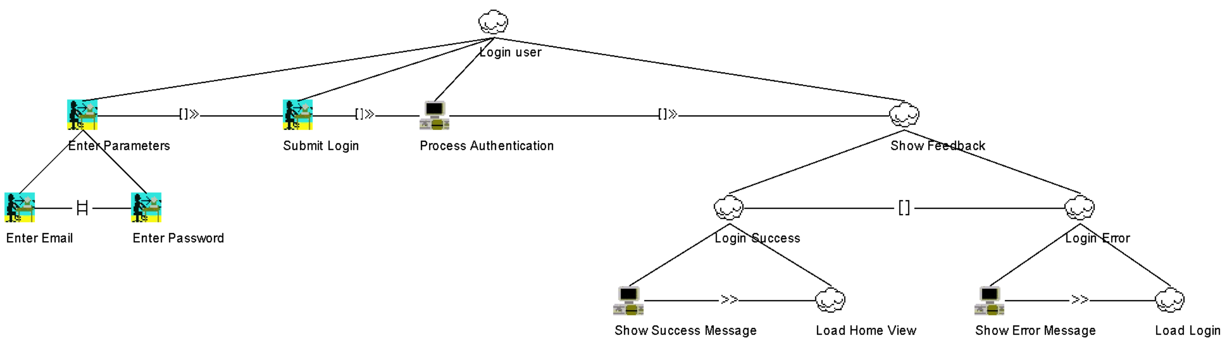

Figure 4.2: The Login Specific CTT

4.5.2 Create Account

A new user has to create an account before he is able to use the application. This has to be as easy and fast as possible. To create an account, the user only has to provide his/her first name, last name, email, and password (twice). After entering these parameters the user can submit the information to create the new account. The model of the *create account* task is given in figure 4.3.

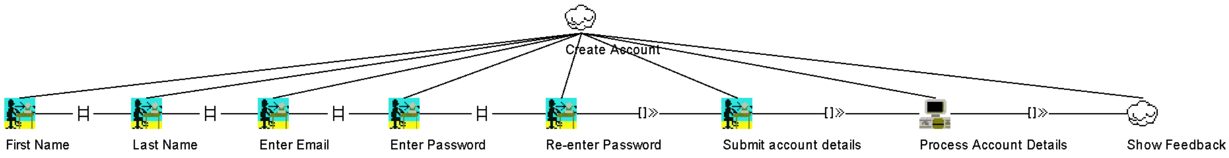

Figure 4.3: The Create Account CTT

4.5.3 Live Data

With the *live data* task, the user sees his live data. This can be the hearth rate, step count, etc. He can request help if something is not clear. This help action results in showing extra information. The user can also consult his notifications and goals. Figure 4.4 displays how we modelled the *live data* task.

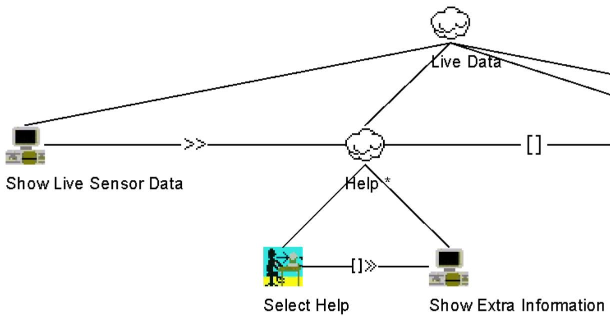

Figure 4.4: The live data CTT

4.5.4 History

In the *history* task the user can select a sensor to obtain an overview of the sensor data history of this sensor. Also in this task the user can ask for help. In figure 4.5 you can see the model of this task.

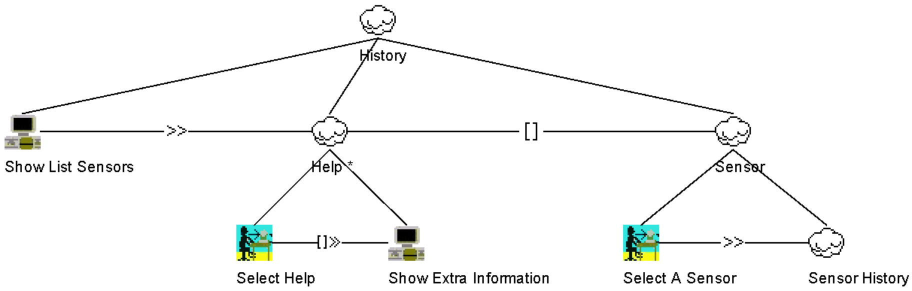

Figure 4.5: The History CTT

4.5.5 Sensor History

The *sensor history* task allows the user to obtain a graphical representation of the historical sensor data with some important indicators. With these indicators we mean e.g. the min and max heart rate indicated on the graph as a horizontal line. By default a week overview is provided but can be adapted by selecting a daily, monthly, or yearly representation. Again, there is the possibility to request help. In figure 4.6 you can view our model of the task.

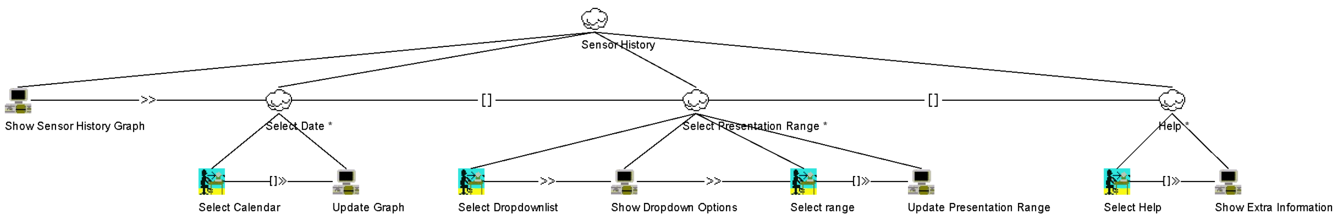

Figure 4.6: The Sensor History task CTT

4.5.6 Medication reminders

Most of the patients that use our application have to take medication every day. It is important that they do not forget it. With *medication reminders* they have an overview of all their medication together with the time they have to take it. The patient has the possibility to add, edit and delete medication reminders. They can consult help when something is not clear. The model for the task is given in figure 4.7.

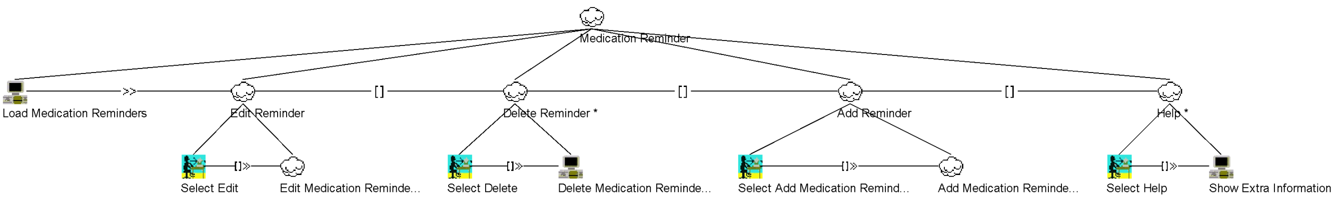

Figure 4.7: Medication Reminder CTT

4.5.7 Add & Edit a Medication Reminder

There is the possibility to add or edit a medication reminder. Both happen in the same way and therefore we only made the model to add a medication reminder as you can see in figure 4.8. In this model you can see that you have to indicate a name for the medication reminder and set a time when you have to take it. A name can be eg. "Dafalgan", "3 Pills Morning", "Green Pill" etc.

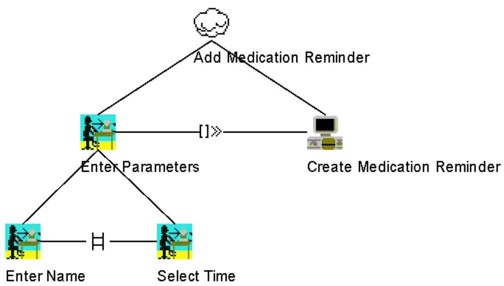

Figure 4.8: Add Medication Reminder CTT

4.5.8 Add Goal

Patients like to work towards goals as concluded in section 2.2. We give the patient the possibility to set flexible goals in a fast way. The patient has to set a goal name and select what type of goal he wants as modelled in figure 4.9. These types will be preset goals due that they have to be visualised later on. Despite these preset goals it is possible to personalise them towards your capabilities. For example you can set a goal with the type steps, with the personalisation to choose the number of steps and the time slot you need to execute this.

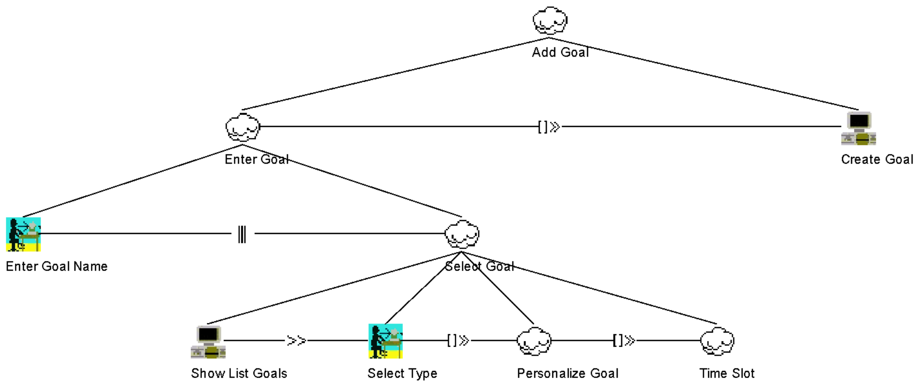

Figure 4.9: Add Goal CTT

4.5.9 Notifications

The *Notifications* are important because we want to activate our patients through it. Notifications can be advices, reached goals, follow up questions, and medication reminders. There is the possibility to filter on the sort of notification. When you select a notification you will go to the detail view. In figure 4.10 you can view our model for the task.

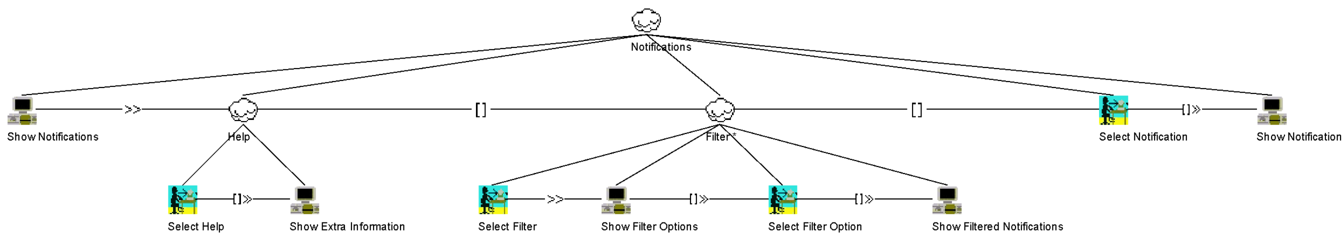

Figure 4.10: Notifications CTT

4.6 User Models

Figure 4.11 shows the overview of our ORM. Each entity will be explained in the following subsections. The LiAM application consists of seven main entities. Before we discuss each entity we will explain the overview. A user can either be a caregiver or a patient. A patient at his turn can have advices, goals, medication reminders, or measurements.

