Personalization in treatment of Parkinson's disease

Using smartwatches to enable personalization and patient-centeredness in treatment of Parkinson's disease

Master's thesis in Interaction Design & Technologies

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Cover:

The prototyped system for enabling personalization in Parkinson's disease treatment.

Abstract

The project was performed in collaboration with Semcon in Gothenburg. The task from Semcon was to optimize Parkinson's disease (PD) treatment and relieve health care staff by helping them account for the individual variations of the disease, which can differ greatly from patient to patient. PD patients see their neurologist very rarely, which poses a risk of receiving unsuitable regimens. This thesis presents a solution to this problem in the form of a prototype consisting of an Android app for smartwatch and smartphone, which enables patients to effortlessly note down their symptoms and moment of medication. The prototype also allows the patients to execute a gait test which produces a numeric result as an indicator of their condition.

The process of designing and developing this prototype was conducted through an iterative design process. At first, the goal was to continuously monitor PD tremors. Upon a discussion with a subject matter expert, the focus was shifted toward a system that can test a PD patient's gait. One of the reasons behind this change was that gait impairment is poorly recognized in research as there is a tendency to focus on tremors. Thus, this project may help in shedding some light on this issue.

Two user tests were performed during the project. The user tests suggested that the gait test is a reliable tool for measuring PD condition. In conclusion, it was recognized that both physical and mental aspects must be in consideration for the system to enable personalization.

Keywords: Parkinson's disease, PD, smartwatch, smartphone, gait, patient centered care, personalization

Acknowledgements

Abbreviations

PD Parkinson's disease

SME Subject matter experts

UCD User centered design

ACD Activity centered design

GDD Goal directed design

HCD Human centered design

Content

1 Introduction

Parkinson's disease (PD) is the second most common chronic neurodegenerative disorder after Alzheimer's disease. Symptoms, which slowly grows over time, includes shaking, slowness of movement and walking difficulty. The incidence of PD rises with age and it is estimated to affect 1% of all 70-year-olds. It is also seen in younger people with 10% of the cases occurring before the age of 50 (Chaudhuri, Clough & Sethi, 2011). One of the primary challenges in treating PD is that the condition progresses uniquely in each individual case.

Currently, there is no official, quantitative way to assess PD progression (Gravitz, 2016). Usually, patients visit their neurologists monthly to determine where they fall on the UPDRS - a well-established scale for assessing PD patients. Although valuable, the UPDRS is labour intensive and must be administered by a neurologist. Also, the results depend on the condition of the patients at the moment of evaluation. Due to these shortcomings, patients may receive unsuitable regimens.

Currently, management of PD does not reach its full potential because there is a lack of knowledge regarding each patient's individual variation. One might say there is an urge to personalize today's treatments. To solve this problem, some researchers suggest monitoring using sensor-packed devices (Silva de Lima, 2016). Many physicians seek reliable systems to perform this kind of monitoring. Smart devices, such as smartwatches, have been suggested as good candidates (Gravitz, 2016).

In recent years, smartwatches have become more pervasive and their sensors more advanced. They can follow the user throughout the whole day, listening to input from the user as well as storing information about their behaviour. For example, a microphone can be used to capture voice, an accelerometer can capture movement and a touch screen can sense finger tapping. For a PD patient, such data may be used to evaluate the effectiveness of a new therapy, test if an old therapy is still effective or if the treatment should change.

By gathering clinically relevant data about their own behaviour, patients are taking a greater role in their own treatment. This has been shown to increase satisfaction and improve treatment outcomes, especially in chronic diseases (Höglund et al., 2010). Furthermore, patient participation also leads to greater belief in their own ability to complete a task, which may hasten rehabilitation processes and overall increase quality of life (Heisler et al., 2002).

This report documents the work of a master degree project from the Interaction Design and Technologies programme at Chalmers University of Technology. The thesis explores the use of smart devices in treatment of PD. Specifically, the aim is to design and develop an interactive, smartwatch-based system that enables personalization and patient centeredness in PD treatments.

1.1 Stakeholders

Stakeholders are defined as people or institutions that either affect or are affected by the result of this thesis. The stakeholders are presented below.

1.1.1 PD patients

The focus of this master's thesis is on PD patients, therefore strong consideration of this group is important.

1.1.2 Health care personnel

Since the system that will be presented in this report is geared towards healthcare, it is important to consider any health care personnel.

1.1.3 Semcon

Employees at Semcon initiated this thesis. They will provide guidance along with the appropriate tools and hardware. Semcon is an international product-development company with offices located across the world. At the moment, Semcon focuses heavily on developing products with human behaviour in mind.

1.1.4 Chalmers University of Technologies

Chalmers (University of Technologies) provided the opportunity for this thesis and will provide academic consultation. Also, Chalmers has standards of quality for the report, which must be fulfilled.

1.1.5 Thesis authors

The thesis is performed by two students in their last semester of their study in Interaction Design and Technologies at Chalmers. Their background is in software engineering and computer science.

1.2 Purpose

Diagnosing PD is challenging and current methods are arguably unreliable (Gravitz, 2016). To get maximum benefit with minimized side-effects it is important that the treatment is adapted to the patient's needs, i.e. personalized. Researchers have shown that monitoring of bodily movements using smartwatches can be used to increase assessment accuracy (Sharma et al., 2014). In addition, patient-centered care and patient participation are both powerful tools in health care services (Heisler et al., 2002; Hibbard et al., 2007; Höglund et al., 2010; Epstein & Street, 2011; Weingart et al., 2011).

There are some PD patients that take responsibility in making sure their regimen is having the intended effect by manually recording their condition and medicine intake. In lack of more convenient options, some of these people use digital spreadsheets for noting down their status and medicine intake. This project seeks to expand on this concept by merging it with the findings presented in the previous paragraph. Thus, the aim of the thesis is to design a smartwatch-based system in which the patient can gather clinically relevant data about their treatment and condition. This includes data gathered from the smartwatch's built-in sensors, such as the accelerometer and gyroscope. The purpose can be summarized in the question below.

1.2.1 Research question

What features should an interactive system, consisting of a smartwatch, have to enable personalization and patient-centeredness in treatment of people with Parkinson's disease?

1.2.1.1 Contribution

The overarching aim is to contribute with a proof of concept which can show the potentiality in applied technology within healthcare, or the lack thereof.

1.2.2 Goals

The goal is to optimize PD treatment and relieve health care staff by helping them account for the individual variations of the disease, which can differ greatly from patient to patient.

1.2.3 Deliverables

The research question will be explored by implementing and practically testing a prototype app for smartwatches that functions as a data gathering tool for patients with PD. This includes the tracking of bodily movement using the smartwatch's built-in sensors. The prototype will also include means of displaying the data, which must fulfil adequate standards. In order to properly answer the research question, much effort will be on identifying features that specifically enable personalization and patient-centeredness. The prototype will also use a simple database so the gathered data can be stored and accessed remotely. Thus, the database is also part of the prototype.

1.3 Delimitations

In order to function properly, the prototype of this project will have to manage a flow of data. Roughly, this flow can be divided into three phases: gathering, processing and outputting (or displaying) of data. Due to the large scope of the research question, this project put its focus on the two ends of this stream, namely gathering and outputting. In other words, the project will not explore approaches in the field of data processing. For example, machine learning algorithms will not be featured or discussed. To an extent, this delimitation also applies to the output of data. The project will not include any research on information visualisation or discuss ways of displaying motion data. Instead, most of our work will revolve around the patient-side of the system. This means we will concentrate on data gathering and how the data can enable personalization and patient-centeredness. Other users, such as physicians and neurologists, will not be the primary focus.

Since the result is a proof of concept, no real dosage of medication will be suggested or administered to any patient. Lastly, there will be no effort to implement a fully featured backend. However, the structure of the backend will be created and there will be some user data stored from one or two test subjects.

1.4 Ethical issues

Since the project will involve PD patients, the need for ethical consideration is important. If the system will be tested on real PD patients, people involved may be required to give a written consent agreeing to take part in the project. The students themselves may also be required to sign a confidentiality agreement, assuring the participants are made anonymous in the documentation. Finally, the students of the master programme, together with representatives from Semcon, will have to come to an agreement regarding any principles of confidentiality within the company.

One ethical issue that can arise is that people that are being passively monitored can find it stressful. This issue was recorded by Berridge (2015), who conducted some tests by passively monitoring older individuals for triggering social alarms. Berridge revealed three insights. First, assumption, built into the system presented a problem for many who experienced unwanted disruptions. For example, the alarm could be set off unintendedly. Second, some participants employed strategies to satisfy the sensors, because the

participant was afraid that the system would give off false alarms. Thirdly, there was a mismatch between the priorities of the participants and those reflected in the monitoring system.

2 Background

The first step in this project is to understand the characteristics of PD. A review of health articles, literature, publication and PD related research allowed for the identification of the most common symptoms and challenges. This chapter gives context to the problem domain and presents a summarized description of PD and its treatment. It also deals with wearables and their appearance in research. Since the use of smartwatches in PD treatment is a relatively new domain, we have chosen to look at some findings from similar fields.

2.1 Parkinson's disease

In the human body, dopamine functions as a transmitter to send signals to nerve cells in order to accomplish bodily movement. After the discovery of dopamine deficiency within PD patients, the first effective treatment was developed - dopamine-replacement therapy. Since then, much research has been done to further understand the nature of the disease.

2.1.1 Clinical features

The most common symptoms of PD are bradykinesia, tremor, rigidity, postural and gait impairment (Nunes et al., 2016).

Bradykinesia is characterized by slowness of movement speed and amplitude. A person suffering from bradykinetic symptoms may experience problems with small movements, such as buttoning a shirt. Other signs of bradykinesia include characteristic facial impassivity and speech which may become quiet and monotonous (Chaudhuri, Clough & Sethi, 2011).

Tremor is rhythmic and involuntary movement of body parts as a result of muscle contractions. Parkinsonian tremor is usually present at rest and is often asymmetric (meaning the tremor symptoms are not equally distributed in the body). In contrary to what is commonly believed, tremor as a result of PD must not affect the execution of fine motor tasks. Instead, body motion may be cramped and executed in a subdued manner.

Gait (i.e. the locomotion achieved through the movement of limbs) is often affected with difficulty initializing movement and dragging steps. Walking may also be rushed with sudden stops. These moment of freezing are often provoked by anxiety or visual stimuli. Many patients develop tricks to overcome these freezing moments, such as marching to a rhythm. Relating to gait, another common motor dysfunction in later stages of PD is decreased arm swing during walk. In 2010, Lewek et al. found that arm swing asymmetry is noticeable even in early stages of PD and that a quantitative evaluation of arm swing may be used for tracking PD progression.

Rigidity consists of an increased resistance to the movement of a limb and occurs throughout the whole movement. As an effect of rigidity, turning around and getting up from a chair becomes more challenging. In addition to making bodily movement harder to perform, rigidity causes stiffness, which in turn may cause pain.

Bent posture and **postural imbalance** are also signs of PD, especially in more progressed cases. Bending limbs, such the knees, may lead to toe walking and bent posture. When the arms are brought forward, some PD patients urge to bend their neck and trunk.

The conditions mentioned above are common features in PD cases. However, it is important to note that each PD patient experience different symptoms. For example, studies have shown that tremor affects 70% (Chaudhuri, Clough & Sethi, 2011). In addition, the disease

progresses individually and there is no certain method of determining the speed of progress. At first, the symptoms are rarely noticed by the patients themselves. Instead, family or close friends are often the first to notice signs of the disease (Lees, Hardy & Revesz, 2009). Finally, the symptoms themselves can be inconsistent and may vary drastically, even in a matter of hours, depending on the state of the patient (Gravitz, 2016).

2.1.2 Non-motor symptoms

Recently, non-motor symptoms have emerged as the most important factor in determining the condition of the patient. These symptoms include dementia, depression, sleep disorders, bowel and bladder problems, fatigue, apathy, pain and autonomic dysfunction. Non-motor symptoms are common and can occur at all stages of the disease. As there is a tendency to concentrate on motor symptoms, non-motor-symptoms have been poorly recognized. This also applies when determining the economic burden of the disease. Symptoms, such as dementia, have a major impact on the cost of illness (Chaudhuri, Clough & Sethi, 2011). In Sweden alone, the annual cost in patients with PD were 1.7 billion SEK in 2009 (Lökk et al., 2012).

2.1.3 Parkinsonism

The main symptoms of PD are also the symptoms of conditions that are grouped together under the term parkinsonism (Parkinson's UK, 2017). Due to their complex nature, the differences between conditions may seem somewhat obscure for the inexperienced reader. In addition, researchers are still unsure about how the different conditions relates to each other (Louis, 2014). The following is a list of some of the most well documented ones.

Idiopathic Parkinson's disease, typically referred to as simply Parkinson's, is the most common condition. Its symptoms include tremor, rigidity and slowness. Idiopathic means the cause is unknown (Chaudhuri, Clough & Sethi, 2011).

Dementia with Lewy bodies is the third most common dementia and people afflicted often suffer from hallucination and PD related symptoms such as slowness and tremors. Since Lewy bodies exist in both cases (Dementia with Lewy bodies and Parkinson's disease), as well as Alzheimer's disease, they can be hard to distinguish and some researcher suggest that they belong to a general neurodegenerative disease (Alzheimer's association, 2017).

Drug-induced parkinsonism is a PD-like disorder that has developed following the treatment of dopamine-blocking agents. If medication stops, most people recovers within months (Parkinson's UK, 2017).

Essential tremor is, similar to PD, a disorder affecting bodily movement. Main symptoms include action tremor, i.e. shaking while performing a movement. Compared to PD, tremor due essential tremor has slightly lower amplitude. Also, essential tremor is much more common (Harvard Health, 2017). Studies show that PD and essential tremors overlap, meaning a person can suffer from both conditions simultaneously.

2.1.4 Epidemiology

Estimating prevalence of PD is problematic as diagnosing can be difficult. According to recent studies, PD affects roughly 10 million people worldwide (Parkinson's Disease Foundation, 2017) and as our population ages, the number of patients is expected to grow. As previously stated, PD is more frequent in old age. Evidence points toward an increased

mortality in the older age, meaning the longer people live with PD, the higher the mortality rate.

2.1.5 Diagnosis

Since PD was first described almost 200 years ago, determining the cause has been problematic. It remains of great importance to properly measure the patient's condition in order to optimize medication and minimize side-effects. Unfortunately, there are yet no specific tests for the diagnosis of PD. The response to dopaminergic agents, such as levodopa, has been used as a diagnostic test for PD (Parkinson's Disease Foundation, 2017). A patient with idiopathic PD typically shows a significant response to dopaminergic agents (Chaudhuri, Clough & Sethi 2011). However, according to Chaudhuri, Clough & Sethi (2011), a diagnosis can only be made with full certainty if Lewy bodies are found in the brain. (Lewy bodies are proteins known to cause parkinsonian symptoms.) In practice, such procedures are only possible post mortem. Brain imaging is generally not used to diagnose PD, but may help to rule out other causes such as tumors or vascular disease.

Postural imbalance can be detected by a simple pull test. The patient receives a quick, backward pull at the front of the shoulders. People with parkinsonian symptoms usually stumble without any self-correction, leading to a fall "in one piece". This also shows how PD patients are exposed to dangerous falls at home. Parkinsonian rigidity is detected by moving the body part slowly and gently. There are two types of rigidity that can be identified with PD. Cogwheel rigidity is a tremor-like, clicking resistance and lead-pipe rigidity is a sustained resistance to the whole range of motion.

2.1.5.1 Unified parkinson's disease rating scale

There are multiple scales for quantifying motor-symptoms of PD. One that is well established is the Unified Parkinson's Disease Rating Scale (UPDRS) (Jankovic, 2008). It is considered to be a universal test that may be used by neurologists worldwide to assess tremor, rigidity and gait (Gravitz, 2016). UPDRS consists of four subscales (Perlmutter, 2009). The first assesses behavioral problems, such as intellectual decline and depression. The second assesses the patient's ability to carry out everyday tasks such as getting dressed and getting out of a chair. The third part covers the motor skills of a patient, the fourth and last part covers treatment complications, painful cramps and irregular medication responses.

Although the UPDRS was not developed for diagnostic use, it has been applied for screening parkinsonism. In some studies, and commercial products (Gravitz, 2016), the UPDRS is used to facilitate "data mining". When gathering data about a patient's condition, one of the main problems is to properly handle the huge number of recordings. Rather than trying to pick out the most important segments, it is preferable to figure out what you are looking for before analyzation. The quantities from the UPDRS can be used as a point of reference to identify specific moments in the recordings and build algorithms using these quantities. In fact, the scale may be applied for identifying non-parkinsonian conditions, such as the effects of a stroke.

Other scales for evaluating PD condition includes the Hoehn and Yahr rating scale and Schwab and England ADL scale. The Hoehn and Yahr was first described in 1967 and is a simple staging method from 0-5 which is commonly used to compare groups of patients and provide gross assessment. The Schwab and England scale is a so called 'activity of daily living' scale (or ADL scale) used to provide a general estimate of the patient's ability to function in everyday activities.

2.1.6 Treatment

Despite ongoing research, PD is still an incurable disease with treatments that solely aim to improve quality of life. Silva de Lima et al. (2016) argued that management of PD treatment seldom reach its full potential because information on individual variations is lacking. With lacking data, it becomes impossible to tailor the care according to the patient's needs.

Typically, a patient with idiopathic PD shows a significant response to dopaminergic agents. These, in combination with an inhibitor, is widely seen as the most effective therapy today. However, treatment of non-motor symptoms is also important at all stages of the disease and do not respond well to dopaminergic therapy. According to Chaudhuri, Clough & Sethi (2011), decisions in treatment should be based on patient needs, disease progression, age and patient preferences.

2.1.6.1 Complications

As PD progresses within a patient and treatment continues, treatment-related complications may develop. Typically, the effects of the therapy wear off which means shorter duration of response. Patients are considered 'ON' or 'OFF', which refers to the duration when medication is working (ON) and when effects disappear (OFF) (Nunes et al., 2016). Although levodopa is generally well tolerated (Lees, Hardy & Revesz, 2009), in the span of 2-5 years, about 50% of the patients under standard therapy will develop dyskinesia (Chaudhuri, Clough & Sethi 2011). Dyskinesia is characterized by spasmodic movements, repetitive motions and lack of coordination. This means it is important to ensure the diagnosis is as accurate as possible and levodopa therapy should be started at the minimal effective dose. Direct side effects, such as lightheadedness or nausea, may be relieved by taking the medication with food or increasing the dose of inhibitors.

2.1.6.2 General care and support

There are some aspects of PD that is not very emphasized in research, but may have a considerable effect on the wellbeing of the PD patient. Early in the course of the disease, patients commonly need good source of information, advice and counseling. Patients should be encouraged to eat plenty of fruit and vegetables to stimulate a sluggish bowel. Skin problems, as well as problems relating to urination, sleep and sex, are also common and need to be addressed.

2.1.7 Computer interaction

A small, quantitative study, performed by Hartikainen & Ovaska (2015) looked at how people with PD experience their everyday computer use and how they overcome some of their challenges. In summary, the findings confirmed that there is a lack of information on available, assistive technologies for PD patients. The result also showed that the PD patients felt responsible to cope with the interaction with ordinary devices, i.e. adapt to the regular way of usage. It was stated that the special condition of PD, and how it affects interaction with technology, is not well understood and more information and recommendation to the public is needed. Finally, the researchers emphasized the challenges of advising a PD patient, since the individual condition can vary significantly.

2.2 About smartwatches

Today, the smartwatch is the most popular wearable device. Although one can argue as to why, some suggest it due to our history of mechanical watches, which has been a fashion statement for centuries. In today's market, many different technology manufactures are making their own smartwatch and there is an abundance of models to choose from.

Seeing the inflexibilities in today's method of assessing PD patients, some people mean that there is much to learn from continuously monitoring the patient's condition and behaviour (Gravitz, 2016). Smartwatches are suggested as good candidates for this type of data gathering. From a technical standpoint, smartwatches have advanced significantly over the last few year and the sensors they carry have become more accurate. Recent models of smartwatches include sophisticated '9-axis' accelerometer, meaning they have built in magnetometers which greatly enhances the accuracy of the accelerometer. In addition, advancements in battery technology mean smartwatches are capable of following the user throughout the whole day. Finally, most smartwatches are designed to work in synergy with other smart devices, making them a flexible tool.

