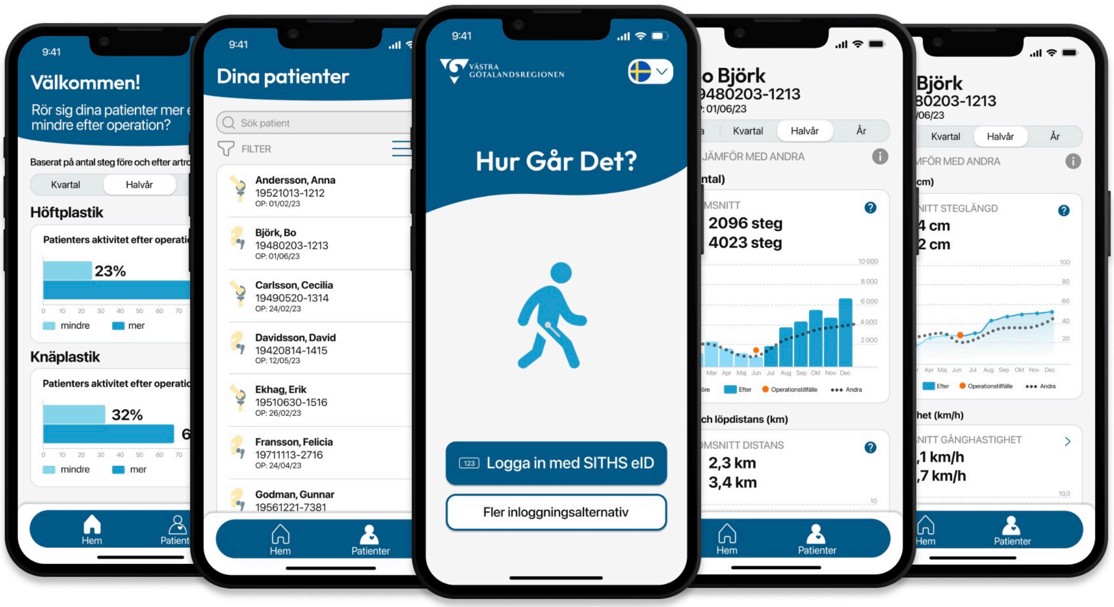
CHALMERS
UNIVERSITY OF TECHNOLOGY
UNIVERSITY OF GOTHENBURG



Joint Venture: Designing a Digital Solution for Monitoring Arthroplasty Patients' Movement Patterns

Master's Thesis in Interaction Design & Technologies

Agaton Ingheden
Sofia Sjöberg

Department of Computer Science and Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
UNIVERSITY OF GOTHENBURG
Gothenburg, Sweden 2024

Master's thesis 2024

Joint Venture: Designing a Digital Solution for Monitoring Arthroplasty Patients' Movement Patterns

Agaton Ingheden
Sofia Sjöberg

UNIVERSITY OF GOTHENBURG

CHALMERS
UNIVERSITY OF TECHNOLOGY

Department of Computer Science and Engineering
Chalmers University of Technology
University of Gothenburg
Gothenburg, Sweden 2024

A Chalmers University of Technology Master's thesis template for LaTeX
Agaton Ingheden
Sofia Sjöberg

Supervisor: Alexandra Weilenmann, Gothenburg University: Applied Information Technologies
Advisor: Ola Rolfsson, Sahlgrenska University Hospital
Examiner: Morten Fjeld, Chalmers University of Technology: Interaction Design & Software Engineering

Master's Thesis 2024
Department of Computer Science and Engineering
Chalmers University of Technology and University of Gothenburg
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Cover: Mock-up of the final high-fidelity prototype of the proposed iPhone application.

Typeset in LaTeX
Gothenburg, Sweden 2024

A Chalmers University of Technology Master's thesis template for LaTeX
Agaton Ingheden
Sofia Sjöberg
Department of Computer Science and Engineering
Chalmers University of Technology and University of Gothenburg

Abstract

This Master's thesis explores the design of a mobile application for enhancing post-arthroplasty care through self-tracking. The primary goal is to provide a user-friendly interface for caregivers to monitor and support patient rehabilitation after arthroplasty.

Current rehabilitation practices within arthroplasty often lack digital solutions that can monitor and encourage patient mobility and compliance. To fill this gap, the proposed application uses self-tracking data from the patient's iPhone to visualise and analyse movement data, offering caregivers real-time insights into patients' progress. This approach aims to improve surgical outcomes and enhance communication between caregivers and patients by providing a platform for continuous feedback.

Through user studies, the needs of caregivers working in relation to arthroplasty have been explored, identifying a desire to incorporate objective evaluation measures to improve current practices. Beyond user studies, the research also reviews related literature on the impact of digital solutions within healthcare, particularly the utility of mobile health applications in promoting physical activity. The application's design process, grounded in the Design Thinking framework, emphasises usability and empathy towards the target group to ensure the application is practical for caregivers.