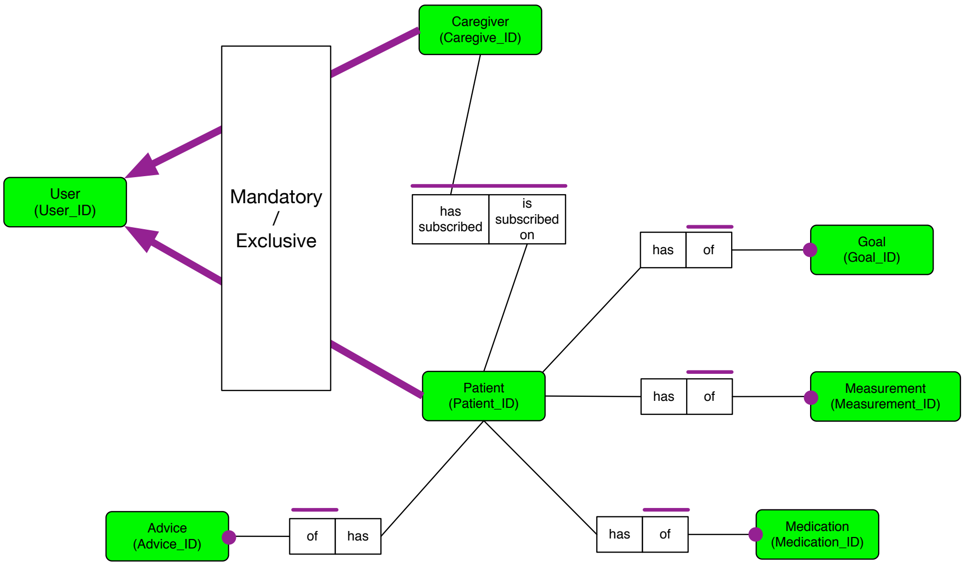

Figure 4.11: ORM LiAM: Overview

4.6.1 User entity

A user has a first name, last name, email, password, and optional a gender and a date of birth. A user can either be a Caregiver or a Patient. In figure 4.12 you can view the user entity.

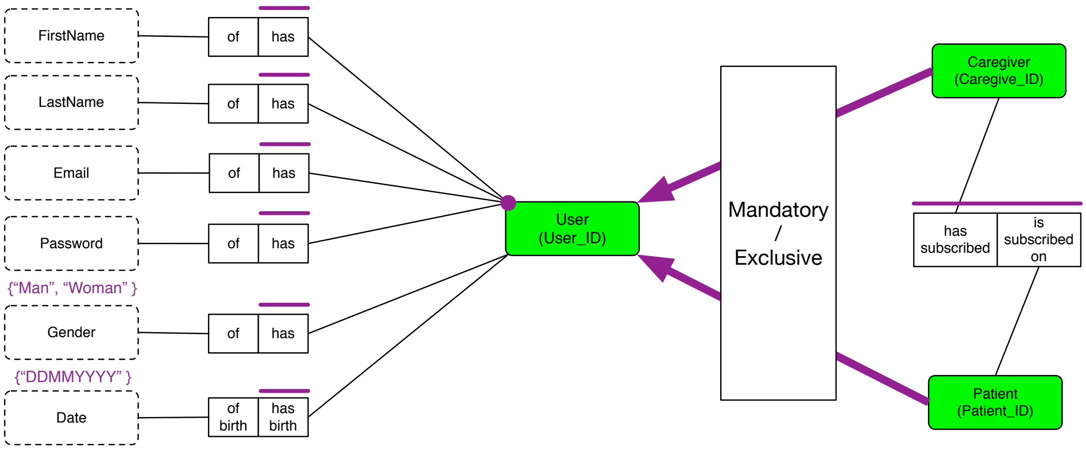

Figure 4.12: User entity

4.6.2 Caregiver entity

Figure 4.13 describes a caregiver. A caregiver has a certificate and works for or owns a practice. A caregiver can have subscribed patients.

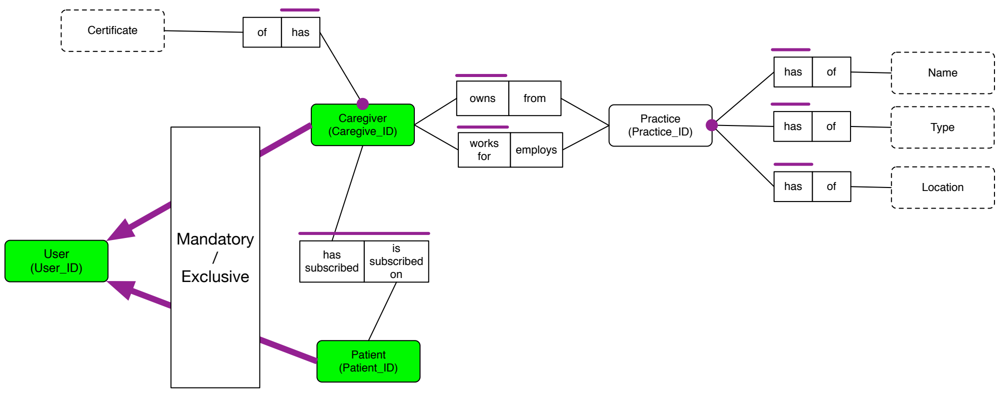

Figure 4.13: Caregiver entity

4.6.3 Patient entity

A patient can be subscribed on one or more caregivers. Besides that, a patient can have goals, advices, medication reminders, measurements, devices, and some specific settings as shown in figure 4.14.

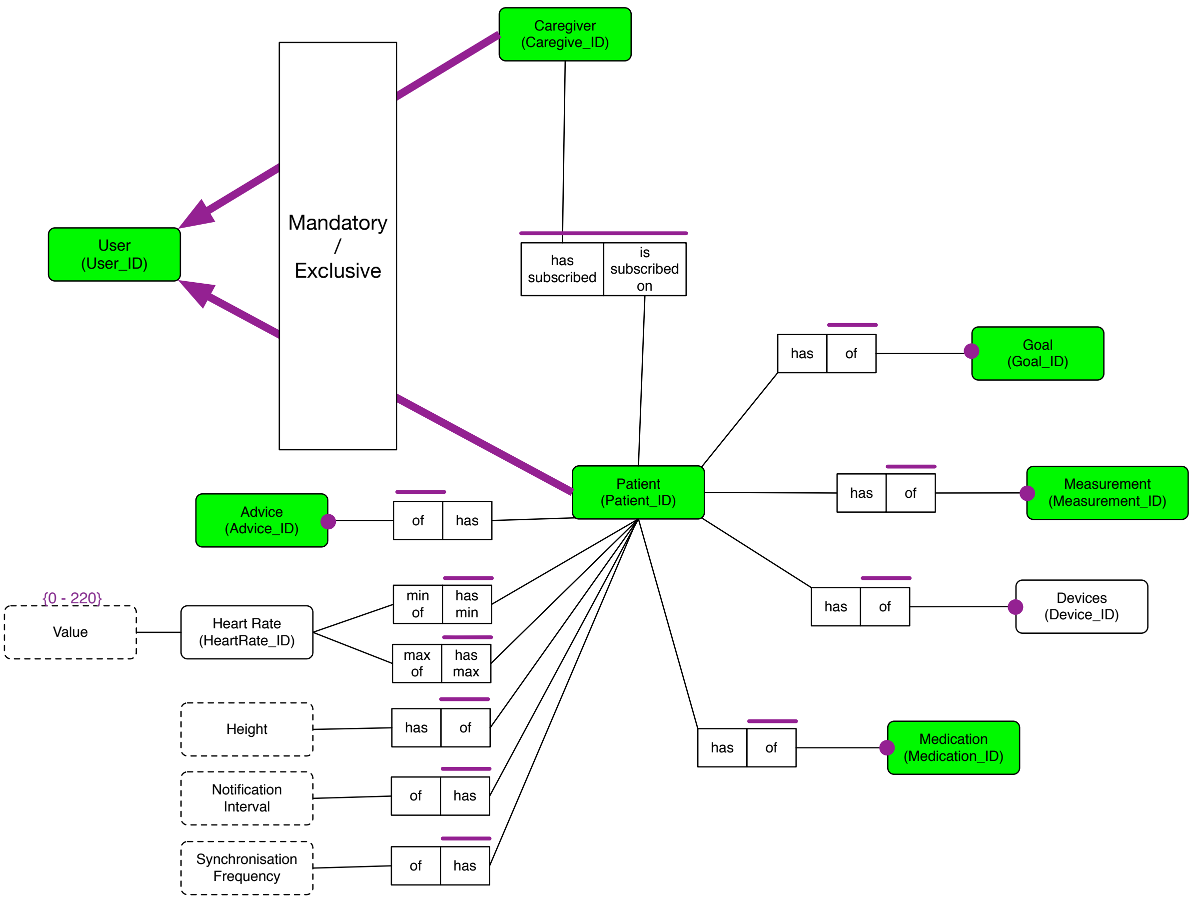

Figure 4.14: Patient entity

4.6.4 Goal, Advice, and Medication entity

Goals, Advices, and Medication Reminders all have some specific Lexical Object Types as shown in figure 4.15.

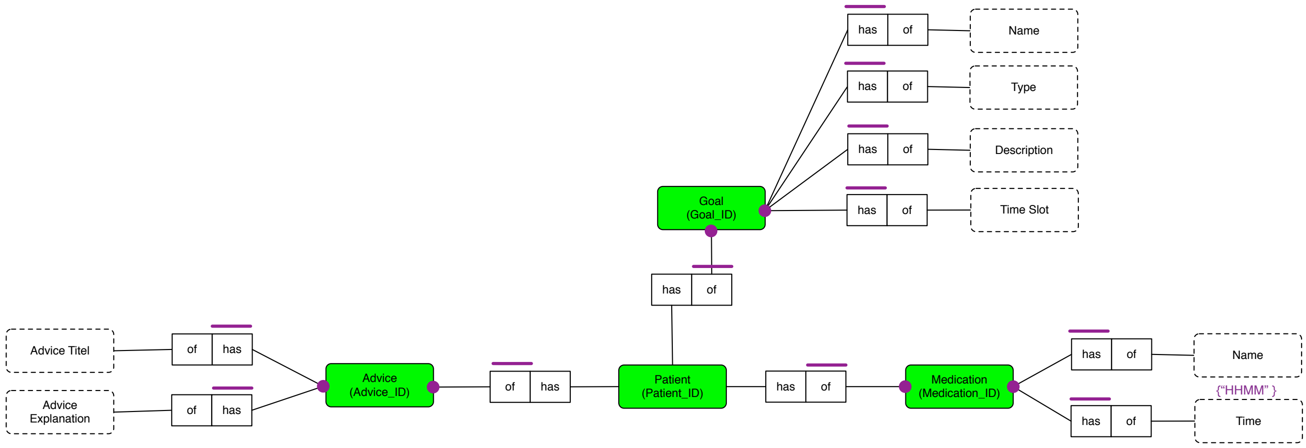

Figure 4.15: Goal, Advice, and Medication entity

4.6.5 Measurement entity

A Device has a sensor, a sensor has a measurement, and both a measurement and a device is from a patient. The all have some Lexical Object Types as shown in figure 4.16.