2.2.1 Wearable devices

Wearable devices are consumer electronics technology based on embedded computer hardware that is worn on the outside of the body (Jackson, 2015). These includes some 'smart' devices such as smart glasses and bracelets as well as smartwatches.

2.3 Previous work

This section presents a mix of researches and studies that in some way relate to wearable devices in PD treatment. Monitoring patients in this way is a fairly new research domain, especially with smartwatches. Therefore, some of the studies presented below may superficially seem to be off topic.

2.3.1 Wearable motion-sensors

In 2014, Wile et al. sought to differentiate postural tremor of PD from essential tremor using accelerometers in smartwatches. Short recordings were used with the participants hands at rest and outstretched. Building on previous research, 80% of the participant were correctly classified as having PD or essential tremors and it was concluded that a smartwatch can in fact provide diagnostically relevant information about postural tremor. The advantage of using smartwatches, as stated by the researchers, is its non-invasiveness, portability and ease of use, which could move the method into routinely checks. Finally, the researchers suggest that smartwatches may be of use for monitoring therapy, including using remote wireless transmission of data from home environments.

Sprung from difficulty in maintaining personalized regimens for PD patients, Sharma et al. (2014) developed SPARK, a modular framework that uses a combination of smartwatch and smartphone technology to monitor different symptoms of PD such as facial tremors, impaired speech, dyskinesia and problems with gait. It is built on the advances in clinical practice, wearable technologies, mobile computing, machine learning and pervasive healthcare. Since it allows telerehabilitation, their work stretches to non-clinical settings. According to their paper, the SPARK framework showed promising results.

Contreras et al. (2016) presented a system which uses sensors in smartwatches (accelerometer and gyroscope) to quantify tremors in PD patients. The system consists of multiple sensor nodes and one sink node. It was tested on twelve patients that were seated and at rest. In the article, the tremor magnitude is presented in the form of linear acceleration and angular velocity. In summary, the results showed that the system was capable of determining the progress of the disease. As highlighted by the paper, a good reason for using sensors inside smartwatches is the fact that they do not disrupt the patient's daily life (Contreras et al., 2016). The software can run in the background, requiring very little input from the user.

Weiss et al. (2016) highlighted smartwatches' wide range of possible uses by identifying hand-based activities such as eating and drinking. They also compared their finding with smartphone-based activity recognition, pointing out that there is a difference in accuracy. There have been studies with smartphones for this purpose, since they also use built-in accelerometers and gyroscopes. However, the issue with smartphones is that they are not worn consistently in one place. Smartwatches are different in that regard because they are worn consistently on the wrist.

2.3.2 Voice capture

As many people with PD suffer from voice and speech disorders, speech-language pathologists prescribe home exercises to enhance speech strategies outside the clinic room. However, PD patients often struggle to follow the exercises once they are home. Abtahi et al. (2016) developed a smartwatch-based system to remotely monitor compliance of the home-based exercises for speech and voice. A small study was conducted, which showed promising outcomes for the system.

2.3.3 Auditory help

It has been showed that marching to rhythms can help PD patients initiate movement. However, few products exist that builds upon this principle. Lopez et al. (2014) analyzed the effect of a portable auditory system, called 'Listenmee', comprising of a special pair of eyeglasses and a smartphone. From tests performed on patients with idiopathic PD, the results revealed significant improvements in gait performance. In conclusion, the authors stressed the need for further studies on portable devices in treatment of PD.

2.3.4 Acceptability of wrist-worn devices

Fisher et al. (2016) performed a small study in the acceptability of body-worn sensors in PD treatment. Thirty-four participants wore two wrist-worn sensors (similar to a smartwatch), one on each hand, for four hours in a research facility and then for one week at home. Prolonged wearing produced a negative view on the comfort of the sensor, although acceptable. Problems with the strap were highlighted. However, accelerometer data proved useful in decision-making about treatment and there was no sign that the participant were less likely to wear the wristband in public.

Wu, LH., Wu, LC. and Chang (2016) performed a study on the general acceptance of smartwatches in consumers, arguing that the identification of such factors can improve user-centered design. The study explored the views of the consumers by applying various user acceptance models, such as the technology acceptance model (TAM). Unlike previous research in the same field, gender proved to have no significant effect. In conclusion, the

results showed that smartwatches are generally well received and are not considered intrusive on everyday activities.

In a similar study, Choi and Kim (2016) looked at the factors affecting the intentions in using smartwatches in everyday life. They acknowledge that the smartwatch is a convergence point of fashion and IT. The findings from 562 respondents showed that the need for uniqueness was a critical indicator of how much one would perceive smartwatches to be enjoyable and useful for expressing oneself. As an IT innovation, results indicated that more innovative people perceived smartwatches as relatively easy to use.

2.3.5 Apps and other commercial products

There are multiple smartphone apps that are meant to gather data on PD patient condition. One of the most well-spreaded apps is mPower, which is an experiment made by a non-for-profit research organization (mPower Mobile Parkinson Disease Study, 2017). The app uses a mix of tasks that activate sensors in the phone to track PD symptoms. For example, tasks include tapping the screen, holding the phone in an outstretched arm or put it in a pocket and walk across the room.

mPower was developed to objectively measure PD symptoms on a daily basis over a long period of time. This results in a huge amount of data that researchers can sift through to improve understanding of different variations of PD and to learn whether sensors in mobile devices can help in assessment of patients. Also, this means the app can provide a long-term view of the progression of the disease, which is a feature that has proved to provide comfort to some patients (Gravitz, 2016). mPower is free but before people can use it they need to consent to some conditions and allow their data to be sent back for analysis.

Great Lakes NeuroTechnologies in Cleveland is a company that develops bioinstrumentation products (Great Lakes NeuroTechnologies, 2017). One of their divisions, "Kinesia: Parkinsons Assessment", focuses on wearable, sensor-packed devices and apps that are dedicated to track the symptoms of PD. Their product line includes Kinesia ONE and Kinesia 360. Both systems measure tremor, dyskinesia and mobility. Compared to Kinesia 360, Kinesia ONE is more lightweight. It uses a sensor that is worn on the finger and transmits motion data wirelessly to another device using bluetooth. The data is being gathered while the user performs different test, such as holding the arm outstretched in front of the body. Kinesia 360, on the other hand, uses multiple wearable sensors and a mobile application to continuously measure PD symptoms during the whole day (from when the user wakes up until just before bed). The system also comes with sophisticated software to help the user document their condition. With these extra features, Kinesia 360 is the more 'premium' option of the two products.

Each product (both Kinesia 360 and Kinesia ONE) comes with a complete kit to help the user get started. For example, the Kinesia ONE kit comes with an iPad mini preloaded with an app, a wearable sensor and a how-to guide. The data from both setups is transmitted to the cloud via WiFi in a secure manner. Physician and researcher can access the data by logging the Kinesia web portal. The data provides objective "scores" for PD symptoms over the course of the day. Symptoms scores are calculated by clinically validated algorithms. Color coding of symptom severity allows easy review of daily fluctuations.

There are a couple of start-up projects that are similar in spirit as the Kinesia 360 and Kinesia ONE. One of those project is a wearable called Trequant, which aims to help PD afflicted understand and analyse their condition (Health Unit, 2016). It records the user tremors, reminds about medication and provide detailed insights about how their activities

and diet affect their tremors. Although the wearable carries a 6-axis accelerometer and a gyroscope, it looks and functions just like regular mechanical wrist-watch. The device communicates with an app and vice versa so that data can be properly visualized and analysed. At time of writing, the project is in a start-up phase.

Another start-up project is the OneRing. The device is a plastic ring with sensor technology attached on the upper side, continuously capturing motion data. It pairs with a smartphone and the user is meant to carry the ring throughout the whole day. After sufficient data has been gathered, the system uses machine learning algorithms to classify PD severity and generate a "smart" patient report (OneRing | Artificial Intelligence for Parkinson's Disease, 2017). The supported classifications include dyskinesia, bradykinesia and tremor. It daily produces reports with statistic allowing clinicians to better understand what treatment to apply. Currently, the project has a complete prototype but still tries to find financial support.

3 Theory

This chapter describes relevant, theoretical concepts.

3.1 Personalization

Today's smart devices, such as smartphones, are an integral part of our lives. Many of them allow the user to tailor the experience and change the behaviour of the device so that it fits the user's needs and preferences. In other words, one can say today's smart devices can be *personalized* by the user. As a general concept, personalization means adapting something so that it better adheres to the user's interest, needs, behaviour, preferences, condition, feelings, or any other attribute, in order to provide the most preferable experience. For example, increasing the dosage of dopaminergic agents, while in therapy, can be an instance of personalization if it results in better adherence to the person's needs.

Every instance of personalization must have a user profile to reference (Petersen et al., 2008). Basically, the user profile is responsible of storing relevant data about the user. The data can refer to a set of preferences, information, rules or settings that are used by a device or a service. One important feature of the user profile is to prevent users from being forced to provide information more times than necessary. A user profile must also be context sensitive, meaning it must dynamically adapt to the condition of the user. Personalization is then achieved by automatically maintaining and updating the user profile. Context sensitivity is important due to the fact that users, even throughout the course of a single day, find themselves in many different situations. In each of these situation, the user may have different needs, which means the user profile must be able to dynamically change accordingly. To easily demonstrate such changes to a user profile, one can use scenarios.

In practice, many products already support functionality for user profiles. However, they are often specific to that product, or exist in a closed system, and can't be used elsewhere. The European Telecommunications Standards Institute has made efforts to standardize the concept of a user profile by releasing guideline documents on user profile management. One of their guideline documents mentions the Design for All approach. It is an effort to adhere to *all* users, which means that accessibility is considered as something that can benefit people regardless of abilities. The said document also provides specific guidelines on how to adhere to disabled users (ETSI - ES 202 746, 2010).

Regarding devices used in health care, adapting to the user is essential for providing a safe and user-friendly system. Thus, personalization means patient treatment can be tailored to suit the patient's conditions and needs, while respecting the different aspects of those conditions (ETSI - ES 202 642, 2010).

3.2 Patient-centered care

The concept of patient-centered care is poorly defined despite a rich field of literature. No "official" definition exists and various versions such as "patient empowerment" and "patient participation" are used interchangeably (Longtin et al., 2010). Patient-centered care relates to aspects of health care that ecompasses decision making, self-medication, self-monitoring, patient education, setting goals and partaking in physical care. In its core, patient-centered care is based on respect for patients as unique beings and the obligation to give them care on their terms (Epstein & Street, 2011). They should be listened to, informed, respected and involved.

Patient participation in healthcare management has been associated with high patient satisfaction and improved treatment outcomes in chronic diseases. Research has showed that patients who participate in shared decision making are more likely to feel secure and may experience a stronger sense of commitment to partake in treatment (Höglund et al., 2010). Furthermore, if a patient is more active in the decision-making process, they become more independent, self-managed and feel more positively towards care quality (Hibbard et al., 2007; Weingart et al., 2011). Patient participation also leads to greater belief in their own ability to complete a task, which may hasten rehabilitation processes and overall increase quality of life (Heisler et al., 2002).

Confusion regarding patient-centered design may lead to changes that do not work directly towards patient-centered care. For example, a hospital may adopt greeters, fashionable interiors or high-end gadgets, all for the reason of increasing patient-centeredness. Although these efforts might enhance the overall experience, they are often merely superficial and do not help to achieve goals of patient-centered care.

Often, efforts resulted in the implementation of infrastructural changes such as electronic health records. These changes are necessary in order to modernise health care, but are not necessarily part of patient-centered care. For example, implementing an electronic health record is not patient-centered in itself unless it is used to strengthen communication between patient and physician, help patient to know more about their condition or facilitate involvement in their own care. If health care in general is to become more patient-centered, it means changing the conventional physician-dominated dialogue. Specifically, the role of physician must change from the one characterized by authority to one that has goals of collaboration.

Relevant to this thesis, one may ask if there is a way to test whether patient-centered care has been achieved. Currently, there is no standardized method for approaching this problem. Epstein and Street (2011) have highlighted shortcomings of the "current approaches". A typical mistake is to confuse behaviour with outcome. Consider the situation in which a patient is satisfied with the skill of the physician, but their condition worsens. Also, there is commonly assumed that the patient is the one who decides whether the care is patient-centered or not. However, the thing patients want is not always the thing they need. Finally, patients should not be trusted with giving subjective assessments regarding how well they have been informed or understand their treatment as patient often overrate. The disconnection between high patient satisfaction and poor participation and understanding is greatest for those with low literacy, poor English fluency and cognitive impairment. This means patients must be trained in giving valid feedback on patient-centered care.

Earlier in the movement of patient-centered care, evaluation of patient involvement simply meant asking the patients if they had the opportunity to ask questions. Patients accustomed to passivity considered themselves "centered" if physicians ask "Any questions?". A patient-centered approach should do much more than this. The physician should take measure to invite the patient to participate. Often, patients usually have questions because treatments can be complicated.

3.3 What is a feature?

To properly answer the research question, one must establish the concept of a 'feature'. For better or for worse, it is a word with many meanings. Some common definitions include "a

distinctive attribute of something" and "a prominent characteristic". Other definitions are "any part the face" (e.g. nose) and "newspaper article". In the field of software development, a feature is "a distinguishing characteristic of a software item" (IEEE, 1998). This type of feature is sometimes called 'software feature' and refers to characteristics such as performance, portability and functionality.

The concept of software features tells us that the meaning of the word 'feature' depends on the context in which the word is being used. For example, if one is at a beauty salon, the term 'feature' likely refers to 'facial features', while in a team of software developers, the word likely refers to 'software features'. Thus, for us to define the term 'feature', we must look at the context in which the word is being used. And the research question reads:

What **features** should an **interactive system**, consisting of a smartwatch, **have** to enable personalization and patient-centeredness in treatment of people with Parkinson's disease?

The word 'features' refers to something inside included in the interactive system. One can say it is an attribute of the system. Let us therefore rephrase the question in the header to "what is a feature of an interactive system?". As we have seen, the term 'feature' depend on the context. Naturally, this leads us to the question "what is an interactive system?". Looking up the word 'system' in a dictionary, one will find something like "a set of components working together to form a complex whole". These components can be software items, tangible parts or something else entirely. An "interactive" system is a system that one can interact with, i.e. someone (like a user) can interact with one or multiple components inside the system. Important to note, we regard the system as the sum of all the components. For example, considering a video-game to be a system, that system includes the game design, the art style, the hardware of the video-game console, the TV, the controllers and so on.

Returning to the rephrased question: what is a feature inside an interactive system? Obviously, one can answer this question in several ways. As a theoretical concept in this project, we define 'feature' as the characteristics of

- the individual components in an interactive system,
- how those components work together and
- the system as a whole.

In this way, we use the traditional definition of the term 'feature', i.e. as a characteristic of something, and merge it with the concept of a system, i.e. components working together to form a complex whole.

3.4 Design frameworks

In interaction design, some of the most widely used design frameworks are User Centered Design (UCD), Human Centered Design (HCD), Activity Centered Design (ACD) and Goal-Directed Design (GDD). To help in forming the design process of the prototype, i.e. the deliverable of the project, effort was made to understand the details of these frameworks.

3.4.1 Human centered design

Human centered design is the process creating things deeply based on human nature. It places human needs and limitations in higher priority compared with other targets during the design thinking (Boy, 2013). Another definition was given in a research paper by Joseph Giacomin, consisting of six characteristics:

- Adopting multidisciplinary skills and perspectives
- Clear understanding to the users, tasks and environments
- User centered evaluation driven design
- Considering the overall consumer experience
- Involving the consumer in the design and production process
- Iterative design process

During recent years, companies such as IKEA, Lego, Google and Apple have shifted their direction to focus on the emotional relation between its products and the consumer instead of focusing on the technology. Now, they use human centered design to examine the products and see if they meet consumer needs. In order to build a sustainable relation between the product and the consumers, the design needs to answer questions regarding the relationships which are established between the product and the people. One representation of such a set of questions are presented in the human centered design pyramid (Giacomin, 2014). The pyramid consists of the classical rhetorical questions, specifically the who, what, when, why and in what way, which have been associated with current design semantics. Structurally, the pyramid is based on the hierarchical order of human characteristics. See figure 1 below.
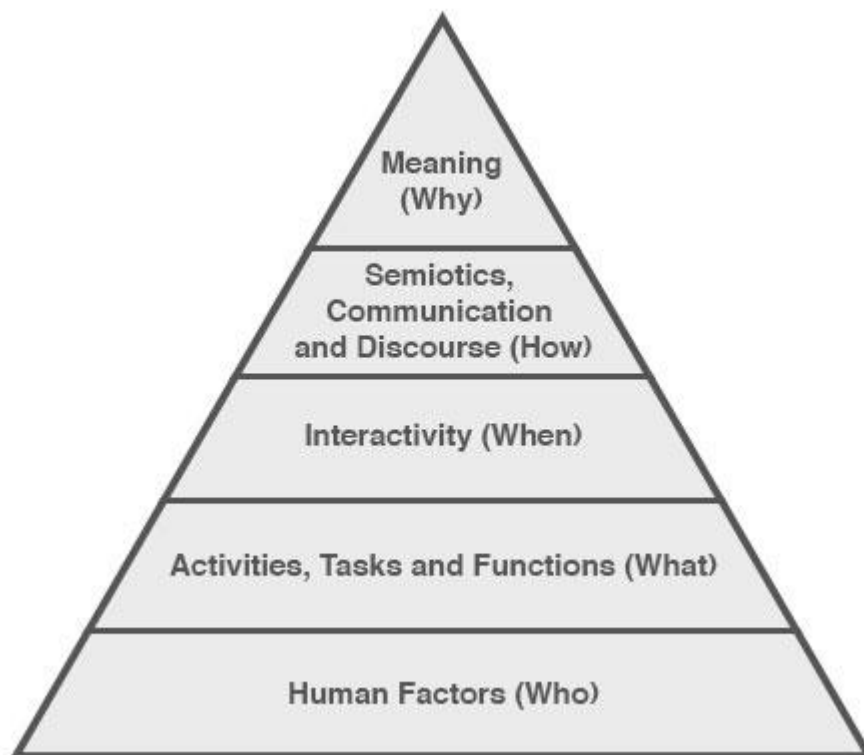
Figure 1: Human centered design pyramid (Giacomin, 2014)

To properly implement a human centered design approach, there are three phases to complete: Inspiration Phase, Ideation Phase and Implementation Phase. In the Inspiration Phase perform user research and learn about the people you design for. In the Ideation Phase, you use user data to develop a concept and prototype a solution. Finally, in the Implementation Phase, you develop a final design and bring that design to the market

(IDEO, 2017). Methods that support a human centered approach includes personas, scenarios and use cases.

3.4.2 User centered design

User centered design is concentrated on not only human characteristics but also specific traits and features of target users. It places the user in the center of design decisions. This does not mean directly asking the users what they want, but rather figuring it out user needs through profiling and identifying their behaviours of use. Gulliksen et al. (2003) defined UCD in twelve principles (see below).

 Twelve principles of UCD:

1. User focus - the goals of the activity, the work domain or context of use, the users' goals, tasks and needs should guide the development throughout.
2. Active user involvement - representative users should actively participate throughout the entire development process and throughout the system's life cycle.
3. Evolutionary systems development - the systems development should be both iterative and incremental.
4. Simple design representations - the design must be represented in such ways that it can be easily understood by users and all other stakeholders.
5. Prototyping - early and continuously, prototypes should be used to visualize and evaluate ideas and design solutions in cooperation with the end users.
6. Evaluate use in context - baselined usability goals and design criteria should control the development.
7. Explicit and conscious design activities - the development process should contain dedicated design activities.
8. A professional attitude - usability experts should be involved early and continuously throughout the development.
9. Usability champion - usability experts should be involved early and continuously throughout the development lifecycle.
10. Holistic design - all aspects that influences the use should be developed in parallel.
11. Process customization - the UCD process must be specified, adapted and/or implemented locally in each organization.
12. A user-centered attitude should always be established.

The UCD process comprises of three core phases: design research, design and design evaluation. During the research phase, the designers learn who the users are, assess the work of competitors and conduct interviews and surveys. In the second phase, the designers create a design based on the findings from the research. In the final phase, once a design has been created, it is evaluated together with users and redesigned if necessary (Williams, 2009).

3.4.3 Activity centered design

Similar to HCD and UCD, activity centered design has its root in human-computer interaction (HCI). An activity centered design approach "emphasizes the design of computer-mediated environments to support and structure the interactions and interdependencies of an activity system". Unfortunately, no definitive text exist that describes the processes that are to be

used by ACD practitioner. In general, ACD focuses on what tasks that must be enabled by the system, rather than what task the user must perform (Saffer, 2010).

3.4.4 Goal directed design

Goal directed design was developed by Alan Cooper et al. between 1983 to 2000. The process contains ethnographic research methods, is qualitative and anthropological. It is comprised of the following steps: research, modeling, requirements, framework, refinement and support. See figure 2 below.
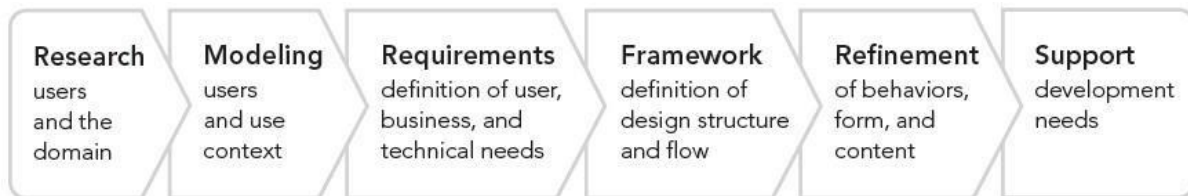

Figure 2: Goal directed design process (Cooper et al., 2014)

Like UCD, GDD research can be quantitative or qualitative, although it is usually qualitative. Cooper lists the following research activities as being most useful: stakeholder interviews, subject matter expert interviews, user interviews, user observation, ethnographic studies, literature review and product and competitive audits. The modeling step includes an iterative process of modeling data from stakeholders and users via deliverables, e.g. personas. The requirement step is the process of setting up goals defined by these deliverables. In the framework step, the designers create a design based on the findings from earlier stages, which is further refined in refinement step. Lastly, during the support step, the designers give support to other members of the team who rely on the result from the GDD process.

3.4.5 Comparing design frameworks

Where ACD consider the tasks that must be enabled by the system, GDD asks why the user must perform those tasks in order to better understand the user's motives. In other words, GDD focuses on the goals of the user. UCD focuses on the user and, in doing so, consider both the task and the human aspects. Comparing HCD and ACD, the first one puts human needs and behaviour in focus, while the second one focuses less on the human aspect of things and more on the task itself.

UCD and HCD share many properties and some people argue that they are interchangeable (Boy, 2013). One can say UCD is a more focused version of HCD, with a deeper analysis of the target audience. Also, HCD is the only approach that comprises the aspects of manufacturing and putting the product on the market. One can say that HCD is the first step to make the design generally applicable, while UCD is the next step to make the design focus on needs of a specific user group.

3.5 Mixing concepts from interaction design and health care

In interaction design, personalization is strongly connected to the concepts of customization and user experience. Amy Shade (2016) argues that there is a difference between personalization and customization. She states that personalization is performed by the system being used while customization is done by the user. In our theory section (chapter 3),

we define personalization as the process of adapting something so that it better adheres to the user's interest, needs, behaviour, preferences, condition, feelings in order to provide the most preferable experience. Using this definition, one can argue that customization is method for achieving personalization. This difference is important to recognize when effort is made to answer the research question. For one to answer the question, one must also be clear on what aspect of personalization they address. Does the system allow for personalization (meaning is it customizable) or is the PD treatment personalized (meaning is the medicine optimal for the patient's need)?

Among our readers, there might exist a slight confusion regarding patient-centeredness and user-centeredness or human-centeredness. In work process of this project, patient-centeredness and user-centeredness (together with human-centeredness) comes in the form of patient-centered care and user-centered design. Although they share the fundamental feature of placing an individual in focus, they differ in almost every other aspect. User-centered design (UCD) is a focused version of human centered design (see section 3.4.2) and concentrates on specific traits and features of target users. It places the user in the center of the design work. Patient-centered care relates to aspects of health care that ecompasses decision making, self-medication, self-monitoring, patient education etcetera (see section 3.2). It is based on respect for patients as unique beings and the obligation to give them care on their terms. Thus, these two concepts apply to completely different areas, one applies to design work while the other one applies to treatments in health care.

4 Methodology

This chapter aims to describe methods that were in consideration during the project's planning phase. They are presented in two different subsections: 'design process' and 'research and iterative design'.

4.1 Research

The research methods described in this section are about collecting qualitative and quantitative data. For example, they can be used to evaluate a prototype or investigate problem areas, potentially causing the design to diverge. Other methods, such as literature reviews, are for laying a foundation for the iterative design process.

4.1.1 Fly-on-the-wall observation

Observing user interacting with a product can be a quick and easy way to understand the usability of a product and the overall user experience. Fly-on-the-wall observation allows researchers to unobtrusively gather information, by looking and listening, without participating or interfering with the participants of the study (Martin & Hanington, 2012). This successfully removes the researcher from direct involvement, minimizing any influence that may occur. Fly-on-the-wall observation usually lacks a predetermined structure except some few guidelines. Instead, researchers try to gather as much data as possible during the duration of the test.

4.1.2 Think-aloud test

Naturally, observing users and taking notes are integrated parts of many common research methods. One of them is the Think-Aloud test in which a user is asked to perform certain tasks while speaking their thoughts out loud (Sharp, Rogers & Preece, 2011). It is often conducted with one note-taker, one moderator who asks question and one user that performs tasks handed to them by the moderator. By letting the user speak unhindered, one can discover what the user "really thinks" about a design, which may help to redesign. However, speaking your mind out loud is not always an easy task for the unaccustomed. It is therefore a good idea to remind the user about the point of the test.

Observations alone may not be able to collect a sufficient amount of data. Therefore, it might be advisable to let data gathered from observation serve as a complement to other methods (e.g. interviews).

4.1.3 Interview

Interviews can be used for different purposes and in different phases of the development cycle, e.g. to collect contextual information on a specific user group or to get feedback on a prototype. In general, interviews follow some kind of approach, such as structured, semi-structured or unstructured (Sharp, Rogers & Preece, 2011). As their name suggest, structured interviews are formal and consists of a fixed amount of predefined questions. Semi-structured interviews are more dynamic as they allow for questions that were not initially planned by the interviewer. Unstructured interviews, on the other hand, have no prearranged questions or directive. There is no rule to adhere to any of these approaches and the form of an interview can vary between them, but the approach should always

depend on the purpose. For example, if the goal is to get direct feedback on a specific feature of a system, a structured interview is more suitable than an unstructured one.

There are some things that are good to keep in mind when conducting interviews. Firstly, it is important to not rush it. Always let the interviewees finish and give them time to think on their answers. Secondly, the interviews should take place in a relax environment without any distractions. It is also possible that the environment is related to the topic of the interview. For example, if a product is being evaluated, it can help to conduct the interview in its "natural environment". An interview that takes place in a user's real environment, such as their living room or workplace, is called a field interview or a 'contexual inquiry' (Beyer & Holtzblatt, 1998). In a contexual inquiry, the interviewer watches the user as they perform actions and then discusses those actions with the user.

4.1.3.1 Stakeholder interviews

Usually, the reason something is being designed is to achieve a specific business outcome. A stakeholder can be anyone with authority or responsibility for the product being design. For example, a stakeholder can be the one who commissioned the work to be done. Interviews with stakeholder should occur before user research, because they usually affect how the user research will be conducted (Cooper et al., 2014). The type of information that should be gathered from stakeholders include product vision, budget, technical constraints and perception of the user.

4.1.3.2 Subject matter expert interviews

Subject matter experts (SME) are experts on the domain in which the product or system will exist and operate (Cooper et al., 2014). Is if often valuable to meet with these people, especially early on in the project when user testing is not yet an option. Some SMEs may use a competitor's product or have been using a previous version of the product that is being redesigned. Cooper et al. suggest that SMEs are brought in, not only in the early stages, but throughout the whole design process. They stress the necessity of SMEs when designing for technical domains such as medical or scientific.

To keep in mind, Cooper et al. warns that the perspective of an expert may misrepresent the general user. Lastly, SMEs are knowledgeable but not designers, meaning all of their ideas may not be valid from a designer's standpoint.

4.1.4 Review of previous work

When conducting research in interaction design, one of the first things you do is to learn about the user and the context through literature and academic papers. Literature is a vital building-block in any research as it is serves as a foundation to lean on throughout the design process. After a proper amount of literature has been studied by the designers, it should be used as a basis for questions to SMEs and stakeholders (Cooper et al., 2014).

For design work, it may be beneficial to look at existing products that have been designed in similar purposes. If a product was received poorly, looking at how the designers failed can help in not repeating the same mistakes. Ideally, the designers should engage in a casual form of expert (or heuristic) review of existing products.

4.1.5 Focus groups

A focus group is a gathering of representative users that are asked a structured set of questions in purpose of collecting user data. The meeting is often record for future reference. Although focus groups have been widely used by marketing organizations, they are in many ways not suitable as a user research method. According to Cooper (2014), focus groups are weak at eliciting data about what people do with their products and how and why they use them. In addition, since a focus group is a group activity, attendants do not always speak their mind as attendants sometimes try to come to a consensus. Often, the group opinion becomes the "loudest" opinion or the opinion of one that is most committed to speaking their mind.

4.1.6 Questionnaires

One of the main ways of finding out about user's opinion is by simply asking them through questionnaires. A questionnaire is a series of questions that are put together to collect information from respondents. In interaction design, they are often structured to quantify the views and opinions of testers of a product or a system. One of the benefits with questionnaires is that they are capable of gathering views from many people in relatively short amount of time. They are also inexpensive compared to many other research methods. This is particularly true for web-based questionnaires, which, in addition, becomes less labour-intensive since data can be stored directly in a database (Sharp, Rogers & Preece, 2011).

Stocké and Hunkler (2007) highlight the risk of questionnaires that are conducted in person and non-anonymously, which can suffer from the 'social desirability bias' phenomenon. This phenomenon describes a type of response bias that is a tendency in respondents to answer in a way that will make them look better in the eyes of the ones conducting the questionnaire.

4.1.7 Expert based methods

Expert based method involve one or more experts who systematically examine the product. Since no users are involved, expert based methods are usually quick and cheap.

4.1.7.1 Heuristic evaluation

In a heuristic evaluation, experts systematically review the system's compliance with a set of 'heuristics'. The primary goal is to find potential usability problems. Although many different heuristics exist, one of the best-known is the set of heuristics developed by Nielsen and Molich (1990). It includes the following heuristics:

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

4.1.7.2 Cognitive walkthrough

Cognitive walkthrough is an evaluation method in which one or more evaluators analyses a system by working through a sequence of tasks (Polson et al., 1992). In contrast to heuristic evaluation, which looks at the system holistically, cognitive walkthrough is task-specific. At each step in a task procedure, the evaluator(s) asks himself the following questions:

- Will the user try to achieve the right effect?
- Will the user notice that the correct action is available?
- Will the user associate the correct action with the effect to be achieved?
- If the correct action is performed, will the user see that progress is being made toward solution of the task?

The evaluator(s) must answer these question with a 'success' or a 'failure'. If it is a failure, he must also motivate why the user might not accomplish the task. These answers can then be used to redesign the system.

4.1.8 Lead Users

The concept of 'lead users' was coined by Eric von Hippel in the mid 80's. He defined the lead user as those users who fulfil the following characteristics (Urban & Hippel, 1988):

- They face the needs that will be general in the marketplace, but face them months or years before the bulk of that market encounters them.
- They are positioned to benefit significantly by obtaining a solution to those needs.

Contrary to many other user research methods, the lead user method does not seek to find representatives of the current market in a traditional way. Instead, the focus is to find 'exceptional' users that are 'ahead' of the majority with respect to a certain problem. Lead users have self-interest in solving such problems, which they have observed much earlier than other users. Often, lead users are engaged in solving the tasks themselves.

When employing the lead-user method for new innovations, the first thing to do is to identify the relevant trend that can result in users taking a 'lead' position. Then, the lead users have to be identified. Finding lead users can be difficult as they should not be sought after within the casual user base. Instead, one should look beyond these and search for lead users in, for example, advanced analog fields. The next step in the method involves deriving data from the lead users to develop a new product concept. Finally, the concept must go through testing to confirm if the concept appeal to typical users.

4.1.9 Design guidelines for people with Parkinson's disease

Researchers have made efforts to put together a set of guidelines for designing user interfaces for smartphone application for people with PD (Nunes et al., 2016). Since the deliverable of this project is a smartwatch, which usually is equipped with a touch screen as well as capabilities of communicating with touch-screen-equipped devices, it was decided that these guidelines should be taken into account. The guidelines are grouped in two categories: touch interaction and information display.

Touch interaction:

- Use tap targets with 14 mm of side
- Use the swipe gesture, preferably without activation speed
- Employ controls that use multiple-taps

- Use drag gesture with parsimony
- Prefer multiple-tapover drag
- Adapt interfaces to the momentary characteristics of the user

Information display:
- Use high contrast coloured elements
- Select the information to display carefully
- Provide clear information of current location at all times
- Avoid time-dependent controls
- Prefer multiple modalities over a single interaction medium
- Consider smartphone design guidelines for older adults

4.1.10 Requirement specification

Widely used in software development, a requirement specification is a document that defines what a system is required to do and the constraints under which this functionality must be provided. One can say a requirement specification is a contract between designers and stakeholder that ensures everyone is working toward a common goal. A requirement can be constructed from user research or with stakeholders. Either way, design decisions should always be left open. Ulrich and Eppinger (2014) argues that the requirement must be measurable, so one can evaluate if they have been fulfilled. It is beneficial if the requirements can be weighed against each other, so the most important one can be identified and prioritized.

4.2 Iterative design

Iterative design methods are used for developing the concept as well as finalizing the design.

4.2.1 Use cases

A use case is a careful description of a task and has a clear start and end. It describes the circumstances of the situation and defines each step that is necessary in order to complete the task. A use case should also define certain factors that are related to the task, such as actors, goals, preconditions etc. (Usability.gov, 2017). In other words, use cases are exhaustive descriptions of the functional requirements of a system. Usually, the focus is on low-level tasks. Use cases are useful since they permit a complete systemization of the different users and their tasks. Their fallback is that they do not say anything about how the tasks are presented to the user (Cooper et al., 2014).

4.2.2 Personas

Personas are not real people, but fictive people created to represent users. A persona can contain information on age, characteristics, personality, profession, interests, experience and knowledge. Personas provide a way of thinking and communicating about how users behave, think, wish to accomplish, and why (Cooper et al., 2014). Through them, designers can develop an understanding of users' goals in various contexts.

Personas often serve as the main characters in a narrative (e.g. scenario). Other, more specific reasons to use personas can be to identify system requirements or evaluate a concept. For personas to be useful, they must be based on the behaviors and motivations of

real people that have been observed during user research. This means personas is tool using data gathered from user research and represent it in an intuitive way.

4.2.3 Scenarios

A scenario defines a product's behavior from the standpoint of a specific user. This means the functionality is not the only thing that is in focus, but also how the functions are presented to the user (Cooper et al., 2014). How a scenario is put together can vary greatly, some can be task-focused while other are on a very high-level. It can contain information on the context of use, the personality and lifestyle of the user (sometimes in the form of personas) and the user's actions and experiences. Scenarios can be used to evaluate the system and help designers think about the characteristics of the user and the context of use. If stakeholders are involved in the design process, the scenario should be formulated so that it is easily understood by outsiders.

4.2.4 Sketching

Sketching is a form of drawing that designers can use to propose, explore, refine and communicate ideas in a tangible format. Often, sketching is used early in the design process to explore concept and "fail fast". Moreover, sketching can assist designers in recording ideas and archiving them for later reflection. Sketches are usually made with a pen and piece of paper, but can come in other forms such as a digital drawing.

4.2.5 Prototyping

A prototype is a simulation of the final product. Its primary purpose is to get valuable feedback so that the prototype can be improved. For example, a prototype can be used to explore potential problem areas (Butterfield & Ekembe, 2016).

4.2.5.1 Low fidelity prototyping

Low fidelity prototypes, or lo-fi prototypes, are rough representations of concepts used in the process of generating and evaluating different design ideas. Their focus is on key functionality and overall design, providing limited functionality and interaction (Saffer, 2010). Due to their simplicity, they require less time, skills and resources to create than more sophisticated methods (e.g. high-fidelity prototypes). Preferably, lo-fi prototyping is employed early in the design process, when it is important to quickly evaluate different concept.

4.2.5.2 High fidelity prototyping

High fidelity prototypes (hi-fi prototypes) are, compared to lo-fi prototypes, more refined and closer to the final product (Saffer, 2010). From a user testing point of view, designers will be able to put more focus on the users and less on making sure the prototype is working properly. However, hi-fi prototyping can be costly in terms of time and resources, especially a lot of changes are made in between tests. For example, when prototyping software, bugs can slow down the process significantly. Therefore, it is appropriate to employ this method when a prototype is close to reaching its final form.

4.2.6 Storyboard

A storyboard is a sequence of low-fidelity sketches that are accompanied by a narrative, similar to how a comic book is laid out. Through storyboards, one can portray how a solution helps users (sometimes provided as personas) accomplish their goals and tasks. Each

interaction between the user and the system can be portrayed in one or more frames. Advancing through the slides can give a check on the interactions' coherence and flow. According to Cooper et al. (2014), spending too much time into storyboards simply is simply a waste of time. He found that storyboards are a highly effective way to explore and discuss solutions without doing excessive work.

4.2.7 Brainstorming

Brainstorming is a technique used both for concept generation and problem solving. Usually, it involves a group of people that together try to come up with different ideas and concepts. In order to keep the creative flow, the participants are encouraged to share their ideas immediately as they come up and to not give any criticism. The goal is to come up with as many ideas as possible in a very short time-span (Wadsworth, 2011).

When a brainstorming session is over, the ideas are usually loosely organized and conceptually scattered. In those cases, the KJ-method can be used to group the ideas and make them more easily managed. First, the ideas have to be written down on notes or cards. The next step is to group the ideas and concepts into clusters, called families, and give these families names (Scupin, 1997). Optionally, a last step can be executed in which the families are grouped into even larger clusters. Although most commonly used for arranging ideas after a brainstorming session, the KJ-method can be used on just about any data expressed in similar manner, i.e. on notes.

5 Work Process

With the exception of the first two subsections, which mostly describes planning, this part of the report will be chronologically broken down into sections that describes each major phase within in the project. In turn, each subsection aims to describe and motivate the methods performed during that period.

Research question

This thesis was carried out over a period of five months. Continuously during this period, time and effort were put into establishing a fruitful and practical research question. A first draft was handed to us via Semcon (see following subsection) in the beginning of the project. However, this version was altered, then altered again, until a final research question was established (which can be found in section 1.2.1). To not undermine the effort of our research, this section also includes the work process that led up to that final version.

5.1 Task description from Semcon

Françoise Petersen, an employee of Semcon, was the one that initiated this thesis. Her work has focused on personalization and now recently on eHealth. She provided us with the following problem:

People suffering from Parkinson's disease can experience considerable relief of symptoms while they are treated with Levodopa (also known as L-dopa). To get the maximum benefit of the medication, with minimized side-effects, it is important that the required dosage is adapted to the patient's needs. Therefore, personalized treatment is of outmost importance. However, the individual needs depend on the patient's various health conditions, which can vary from day to day, even change throughout the course of a single day. Due to this, deciding on the correct dosage is problematic. We seek to develop a hand-worn measuring tool that can determine the PD patient's health condition and quantify the optimal dosage of medication.