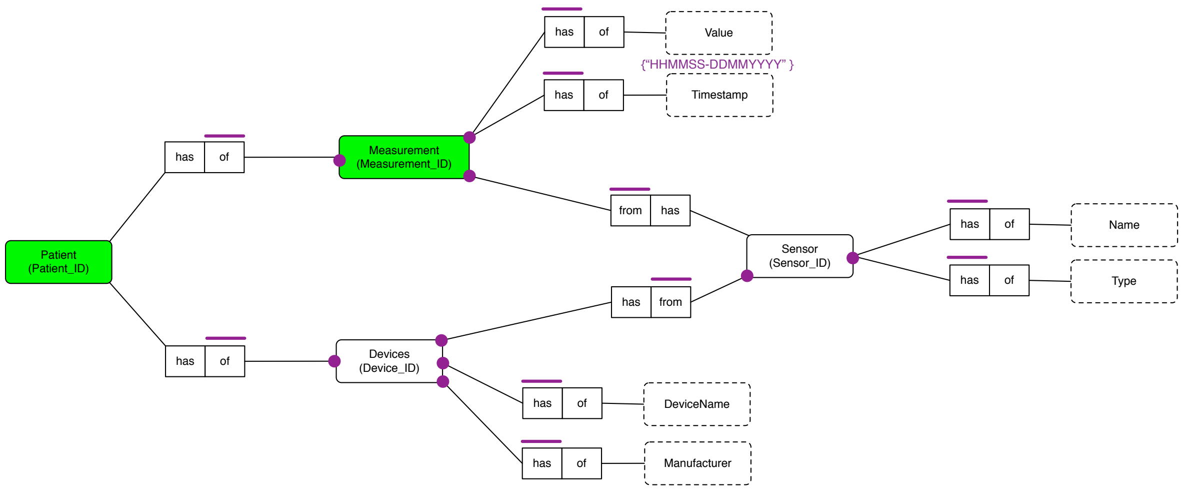

Figure 4.16: Measurement entity

4.7 Style Guide

The style guide of our Android application is based on the standards of Google's own Material Design[10] style guide.

4.7.1 Standards for Window Interaction

- To open the main navigation menu, the user should swipe from the left side of the screen to the right side, or select the three stripes navigation icon on the left in the app bar as shown in figure 4.17. The navigation menu floats temporarily over the page as shown in the left image of figure 4.19.
- Closing the main navigation menu is done by either swiping back from the right side of the screen to the left side or by selecting an item in de navigation menu.
- Closing the application is done by using the standard Android home button.
- Closing dialog windows is done by tapping on the *Ok* or *Cancel* button, respectively confirming and cancelling the dialog window as shown in the right image of figure 4.19
- On the Home screen, there is a short cut to swipe left or right to go to the Notification or Goals page.
- On the History screen of a specific sensor, there is the possibility to quickly swipe trough all the sensors.
- On the top right of the app bar the user can select the information icon which will result in an overlay which contains extra information about the page as shown in figure 4.18.

[10]https://www.google.com/design/spec/material-design/introduction.html

Figure 4.17: Layout and structure of the app bar

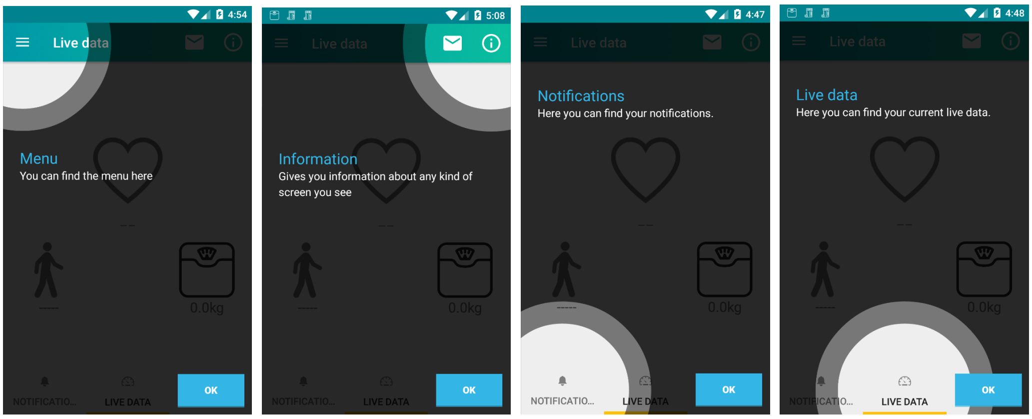

Figure 4.18: Some of the information overlays

4.7.2 Standard Window Layout

We use the app bar, content area and side navigation as described in the Layout section of Material design[11]. In figure 4.19 you can see our structure in the middle image. We only use the bottom bar as a tab interface on the main view. In figure 4.17 you can see an example of the structure of our app bar.

All pages include an information action icon and for the prototype in the right corner of the app bar as shown in the right figure 4.17. This is done to support the elderly people who do not know how the page is used. The icon can be hidden by switching it off in the settings. Some pages consist of an extra action menu to allow filtering, or other extra features. This extra menu is placed on the right side of the app bar and looks like three dots under each other as shown in figure 4.17. The main navigation menu is accessible from the navigation icon, the one with three stripes under each other, on the left side in the app bar. When navigating to detail pages, the navigation icon will change to a backarrow action button. The title in the app bar reflects

[11]https://www.google.com/design/spec/layout/principles.html

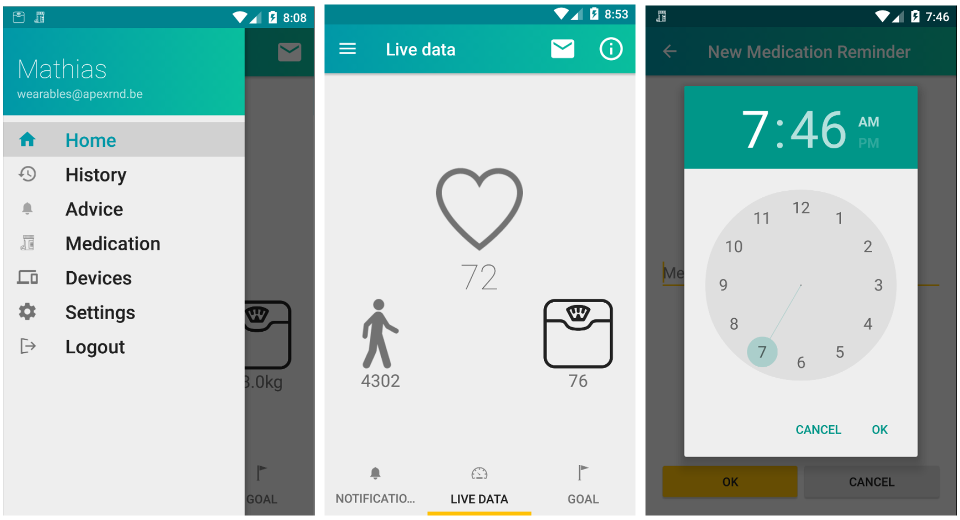

Figure 4.19: Layout and structure on a mobile app

the page where the user is currently on. Dialogs[12] are only used to select the time when adding or editing a medication reminder as shown in the right image of figure 4.19.

4.7.3 Standards for Menus and Push Buttons (i.e. naming, appearance, sequence, behaviour)

Under the Components section of the Material Design Style Guide, we can find the standards for buttons[13] and menus[14]. There are three sorts of buttons (as shown in figure 4.20): flat buttons, raised buttons, and action button. A flat button is a button which is not lifted, it is on the same level as the other components around it. While a raised button is lifted from the surrounding components. An action button floats over the display and is used to initiate an action.

In our Android application, the raised button is used as primary button and the secondary button is a flat one. A floating action button is used when adding a device or medication reminder. The action buttons will be amber (FFC107) as described in section 4.7.8. Secondary buttons are used in menus. They do not have a background color and they are used to avoid excessive layering. The naming of a button always happens in a clear and understandable way using upper-case letters. The floating button is on the

[12]https://www.google.com/design/spec/components/dialogs.html
[13]https://www.google.com/design/spec/components/buttons.html
[14]https://www.google.com/design/spec/components/menus.html

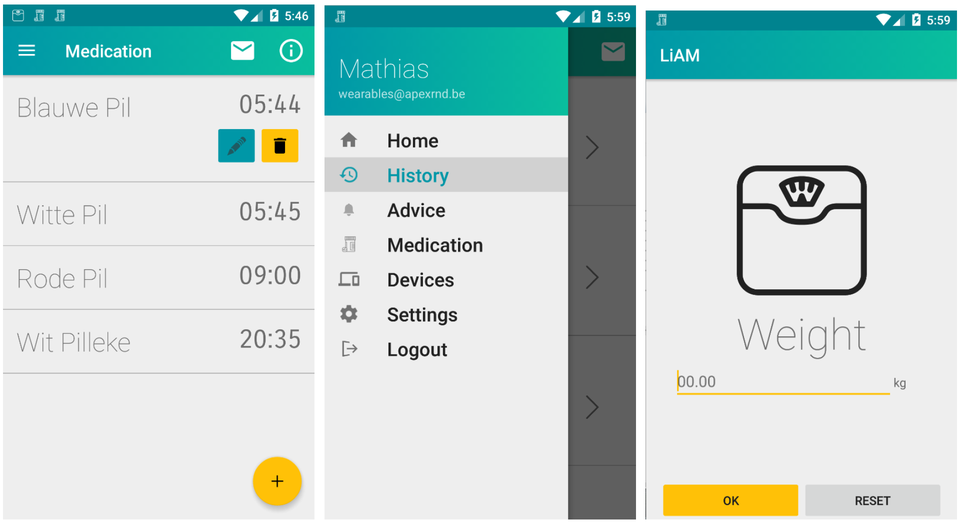

Figure 4.20: the left image shows an actionbutton and two raised buttons, the middle image shows the navigation which is constructed out of flat buttons, and the right image shows two raised buttons respectively "OK" and "RESET".

same elevation offset as the underlying component, while the raised button is at 2dp and the floating action button is at 6dp. When they are pressed, their elevation offset increases by 6dp.

4.7.4 Standards for Menus and Gestures for Touch Screen Devices

For our main menu, we use the navigation drawer[15]. This is a side menu which slides in from the left as shown in the middle image of figure 4.20. It is commonly used in Google Apps and thus gives a consistent Android feel to our application. All the standard touch screen gestures are possible[16]. These touch screen gestures are separated into two categories: Touch Mechanics (what your fingers do on the screen) and Touch Activities (results of specific gestures). The most important touch mechanics that we use are touch, pinch to zoom, and swipe gesture. These touch mechanics have a touch activity such as zoom in on the graphs, show the menu by swiping, opening a detail view by touch selecting, etc. as result.

[15] https://www.google.com/design/spec/patterns/navigation-drawer.html
[16] https://www.google.com/design/spec/patterns/gestures.html#gestures-touch-mechanics

4.7.5 Standards for use of Keyboard Keys

The application uses the standard Android keyboard which is installed on the device.

4.7.6 Standards for Use of Graphics, Tables and Diagrams

We do not use tables or diagrams of any sort in our application. We do use graphs to visualize the historical measured data. Here we use the MP Android Chart[17] library. We have used them in a minimalistic way to keep them as clean and understandable as possible. Colour use we minimalised to the colours we have selected in section 4.7.8 combined with a red line to indicate dangerous values. For more graphical uses, we refer to the standards described in the style section of Material Design[18]. When listing items we use the Lists[19] or Cards[20] in combination with Expansion Panels[21].

4.7.7 Standards for Use of Window Controls, and Mapping of Data Types to Window Controls

We use a dropdown box to indicate the time range that a graph should display. When we set or edit a medication reminder we use the standard Android time picker[22].