In addition, Françoise set up a meeting for us with Martin Rydmark (a professor of medical informatics and computer assisted education at the institution for biomedicine at the University of Gothenburg). We were informed that Martin had been part of similar projects and that he could help us put together a hand-worn device for measuring PD condition and determining L-dopa dosage. At that time, it seemed that a solution already existed and that our task was to make it usable in PD treatment.

The problem description, provided by Semcon, resulted in the following research question:

How to apply personalized treatment for Parkinson's patients using a tool for measuring fine motor skills?

As previously explained, this question would come to change on a multiple occasion throughout the work process.

5.2 Planning

The work process started by creating a general plan on how the *current* research question was going to be answered efficiently. In this process, we considered which design framework to adopt: human centered design, user centered design or goal directed design (see section 3.4). We came to the conclusion that there will be no absolute commitment to

any of these. The time and effort needed to *strictly* follow a design approach, especially the GDD, would not be worth the gain. Despite this, it was recognized that a good design process need elements such as user research and testing. Therefore, the decision was made to *loosely* base the design process on UCD with elements from GDD. The word 'loosely' refers to the ability to *not* follow the regular course. We saw no direct reason to follow the HCD approach. Naturally, by adopting a UCD approach, one does largely adhere to the discipline of HCD.

The UCD process comprises of three core phases: research, design and evaluation. During the research phase, the designers learn who the users are by, for example, assess the work of competitors or conduct interviews and surveys. In the second phase, the designers create a design based on the findings from the research. In the final phase, once a design has been created, it is evaluated together with users and redesigned if necessary.

The GDD is a fleshed-out design process largely developed by Alan Cooper (Cooper et al., 2014). It contains six phases in which each phase has one or more activities (see figure 3 below).
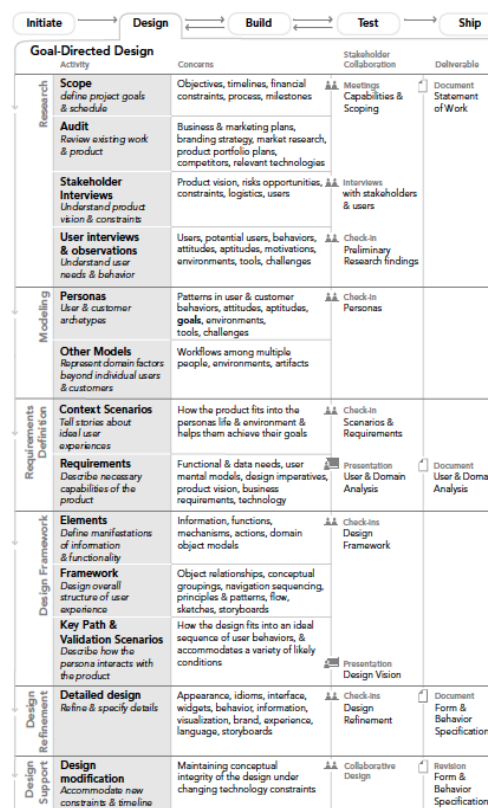

Figure 1-6 A more detailed look at the Goal-Directed Design process.

Figure 3: Detailed look at the Goal-Directed Design process (Cooper et al., 2014)

More information on UCD and GDD can be found in section 3.4, along with information on other design approaches and methods.

5.2.1 Planning report

Influenced by UCD and GDD, the design process of the project was divided into three phases. The first phase was the research and ideation phase, the second phase was the

iterative prototyping phase and the third and last phase was the showcase phase. In the early stages of the project, a planning report was produced to properly document the plans.

The following is a summary of the plans made in the planning report. Each phase is highlighted in bold.

*During the **research and ideation phase**, qualitative literature review will be conducted to find relevant papers. When the papers have been reviewed the ideation will be done through brainstorming sessions, which will be evaluated through the KJ-method. Although interface design guidelines for PD patients may be used for ideation, they will probably be of most use during the iterative prototyping phase. When the research and ideation phase closes, the **iterative prototyping** will be initiated. The system will be developed in steps where each step is evaluated to further help the progress of the prototype. During the **showcase phase**, use cases, scenarios and possibly a storyboard will be made to showcase the system for stakeholders. Since the system is mainly a proof of concept, the showcase phase will show the potential of a fully completed system.*

The following section, section 5.3 and 5.4, are representations of the two first phases in the planning report, i.e. the research and ideation phase and the iterative prototyping phase. The showcase phase is mentioned and discussed in chapter 7, Discussion.

5.3 Research and ideation phase

The research stage consisted largely of literature reviews, product audits and interviews with stakeholders, subject matter experts and lead users. Ideation was performed in bursts throughout the whole phase, but with more focus after periods of research.

5.3.1 Semi-structured interview with subject matter expert

Semcon arranged for us to meet with Martin Rydmark, a professor of medical informatics and computer assisted education at the institution for biomedicine at Sahlgrenska Academy (University of Gothenburg). Martins educational efforts are in the fields of anatomy, biomechanics and medical informatics. His research interests cover neuroscience, image analysis, 3D visualization, haptics, neurorehabilitation, virtual reality and learning.

Martin was considered to be a subject matter expert, in other words an expert in the domain of this project. In addition to his medical merits, he had recently been supervising an older thesis on Parkinson's disease. Particularly, the thesis was about the use of depth-cameras for distance study of motor skills in PD patient. He had also been involved in a thesis on motion tracking cameras for home rehabilitation exercises.

To help us prepare for this interview, we had been informed that Martin could provide us with a technique to measure the health condition of a PD patient and, with the help of those measurements, determine the optimal dosage of medication. Naturally, interviewing him was of great interest.

Regarding the interview, we aimed for a semi-structured interview, leaning toward the unstructured approach. In this way, both parties could discuss and share views with each other freely, and if an interesting topic would come up, there would be nothing hindering us to explore it further. In preparation, we wrote down some open-ended question to spark a discussion. The questions did not aim to gather as much information on PD as possible, but rather to discuss broad aspects that could be relevant for us.

The following is a selection of those question:

- *To prevent this from repeating someone else's work, what's the difference between this project and previous theses on sensor-based treatments for PD patients?*
- *Is the* Unified Parkinson's Disease Rating Scale *relevant for us? If so, what role should it serve?*
- *Regarding motion sensors, what performance is preferable for this purpose?*
- *What program language/software architecture is preferable/necessary?*
- *Are there any "pitfalls" in this field we should be watch out for?*
- *Do you have any recommendation concerning literature, papers and other sources of information?*
- *How should we go about to find user/test groups?*

Overall, the interview was a success. But, contrary to what Semcon had told us, Martin did not provide us with a method to measure the health condition of PD patients. It was assumed that a misunderstanding had occurred. However, this did not stop Martin from providing us with useful information.

The following is a summary of what was gathered during the interview:

- The system should
  - not be costly - the price must be feasible for most people.
  - be small in size, i.e. not big and clumsy.
  - not draw attention to the user. Martin explained that people, in generally, do not want to identify themselves with their disease. In other words, move focus away from the disease.
  - be customizable to fit the user's needs.
  - have an interface that is very simple and easy to interact with. Martin suggested a one-view app for touch screen tablets.
  - not to be a gimmick since people, especially elder, tend to not want to interact with such systems.
  - be connected to a network and enable easy communication with physicians and health care personnel.
- Push buttons are more preferable than touch based buttons.
- Fall injuries is a huge problem for PD patients.
- To minimize side-effects and ensure a good quality of life, it is of utter importance that the medication regimen is as accurate as possible. Many patients struggle with the 'ON' or 'OFF' phenomenon.
- The concept of "fun" is a powerful tool if properly wielded. However, what is considered fun for patients can vary greatly.
- Finding legitimate test user can be both cumbersome and unrewarding. Martin suggested that a good amount of testing can be performed by the designers themselves.
- Martin suggested searching the institutional library of Biomedicine at the Sahlgrenska Academy and PubMed.org for literature/papers.

For further input, Martin suggested that we contact the following people:

- **Sara Riggare**, a researcher and an advocate of self-tracking and patient empowerment. She also has PD.

- **Jurgen Broeren**, with a Ph.D. in Medical Science, he is an expert in the field of rehabilitation with the support of games. According to Martin, Jurgen was a good source of first-hand information on PD.

It was agreed upon that these two contacts, in addition to Martin Rydmark, could provide help in research and with evaluating future concepts and prototypes.

As final notes on the results from interviewing Martin Rydmark, he insisted that we do not follow the footsteps of the old thesis that studied PD patients using depth-cameras. Instead, he wanted us to "think new" and try to come up with our own solution.

5.3.2 PD literature review

Literature is vital for building a good foundation for research. Thus, a lot of literature and research paper were investigated with PD in mind. Because PD is such a complex illness, it was important to get a strong general understanding of its clinical features and related concepts. Our findings are largely summarized under Parkinson's disease in chapter 2, Background.

Learning about PD served the following purposes:

- Increased understanding of the user group, allowing us to take informed design decisions
- Build a strong vocabulary with PD-related terms, allowing us to more easily communicate with stakeholders and SMEs.
- Use it as a basis for developing questions to ask stakeholders and SMEs

Besides looking into the intrinsic nature of PD, efforts were put into learning about personalization. The result of this particular activity can be found in chapter 3, Theory.

5.3.3 Recognition of technology in relation to PD

In our literature review, we worked on finding papers that contained information on the use of technological devices in PD treatment. Particularly, we searched for use of devices equipped with sensors for data gathering, which meant a direct correlation with our current research problem.

The following is a list of technological device that were recognized in our literature review. In other words, these devices have been used to monitor PD symptoms in previous research projects:

- Touch screens, including multi-touch.
- Smartphones and tablets
- 'App' for smartphones and tablets
- Wrist-worn accelerometers and gyroscopes
- Smartwatches
- Depth-cameras (usually a Microsoft's Kinect or a Leap Motion)
- Pedometer
- Sensors (usually accelerometer) on index finger and thumb
- Sensor-packed gloves

5.3.4 Brainstorming and KJ

After the literature review, a large base of knowledge was acquired. In order to summarise their findings and search for ideas to develop, two separate brainstorming session was held, each followed by a KJ-session.

The first brainstorming session focused on technological devices in PD treatment (see figure 4 below). It chiefly explored tools for motion data gathering as well as the attributes that are connected to such tools. Since the task description from Semcon implied that the goal of the project was to measure tremors, focus lay on finding a desirable device or technology for just that.
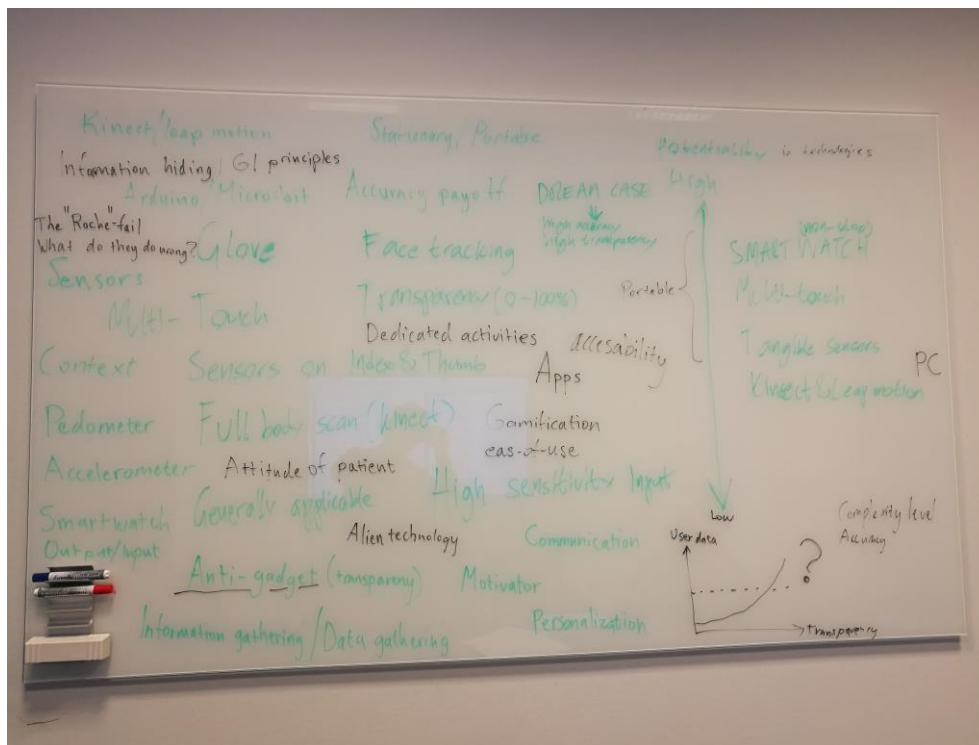

Figure 4: Brainstorming session (Photo)

The following is a summary of candidates for motion data gathering that was discussed during the brainstorming sessions:

- Smartwatches
- Smartphones and tablets
- Separate hardware sensors (accelerometers)
- Depth cameras

From the KJ-method that followed, a list of points was produced to better evaluate the candidates:

- Non-gimmicky
- Alien technology
- Non-intrusiveness
- Accuracy in measuring tremors
- Cost

- Size
- Accessibility
- Portability
- Personalization potential
- Experience goals (Cooper et al., 2014)
    - Feel smart or in control
    - Have fun
    - Feel cool or hip or relaxed
    - Remain focused and alert

After the completion of the KJ-method, the main topic of discussion was the preferability of the different technological devices that had been recognized in the literature review. One important subject was that the system must not to be gimmicky, something Martin Rydmark has warned us about. Another important factor was that the system should not be costly, i.e the price should be feasible for most people. Based on previous experience, we assumed that all of the technology candidates were capable in measuring motion data.

It was agreed upon that the system should neither significantly impact the user's daily life or be an indicator of the patient's illness. In other words, it should not be immediately obvious that the user is interacting with a system with the purpose of measuring PD symptoms. This is based on the notion that people, in general, do not want to identify themselves with their disease. Keeping this in mind, along with the evaluation points from the KJ-method, the smartwatch was chosen as the most preferable technological device for patients to gather data with.

Compared to the other candidates, smartwatches excel on almost all evaluation points. It has potential to act and function very similar to a regular, mechanical watch (except for recharging), which makes it a naturally choice if the goal is not to make the system feel gimmicky, come across as alien or draw attention to the user. It is also small and portable, it has networking capabilities as well as customizable exteriors in the form interchangeable straps (thanks to a growing smartwatch industry). Finally, there has been a lot of research praising smartwatches for its potential use of gathering clinically relevant data for patients (Wile et al., 2014; SHarma et al., 2014; Contreras et al., 2016; Weiss et al., 2016).

The separate hardware sensors were dismissed due to their ability of coming across as strange and alien. For example, a glove with accelerometer sensors on index finger and thumb is an unusual device for most people. Depth cameras, such as Microsoft's Kinect and Leap motion, were dismissed due to the fact that they must remain stationary when in us. Most of them are not portable and often need to be connected to a computer. High portability was an important factor since it allows for a much less hindered way of living.

Looking at older product in PD treatment, smartphones and tablets are used frequently (see section 2.3). Both devices are portable and packed with sensors. Besides, a smartphone is often necessary to properly access a smartwatch's features. Thus, we did not wish to dismiss these devices.

We theorised that it would most likely be difficult to acquire both high accuracy and little intrusiveness. There were no proof smartwatches were the most accurate sensor available, but it was clear that they will most likely provide functionality for continuous monitoring. We agreed upon that, in an optimal solution, a patient's condition could be tracked continuously

throughout the whole day, without them even noticing it. This would result in large amount of data to rely on during analysis and very little effort would be required from the patient.

The goals of second brainstorming were to focus our current knowledge on PD (see figure 5 below). It helped in finding ways to exploit the beneficial aspects of using smartwatches in PD treatment.
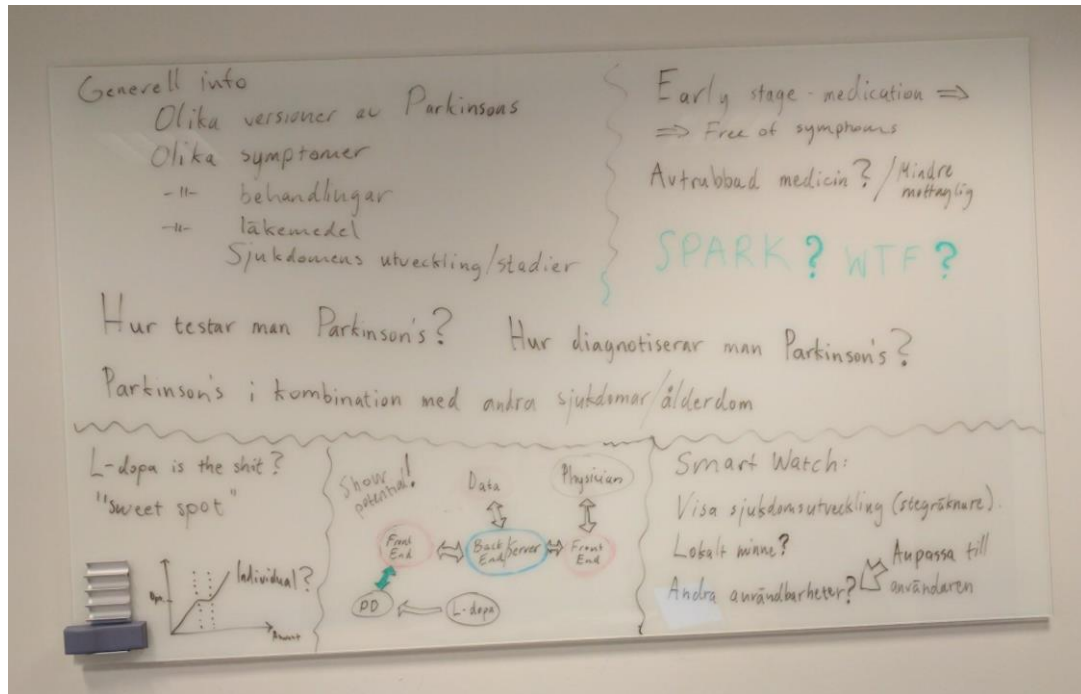

Figure 5: Second brainstorming session (Photo)

As the previous one, this brainstorming session was followed by a KJ-session for data management. The sum of this activity served as a basis for questions to ask stakeholders (mainly Semcon) and SMEs.

5.3.5 Unstructured interview with stakeholder

In the course of this project, we have had many meetings with stakeholders, in particular with Semcon. We had weekly meetings with Françoise Petersen and Jenny Forsberg, both employees of Semcon, who helped us shape and evaluate the design. During an upcoming meeting with Semcon, after our brainstorming sessions, we pitched the idea of using a smartwatch for measuring tremors. It was received very well. A major factor was the potentiality that exists within smartwatches, which some of the other candidates from the brainstorming session lacked.

Below is a summary of the discussions with Semcon from the early stages of the project.

Different users. It was agreed upon that the system should support different users. For example, the PD patient should only need to worry about the smartwatch itself, while caretakers may want to access secondary devices that are connected to the smartwatch, such as a smartphone or a tablet. Secondary devices may be necessary in order for smartwatch to work properly. Other users under discussion were physician. It was decided that the purpose for physician of using the system would be to analyse the data and

potentially change the regimen of whom the data belongs to. In that case, physicians and neurologist would use a completely different interface, such as a web page or a desktop app.

Web service and database. In order for physician to access motion data, it was decided that a database would be required. In addition, it was decided that, if physician or health care personnel wish to view the data via a web page, this would also require a database.

Personalization. One of the people we had weekly meetings with, Françoise Petersen, has written papers on personalization and user profile management and was considered a valuable resource in making the system adhere to those standards. When we pitched the smartwatch idea, it was deemed to have personalization potential. Regarding an interactive system that aims to optimize PD treatment, such compound can be personalized in many different aspects. For example, the PD treatment itself can be personalized, meaning the regimen of medicine that the patient follow is optimized to fit their needs. Then, the interactive system can adhere to personalization standards by allowing it to be customizable, either by the user itself or indirectly from user interaction.