4.7.8 Standard use of Colour Type Fonts

We used the Material Palette Guideline[23] to choose our colouring. As primary colour we took Cyan in combination with the accent colour Amber. The Material Palette creates automatically the other best colors to use with them. Table 4.1 shows the list of colours that are used. The font colour is not completely black but a bit lighter. The text font that we use is the Roboto standard and the titles use the Roboto Thin. To indicate that a notification is unread we use the Roboto Bold.

[17] https://github.com/PhilJay/MPAndroidChart
[18] https://www.google.com/design/spec/style/imagery.html
[19] http://www.google.com/design/spec/components/lists.htmllists-usage
[20] https://www.google.com/design/spec/components/cards.html
[21] https://www.google.com/design/spec/components/expansion-panels.html
[22] https://www.google.com/design/spec/components/pickers.html
[23] https://www.materialpalette.com/cyan/amber

type	color name	color code
primary	cyan	#0097A7
primary dark	dark cyan	#00838F
primary light	light cyan	#4DD0E1
accent	amber	#FFC107
primary text	black	#212121
secondary text	dark gray	#727272
text/icons	white	#FFFFFF
divider	gray	#B6B6B6

Table 4.1: color palette

4.7.9 Standards for Common User Objects

- The home page contains a tab component[24] to make it possible to switch between live measurements, notifications, and goal. This is shown in the middle image of figure 4.19.
- Notifications are shown in the standard lists component[25]. Each notification contains an icon, title, and the beginning of the text. When a notification is not yet read, it will have a amber color line in front of it as indicated in figure 4.21.
- The sensor history overview is also build with the standard lists component. The component shows the icon and title of the sensor as shown in figure 4.21.
- The advices are shown using a cardview[26] in combination with expansion panels[27]. The cards contain an icon and a title. The expansion panel displays a short part of the whole advice with a button that you can select to read it completely as shown in figure 4.21.

[24] https://www.google.com/design/spec/components/tabs.html
[25] https://www.google.com/design/spec/components/lists.html
[26] https://www.google.com/design/spec/components/cards.html
[27] https://www.google.com/design/spec/components/expansion-panels.html

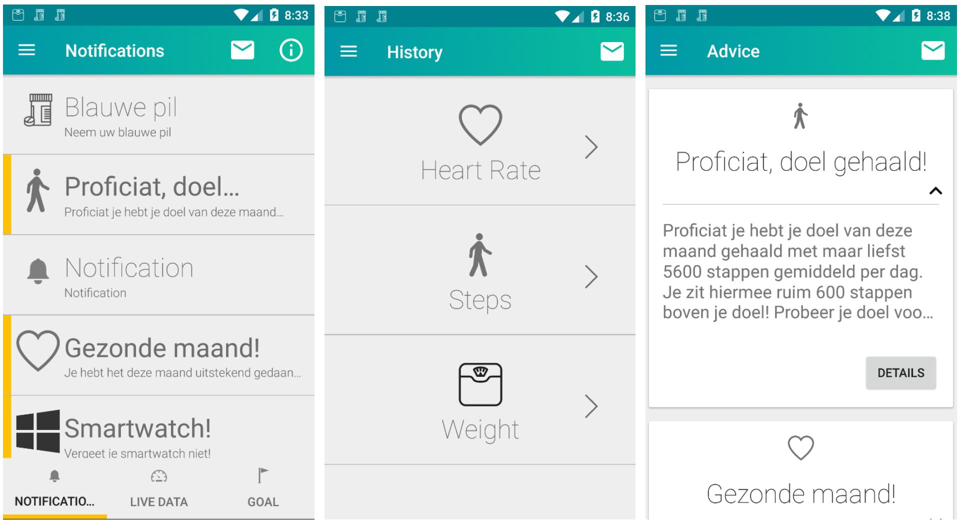

Figure 4.21: Left image shows the unread notifications, the middle shows the sensors history overview, and on the right the expansion panel of an advice

4.8 Chapter summary

After a long period of requirements gathering, which consisted out of doing research and meeting with medical experts and patients, we finally were able to specify our users and construct our usability requirements. In section 4.3 we specify our two user classes extensively, cardiac patients and caregivers (which can be a doctor, nurse, etc).

In section 4.4 we constructed our (non-)functional and usability requirements by combining research from chapter 2 and our own requirement gathering. These requirements give a direct answer to our RQ3. After the requirements specification list we had every bit of information to construct our task models and user models. The last step of this chapter was the configuration of our style guide. We decided to go with the Google's Material Design style guide.

5 Prototyping

In this chapter you can view the prototype that we have build. To construct the prototype we have followed a task-model approach **??**, i.e. we started from the CTT diagrams, constructed the enabled task sets and made a prototype based on the enabled task sets. Enabled task sets are a set of tasks that can be done by the user at the same time **??**. These tasks should be presented in a single presentation unit in the user interface (UI). Some of our prototype UI's are build without the use of this task-model method due to the simplicity. On most of the screens there is a feedback icon in the top app bar which is not mentioned in the enabled task sets.

5.1 Login

The enabled task sets for the Login task are:

- Set 1: {Enter Email, Enter Password, Select Create Account}
- Set 2: {Submit Login}

Figure 5.1 shows the login screen of the application. A user first has the possibility to enter his username and password or to select to sign up.

After the first login the smartphone will remember the login credentials. There is the possibility to sign up when a user is not yet registered.

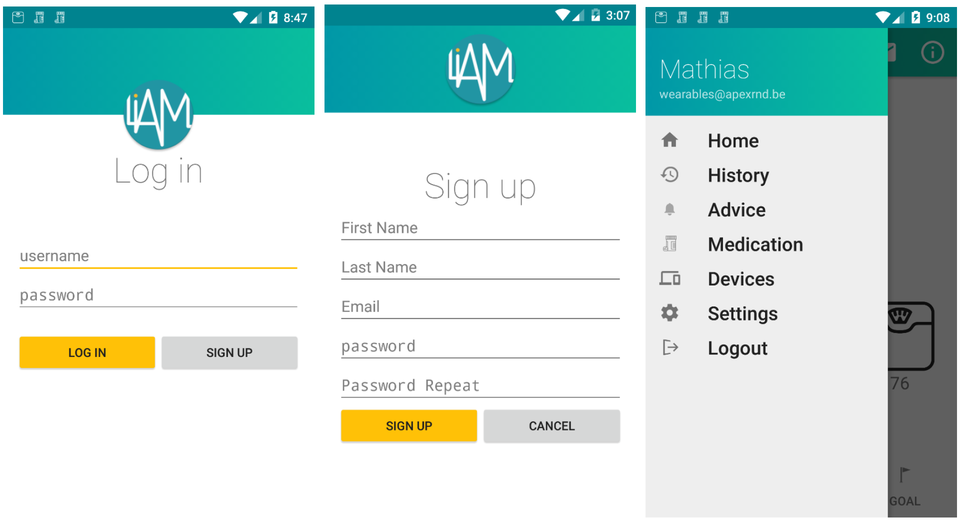

Figure 5.1: Login screen is visualized on the left, in the middle is the Create Account screen, and on the right is the Navigation

5.2 Create Account

The enabled task sets for the Create Account task are:

- Set 1: {First Name, Last Name, Enter Password, Re-enter Password}
- Set 2: {Submit Account Details}

When creating an account, the user has to enter some basic information as shown in figure 5.1.

5.3 Navigation

As the navigation is quite straightforward, we have not made any CTT's for this. Actually, the user can navigate to the different functionalities offered any time. Therefore we designed a navigation menu following the Material Design Navigation Drawer guideline[1]. In figure 5.1 you can view our design for the navigation menu.

[1]https://www.google.com/design/spec/patterns/navigation-drawer.html

5.4 Home

The enabled task sets for the Live Data task are:

– Set 1: {Show Live Sensor Data}
– Set 2: {Select Help, Show Notifications, Show Goals}

The enabled task sets for the Notifications task are:

– Set 1: {Show Notification}
– Set 2: {Select Help, Select Filter, Select Notification}
– Set 3: {Show Filter Options}
– Set 4: {Select Filter Option}
– Set 5: {Show Filtered Notifications}
– Set 6: {Show Notification}

The enabled task sets for the Goal task are:

– Set 1: {Show goal}
– Set 2: {Select Help}

In the figure 5.2 you can view our designs for the notifications, live data, and goal. The user can easily swipe trough these screens and select some of the objects like: notifications, measurements, etc. on the screen. In the top right corner there is the possibility to get more information about the page layout. We have adjusted our design towards the users needs, that is why the design of the prototype is not exactly as the enabled task sets describe. The filtering on the notifications is left away on the present prototype. There is the possibility that it will return in a late stage of development. The sensor images on the Live Data page is also made selectable due a patient suggested that it would be better and a faster way to go to the history detail of that sensor.

5.5 History

The enabled task sets for the History task are:

– Set 1: {Show List Sensors}
– Set 2: {Select Help, Select A Sensor}

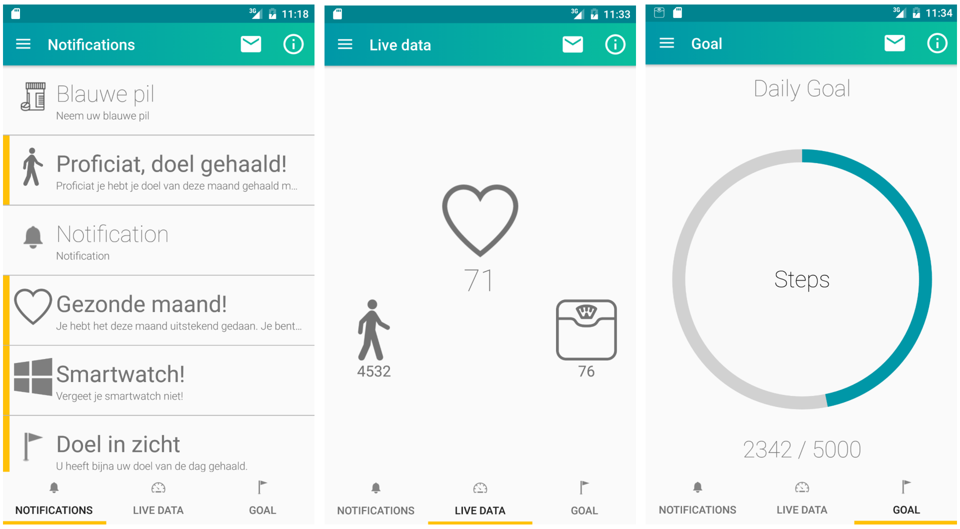

Figure 5.2: The first image is the Notifications view, the second the live data view, and the third is the goal view. The user has the possibility to swipe trough the screens

On the history page you can see an overview of the sensors that are tracked trough our application. In figure 5.3 you can see the currently supported sensors.

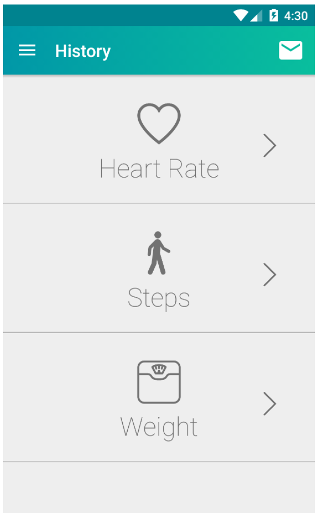

Figure 5.3: Overview of the sensors

The enabled task sets for the Sensor History task are:

- Set 1: {Show Sensor History Graph}

– Set 2: {Select Calendar, Select Dropdownlist, Select Help}
– Set 3: {Show Dropdown options}
– Set 4: {Select Range}

On the details page of such a supported sensor you get a graphical overview of the measured data. After the graphics are loaded you can select one of the two dropdown menu's to select a time representation or you can select the information icon. We changed the calendar action from the enabled task to a dropdown because it seemed better. In figure 5.4 you can view the graphs.