Patient-centered care. This was a concept that had been recognized via literature review previously in the project. It had been associated with high patient satisfaction and improved treatment outcomes (see section 3.2). We agreed upon introducing this concept as one of the main focus points of the project.

Information visualization and data analysis. Since it was agreed upon that there would be users that would need to analyze the data in some way, it was decided that some sort of information visualization would be beneficial. Simple graph plotting, that displayed tremor intensive areas, was considered a viable option.

User testing. Semcon stressed the importance of user testing. However, during the interview with Martin Rydmark, he warned of the difficulties in arranging tests with 'real' patients. Despite this, it was agreed upon that efforts would be made to arrange for user testing.

Following these discussion, it was settled that a smartwatch would be used for gathering motion data. Thus, the research question was altered into:

Can motion data, gathered with a smartwatch, be used to enable personalization and patient-centeredness in PD treatment?

In addition, efforts were made to acquire test users. This meant contacting Gothenburg's Parkinson Association as well as the contacts Martin Rydmark had provided. One of the employees from Semcon could also provide a tester.

5.3.6 Review of smartwatches

In recent years, the smartwatch industry has been growing, resulting in a huge selection to choose from. When the decision was made to use smartwatches for gathering of motion data from PD patients, it became necessary for us to choose a smartwatch model to work with. To narrow it down, the following requirements were agreed upon. First, the smartwatch must, as closely as possible, resemble a regular, mechanical watch. Particularly, this meant a round design. This requirement was based on one of the evaluation points from the brainstorming session, which stated that technology that may come across as alien is unwanted. It was agreed upon that a round design would seem less alien for someone unaccustomed to technology, compared to a square design, which may look more like a 'technological device' than a 'watch'. Secondly, the smartwatch must run the Android

operating system. We had had some previous experience with the Android platform, which made it a natural choice. Also, Android is a more widely used operating system, compared to, for example watchOS on Apple's smartwatches, which meant the code would be accessible to a larger number of people. Thirdly, the smart must have a physical push button. Since our research had told us that push buttons were preferable compared to touchscreen buttons, it was theorised that such a button could be accessed inside the code and used for something important in the system. Thirdly, since smartwatch would be used chiefly for gathering motion data, a high-quality accelerometer was of utter importance. In this regard, it was understood that a 9-axis accelerometer was of good quality, partly due to the fact that it hindered build-up errors inside the sensor by using a magnetometer. Below is an image (see figure 6 below) that summarize a handful of the models that were under consideration.

Figure 6: Smartwatch specs chart. Available at:
http://smartwatchme.s3.amazonaws.com/136822b518b452b48ae472816534e37d527e1d154851.jpg.
[Accessed 22 February 2017].

After much consideration, we chose Motorola's Moto 360 (second generation) (see image 7 below), which fulfilled all the requirement described in the previous paragraph. It was purchased by Semcon. Although we were glad that Semcon could provide us with a sample, only one was acquired, which affected both development and testing.

Since Android was going to be the development platform, it meant reading up on official Android guidelines, especially on the ones regarding smartwatch apps (also known as Android Wear apps).

The official website on designing Android Wear apps gives three things to consider (Android Wear design guidelines, 2017):

- Understand use cases
- Focus on core functionality
- Test design

Understand use cases. When designing apps for smartwatches, users should get information at a glance (called high glanceability) and be able to act quickly. A smartwatch provides unique usage options, such as input enabled by physical body connection. For example, features can be activated with the flick of the wrist. However, a smartwatch also comes with a list of limitation, including smaller screen (especially for round screens), less information density, less processing power and limited battery life. Tasks should be accomplished easily and heavy workloads offloaded to the smartphone. Do not use items like spreadsheets or other complex components, which may be difficult to edit and view on a small screen.

Focus on core functionality. Smartwatch apps should be designed to a few number of functions. Do not include unnecessary features, actions, or content on the app's UI. Instead, choose the most critical functionality. For example, an email app for Android Wear should focus on reading messages and sending replies. It should not include options for adding attachments or editing recipients.

Test design. Designs that work well in a controlled development environment may not work in everyday situations. People wearing smartwatches are regularly in motion, whether they are gesturing, walking or running. Therefore, it is important to test the design in situations that involve user movement to make sure the design is usable, even when only glancing at the UI.

5.3.7 Experimenting with Android Wear

With the guidelines in mind, a period of experimentation was entered with the development environment and the Java programming language. Although everyone had previous experience with Android, there was much to learn. Android's API provides a rich framework

that lets developers build apps as a combination of components for a range of different devices. This means that the same type of components that are used for smartphones and tablets are used for smartwatches.

As a result of our efforts, a very simple app was produced that could detect shake events. The screen of the smartwatch turned green whenever the output from the accelerometer surpassed a certain threshold. Also, the screen displayed the value from the accelerometer, which was out-printed each time the value changed.

Besides creating a simple shake detection app, we succeeded with sending notifications from phone to the smartwatch. While experimenting with these features, we came to realise that a system not containing a smartphone would not be feasible in practice. Today, Android Wear is highly dependent on the user's smartwatch to be connected with the phone. In accordance with the guidelines, only the core functionality of an app is presented on the smartwatch, while advanced features exist in the smartphone version. Furthermore, Android Wear cannot in and of itself get data via a mobile data network, but need a smartphone to access those services.

To thoroughly test out the sensors, an open source app called SensorDashboard was used (see figure 8 below) (GitHub, 2017), which displayed the output of the smartwatch's sensors on the smartphone. This allowed to better grasp how the sensors, especially the accelerometer, functioned. Below is a screenshot of the app "in-action", outputting the value from a sensor known as "Game Rotation Vector".
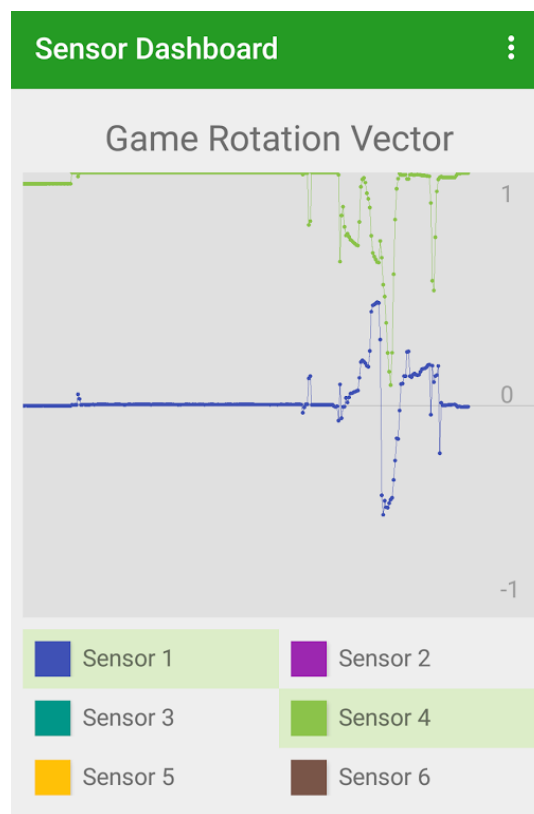
Figure 8: Sensor Dashboard app (Screenshot)

The app also allowed for the gathered data to be exported, which opened our eyes to the shear amount of data that was being gathered. A few seconds of data, gathered via the

accelerometer, equaled a file size in megabytes. This realisation raised concerns about how to continuously gather data throughout the course of a whole day.

5.3.8 Unstructured interview with subject matter expert

Together with Semcon, we set up a meeting with Jurgen Broeren, who was one of the experts Martin Rydmark recommended. Jurgen has a Ph.D. in Medical Science from the University of Gothenburg. His expertise lies in rehabilitation with the support of games. He currently works to share insight about innovation in the healthcare sector, mixing gamification and "neuro-rehab".

Jurgen suggested that we should not strive to gather as much data as possible, but rather focus on capturing fewer, more interesting moments. More data is not always preferable due to the labour-intensive process of data mining. In other words, quality is preferable to quantity. For example, data gathered around the moment of medication is especially useful for evaluating the patient's regimen.

Additionally, Jurgen stressed that it could be beneficial to track other symptom, such as gait difficulty, freezing, length of steps, and not only look at tremors. One common test when evaluating motor skills is to measure the amount of time it takes for the patient to pick up a glass of water.

Lastly, Jurgen advised against analyzing the data in purpose of determining an optimal dosage of medication (L-dopa). Such examinations are performed by trained physician and neurologist. Our focus should not be to analyze, but to gather and present relevant medical data with potential to help determine the condition of the patient and, if deemed necessary, make changes to their treatment. Françoise Petersen, an employee of Semcon who participated in the meeting, agreed with Jurgen's thoughts and suggested the term "clinical decision support system" should be used for describing such a tool.

The discussion with Jurgen made us contemplate whether the gathering of data should be 'focused' or not, meaning if it should occur during interesting happenings, such as when the patient is reaching for a glass of water or is taking medicine, or if data should be gathered continuously throughout the whole day. It was agreed upon that noting down moment of medication is an important feature and should be supported by the system.

5.3.9 Use cases

To flesh out the ideas that spawn from the SME interview with Jurgen, we chose to produce a couple of use cases (see below). These are not fully developed use cases by any standard (for example, each use case shows only one flow of actions).

Use case 1

Use case description:

● The process of gathering and uploading motion data, using the smartwatch, before moment of medication.

Actor:

● User: PD patient with average experience with technology.

Triggers:

● The user indicates that they want to gather motion data.

Precondition:

- There has to be a sufficient amount of time until the moment of medication. If there is no time left, no data will be gathered.

Normal Flow:

1. The user presses and holds the push button until a vibration is felt.
2. The user performs some form of motion exercise that will produce relevant medical data.
3. The user hears a beep, feels another vibration and the smartwatch's home screen prints "Done".
4. The user takes prescribed medication.
5. The user enters the amount of medication.

Comment: Data from this session is sent to a database to serve as decision support for physician.

Use case 2

Use case description:

- The process of gathering and uploading motion data, using paired smartphone, before moment of medication.

Actor:

- User: Caretaker of a PD patient with dementia.

Triggers:

- The user indicates that it is soon time for medication.

Precondition:

- There has to be a sufficient amount of time until the moment of medication. If there is no time left, no data will be gathered.

Flow:

1. The user knows it is soon time for medication for PD patient.
2. The user starts the process of gathering motion data from patient.
3. The system alerts the user when a sufficient amount of data has been gathered.
4. The user distributes the medicine to patient and notes the dosage.

Comment: Data from this session is sent to a database to serve as decision support for physician.

Use case 3

Use case description:

- The process of continuously gathering data throughout the whole day.

Actor:

- User: PD patient with average experience with technology.

Triggers:

- When the user puts on the smartwatch.

Precondition:

- The smartwatch has been switched on, electrically powered and worn by the user.

Flow:

1. The user puts on the smartwatch in the morning.
2. The user wears the smartwatch throughout the whole day.
3. The user is reminded by the smartwatch to take their medicine.
4. The user removes the smartwatch before bedtime.

Comment: During the day, data has been sent in intervals to a database to serve as decision support for physician.

Use case 4

Use case description:

● Allowing PD patients to gather motion data when reaching for a glass of water.

Actor:

● User: PD patient with average experience with technology.

Triggers:

● The user indicates that they will reach for a glass of water.

Precondition:

● The system does not need to fulfill any immediate condition.

Flow:

1. The user presses and holds the push button.
2. The user hears a beep, which indicates that motion data is being gathered.
3. The user reaches for the glass, drinks it and puts it down.
4. The user presses and holds the push button.
5. The user hears a beep, which indicates that motion data has been gathered.

The reason for synthesizing these use case was to explore the interaction with a clinical decision support system. In order to properly evaluate these ideas, it was agreed upon that more involvement of SMEs was required. Thus far, there had been no interaction with 'real' PD patients. Therefore, a meeting was set up with the remaining contact provided by Martin Rydmark, namely Sara Riggare.

5.3.10 Lead user

We were fortunate enough to meet with Sara Riggare, who is a researcher at the Health informatics Centre, department of Learning, Informatics, Management and Ethics at Karolinska Institutet. The goal with her research project is to explore and enhance the user of active self-care in chronic diseases, using PD as an example. She is the founder and chief patient officer at Nerve Labs, a company that develops intelligent self-care, patient empowering tools for people with chronic disease who aims to improve their living quality.

The meeting started out with pitching the idea and showcasing the sofar concept. Similar to Jurgen Broeren, Sara was keen on shifting the focus from tremors to other symptoms, especially to those related to gait. Regarding motor symptoms, gait has been poorly recognized in PD research since there is a tendency to focus on tremors. Also, PD tremor responds poorly to domarminergetic agents, while gait is more strongly affected. We suggested to use arm swing (both magnitude and speed) as an indicator of PD, which Sara agreed with. She stated that, by tracking arm movement during walks, and storing it for reference, it would be possible to make out if symptoms are strong or mild.

Sara agreed that allowing the user to note down moment of medication is a useful feature. She emphasized the importance of making such a feature very simple; to the point that it is basically only one button - "Note medication". The specific timestamp for the medication could then be handled automatically by the system. She recommended that we do not add functionality that allows the user to specify the amount/type of medicine, arguing that such options would be too cumbersome and lower frequency of use. (Data that lacks such details is better than no data at all.) Besides, correct dosage can often be worked out from the current regimen (using backtracking).

Furthermore, Sara wanted to expand on the idea of noting down medication to include other types of data. In particular, she saw it useful to gather data on how patients perceive their symptoms. Similar to noting down medication, this information must be easy and simple to note down, and she recommended a simple scale of 1-5 or 1-10 that represents the range of perceived symptoms in total. A low score would indicate the patient is suffering from strong symptoms, while a high score would indicate the symptoms are mild. Importantly, such a feature would include non-motor symptoms as well.

Lastly, Sara stressed that if functionality for uploading perceived symptoms was to be implemented in the system, the patients need a way to access their individual data. This would allow for patient involvement, which has been associated with high patient satisfaction and improved treatment outcomes. A more general term for this phenomenon is "patient centered care" (see section 3.2).

Although no prior plans on doing so, we chose Sara to be a lead user for this project. Lead users are people that have self-interest to develop or modify a certain product to improve on a problem that they themselves have observed. They face the needs that will be general in the future, but they face them before anyone else. With today's technology, researchers and healthcare companies have just recently opened their eyes to the beneficial aspects of self-tracking (Graitz, 2016), but they do not yet provide PD patient with a proper self-tracking tool for medication and symptoms. Currently, Sara is tracking her medicine intake using digital spreadsheet, and she has no tool for measuring her gait-related symptoms. Our system could allow her to note down data more easily and provide her the means of measuring her gait for evaluation.

Until this point, users of the system had been vaguely defined as "PD patients and healthcare personnel". Now, as Sara as a lead user, two different user groups inside "PD patients" were identified; a primary and a secondary one. The *primary* group consists of patients that are capable performing self-tracking by themselves, and can interact with the smartwatch without any issues. The secondary group are people that cannot or are struggling to perform, or comprehend, the actions of self-tracking. For example, these are patient that, in addition to PD, also suffers from dementia. It was decided that the main focus of the system, and the focus of the rest of the design process, should be shifted towards the primary user group. If they were deemed too time consuming, features aimed for the secondary user group could be discarded. It was argued that the scope of targeted users was in need of narrowing in order to allow the project to be finished in time. Possibly, the primary user group could be broadened later on.

As a result, from our meeting with Sara, the focus of the project shifted from tremor based data gathering to a wider concept of tracking medication and perceived symptoms (including non-motor symptoms) and gait testing. As Sara stated, gait has been poorly recognized in PD research since there is a tendency to focus on tremors. Thus, this project may help in shedding some light on this issue. She also stated, PD tremor responds poorly to

domarminergetic agents, while gait is more strongly affected. This means it will be easier to see a correlation between moment of medication and gait, compared with moment of medication and tremors. Another more practical reason we chose to focus on gait instead of tremors was that we assumed the amount of data from tracking gait would be more manageable and condensed compared to tracking tremors, which would make the whole project more doable. This affected the research question, which was restated into:

What features should an interactive system, consisting of a smartwatch and smartphone, have to enable personalization and patient-centeredness in treatment of people with Parkinson's disease?

which is the current research question, meaning the question did not undergo any more alterations.

Besides looking into the intrinsic nature of PD, efforts were put into learning about personalization and patient-centeredness. The result of this particular activity can be found in chapter 3, Theory.

5.3.11 Sketching

After the meeting with the project's lead user, Sara Riggare, we started sketching to design the user interface. To represent the different amounts of perceived symptoms, it was decided that similar scale as Wong-Bakers Pain Rating Scale (see figure 9 below) was to be used. However, to keep the design simple, it was agreed upon that five different options would be enough.

Figure 9: Wong-Baker pain ratings scale (Wong-Baker FACES Foundation, 2017)

We further contemplated whether to use full screen smileys or implement a scrollable list with item buttons for each smiley. An sketch was made for full screen smileys (See figure 10 below). The benefit of using a full screen smiley is that the smiley can be recognized easily, even if the user is on the move. The disadvantage is that there might hard to notice that there are other options available. On the other hand, a scrollable list with smiles is a much more compact method of displaying the scale, which makes it easy to display more than one alternative at once. However, an item list presents smaller images, which means it will be harder to handle the interface while on the move.
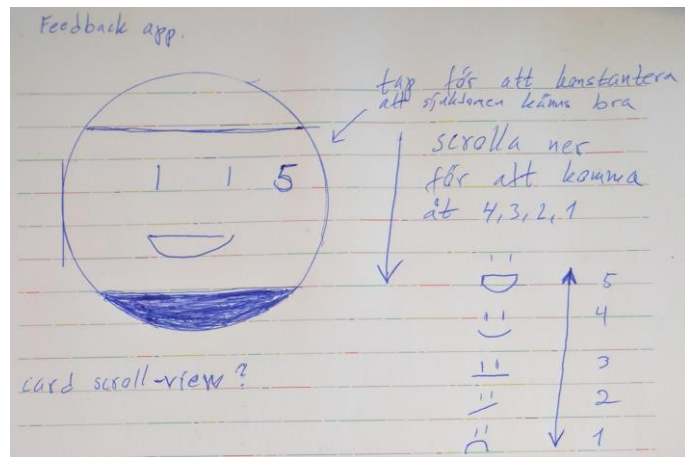
Figure 10: Early design sketch (Photo)

We also looked at ways to display a week's test results from, for example, a gait test that measures the total amount of arm activity during walks. In the sketches below, the result of such test corresponds to a single value (see figure 11 and 12 below).
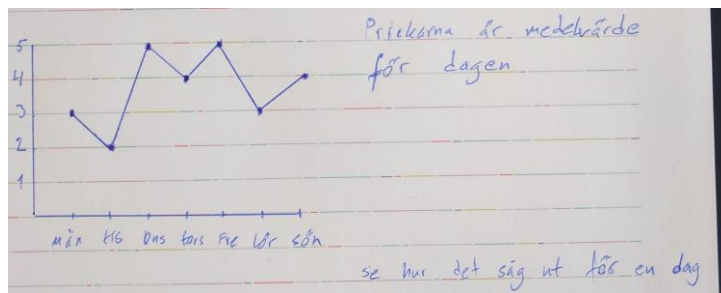
Figure 11: Design sketch graph (Photo)
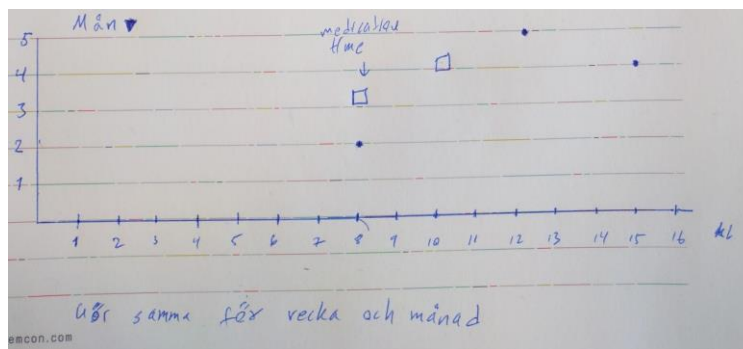
Figure 12: Design sketch graph 2 (Photo)

5.4 Iterative prototyping

The iterative prototyping phase was a back and forth process between Android development and evaluation from UX designer, SMEs and lead users. In the later stages, user testing was employed with a couple of PD patients.

5.4.1 Prototyping

Using sketches as guidance, a simple rating scale was developed as an Android Wear app. It contained five levels of perceived symptoms, where each level was given a state ranging between "Very Good" to "Very Bad" (see figure 13 below). The decision was made to use the vertical, scrollable list for displaying the different option. It provided a sufficiently clear and easy-to-use UI, and a manageable implementation difficulty. Evaluation techniques would have to be employed before any deeper usability-related conclusion could be drawn.
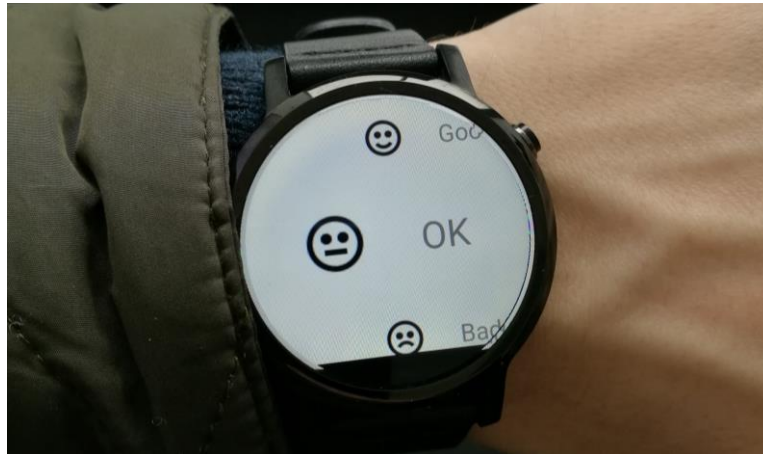
Figure 13: Early smartwatch prototype app (Photo)

Simultaneously with the development of this prototype, the database was implemented using Firebase, which is a web application development platform produced by Google. Firebase offers a range of services, such as analytics, hosting, crash reporting, where real time database is one of them.

During prototyping, we planned to implement the following functionality:

- Be able to note down perceived symptoms via a 1-5 scale
- Be able to note down moment of medication
- Be able to initialize a test that gathers data on arm swing

However, we came to realise that we needed to structure our software in a more manageable way. Thus far, we had one project (meaning one app) for each function. To make it more manageable, the decision was made to merge all three projects. As a result, all functionality would be reached from one single app. This was not considered a problem, since it allowed for easy access from the quick start menu on the smartwatch.

Until this point in development, no decision had been made regarding the smartphone app. It had been established that a smartphone app was required to be able to access useful features, such as mobile data network. A simple smartphone app had been developed to only serve as a pass-through node (where data would go from the smartwatch, to the smartphone and then reach the database). However, during prototyping, this app became a testing tool for uploading note to the database. This spawned the idea of integrating the smartphone into the system. Instead of only being able to upload notes via the smartwatch, it was decided that the smartphone app was going to support the same features.

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When implementing the smartphone app, the potential of being able to start a gait test remotely using the smartphone was realized. It would be particularly valuable for caretakers who would be able to start the test for patients that are in special cases. Patients may be severely physically impaired and cannot start the test themselves via the smartwatch. Thus, it was agreed upon to implement such a feature into the system. Note that this feature strongly supports the secondary user group (which was defined during the research phase).

5.4.2 Lead user

We met sporadically with the project's lead user, Sara Riggare, throughout the iterative prototyping phase. Again, the subject of data analysis was brought to the table. Sara and us came to the agreement that the application should not clinically analyse the gathered data. Implementing such processes was considered a too difficult task. Also, it was decided that the user's data should not be compared to 'normal' test result. Sara feared that such feature could a be interpret as competition and stress the user. In other words, users should not compare themselves with others. Instead, users should only focus on their own progress, i.e. compare with themselves internally. For visualizing the data, Sara suggested Highcharts which is a charting library written in Javascript. It offers a way to add interactive charts to websites and mobile web application.

Following Sara's suggestion, a simple web application was developed in Highcharts for visualizing results from the not-yet developed gait test. The charts inside the application was updated in real time with test data from the database via Firebase, allowing the user instant feedback on their tests (see figure 14 below).
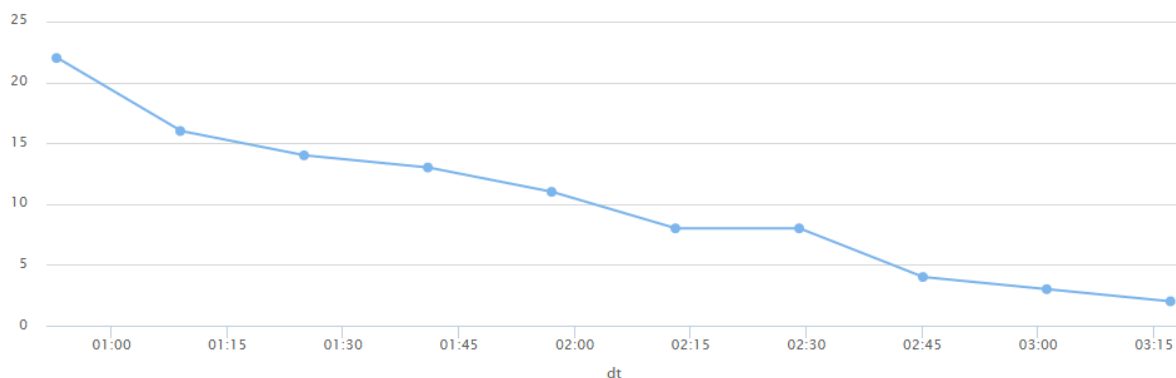
Figure 14: Highcharts (Screenshot)

5.4.3 Expert based evaluation

Semcon provide help with evaluating the current prototype by arranging a meeting with David Gillblom, a UX engineer and employee of Semcon. We presented the idea to David and demonstrated the different functions inside the system. Overall, David was pleased with the design, especially with scrolling list, which according to him, was sufficiently clear in displaying the scale of perceived symptoms and adequately easy-to-use for someone accustomed to touch screens.

David's primary concerns was with the UI's flow. For example, how do the user move from uploading perceived symptoms to noting down the moment of medication? He also recommended that we reconsider the amount of options for the user. Even though using a 1-

5 or a 1-10 scale can be useful for showing detailed fluctuations, it might be enough to simply use a 1-2 scale, in which one option translates to "Experiencing severe symptoms" and another to "Experiencing only mild symptoms". I was argued that using such a scale would allow for even simpler interaction while still providing relevant data. In addition, fewer options would make room for other selection inside the scrollable list, such as noting down medication and starting gait tests. This idea was developed into the following layout.

The options presented by the scrollable list:

- Noting down medication
- Register severe symptoms
- Register mild symptoms
- Start gait test

5.4.4 Prototyping (#2)

Prototyping was employed in purpose of finding good ways to visualize the data from noting down medication and registering symptoms. This resulted in two different versions of graphs, both using a simple timeline with time stamps. In addition, simple icons were constructed to represent the different alternatives: blue icons were added to show moments of medication, green icons were registrations of mild symptoms while red were for severe symptoms.

Version 1

One of the versions used a "scoring system" to show trends in perceived symptoms. "Register mild symptoms" meant an increase in the y-axis, while "Register severe symptoms" meant a decrease. The x-axis represents the flow of time (see figure 15 below).

Figure 15: Plot for displaying system values version 1 (Screenshot)

Version 2

The second version simply outputted each upload on the timeline, without adding any extra dimension (see figure 16 below).

Figure 16: Plot for displaying system values version 2 (Screenshot)

5.4.5 Unstructured interview with subject matter experts

Half through the prototyping phase, we met with Stefan Candefjord och Leif Sandsjö. Stefan is an assistant professor in the biomedical electromagnetics research group at Chalmers University of Technology. His research area stretches from monitoring cyclists to detect accident using Smartphones, to improving prehospital care for victims in road traffic accidents. Leif is a researcher at the University of Borås. His area of expertise includes eHealth, digitization within health care and welfare technology.

In purpose of evaluation, we asked Stefan and Leif for their opinion on the prototype, including the two versions of the time line graph. In summary, their main complaint was about **Version 1** (see previous subsection), which they meant showed an 'interpretation' of the data, rather than visualizing it. They argued that "score system" was subjective in the sense that it added meaning to the action of noting down medication or registering a symptom, an interpretation the patient did not necessarily agree with. This was taken into consideration and the decision was made to only use **Version 2** (see previous subsection).

5.4.6 Finalizing the prototype

Starting from the first meeting with our lead user, Sara Riggare, the plan was to create a gait test that could measure magnitude and frequency of a PD patient's arm swing during short walks. The gathered data then be analyzed by a physician or a neurologist to help determine the condition of the user (PD patient). To not mix it up with the term user test (as in user testing), and to make it come across as less competitive, it was decided to name the test feature "Record walk cycle", instead of "Gait test".

At first, the idea was to use accelerometer data to continuously determine the smartwatch's position while recording gait data. This turned out to be a much more difficult task than expected. In short, the problem lay in combining accelerometer data with orientation data from the gyroscope. Since the accelerometer cannot give information on the force's' direction, it is necessary to first apply the rotation. When these problems appeared, the question was raised if similar, beneficial data could be gathered without having to continuously determine the exact position of the smartwatch. We performed a brainstorming session to come up with an alternative method, again using the open source app SensorDashboard to explore the smartwatch's sensors. It was then realized that the gyroscope alone can produce a fairly good estimation of how the user is moving their "watch arm" during walking. The following image (see figure 17 below) shows the concept behind the idea of only using the smartwatch's rotation for measuring arm swing.
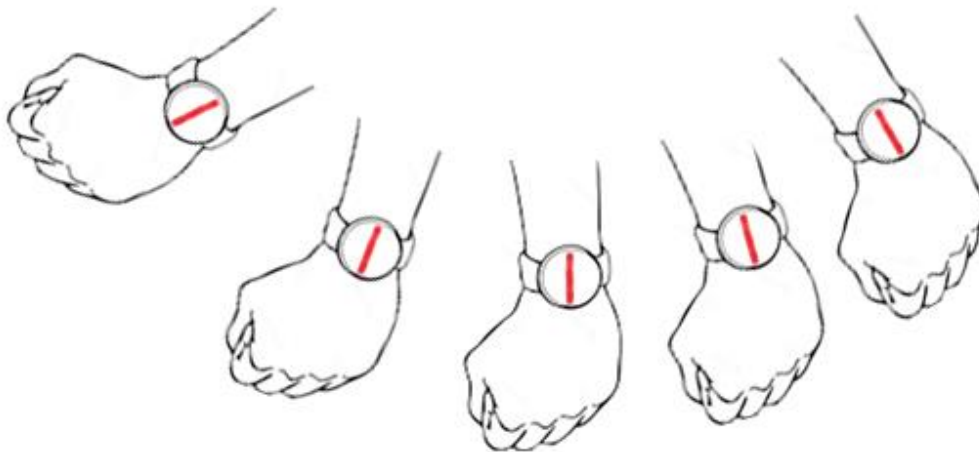
Figure 17: Smartwatch rotation pattern (Sketch)

Notice how the red line that goes along the arm of user is rotating as the wearer swings their arm back and forth.

While worn and the user is resting their "watch arm" by their side, the axes of the smartwatch are as following:

- x-axis points straight down.
- y-axis points in the direction of the user's back.
- z-axis point outward from face of smartwatch.

The graph below (see figure 18 below) is screenshot of the SensorDashboard app plotting the rotation around the z-axis while the wear of the smartwatch swing their arm back and forth.
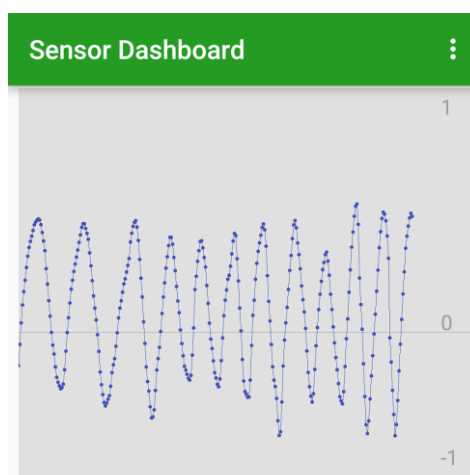
Figure 18: Sensor Dashboard app plotting z-axis rotation (Screenshot)

With these finding, we could easily put together an Android activity that, for a given amount of time, continuously gather data on the user's arm swing. Without any definitive fact, it was

decided that ten seconds was well more than enough to make out if the user is swinging their arm very little (thus suffer strong symptoms) or with normal swing (no symptoms). This was confirmed by us, which performed tests where we walked similar to people with severe PD-related gait difficulties contra where we walked normally. Still, it was agreed upon that user testing is necessary for drawing deeper conclusions regarding the time span of the recording.

As previously stated, plans on using Highcarts for visualizing gait-related data were made. However, this idea was discarded for a much simpler, but equally adequate, solution. Since the most important aspect of the test was to measure the extent of the user's arm activity, the idea of storing the rotational data as a function (see image above) was scrapped. Instead, the recording was reconstructed to summarize the rotational changes (in z-axis) and represent the result as one single value, i.e. the total amount of degrees (in z-axis) the smartwatch has rotated from the start of the test. Naturally, this value is an indicator of the total amount of arm activity that occurred during the test. This solution is inspired by Kinesia 360 and Kinesia ONE (Great Lakes NeuroTechnologies, 2017), which both provides objective "scores" for PD symptoms over the course of a single day. In their case, however, symptoms scores are calculated by clinically validated algorithms. We have also adopted their method of color coding symptom severity, which allows for easy review of daily fluctuations.

Since the result of the "Record walk cycle"-feature was a single value, the result could easily be added to the layout of the graph. Below is an image that shows a graph with a gait recording.
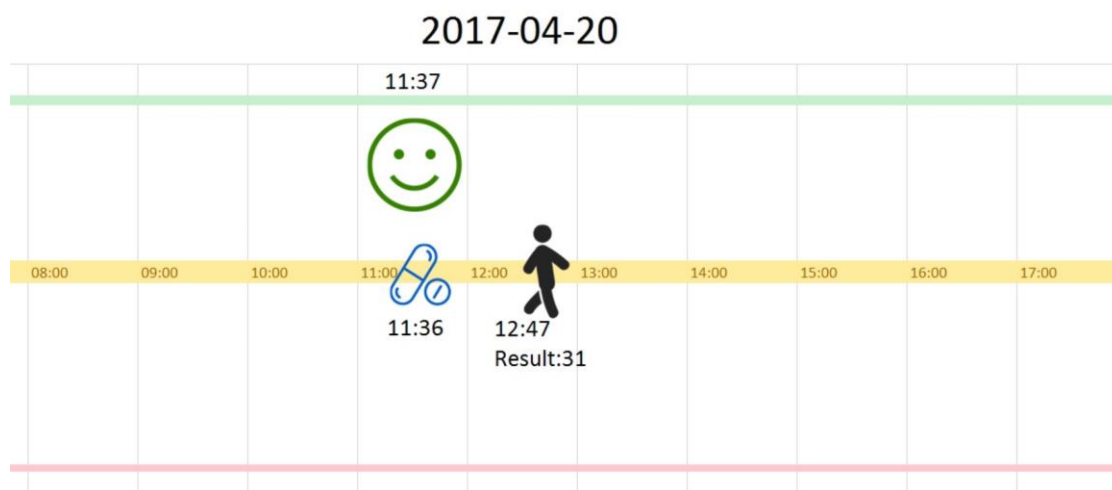
Figure 19: Plot with values (Screenshot)

With all four main features implemented, it was decided that the prototype was ready for usability testing.

As concluded during the first prototyping session of the iterative prototyping phase, plans were made to develop a smartphone app that directly mirrored the functionality of the smartwatch app. These plans were successfully followed through. In addition, we managed to add the feature of starting the "Record walk cycle" directly from the smartphone app (see figure 20 below).
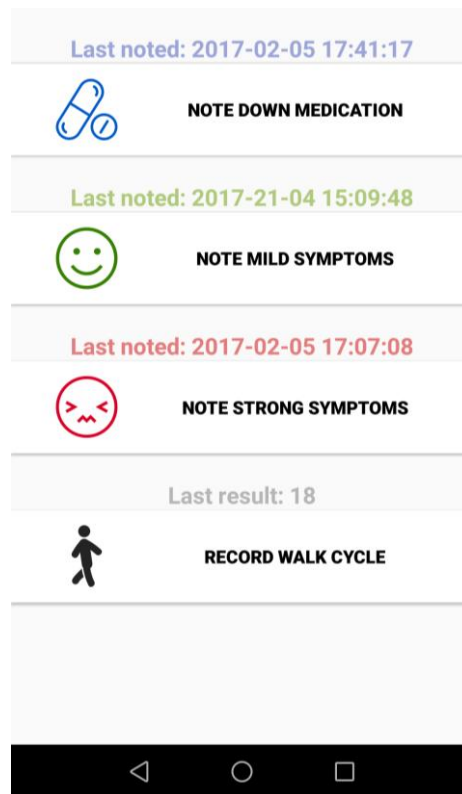
Figure 20: Smartphone app of the developed system (Screenshot)

5.4.7 Usability testing

In our first interview with a SME, we were warned about the difficulty in acquiring permission to perform research on 'real' patients within the health care. Thus, it was decided to not use any "official" procedure (via health care services) for finding test users. Instead, we found three testers by searching for individuals in our vicinity via other means. All three test users interacted with the system throughout the span of roughly two days each, where two of them tested simultaneously as different user roles (patient and caretaker). These activities can be summarised in two different tests, test 1 and test 2. Feedback was gathered in the form of a questionnaire in test 1 and via an unstructured interview in test 2. When conducting test 1,

we met and interacted with a PD patient. This allowed them to engage in casual observation, seeing the patient move around in his home residence.

Inspired by Kinesia 360 and Kinesia ONE (Great Lakes NeuroTechnologies, 2017), we constructed a 'kit' for the test user consisting of a smartwatch and smartphone with our software pre-installed.

5.4.7.1 Test 1

The first test user was a middle-aged man diagnosed with PD roughly 8 years ago. He had great interest for technology and was estimated to have more than average' experience in dealing with smart devices. Before the test, he was informed about all the features of the prototype and what purposes each function served. It was decided that he would have the smartwatch for two days in full (not counting the starting day). The test user was encouraged to use the prototype on his own accord. Thus, he received no direct directives to follow. To

be able to access his data, it was agreed upon that a graph would be sent to him in the morning containing data from the previous day. The test lasted for three days, after which a questionnaire was sent to the tester to gather feedback on the system (see appendix A). The following is a summary of what was gathered from that questionnaire.

Overall, the test user was happy with the performance of the UI of the smartwatch app, giving high scores on both precision and responsiveness. Regarding the feature of noting down medication, the test user missed the option of being able to plan medication moments on beforehand, i.e. to not having to note them down in real time, by either adding hours into a list or setting an interval. This means the test user was positive to the idea of using notifications, which can appear either on the smartwatch or the smartphone. For example, a notification on the smartwatch that tells him that it is time to take his medication. Lastly, regarding noting down medication, the test user would find it beneficial to be able to add what type of medication (he was using a two different types). It was not as important, however, to be able to add the exact amount of medicine that was taken (only type).

Regarding the noting of perceived symptoms, the test user stated that it would be beneficial to increase the number of levels in the scale, i.e. to not use a 1-2 scale but something bigger. For example, a scale ranging from 1 to 10 would be more preferable since would allow for greater level of details and fluctuation.

Besides widening the scale, the test user wanted to have the option of adding "user defined" buttons which could track more specific symptoms. They would work very similar to the functions that already exist, but less generalized since they are "custom made" by/for the user. For example, the test user suffered from severe stiffness during morning, thus the user should be able to create a button that notes down perceived stiffness. Such a function could also make use of a scale, meaning there could be a "stiffness scale" in which the user could rank the total amount of stiffness.