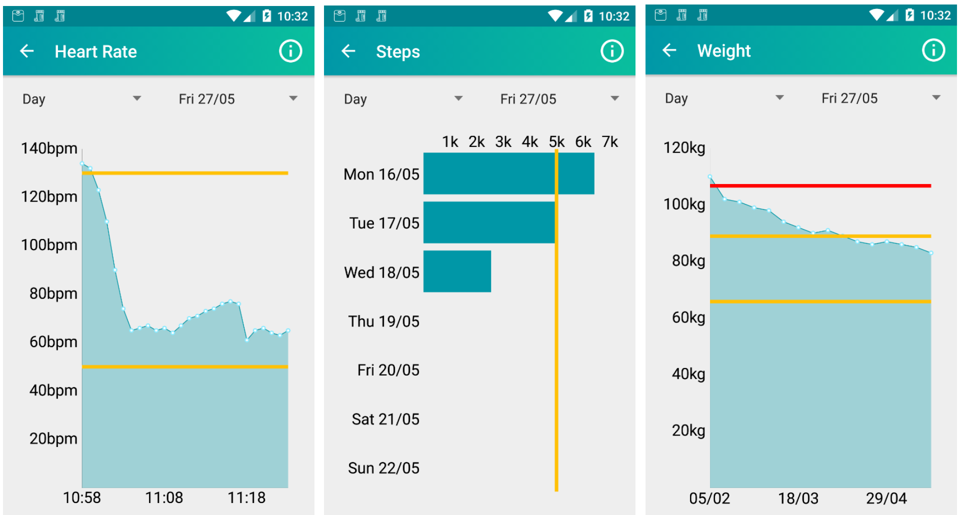

Figure 5.4: The left images is the Heart Rate Sensor history chart, the middle is the Step history chart, and on the right you can see the Weight history chart

5.6 Advice

We did not make a CTT for the Advice view because there is no real task except visualizing the advices. In figure 5.5 you can view the advices, expansion panel of an advice and the details page of one.

5.7 Medication Reminder

The enabled task sets for the Medication Reminder task are:

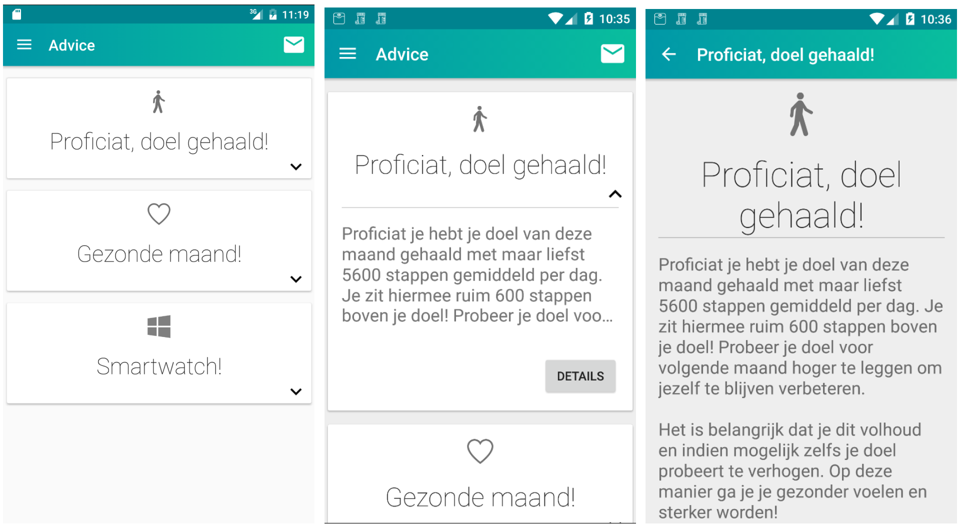

Figure 5.5: Advice Views

- Set 1: {Load Medication Reminders}
- Set 1: {Select Edit, Select Select Delete, Select Add Medication Reminder, Select Help}

Medication reminders almost work in the same way as the advices. Only in this case, the expansion panel gives the patient the possibility to edit or delete a reminder instead of showing a short text preview. There is also the possibility to add a reminder by pressing the amber plus action button. In figure 5.6 you can view the medication reminder views. The page first loads all the medication reminders that are already set. After it is loaded you can either edit, delete, or add a medication reminder, or select help.

The enabled task sets for the Add/Edit Medication Reminder task are:

- Set 1: {Enter Name, Select Time}

You have to enter the name and select a time when adding a medication reminder as you can view on the right images of figure 5.6.

5.8 Devices

To design the devices view we did not use a CTT because it is very simple, just a list of devices and the possibility to add a device. In figure 5.7 the devices views are given.

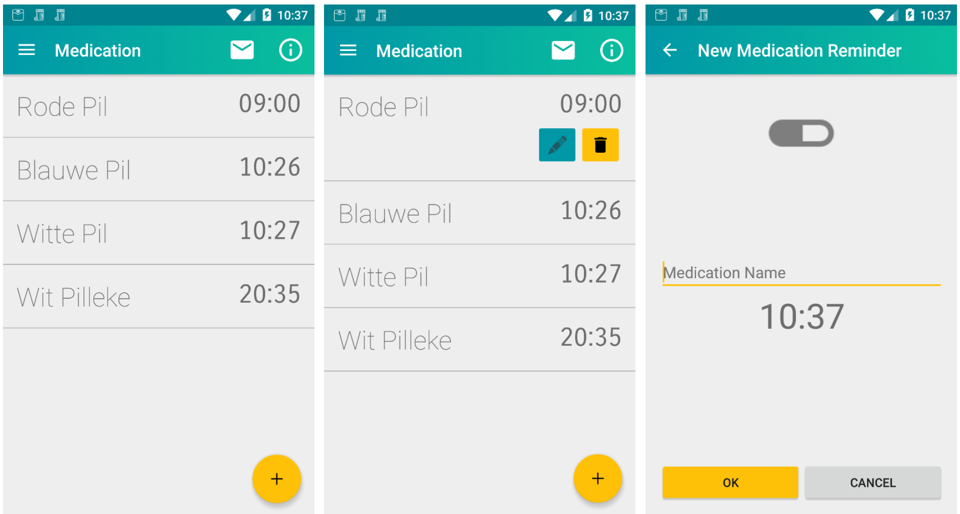

Figure 5.6: Medication reminders view with on the left the overview of your reminders, in the middle the expansion view of a specific reminder where you can select to edit or to delete them, and on the right the add or edit a reminder view.

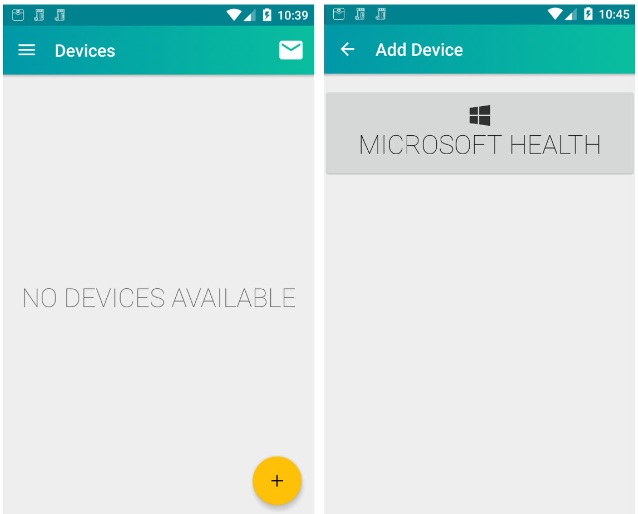

Figure 5.7: Devices View

5.9 Settings

Settings are constructed conforming to the standard android settings. In figure 5.8 you get an overview of the settings.

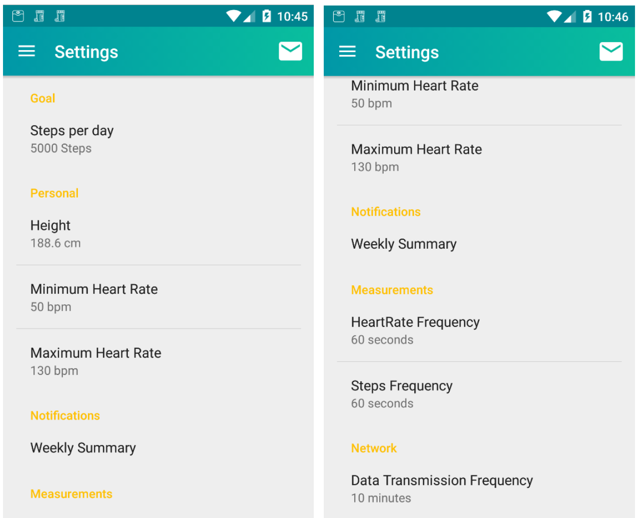

Figure 5.8: Settings View

5.10 Overlays

In figure 5.9 you can view some of the help views realized by means of overlays.

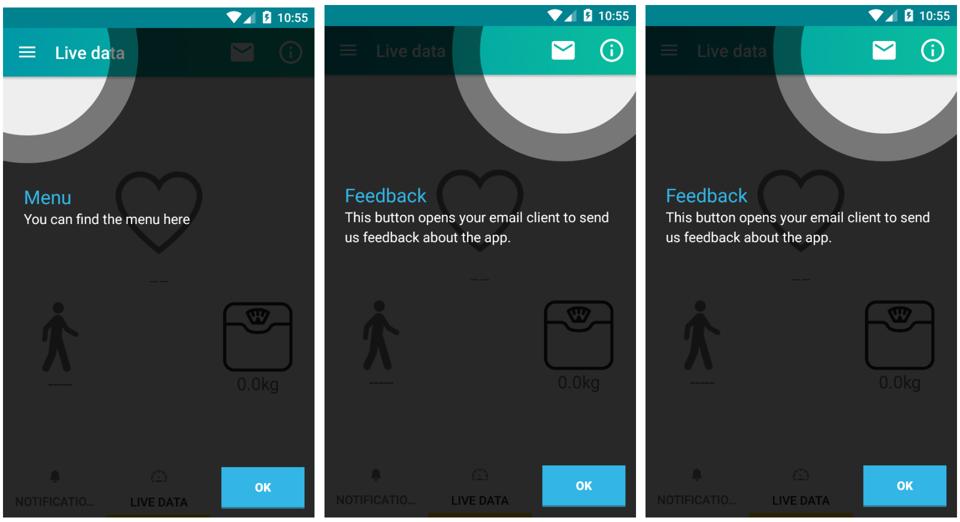

Figure 5.9: Overlay View

5.11 Error messages

In figure 5.10 you can view a few of our error response messages when entering wrong values.