Unexpectedly, the test user only recorded his walk cycle once over the course of three days, and gave mediocre score regarding the usefulness of the feature. He suggested that, instead of having to be manually started, the recording should be automatized so that it automatically starts to gather motion data when it is deemed relevant. Finally, regarding the visualization of the gathered data, the test user thought they were easy-to-grasp and felt that they provided useful feedback.

5.4.7.2 Observation (from test 1)

For preparation of test 1, we met with the test user for a total of roughly 90 minutes. For a considerable amount of this time, the test user walked around in his residence. During our stay, we experienced PD gait-related symptoms first hand. It became clear just how big the difference is between the ON and OFF states. In the beginning of the meeting, the test user moved quite normally - his arm was relaxed at his side, swinging back and forth as he walked, and his steps was of some length. However, as the meeting progressed, motion symptoms became increasingly noticeable. Most noticeable was the change in his gait. When he walked, the arms were bent and fixed at his side, his posture became more bent and his steps decreased significantly in length.

5.4.7.3 Test 2

This test was different from test 1 in the sense that it involved two test users. One of them was an elderly woman diagnosed with both PD and dementia; the other one was her daughter. During the test, these two individuals represented a patient (elderly woman) and

their caretaker (her daughter). This setup helped investigating the use cases in which someone that is not wearing the smartwatch starts the "Record walk cycle"-feature from the smartphone app. Such feature allows a caretaker to gather motion data without notifying the patient.

For this test, a couple of unstructured interviews, along with a written summary of the experience, provided us with feedback. These findings are summarized in the following paragraphs. For making it easier to reference them in the text: the elderly woman with PD is referred to as test user 1 while her daughter, who took the caretaker role, is referred to as test user 2. Lastly, during the test, test user 1, i.e. the one who was wearing the smartwatch, was not aware that her walk cycle was being recorded, nor that the smartphone which was carried by test user 2, was part of the system.

Test user 2 explained that the process of equipping the test user 1 with the smartwatch went smooth and easy. During the test, she thought the usefulness in having the same functionality in both the smartwatch and the smartphone became apparent. Since test user 1 was impaired due to combination of old age and PD, it would have been hard for her to directly interact with the smartwatch app. When both of them were out on walks, test user 2 often started the "Record walk cycle"-feature without test user 1 noticing it.

During the first day of testing, and twice within 10 minutes, test user 1 got the result of 2 from the recording her walk cycle. While performing these tests, test user 1 was visibly experiencing strong motor restrictive symptoms (due to PD). Therefore, test user 2 concluded that a result of 2 indicated a poor result (symptom-wise). During the second day of testing, the test user 1 managed to get higher results. One of the recordings resulted in a 9, and unsurprisingly she was, according to test user 2, in good condition regarding PD symptoms.

When test user 2 wanted to note down test user 1's perceived symptoms, she simply asked her how she was feeling and used the functions of noting down symptoms in the smartphone app. When test user 1 took her PD-specific medicine, test user 2 used the "Note down medication"-feature to notify the system of event. Overall, test user 2 thought that the smartphone app was simple (in a good way) and easy to use. Since she never interacted with the smartwatch app, she could not comment on its UI.

One aspect that the test user 2 felt could be improved on was the amount of feedback from the "Record walk cycle"-feature. Since it could be started from the smartphone app, she thought it would be beneficial to be able tell easily when a recording has finished. She was aware that the text field above the button (the "Last result"-field) changed value when a new result was registered in the database. Still, she wanted to some more direct feedback in the form of a vibration or a pop-up.

5.4.8 Test results

With usability testing over, a list of changes was agreed upon that could potentially deal with some of the issues that had appeared:

- Add functionality for adding reminders and notifications for medication (Test 1)
- Widen the range of the perceived symptom scale (Test 1)
- Add functionality for adding user defined symptoms with corresponding scales (Test 1)

- The "Record walk cycle"-feature should be automated, meaning it should start automatically in certain situations. For example, it should learn to start if user is out taking a walk (Test 1).
- There should be direct feedback inside the smartphone app when the smartwatch app is done recording the wearers walk cycle (Test 2).

It was understood that these fixes were not to be implemented due to time constraints. Instead, it was decided to gather the results and end the design process here.

6 Results

The research question has been explored by implementing and practically testing a prototype. This chapter carefully describes this prototype; its physical appearance, UI design and features. In addition, in the process of designing the prototype, and to properly answer the research question, as set of features has been identified. These features are presented in section 6.2, Features.

6.1 Prototype

In this project, a system was developed to help enable personalization and patient-centeredness in PD treatment. The system is largely comprised of an Android app, running on both an Android wear smartwatch and a smartphone. The prototype lets the patient note down the gravity of their symptoms along with the moment of their medicine intake. The app also features a gait-related walk test which lets the user record their arm activity during short walks. The result of this test can serve as an indicator of how strong PD symptoms the user is experiencing throughout the day. Since the app exists in both smartwatches and smartphones, both version features similar functionality. However, the smartwatch must be worn for the walk cycle to be properly recorded. Lastly, in order for the user to access their data, timeline charts were designed for visualization purposes.

Broken down, the prototype includes the following parts:

- Smartwatch along with the smartwatch app
- Smartphone app
- Graphs for data visualization
- Database access

The remainder of this chapter is divided into subsections, one for each of these parts, starting with the smartwatch.

6.1.1 Smartwatch and smartwatch app

The smartwatch is one of Motorola's Moto 360 (second generation) watches. It has a round design, which makes it resembles an ordinary, mechanical wristwatch, and runs Android Wear. Due to hardware limitations and software architecture, the Android Wear smartwatches need a coupled smartphone to access commonly used services such as mobile data networks.

The Android app that was developed for the smartwatch has the following features:

- Noting down medication
- Noting down symptoms
- Recording walk cycle

All features can be directly accessed via a vertical scrolling list on the main page of the application.

6.1.1.1 Noting down medication

This simple feature allows the user to note down the moment of their medicine intake. It is the first item in the scrollable list, represented by a blue medicine icon (see figure 21 below).

Figure 21: Note down medication button on developed smartwatch app (Photo)

By clicking this item, the user is brought to a confirmation screen, allowing the user to either cancel the request or continue (see figure 22 below).
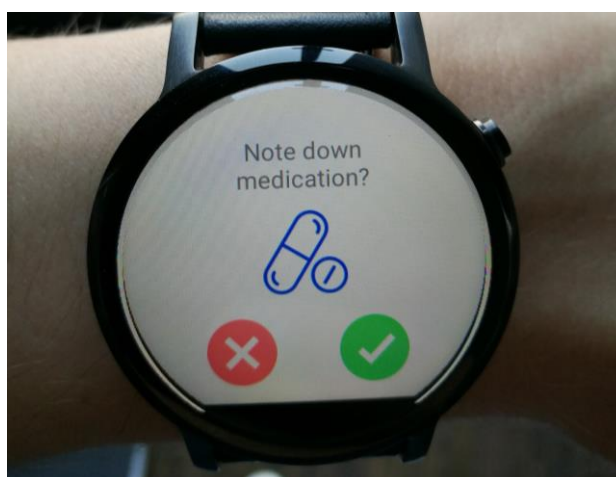
Figure 22: Confirm note down medication (Photo)

If the user confirms this action, the system will automatically upload the information as a timestamp in a database. In addition, a unobtrusive pop-up will appear in the bottom of screen, providing feedback to the user (see figure 23 below).

Figure 23: Noting medication (Photo)

6.1.1.2 Noting symptoms

These features allow the user to log their condition. It presents two different options to the user in the form of a scale of perceived symptoms, ranging from mild to strong symptoms. The scale is directly accessible through the scrolling list on the main page (see figure 24 and figure 25 below). Before uploading the information, the user needs to confirm the selection (similar to the noting down of medication). This will also upload the information to a database, along with the exact point in time.

Figure 24: Noting mild symptom (Photo)

Figure 25: Confirm strong symptoms (Photo)

The two different options are represented by two different extremes - a green happy smiley and a red sad smiley.

6.1.1.3 Recording walk cycle

A recording of the wearer's walk cycle can be initiated by pressing list item "Record walk cycle" which has an icon of a walking stick figure. After confirming the selection, the smartwatch prompts the user by text that the recording soon will start. When the recording is over, after 10 seconds, the smartwatch vibrates to prompt the user that the process has finished. The result is then displayed as a pop-up screen, which automatically closes after a short while. In short, the result is a sum of the rotational changes (in z-axis) that occurred during those 10 seconds. It is important to note that there is nothing that assures the users is walking when this feature is activated. As explained, the smartwatch simply gives the user a heads up (see figure 25 below).

Figure 26: Record walk cycle (Photo)

6.1.2 Smartphone app

As stated, the smartwatch app has a smartphone counterpart. All of the features that exist inside the smartwatch app can also be accessed through the smartphone version (see figure 26 below). The main difference is that the "Record walk cycle"-feature cannot be handled by the smartphone version alone, but is dependent on the on smartwatch to be present.
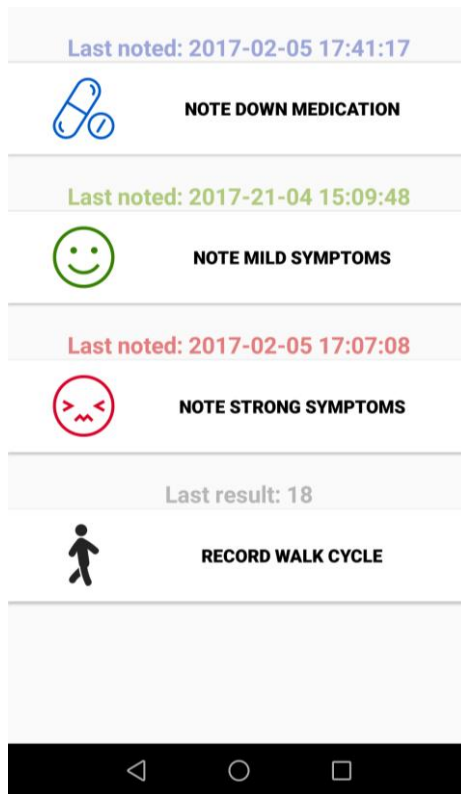
Figure 27: Smartphone-app (Screenshot)

Another difference is that the smartphone version presents the last noted (or recorded) result for each individual feature. The information is presented as text above each button and the text is colored as the corresponding icons.

6.1.3 Plots for data visualization

The prototype supports data visualization in the form of a timeline plot. The plot is constructed so show data gathered throughout the course of a single day. This means the timeline stretches an entire 24 hours. The different input variations (that can be uploaded via the app) are displayed as timestamps onto the timeline. The plot shows moments of medication, noted mild symptoms, noted strong symptoms and recorded walk cycles with results. The timestamps for mild and strong symptoms are also separated vertically in two different rows (see figure 27 below).

Figure 28: Timeline plot of possible data-values (Screenshot)

6.1.4 Database

The data collected using the prototype during was stored in a database provided by Firebase. Firebase is a web application development platform produced by Google. It provides a cloud-based, NoSQL database that saves data in realtime. Every time a function, such as noting down medication, is activated, on either the smartwatch or smartphone, the value is stored in the Firebase database along with date and time. The smartphone is responsible for uploading all data to the server, being able to access a mobile data network. That means that the smartwatch sends instructions to the paired smartphone to upload the correct data to the Firebase server. Below is an image that displays the layout of the database service inside Firebase (see figure 28 below).


```
├─ Gait
│    ── -KkfsiM_CABPM7gXSUa1: "7 2017-21-05 18:41:4
│    ── -KkfuoXvp18KFOWgf3NY: "8 2017-21-05 18:50:5
│    └── -KkjSgS8yWJTem_ooYoh: "9 2017-22-05 11:22:1
├─ Medication
│    └── -KkjZq92dZ1WMeYb1VCM: "Medication   2017-22-05 11:53:
├─ Mild Symptoms
     ── -Kkfsw_o5pMSysQmTuac: "Mild Symptoms  2017-21-05 18:42:
     └── -KkjSk7EW65grZE7sMnd: "Mild Symptoms  2017-22-05 11:22:
```
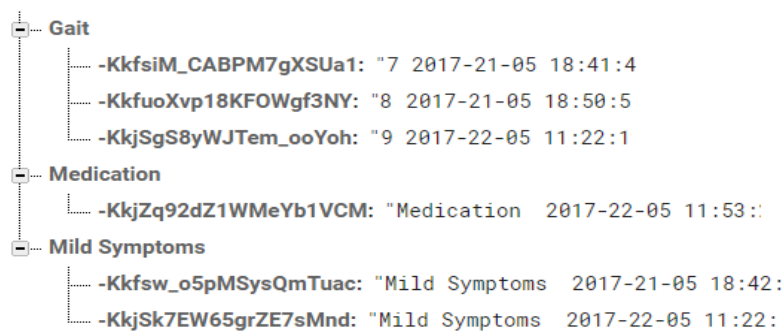
Figure 29: Firebase data node structure (Screenshot)

6.2 Features

By developing and practically testing the prototype described in the previous section (6.1), a set of features was identified. These features were singled out during the work process as important factors for enabling personalization and patient-centeredness. Thus, the set of features serves the purpose of answering the research question. This section presents these features, along with rationales for each of them. Each subsection describes one or more feature. Since the project was limited to mainly focus on the patient, the list mainly contains features that belongs to patient-side of the system.

6.2.1 Focused monitoring

During one of our subject matter interviews (see section 5.3.8), the interviewee opposed the notion that one should strive to gather as much data as possible. Rather, it is better to focus on capturing fewer, but very interesting moments. More data is not always preferable due to the labour-intensive process of data mining. (Data-mining is used to break apart huge datasets when searching for valuable data.) Regarding PD treatment, the SME suggested that data before, during and after moment of medication is for especially useful for evaluating the quality of the patient's regimen. The same thoughts were expressed in an interview with employees of Great Lakes NeuroTechnologies in Cleveland (Gravitz, 2016) which is a company that develops bioinstrumentation product for people with PD. Thus, our findings suggest that focused monitoring, i.e. an effort of capturing the most interesting moments in the day of the patient, is an appropriate feature for gathering clinically relevant data. This data can then be used to personalize the treatment of the patient.

Since the following features strongly relate to the process of gathering data during the most interesting moments during the day, we have added them as sub-features to focused monitoring.

6.2.1.1 Note down symptoms

Recently, non-motor symptoms have emerged as the most important factor in determining the condition of the patient (Chaudhuri, Clough & Sethi, 2011). These symptoms include dementia, depression, sleep disorders, bowel and bladder problems, fatigue, apathy, pain and autonomic dysfunction. As there is a tendency in research to concentrate on motor symptoms, non-motor-symptoms have been poorly recognized, which makes personalized treatments harder to achieve. This was further reinforced by the lead user of this project, Sara Riggare (see section 5.2.10). She saw it useful to gather data on how patients perceive their own symptoms, both motor and non-motor. From user testing (see section 5.4.7.3), it was suggested that such a feature must allow patients to note down *their own* types of symptoms. Therefore, it is beneficial if the patient themselves can add what type of symptoms to note down. For example, if someone is experience cramps, the patient should be able to add that symptom to the ones featured inside the system.

6.2.1.2 Note down medicine

From our findings on focused monitoring, largely from interviews with SMEs (see section 5.3.8 and 5.3.10), it was concluded that recording moments of medication is of great importance when evaluating PD treatment. Sara Riggare, our lead user, suggested a feature in which the user notes down medication without specifying amount or type. Sara argued that it is more valuable to know *when* medicine is taken, rather than the exact details on amount/type. However, during user testing, one of our test users missed the feature of specifying what type of medicine. In summary, our finding suggest that it is important that the system support the recording of medicine intake. Whether the system should allow user to specify medicine type or not is still unsure. Thus, we leave it as an optional feature.

6.2.1.3 Reminders

Our finding suggests that reminders for medication is beneficial to the user. The importance of this features was stressed during test 1 (see section 5.4.7.1). These reminders can be notifications that pop up on the smartwatch or the paired smartphone. Medication reminders are proven to be helpful in making a treatment regime effective (Kunawararak et al., 2011).

6.2.1.4 Test motor symptoms

Since perceived symptoms are subjective and depend on how the patient *perceive* them, they are not enough to provide a complete picture of a PD patient's condition. This became clear during test 2 (see section 5.4.7.3), where the test user was experiencing strong symptoms although not aware of it. On the contrary, the test user was feeling good. Thus, our findings suggest that it is important to have features that can give non-subjective results. For the prototype of this report, that feature was in the form of a walk test which gathered data on arm swing.

6.2.1.4 Automated features

This feature is more of a "type of feature" than a feature in itself. From test 1 (see section 5.4.7.1), it was suggested that automated features are beneficial for data gathering on motor-symptoms.

6.2.2 Portability and accessibility

Since PD varies a lot throughout the day, and since the patient may not stay at one place throughout the course of a single day, it is important that the system should be portable. If the user is out for a walk and, for instance, experiences symptoms, the system allow for data gathering. Our lead user, Sara Riggare (see 5.3.10), stressed that patient should not be confined to their home in order for them to use the system. This was also brought up during the brainstorming session, described in section 5.3.4.

6.2.3 Low cost

In section 5.3.1, Martin Rydmark, a SME in this project, was very clear on that the system should not be too expensive. Medical devices often pose a big monetary cost (Kass et al., 2015), which makes the devices less attainable. Martin suggested that the total price of the system must be affordable to most people so that the system is as attainable as possible.

6.2.4 Discretion

During our brainstorming session with KJ, it was gathered that the system must not be an indicator for the user's PD (see section 5.3.4). In other words, it should not be immediately obvious that the user is interacting with a system with the purpose of measuring PD symptoms. This is based on the notion that people, in general, do not want to identify themselves with their disease. This idea was largely put together with information from an SME interview (see section 5.3.1).

6.2.5 Familiarity

Similar to the feature of discretion, this was brought forth during the brainstorming session after a period research (see section 5.3.1-5.3.4). It was gathered that it is beneficial if the user feels familiar with the system. For example, since many are accustomed to the experience of wearing a mechanical watch, it is beneficial if the system, using a smartwatch, is very much like that experience. Of course, this is a generalization. The idea is based upon the fact that Parkinson mostly afflicts elderlies that may lack experience with today's technology. In addition, interviews with SMEs indicated that there is an anti-technology way of thinking in a large portion of the elder population.

6.2.6 Customizability

This feature is a generalization of what was described in Note down symptoms (6.2.1.1). Customizability allows the users to personalize the system to fit their needs. This was noticeable in test 1, section 5.4.7.1, in which the test user agreed that a feature allowing the user to add custom "Note down"-buttons would help him in tracking his symptoms. For example, the user can add a button called "Note down stiffness" if he often experiences that type of symptom. Another user might not experience stiffness but tremors, and can another button for that purpose. Important to note, this is only one case in which customizability is beneficial. We suggest employing customizability in one than more aspect. For example, regarding the process of noting down medicine (6.2.1.2), one can allow the user to decide themselves whether they need to specify type of medicine or not.

6.2.7 Different users

As stated, this project focuses solely on the patient-side of the system, meaning neurologists as users are completely left out. Still, the involvement of physicians is a crucial component in evaluating the PD patient's condition and treatment. This matter was stressed during a SME

interview (see section 5.3.8). As a user of the system, the physician will take the role of data evaluators.

The caretaker also has a legitimate role as a user of the system. Since she is working closer to the patient compared to physician, this interaction was given more attention during the project. User testing (see section 5.4.7.3) suggest that involvement of a caretaker, as a user, can be beneficial for patient inexperienced with smart technology, such as smartphones. Using a caretaker user, it removes some of responsibilities of the patient.

6.2.8 Connectivity and data accessibility

The data gathered by the user must be accessible by appropriate people. This includes the user who gathered the data, along with physicians that wishes to analyze it. The importance of this feature was stressed by the lead user of this project, Sara Riggare (see section 5.3.10). She argued that, if patient can access their own data, which must be visualized appropriately, patients can become involved in their treatments. In section 5.4.7.1 the test user expressed that the plot provided him with useful feedback, further strengthening the reason for this feature.