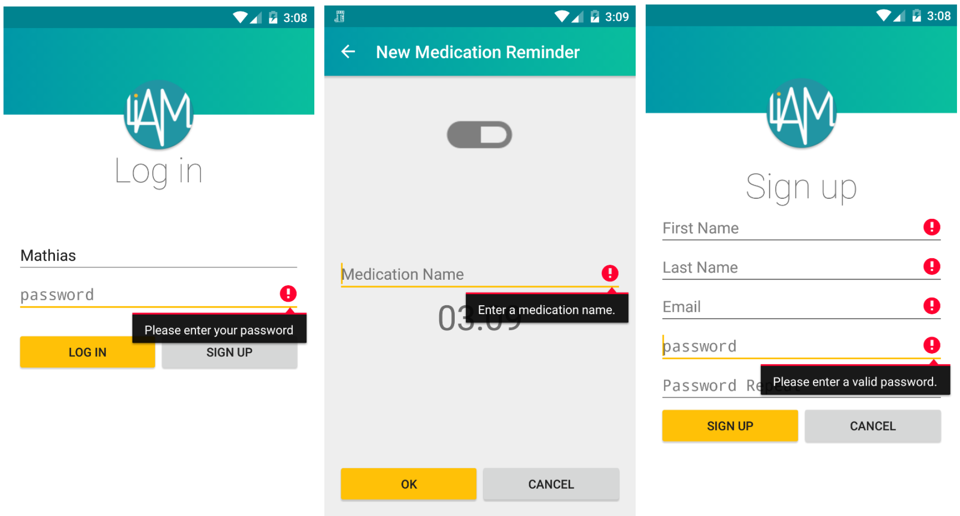

Figure 5.10: Error Views

5.12 Chapter summary

We have constructed prototype screens according to the enabled task sets that were generated from the CTT's from section 4.5. Some of the prototype screens were created without the use of a CTT due that they were intuitive to make. With some of our screens we were obligated to deviate from the enabled task sets. The reason behind these deviations was either due to the evaluations of the prototypes or due to functionality that is left out for the moment.

6 Evaluation

In this chapter we will discuss the two evaluations we did. The evaluations were both formative evaluations due to the fact that the development of the application is still ongoing. To evaluate our interface, we did a field study where we applied a number of evaluation methods, i.e. task scenario's where users had to talk aloud, questionnaire using a likert-scale, and an interview. We think this combination of methods was best to get as many insights on the usability of our application as possible. In the first section you can find our first evaluation. In the second section you can find our iteration on the design and the second and final evaluation.

6.1 First Evaluation

6.1.1 Introduction

The first evaluation was conducted on 18 May 2016 with three Harpa[1] members. We selected those members who already had a smartphone. They were all males around the age of 63 and were well educated. The fact that they were well educated could give a wrong view on the learnability. Therefore, In the second evaluation we would try to find less educated participants. They all were cardiology patient for about 8 years.

The evaluation happened after their training. We structured it by starting with a brief explanation of the platform, followed by a short try out of the application. After this introduction asked them to do the task scenario's in combination with the think aloud technique. As last we provided them with a short likert-scale questionnaire to obtain a better view on their opinion about the overall working of the application. In appendix A.3 you can find our evaluation form.

6.1.2 Evaluation Session

The first participant was a 60 years old man with a university degree. He had no real complaints about the usability of the application, although there were some crashes. However, he had some remarks on the concept of the application. During this evaluation we also noticed that he already had a smartwatch and that is probably why his first complaint was: *"What makes you different to the applications that are delivered together with a smartwatch?"*. He indicated that we had to show the difference. His second remark was that he did not really saw the benefit of having a caregiver following his data. He said that a heart rate measurement alone is not useful enough for a caregiver. While doing the evaluation of patient one there was another Harpa member who gave his short opinion on the application. He gave us some advice on the things that he thought were important. He said that it had to be easy and minimalistic, *"do not put functionality in it that is not useful"*. The medication reminders were redundant in his opinion. He indicated that we had to determine our critical success factors. Another complaint was that the text size should be bigger and

[1]http://www.harpa.be

that it should be compatible on a tablet. He said that statistics are very interesting when they are kept simple and only show the important information. He was not convinced about the personal advices where he had as argument: *"I know what activities I can and have to do"*.

The second and third participant we interviewed at the same time due to time limits of the participants. Patient 2 forgot to answer the personal questions but the third patient was 63 years old, owned an iPhone, and had a university degree. The usability of the application was quite clear to them and in no time they knew how the application worked. With the graphs there were three issues which you can observe in figure 6.3. The first issue was that it was not clear what the indication lines mean due the fact that the text that goes with those lines was very small. Second issue was a lack of indication whether the values where in kilo, pounds, steps, etc. Third was that when a patient sets a goal higher than the current values available in the step history graph, the goal would not be shown in the graph because it lies outside the boundaries.

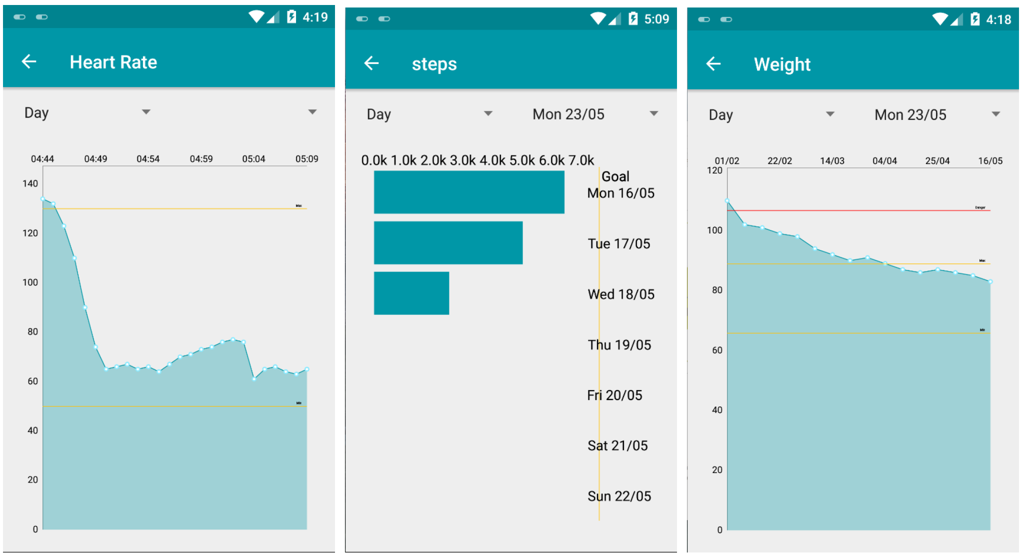

Figure 6.1: First graph shows the heart rate graph with the min, max indication line, the second graph shows the steps with the goal that is outside the boundaries, and the third graph shows the weight with min, max, danger indication line.

A complaint against the system was that they did not saw the difference between this and a Fitbit application like patient one also indicated.

We will have to make it more clear where we want to differentiate ourselves from Fitbit alike applications. Some issues were noted while they executed the tasks. The first was that patient 3 thinks it makes more sense to make it possible to select the icon of a live measurement and go directly to the detail history view of that sensor. He indicated that it would be like an online banking system where you see your account with the money amount and when you select it, you go to the detail view of your account. Another problem was with the navigation menu. Patient 3 selected the wrong item in the navigation due to the fact that his fingers were a little bit to thick. It is maybe a good thing to make the navigation items bigger. When entering a medication reminder there was no feedback whether he correctly entered the reminder and the system had accepted it. Except for these issues, they were both quickly familiar with the system.

Patient 2 explained his global opinion on the application. He said that someone who is motivated and interested will buy such a device like a Fitbit and will put enough effort in it to make sure he achieves his goals. But someone who is not motivated or interested in staying healthy will not become it by buying such a device: "When I look at myself, if I did not join Harpa I would not be active enough. Now I am due to the obligation and social contact." Patient 3 agreed with patient's 2 opinion.

6.1.3 Conclusion

We can conclude that the overall user interface design of our LiAM application is already quite good although there are still some small but important issues. Besides these small design issues it is maybe important to think about the critical remarks about the system itself that were given and rethink the solution to adjust the solution even better to our patients needs. But for now we will focus on the basic finalisation of our application. The usability issues that we really need to solve are the text size, the graph indications which should be labelled better, making the live measurements selectable to go directly to the detailed history of that sensor, and providing feedback when entering a medication reminder. Besides solving these issues we would also like to finalise the information overlay functionality to test if it is really as useful as we think.

6.2 Design Iteration Second Evaluation

6.2.1 Introduction

Before we started the second iteration, we did some graphical adjustments to meet the users needs even more. The adjustments were: increasing the text size, improving the labelling on the graphs, making the live data icons selectable, and providing feedback when entering a medication reminder. We also added some extra functionality like the overlay information screens and a bottom bar on the home screen to indicate the scroll view better. You can view the comparison of the home screens in figure ??.

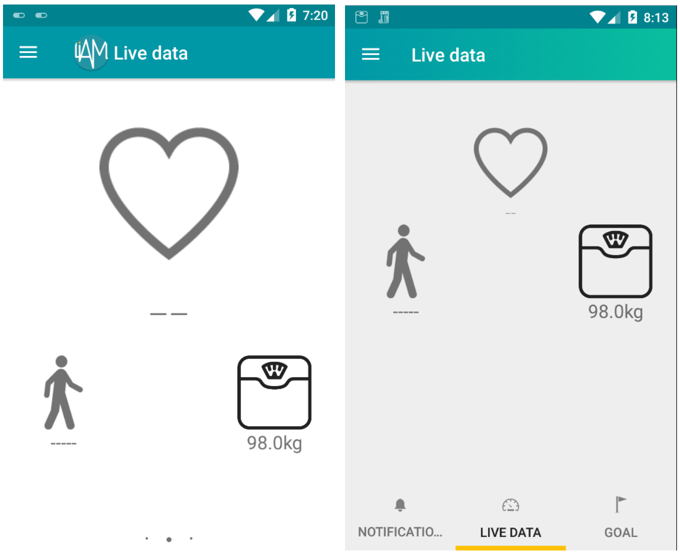

Figure 6.2: Comparison of the home view between two iterations. In the left image is the old design and on the right the new.

For the second evaluation, we have adjusted the task scenarios to be performed. We did this because the structure of the first evaluation was good and resolved a lot of issues. To evaluate the newly added functionality we had to add some task scenarios like, "how do you get extra information?", "how do you add a new device to the application?". In the second section of the interview we added one question about if they thought the information overlay was useful. In appendix A.4 you can view the second evaluation form. We tried to choose different kind of participants this time but we were able to interview only two persons despite the chocolate rewards they would get. We selected subjects that did not own a smartphone.

6.2.2 Evaluation Session

Like indicated in the introduction, we could only interview two persons. This was a bit disappointing as we also wanted to interview at least a woman. The first person that we interviewed was a male of 71 years, he was already a cardiovascular patient for 10 years, had no smartphone but did own a tablet, and he had a university degree. He was a bit conservative and critical in a good way. The second participant was 58 years old, cardiovascular patient for 2,5 years, had no mainstream smartphone but a Blackberry where he checks his mails on, and he also had a university degree. He owned a polar sports watch. He said that he uses the polar website a lot to check his data and that he is even a bit maniacally about it. He sometimes prints his data to show it to his cardiologist or his general practitioner. His general practitioner said that he is mostly interested in his daily activity time. With activity time he means the time one is above the rest heart rates and effectively delivering an effort to get the heart pumping. He was very interested in the concept of our project, he even gave us his mail to send him updates.

The first problem that showed up was with the graphs indication lines. The first patient thought the lines were not very visible and indicated that they should be in another color and in bold. He did understand the meaning of the lines quite fast. The second patient indicated that the lines were clear and easy to understand, however the dates at the top of the weight graph where less clear.