As stated, the data should not only be accessible to user performing data gathering, i.e. the users, but also to health care personnel. For the data to be accessible, the system must be connected to a database of some sort. Ideally, the process of download/upload is handled solely by the system, without any further action required from the users.

6.2.9 Push buttons

During our research, we found that push buttons are preferable than touch based input, which was also confirmed by an SME (see section 5.3.1). Preferably, the smartwatch should have more than one push button, since it allows for a more diverse interaction if those buttons are the only viable means for interacting with the system. Since these buttons can be used to start certain features, they significantly lower the number of steps inside the UI. For instance, a feature for testing motor-symptoms, such as a walk test, can be initiated from a push button. Note down medication can also be controlled by push button, lowering the steps in the interaction as well as making it easier to perform.

6.2.10 Glanceability

Glanceability is a feature inherited from the Android Wear guidelines (see section 5.3.6). When designing apps for smartwatches, users should get information at a glance, called "glanceability". The guidelines states that developers must "understand use cases" (Android Wear design guidelines, 2017). People wearing smartwatches are sometimes in motion, whether they are gesturing, walking or running, and the system must be designed so that it takes this into account. Regarding this project, this feature relates strongly to accessibility and discretion (6.2.2 and 6.2.4). Even if the user is walking outside, it must be easy for them to interact with the system. It must not draw too much attention or be too intrusive, else the system might serve as an indicator of illness. The task must also be completed easily, else it might become too much hassle for the user (relating to feature described in 6.2.11).

6.2.11 Balanced number of features

Because our intent is that the prototype should not be intrusive, it is important that the prototype has a balanced number of features and a balanced number of screens that the user navigates through. Making the user navigate through a lot of features and screens disorienting kind of navigation, especially on a small screen. If users constantly must navigate between pages to achieve their goals they will get frustrated (Cooper et al., 2014).

7 Discussion

This section discusses all of the major phases of the research project, including the final result. It is divided into four sections: methods and process, user testing, results and future work. The first part discusses the process in relation to the methodology. The second part looks at strength and weaknesses with the user tests. Then, the result section comments the outcome of the project. Finally, the last section gives suggestion on future development and how some of the current issues can be dealt with.

7.1 Methods and process

Many methods were investigated as possible candidates for use during this project, most of which are from the field of interaction design. During the research phase, three methods stood out: namely 'reviewing of previous work', 'subject matter interviews' (SMEs) and 'lead user'. Literature reviews provided with a good foundation on PD, which proved useful when conducting and putting together questions for the interviews. Thus, the literature reviews were vital for the design process. Product audits gave a good understanding of what had already been achieved and highlighted pros and cons with different methods of gathering motion data. As student of interaction design, we were not accustomed to the concept of lead users. Instead, it was a method that was discovered in our interaction with Sara Riggare (see section 5.3.10). With hindsight, we deem it a useful method, especially for "thinking new".

It is our opinion that the reason SMEs and lead user were beneficial to such an extent was because we had no previous first-hand experience with PD. Therefore, it was very important to get some input, and keeping in touch, with people who have interacted with PD patients before. Alan Cooper (2014) states that if you are designing for a technical field, e.g. a medical domain, you will likely need some guidance from SMEs (unless you can consider yourself an SME yourself). Cooper also states that it is important to keep in touch with SMEs throughout the whole design process. Conducting questionnaires and interviews, especially on large user group, would likely been equally adequate. However, SMEs in the initial phases of research phase warned about the difficulties in performing such research. The fact that we reached out to the Gothenburg's Parkinson Association without any success can further support this claim. In addition, the method of conducting interviews with a lot subject has a couple of downsides, such as being time consuming and labour intensive. We are thus certain SMEs interview lead user meetings provided a good substitute in this project.

Use cases proved useful for identifying system functions before the actual programming began. As stated in this thesis, use cases were constructed after an interview with an SME. This helped in focusing the design toward not-yet-considered user actions such as starting and stopping the gathering of motion data. Before the use cases, the concept was very vague and we lacked any idea of how the user would interact with the system. The use cases also made us realize that different users might have different needs in operating the system. For instance, the difference in motivation for an self-reliant PD patient versus a patient that needs a help from caretakers.

With hindsight, the content of the planning report (see section 5) seems naive and questionable at best. Few elements were implemented as planned. Still, we did end up following the overall flow of the planned phases; from research to iterative prototyping, to showcasing of the system. The showcasing phase is not featured in this thesis. It was as carried out in the form of a live demo presentation for Semcon (stakeholder). Throughout the

project, it became noticeable that the phases blend together and certain activities that may seem to belong in one phase appears in another. For example, spontaneous brainstorming session occurred in short burst throughout the whole project. It was used during the research phase, together with a KJ-session, as a way to synthesize data and as a problem-solving tool for dealing with the issue of tracking arm activity during short walks.

Several methods that were described in chapter 4, Methodology, were not officially used during the work process. They include fly-on-the-wall observation, think-aloud test, focus groups, heuristic evaluation, cognitive walkthrough, designing guidelines for PD patients, requirement specification, personas, scenarios, low and high-fidelity prototyping and storyboard. Afterwards, we have realized that we actually used some of these methods but with slight modifications or in similar fashion. For example, although fly-on-the-wall observation was not employed directly, we performed observation during test 1 (see section 5.4.7.2). Regarding expert based evaluation, we did not employ heuristic evaluation or cognitive walkthrough. Instead, we chose to perform a more casual version of expert evaluation by simply presenting our prototype to a UX engineer from Semcon. In addition, many of the heuristics (see section 4.2.7.1) were subtly considered during the design of the prototype. As students of interaction design, we find that many of these heuristics have become a natural part of our toolbox as designers. Thus, we do not consciously use them for designing or evaluating. Furthermore, short and simple tests were performed with Semcon (stakeholders) in which the tester (one of our supervisors) used the prototype and spoke their mind openly when using it. System requirements were developed in relation with use cases but were not documented properly.

Although they serve an important role in GDD, we did not produce any personas. We believe this to be a consequence of not committing ourselves to the GDD design approach (see section 5.2). Also, we did not construct any 'real' storyboards. We did, however, construct simple sketches, along with our use cases, that explored the interaction with the system. Regarding prototyping, the final prototype may serve as a high-fidelity prototype (although not specifically using that term) while our sketches serve as a low-fidelity one which was evaluated by us. Regrettably, we did not pay much attention to the design guidelines for smartphone application for people with PD. They more or less forgotten among our other tasks. It may be beneficial performing tests in which the prototype is evaluating with these guidelines in mind. Finally, we did not use focus group, mostly due to Cooper's advice against them (Cooper et al., 2014) them and the lack of participants.

Another concept that we did not use or mention in our work process is the concept of 'dynamic user profiles'. Our theory chapter (see section 3.1) states that every instance of personalization must have a user profile to reference (Petersen et al., 2008). The user profile is responsible of storing relevant data about the user. One important feature of the user profile is to prevent users from being forced to provide information more times than necessary. In our opinion, the concept of user profiles was not feature in the work process due to the simplistic nature of our prototype. For example, there is no option-page in which the user can modify the interface. However, the Android OS do carry a dynamic, context-sensitive user profile innately. For example, the brightness of the screen changes to better fit the environment of the user.

7.2 User test discussion

Two different user tests were performed during this thesis. Both tests included individuals diagnosed with PD, who both were found through 'private means', meaning there was no cooperative process of finding users through official health care services.

Even though only two user tests were conducted, they were qualitative in their nature and could provide valuable feedback. In our opinion, a beneficial factor was that our test users were significantly different from each other. The first test user was a middle aged, self-reliant man with much experience with smart devices. The other test user was a 84-years-old woman with very little experience with technology in general. Thus, they differed in both age and technological knowledge. Their general condition was also very different, since the woman suffered from dementia.

During testing, the greatest difference regarding user interaction lay in the smartwatch-smartphone usage quota. The first test user (the middle-aged man) used the smartwatch exclusively, i.e. did not interact with the smartphone. Meanwhile, the other test user (the elderly woman) did not interact with any device, but instead had a caretaker (who is technically also a test user) that interacted with the system exclusively via the smartphone. As designers, it was valuable to make sure that both entry points provided an equally adequate service for the patient.

One of the main features of the prototype is the "Record walk cycle" which allows the user to record the total amount of arm activity for a set period. Naturally, one would think that a person who often is outside, taking walking or uses walks as a method of exercising is inclined to use such a feature more often than someone who very seldom takes walks. Unfortunately, during user testing, the test users were not asked question regarding their walking habit. Since the "Record walk cycle"-feature were used very sparsely (only one time), one can theorize that the test user simply very seldom were out walking and thus the idea of using the feature seldom came to his mind. Of course, this is guessing from our part, and it highlights a flaw in the execution of our user testing.

Another factor that may weaken the "Record walk cycle"-feature is the concept of the "self-aware user". When we as designer tested the feature on ourselves, we noticed that we became much more aware of how we walked and moved our arms, which potentially altered the result from the recordings. Since one way to start recording is to click the button on the smartwatch, in those cases, the user will be aware that their walk cycle is being recorded taking place. Consequently, result from such recording may differ from to those started via the smartphone, which allows it to be started "in secret". In test 2 (with the elderly woman), the woman wearing the smartwatch was not aware she was being recorded, and the test results matches her symptoms during the moment of testing. In other words, we have showed that the "Record walk cycle"-feature provide a fairly good estimates when the patient is not aware that she is being recorded. This argues for an even bigger demand for an automated "Record walk cycle"-feature.

As stated, test user 1 was an elderly woman diagnosed with PD. When she was actively using the system, she had had a pleasant day, spending time with friend and relatives. She stated that she was feeling good (mild symptoms). However, the acting caretaker could tell that the woman was struggling with her PD symptoms and was in fact experiencing strong symptoms. Therefore, it is clear the plots showing the user's input from the prototype must be seen as subjective indicators of the patient's condition.

Lastly, our testing methods can have fallen victim to the 'social desirability bias' phenomenon. Nancarrow and Brace (2000) describes this phenomenon as a type of response bias that is a tendency in respondents to answer in a way that will please the ones conducting the questionnaire.

7.3 Result discussion

At first, the goal was to only design and implement the smartwatch's front end and only use the smartphone for uploading data. However, this was changed due to the fact that people suffering from PD have shifting needs and symptoms. Some people have severe tremor symptoms, while others experience no tremor at all (Chaudhuri, Clough & Sethi, 2011). Therefore, the small screen of a smartwatch could be troublesome to some PD patients. In an attempt to include more users, it was decided that all functionality inside the smartwatch app should be accessible through a paired smartphone. This change also enabled caretakers to operate inside system (as seen in one of the user tests).

The "Record walk cycle"-feature is only useful when the results can be compared with each other, and from the same user. In such a case, it is possible to see fluctuations in result and therefore get a better understanding of when a patient is experiencing stiffness or bradykinesia. Currently, there is no area that is considered "normal" for the "Record walk cycle"-feature to result in. A large number of clinical tests would most likely be necessary for such an area to be found. It is apparent from user testing, however, that a very low score is an indication of stiffness and bradykinesia. Therefore, it is difficult at this point to compare the result from two different patients. One must also consider that people may differ in their natural gait.

During our meeting with the UX engineer from Semcon, it was argued that having few options regarding the perceived symptoms, i.e. either note down mild or note down strong, was better than having, for example, a scale of 1-10 since a wide scale might result in more vague answers or no answers at all due to overchoice. This claim does not lack ground completely, since research has shown that too many choices can have negative outcome on the experience (Misuraca, Teuscher & Faraci, 2016). However, after the first test, the test user stated that he would have liked a to have more options than only two. Perhaps, a Likert scale (Likert scale, 2014) would have been more preferable for him.

It has also been decided that the primary user group of the prototype are people who use smartphones on a daily basis. This serves the purpose of simplifying the whole project and making the development of the prototype more doable. Important to note, it has been taken into consideration that a large portion of the people afflicted with PD may be of old age that lack experience with smart devices. Looking ahead, though, this situation will surely change as a new generation of elderlies is coming to be. Soon, smart devices will pervade all different age groups of our society. In addition, one might argue that the prototype of this project is the beginning of a much larger thing that will include larger user groups as it grows. This project is, on the other hand, merely a beginning, with limited resources, and must therefore limit its scope.

8 Conclusion

During this thesis, the concept that in the end became the prototype was developed iteratively. Changes were made to push the project and make it come closer to answering the final research question:

What features should an interactive system, consisting of a smartwatch, have to enable personalization and patient-centeredness in treatment of people with Parkinson's disease?

In order to personalize PD treatment, it was concluded that a system must have features that cover both the physical and mental aspects of PD. The mental aspect of PD has been severely underestimated. People suffering from PD are often at risk of falling into depression. In fact, 30-40% of all PD patients also suffer from depression (Frisina et al., 2008). The feature of noting down symptoms can help in gathering data on non-motor symptoms, such as tiredness or sleep problem, while the "Record walk cycle"-feature focus on bodily movement. From user testing, the "Record walk cycle"-feature seems to be an effective way of measuring a PD patient's condition. This conclusion can be drawn from test results from the second user test (see section 5.4.7.3). To be able to draw deeper conclusions, however, a more extensive testing is required.

Furthermore, user testing showed that customization is a beneficial feature. For example, the system may allow the user to define their own symptoms to note down. It was also showed that some features, such as the recording of bodily movements, must be partly automated to properly adhere to the user's need. Finally, noting down medication is helpful when understanding the relation between symptoms and medicine intake. Thus, in order to optimize treatment, the system must allow the user to note down the moment of medication (or automate the process).

Our finding suggests that, for the system to enable patient-centeredness, the features and their feedback (i.e. what they result in) must be completely *open* from the standpoint of the user. In other words, the system must not hide relevant information or in any way "freeze out" the user. Instead the system must be translucent in its design. Along with this, the system should not be costly, meaning most people should be able to afford it. Furthermore, the system should not be an indicator of PD, meaning one should not be able to tell that the user has PD by observing the interaction. The system should also be connected to the internet in order to keep the data safe and accessible by the user.

To answer the research question, we have produced a set of feature that enables both patient-centeredness and personalization:

- Focused monitoring
  - Note don symptoms
  - Note down medicine
  - Reminders
  - Test motor symptoms
  - Automated features
- Portability and accessibility
- Low cost
- Discretion
- Familiarity
- Customizability
- Different users

- Connectivity and data accessibility
- Push buttons
- Glanceability
- Balanced number of features

These features are described in detail in section 6.2.

On future work, one of the current issues with the prototype is the lack of automation, specifically regarding the "Record walk cycle"-feature. Possibly, one solution would be to make the system recognize when the wearer is taking a walk and let the smartwatch start the test without notifying the user. This would likely lead to more test data to analyzed. Another issue is to further improve on the algorithm that measures the user's arm swing and be able to give the user some even more precise results.

It might be of interest to incorporate a feature that encourages the user to switch "watch arm" and compare the arm activity for both arms. This would provide clinically relevant data, since PD patient may suffer from gait asymmetry (see section 2.1.1). In other words, measuring the difference in arm activity between both arms can potentially help in determining PD condition. Another activity that would be of interest from a clinical standpoint is the activity of reaching for a glass of water (to drink) in which the smartwatch can measure how quickly the action is executed (this is discussed in section 5.3.8.)

In was concluded from one of the user tests that a way to increase the personalization is to add customizable buttons. This way the user could add "their own buttons" that can target specific symptoms, e.g. create a button called 'Cramps'. This will allow users to note down symptoms that are specific to their case of PD. Finally, another high-priority issue is the creation of dynamic plots that update automatically according to the user's input. At its current state, the plots must be put together manually from the gathered data.

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Appendices

A - Questionnaire for test 1

Parkinson Smartwatch System Survey

This survey is anonymous

How would you rate the precision of the UI in the Smartwatch app?

Precise 1 2 3 4 5 Inprecise

How would you rate the responsiveness of the UI in the Smartwatch app?

Unresponsive 1 2 3 4 5 Responsive

In rough estimate, which app did you use the most, the Smartwatch app or the Smartphone app, or both equally much?

- The Smartwatch app
- The Smartphone app
- Both equally much

Would you prefer that the feature of noting down medication was different, if so, in what way? Please, write your answer in the text field below. (Use the images below for reference.)

Button for noting down medication

Confirmation screen for noting down medication

The following are some suggestions on how the feature of noting down medication might be different. If you agree with one or more of the suggestions below, fill in the checkbox that corresponds to that suggestion.

- Be able change the type of medicine
- Be able to change the amount of medicine
- Be able to set reminders on when to take medicine

Were there any further issues with the feature of noting down medication, if so, what were the issues? Please, write your answer in the text field below.

Would you prefer that the feature of noting symptoms was different, if so, in what way? Please, write your answer in the text field below. (Use the images below for reference.)

Button for noting symptom

Confirmation screen for noting symptom

The following are some suggestions on how noting symptoms might be different. If you agree with one or more of the suggestions below, fill in the checkbox that corresponds to that suggestion.

- Wider range of symptom severity, i.e. more options to choose from.
- Be able to add more specific symptoms such as cramp, headache, fatigue etc.
- Only use specific symptoms such as cramp, headache, fatigue etc.

The following are some suggestions on how noting symptoms might be different. If you agree with one or more of the suggestions below, fill in the checkbox that corresponds to that suggestion.

- Be able to change the amount of medicine.
- Be able to set reminders on when to take medicine.
- Only use specific symptoms such as cramp, headache, fatigue etc.

Were there any further issues with the feature of noting symptoms, if so, what were the issues? Please, write your answer in the text field below.

In rough estimate, which device did you most often use to start the "Record walk cycle"-feature?

- Smartwatch
- Smartphone
- Both equally much

How did you perceive the usefulness of the "Record walk cycle"-feature that was included in the app?

Useless 1 2 3 4 5 Useful

Only answer this question if you answered the previous question with a 3 or below. What aspect of the "Record walk cycle"-feature made it seem less than useful? Please, write your answer in the text field below.

Would you prefer that the feature of recording your walk cycle was different, if so, in what way? Please, write your answer in the text field below. (Use the images below for reference.)

Button for recording walk cycle

Confirmation screen for recording walk cycle
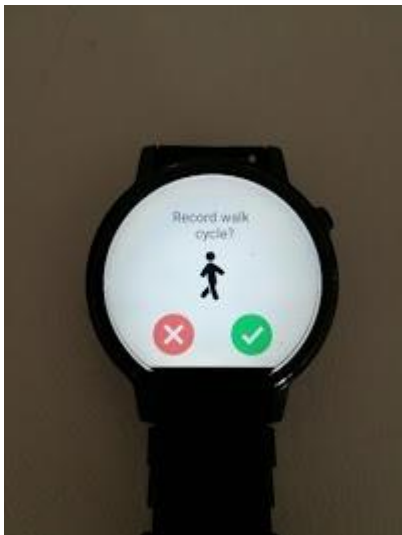
The following are some suggestions on how the feature of recording your walk cycle might be different. If you agree with one or more of the suggestions below, fill in the checkbox that corresponds to that suggestion.

- The app can record the walk cycle without the user being aware of it.
- The user can set the length of the recordings.

Were there any further issues with the feature of recording your walk cycle, if so, what were the issues? Please, write your answer in the text field below.

How did you perceive the usefulness of the plots that visualized your gathered data? (Use the images below for reference.)

Useless 1 2 3 4 5 Useful

Plot for visualizing gathered data

Only answer this question if you answered the previous question with a 3 or below. What aspect of the plots made them seem less than useful? Please, write your answer in the text field below.

Would you prefer that the method of visualizing you gathered data was different, if so, in what way? Please, write your answer in the text field below.

Some of the suggestions presented in this form includes a reminder service (much like notifications) inside the app. The following are some specific suggestions about the reminder service. If you agree with one or more of the suggestions below, fill in the checkbox that corresponds to that suggestion.

- Notifications on the Smartwatch
- Notification on the Smartphone
- Be able to decide if and when to get notifications.

Were there any other issues with system? For example, was the battery life a problem? Please, write your answer in the text field below.

Finally, do you have any general thoughts on the system that you would like to share? Please, write your answer in the text field below.