Both participants had trouble with using the swipe functionality on the home and history details screen. This is probably caused by their lack of experience with smartphones. Once we explained how the swiping functionality worked they were convinced that it would be easy to use for normal smartphone users.

A returning issues with the system is the fact that medication reminders are perceived as redundant. Participant one indicated, *"I never forget to take my medication, after ten years it is an automatism for me."*. Participant two replied with, *"A medication box where the days are indicated is the best way to never forget your pills."*. Out of these returning comments we will have to decide either to remove the medi-

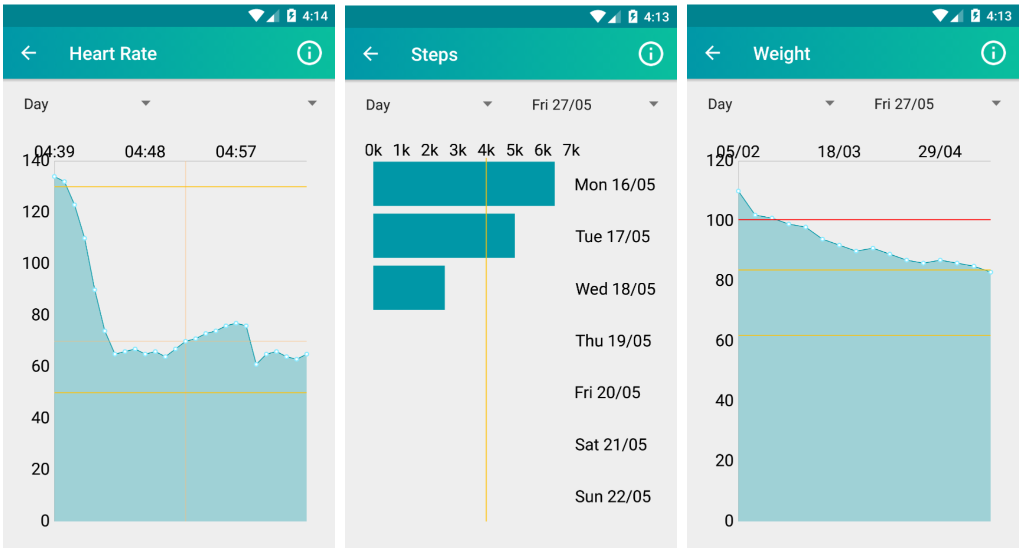

Figure 6.3: First graph shows the heart rate graph with the min, max indication line, the second graph shows the steps with the goal that is outside the boundaries, and the third graph shows the weight with min, max, danger indication line. The text that was next to the indication lines is removed and the indication lines will be explained in the information overlay.

cation reminders or find another way to use them. Maybe we can use the medication page to give the patients an overview of their current medication.

Both gave some good advices about the overall functionality and workings of the system. They indicated that the interaction with the system has to be as minimal as possible; this was also mentioned in the first evaluation. Participant two went further and mentioned the well-known KISS principle, which means "Keep It Simple Stupid". He indicated that we were doing a good job with our application. The weight functionality they both really liked. Participant one has the habit of entering his weight into an excel sheet every day. When he would use the system, it could be easier to visualize and analyse his weight over a certain period. His only remark on the current working of our weight functionality is that he does not want to get a notification to force him to enter his weight, he just wants to enter the value when he decides to do so. He also did not like the concept of getting notifications.

Participant one was also not convinced about the benefit of having a caregiver receiving your data. Once we explained why and how it could benefit him he changed his mind and agreed that it could be useful.

6.2.3 Conclusion

As also concluded from the first evaluation, we will really need to take a closer look at the system of giving medication reminders. The usability issues that resulted from the first evaluation where mostly solved except we still had some extra issues in the visualization of the graphs. The overlay information functionality was received as helpful. New issues we need to solve are the indication lines and overlapping labels with the graphs, making an overlay to explain the swipe, and some small issues like a missing measuring unit when entering the height which made it unclear if it was in meters or centimeters.

6.3 Evaluation Conclusion

We were surprised that we were only able to attract participants with a higher education in our evaluations. This could indicate that less educated people are less interested in such an application.

Besides this fact, we will have to change the medication reminders functionality to something more useful for the users. We will need to do some extra requirement gatherings to search for the right way to use this concept.

From the first evaluation we could conclude that we need to better define our critical success factors and find a way to show the benefits of our application to the potential users.

Many of our patients did not own a smartphone but they owned a tablet. Thus we should also make our application usable on tablets.

For the rest, both evaluations were very positive. Learnability and usability was very high. We could say that we have succeeded in building a good usable platform for elderly with basic functionality. This is supported by the second evaluation with the non smartphone users. However we have to take into account that all participants were highly educated people. If they would be willing to use LiAM in the near future still remains a question. Some of them may be very interested like participant 2 from the second evaluation, but there is a true risk that most of the patients will not be interested unless we really come up with a very strong convincing argument for using the system. This shows that usability and acceptability are both important to consider when developing a new system.

7
Conclusion & Future Work

In section 7.1 we will reflect on the research problem and questions and summarize the work done in the context of this thesis. In section 7.2 you find our ideas for future work.

7.1 Conclusion

In this thesis, we have focused on solving a practical problem *"Design an optimal User Interface for a mobile Android application where Cardiac patients are monitored and activated"*. To achieve a good solution for this question we had to solve three research questions as mentioned in section 1.2. These were all knowledge questions. We were not able to solve each knowledge question completely due to the complexity of human behaviour.

To answer RQ1 (*What are the available applications which perform a similar task as formulated in our practical problem and what are their (design) strengths and weaknesses?*) research was done about the available applications. We reported on this in chapter 2. In this chapter, we also discussed research towards related issues. We could conclude that there were no similar applications available yet, but some of the closely related ones could become similar in the future. In the context of related academic work, we came across two very interesting studies: PATHway (Buys, 2016) and Picasso-TX (Dobbels & Vandenberghe, 2015). Both are focussed on Patient Empowerment. From these two studies we were able to collect some early user requirements and insights in our user base. Some of the important conclusions were the importance of personalisation and the ability to set objectives.

Which brings us directly towards RQ2(*How can we activate and motivate patients in a durable way?*). One of the possibilities to activate and motivate patients on the long term that we investigated was by giving them the possibility to work toward goals. However, in the evaluation it was clear that, due to the difference between humans, this approach would not be acceptable by all users. In section 7.2 we described possible options that could be investigated in the further to solve this question. We do not think that there will be a "one solution solves all" due to the complexity of human behaviour.

To answer RQ3 (*What are the requirements of our stakeholders for such a platform?*) we have done a requirements gathering. The whole process is described in chapter 4. It was not easy to collect the requirements as it concerns a new application which made it hard for the users (patients) to see how such an application could help them in the future. They were also lacking experience with smartphones and smartwatches. In section 4.4 the whole list of (non)functional and usability requirements is provided.

By solving these three questions we were able to solve our main practical problem. We delivered a mobile Android application with the basic functionality as mentioned in the requirements study of section 4.4. We made sure that all this functionality was easy to use and understand. From the evaluations that we performed (and described in chapter 6) we can conclude that the prototype (described in chapter 5) is has a very good usability even for elderly people who have no smartphone of their own. Although we have to nuance this statement because all participants in the evaluations were highly educated.

7.2 Future Work

When starting this work we aimed at building a basic mobile Android application for an elderly audience with a cardiac disease. The two main goals were: easy interaction and basic activation methods. From our evaluation we can tentatively say that we were successful in this respect. The basic functionality was accepted and easy to understand and use.

However for the acceptability of the application itself (i.e. are patients with cardiac diseases prepared to use the application) there is still al lot of work. We need to figure out the best way to optimally reach patients and engage them for a long term. Although we used a user centered development approach, we will need to include the patients even more in the future development of the application. This in order to find the extra functionality that will convince them to use the system. The requirement gathering needs to be done more thoroughly than it is done in the scope of this thesis. With more thoroughly we mean: it should be more focussed on aspects that could enable patient empowerment and activation. But how to achieve patient empowerment and activation is not obvious. This goes beyond the scope of our field; it has a lot to do with psychology. In additions, experiments will be needed to evaluate the possible solutions. A few ideas for future experiments:

- To combine gamification with some social interactions like participating in group challenges, competing against each other. Although the majority of elderly patients will probably not be enthusiastic about this idea.
- To stimulate patients to reach goals by coupling rewards to the achievements of these goals, like giving reduction on healthy food. In this way we could couple an extra business model to our application.
- To use the principle "the simpler the better". Setting simple goals could maybe be the best way to activate patients.
- To let the patient choose between one of the above solutions that fits the most. This is a form of personalization, which may be very important with our users due to the major difference between them.

Another possible solution to the acceptability problem is to integrate it into a whole caregiver approach. By this we mean that caregivers as well as patients should use the system in an integrating way offering benefits to both parties. Some of the patients were open for the idea, others were totally not interested. However, integrating the system into a larger caregiver approach will require a good collaboration with possible caregivers. Actually the problem of acceptability will be transposed to convincing the caregivers instead of the patients.

Furthermore, our evaluation also indicated that some patients really do not like to receive notifications. We will have to remove them or find a better (fun) way that they perceive as less annoying. Some of the possible solutions could be:

- Further optimize the personalization of the notification frequency.
- The patient should be able to set medication reminders without receiving notifications when to take them. Setting the medication reminders are important because we want the responsible caregiver to have an overview of the medication that the patient is currently on.

A
Appendix

A.1 35 Heuristics for Mobile Applications for elderly

Table 1. List of 35 heuristics

O	F	Heuristic Description
Cognition		
H1	H1	Focus on one task at a time instead of requiring the user to actively monitor two or more tasks, and clearly indicate the name and status of the task at all times.
H2	H2	Avoid the use of interaction timeouts and provide ample time to read information.
H3	H3	Avoid the use of animation and fast-moving objects.
H4	H4	Leverage mental models familiar to older adults.
H5	H5	Reduce the demand on working memory by supporting recognition rather than recall.
H6	H6	Aim at creating an aesthetical user interface, by using pictures and/or graphics purposefully and adequately to minimize user interface clutter and avoid extraneous details.
Content		
H7	H7	Give specific and clear instructions and make help and documentation available. Remember that it is better to prevent an error than to recover from it.
H8	H8	Provide clear feedback and when presenting error messages make them simple and easy to follow.
H9	H9	Make sure errors messages are descriptive and use meaningful words and verbs when requiring an action.
H10	H10	Write in a language that is simple, clear and adequate to the audience.
Dexterity		
H11	H11	Avoid pull down menus.
H12	H12	Avoid the use of scrolling.
H13	H13	Enlarge the size of user interface elements in general; targets should be at least 14mm square.
Navigation		
H14	H14	Keep the user interface navigation structure narrow, simple and straightforward.
H15	H15	Use consistent and explicit step-by-step navigation.

Figure A.1: Part one of the 35 heuristics taken from (Silva et al., 2015)

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O	F	Heuristic Description
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H5	H5	Reduce the demand on working memory by supporting recognition rather than recall.
H6	H6	Aim at creating an aesthetical user interface, by using pictures and/or graphics purposefully and adequately to minimize user interface clutter and avoid extraneous details.
Content		
H7	H7	Give specific and clear instructions and make help and documentation available. Remember that it is better to prevent an error than to recover from it.
H8	H8	Provide clear feedback and when presenting error messages make them simple and easy to follow.
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Figure A.2: Part one of the 35 heuristics taken from (Silva et al., 2015)

A.2 User Requirements Survey

Enquête: LiAM = Life Assistant Monitoring

Dit is een anonieme enquête. Het is de bedoeling dat je eerlijk antwoord. Er zal nooit afgeleid kunnen worden welke enquête van wie is. Elke enquête zal een nummer toegewezen krijgen.

Alvast bedankt!

Standaard vragen

Vul aan.

Q1: Ben je een man of een vrouw?

Q2: Hoe oud ben je?

Q3: Hoe lang ben je al een cardiovasculaire patient:

Q4: Wat is jouw niveau van opleiding? Doorstreep wat niet voor jouw van toepassing is:

- lager onderwijs
- middelbaar onderwijs
- hoger onderwijs
- universitair onderwijs

Q5: Heb je een Smartphone?

Als je geen smartphone hebt, ga dan naar vraag Q9.
Als je wel een smartphone hebt, ga dan hier verder.
Q6: Hoe vaak gebruik je je smartphone?

Q7: Welke applicaties gebruik je vaak?

Q8: Welk merk van smartphone heb je?

Q9: Heb je een tablet?

Als je geen tablet hebt, ga dan naar vraag Q11.
Als je wel een tablet hebt, ga dan hier verder.
Q10: Hoe vaak gebruik je je tablet?

Q11: Heb je een laptop of desktop computer?

Q12: Hoe vaak gebruik je je computer?

Q13: Heb je een "wearable" of activiteit volger?

Q14: Zou je zo een "wearable" of activiteit volger willen dragen als je het zou hebben?

Q15: Zou je een mobiele applicatie die je gezondheid opvolgt willen hebben op je smartphone? Als je geen smartphone hebt, zou je daarvoor er wel één aankopen?

Q16: Waarom wel/niet? Wat zou het moeten kunnen?

Q17: Als je dit wel zou willen. Hoe zou je het vinden dat je meldingen krijgt van de applicatie over of je al dan niet gezond leeft?

Q18: Hoe frequent/veel mogen deze reacties/meldingen er zijn? Waarom?

Duid aan hoe nuttig je volgende zaken zou vinden.

	helemaal niet nuttig	Weinig nut	neutraal nuttig	Vrij nuttig	Heel nuttig
Meldingen over hoe actief je bent geweest gedurende de dag					
Directe berichten sturen naar de medisch adviseur					
Doelen instellen in verband met actief zijn doorheen de dag (bv. 2000 stappen per dag)					
Meldingen als je je doelen niet haalt					
Je activiteiten in een grafisch overzicht kunnen opvolgen					

A.3 First Formative Evaluation

Evaluatie LiAM = Life Assistant Monitoring

Dit is een **anonieme** evaluatie van onze applicatie. Het is de bedoeling dat je **eerlijk en kritisch antwoordt**. Alvast bedankt!

Standaard vragen

Vul aan of duid aan:

- Geslacht? Man / Vrouw
- Leeftijd?
- Hoe lang bent u al een Cardiovasculaire patient?
- Heeft u een smartphone? Ja / Nee
- Niveau van opleiding: Lager/Middelbaar/Hogeschool/Universiteit

Stappen van de Evaluatie

U zal een korte uitleg krijgen over de LiAM applicatie vooraleer de evaluatie begint. Deze uitleg kan u ook nog eens lezen op dit evaluatie formulier. Nadat u deze uitleg gekregen hebt zal u de applicatie eerst een 5-tal minuutjes mogen uitproberen. Als de 5 minuten om zijn zal u enkele taken moeten uitvoeren terwijl u hardop praat over wat u ziet of doet. Van zodra deze taken uitgevoerd zijn zal u gevraagd worden om enkele vragen te beantwoorden gevolgd door een kort interview.

Het hele proces duurt hoogstens een half uurtje.

Korte applicatie beschrijving: LiAM = Life Assistant Monitoring

De applicatie bestaat uit 3 delen. Meten, analyseren, en communiceren.

Het meten gebeurt aan de hand van draagbare technologie zoals een slimme horloge of een slimme weegschaal. Met deze toestellen kunnen er enkele parameters zoals hartslag, aantal stappen, activiteit, gewicht, etc. gemeten worden.

Het analyse gedeelte bestaat uit de grafische weergave van de gemeten parameters. In deze weergave kan men zelf de gemeten waarden bekijken en controleren.

Het communicatie gedeelte bestaat uit adviezen, medicatie herinneringen, doelen, en vragen.

1. Taken scenario's

Tijdens deze taken is het de bedoeling dat u **luidop bespreekt** met de interviewer wat je nu precies allemaal doet en waarom. Geef ook elke taak een **score** voor het **uitvoeren**. Moeilijk of vervelend uit te voeren = 1, makkelijk en leuk uitvoerbaar = 5.

1. Inloggen (score: …)

Probeer in te loggen met volgende gegevens:

- Gebruikersnaam: "je voornaam" (vb. Jos)
- Wachtwoord: "password"

2. Bespreek (score: …)

- Wat je waarneemt op het beginscherm. Icoontjes? Wat betekenen ze?
- Hoe je nu verder moet navigeren

3. Navigeer (score: …)

- Navigeer naar je meetgeschiedenis in zo weinig mogelijk stappen vanaf het beginscherm.
- Navigeer naar je dagelijkse doel in zo weinig mogelijk stappen.
- Navigeer naar je notificaties/meldingen in zo weinig mogelijk stappen vanaf het beginscherm.

4. Instellingen (score: …)

Personaliseer volgende instellingen naar jouw eisen:

- Stappen per dag
- Hoogte
- Notifications

5. Medicatie herinnering toevoegen (score: …)

Probeer volgende medicatie herinnering toe te voegen.

- Medicatienaam: Dafalgan
- Inneem tijdstip: 18u

6. Advies (score: …)

Lees een advies en vertel wat het wil zeggen.

7. Meet Geschiedenis (score: …)

Verklaar wat je ziet op de meetgeschiedenis van het aantal stappen. Wat versta je onder de verticale lijn?
Doe dit ook kort voor de hartslag en gewicht.

2. Algemene vragen + interview

Duid aan in welke mate u akkoord gaat met het gestelde.
Volledig niet akkoord = 1 en volledig akkoord = 5.

	1	2	3	4	5
De icoontjes waren duidelijk en ik begreep ze meteen					
Ik moest niet veel onthouden om een taak uit te voeren					
Ik begreep alles en vond het taalgebruik duidelijk.					
De foutmeldingen waren zeer duidelijk en ik wist wat ik verder moest doen.					
Ik kon vlot werken met het menu					
De feedback bij het invullen van een waarde was duidelijk					
Ik begreep de “swipe” op de hoofdpagina					
Ik begreep de “swipe op de geschiedenis pagina					
Ik begreep de werking van de applicatie direct					

Hartelijk bedankt!

A.4 Second Formative Evaluation

Evaluatie LiAM = Life Assistant Monitoring

Dit is een **anonieme** evaluatie van onze applicatie. Het is de bedoeling dat je **eerlijk en kritisch antwoordt**. Alvast bedankt!

Standaard vragen

Vul aan of duid aan:

- Geslacht? Man / Vrouw
- Leeftijd?
- Hoe lang bent u al een Cardiovasculaire patient?
- Heeft u een smartphone? Ja / Nee
- Niveau van opleiding: Lager/Middelbaar/Hogeschool/Universiteit

Stappen van de Evaluatie

U zal een korte uitleg krijgen over de LiAM applicatie vooraleer de evaluatie begint. Deze uitleg kan u ook nog eens lezen op dit evaluatie formulier. Nadat u deze uitleg gekregen hebt zal u de applicatie eerst een 5-tal minuutjes mogen uitproberen. Als de 5 minuten om zijn zal u enkele taken moeten uitvoeren terwijl u hardop praat over wat u ziet of doet. Van zodra deze taken uitgevoerd zijn zal u gevraagd worden om enkele vragen te beantwoorden gevolgd door een kort interview.

Het hele proces duurt hoogstens een half uurtje.

Korte applicatie beschrijving: LiAM = Life Assistant Monitoring

De applicatie bestaat uit 3 delen. Meten, analyseren, en communiceren.

Het meten gebeurt aan de hand van draagbare technologie zoals een slimme horloge of een slimme weegschaal. Met deze toestellen kunnen er enkele parameters zoals hartslag, aantal stappen, activiteit, gewicht, etc. gemeten worden.

Het analyse gedeelte bestaat uit de grafische weergave van de gemeten parameters. In deze weergave kan men zelf de gemeten waarden bekijken en controleren.

Het communicatie gedeelte bestaat uit adviezen, medicatie herinneringen, doelen, en vragen.

1. Taken scenario's

Tijdens deze taken is het de bedoeling dat u **luidop bespreekt** met de interviewer wat je nu precies allemaal doet en waarom. Geef ook elke taak een **score** voor het **uitvoeren**. Moeilijk of vervelend uit te voeren = 1, makkelijk en leuk uitvoerbaar = 5.

1. Login (score: …)

Probeer in te loggen met volgende gegevens:

Gebruikersnaam: "UwNaam" (bv. Jos)
Wachtwoord: "password"

2. Apparaten (score: …)

Voeg de microsoft band toe bij apparaten.

3. Zoek

Hoe verkrijg je extra informatie over het hoofdscherm?

4. Bespreek (score: …)

- Wat je waarneemt op het beginscherm. Icoontjes? Wat betekenen ze?
- Hoe je nu verder moet navigeren
- Hoe zie je dat een melding nog niet gelezen is?

5. Navigeer (score: …) (Noteer het aantal stappen achter de zin)

- Navigeer naar je meetgeschiedenis in zo weinig mogelijk stappen vanaf het beginscherm. (aantal stappen = …)
- Navigeer naar je dagelijkse doel in zo weinig mogelijk stappen. (aantal stappen = …)
- Navigeer naar je adviezen in zo weinig mogelijk stappen vanaf het beginscherm. (aantal stappen = …)

6. Instellingen (score: …)

Personaliseer volgende instellingen naar jouw eisen:

- Stappen per dag
- Hoogte
- Meldingen
- Heart Rate

7. Medicatie herinnering toevoegen (score: …)

Probeer volgende medicatie herinnering toe te voegen.

- Medicatienaam: "Dafalgan"
- Inneem tijdstip: 18u

8. Meet Geschiedenis (score: …)

Verklaar wat je ziet op de meetgeschiedenis van het aantal stappen. Wat versta je onder de verticale lijn?
Doe dit ook kort voor de hartslag en gewicht.

2. Algemene vragen + interview

Duid aan in welke mate u akkoord gaat met het gestelde.
Volledig niet akkoord = 1 en volledig akkoord = 5.

	1	2	3	4	5
De icoontjes waren duidelijk en ik begreep ze meteen					
Ik moest niet veel onthouden om een taak uit te voeren					
Ik begreep alles en vond het taalgebruik duidelijk.					
De foutmeldingen waren zeer duidelijk en ik wist wat ik verder moest doen.					
Ik kon vlot werken met het menu					
De feedback bij het invullen van een waarde was duidelijk					
Ik begreep de "swipe" op de hoofdpagina					
Ik begreep de "swipe op de geschiedenis pagina					
Ik begreep de werking van de applicatie direct					
De extra informatie bij de schermen vond ik zeer nuttig					

Hartelijk bedankt!

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