Key findings from user testing suggest that the application can contribute to a more personalised and responsive care process. Through iterative design and testing, the application has been refined to meet the specific needs of its users, with particular attention to intuitive design and ease of use.

In conclusion, this thesis presents a step towards integrating digital health solutions in post-arthroplasty care, potentially leading to better patient engagement and improved health outcomes. It calls for further research into the long-term impacts of such applications and their integration into standard care practices, suggesting a paradigm shift towards more technologically integrated healthcare solutions for ageing populations.

Keywords: Arthroplasty, Self-tracking, mHealth, Design Thinking, User-interface Design, User Experience Design, Caregiver Communication, Rehabilitation, Interaction Design

Acknowledgements

We want to thank our supervisor, Alexandra Weilenmann, for the supervision throughout the past months and the insights we gained from our weekly meetings. We would also like to thank Sebastian Andreasson, who provided valuable feedback on the application design. Furthermore, we would like to direct a big thank you to Ola Rolfson and Aurora Tasa at Sahlgrenska University Hospital for the medical insights needed, and for allowing us to create a suggestion of the application design for the project: *Movement Patterns Before and After Joint Replacement.*

And finally, thank you to all of the participants that were a part of the interviews and usability tests.

Agaton Ingheden & Sofia Sjöberg, Gothenburg, 2024-06-11

Contents

List of Figures

List of Tables

1

Introduction

With an ageing population and an increase in chronic diseases, the World Health Organization (WHO) [1] has estimated that the number of people over the age of 60 is expected to double between 2020-2050, from 1 billion to approximately 2.1 billion. A common condition related to ageing is osteoarthritis [1], a degenerative joint disease associated with pain, stiffness and reduced mobility [2]. Arthroplasty refers to the surgical replacement of a joint with an artificially produced material, whereas the knee and hip joints are the most commonly replaced [3]. Symptomatic osteoarthritis is a common cause for the need for an arthroplasty, whereas the average age of the patients who have undergone surgery is between 60 to 70 years [3]. There are also no signs of a decrease in the need for arthroplasty. In the US, Total Hip Arthroplasty (THA) procedures are expected to increase by 176% by 2040, and a similar increase of 139% is predicted for Total Knee Arthroplasty (TKA), based on 2019 figures [4]. Increases have been estimated for hip implants, with an estimated average increase of 49% between 2015-2050 across OECD countries and increases as high as 120% in some OECD countries [5]. Although hip implants are not the same procedure as THA, it is still helpful to recognise that the need for joint replacement procedures is increasing.

A problem that exists in today's post-arthroplasty rehabilitation landscape is limited compliance with therapy. This is due to protocols and technologies used in rehabilitation that are considered outdated. One example is the Harris Hip Score, a standardised questionnaire to assess hip surgery outcomes. Another example is EQ-5D-5L, a more general health questionnaire, which is often used after TKA and THA to evaluate a patient's quality of life, with elements ranging from mobility, self-care, pain, usual activities and anxiety [6]. Unfortunately, using these standardised assessment tools alone does not always adequately capture the entire dynamic situation, and the caregiver struggles to provide appropriate feedback to the patient and vice versa. The lack of clarity in caregiver-patient communication can lead to limited therapy compliance, affecting the rehabilitation process [7]. In addition, outdated rehabilitation technologies and protocols prevent caregivers from properly monitoring and assessing patients' daily activities. As a result, patients run the risk of, for example, not putting enough weight on the operated limb, delaying full recovery [8].

During the past decade, self-tracking has become an increasingly wide phenomenon, or in other words, a trend. Through a stream of new smartphone applications and mobile sensors, the user can track and monitor health-related issues such as sleep patterns, food intake, mood and daily activity [9]. Sharon [9] describes how the increased use of self-tracking tools points towards a future in which individuals will be more involved in their health management. The information gained from self-tracking can benefit clinical decision-making and is a move towards personalised healthcare instead of a "one size fits all" approach [9]. Personalised healthcare consists of two fundamental components: the focus on data and the focus on individuals. These two aspects are intertwined in self-tracking devices since the users allow the devices to collect data, which integrates a wide array of diverse data types to address health experiences [9]. For individuals to be more involved and participate in their health, advocates for more personalised health care should enable individuals to become more informed, engaged and in control of their health [9].

On the assignment of Sahlgrenska University Hospital in collaboration with the University of Gothenburg, this Master's thesis is part of a research project named *Movement Patterns Before and After Joint Replacement*. The main project aims to develop an iPhone application, named *Hur går det?*, with one version for the patient and one for the caregiver, that provides individual information on the patient's movement patterns pre- and post-arthroplasty through self-tracking. The overall research aims to, with the help of the smartphone application, answer questions regarding how the movement patterns after joint replacement change, which factors (such as age, gender and general health) affect activity and movement patterns after surgery, what the relationships are between changes in movement and patient-reported outcomes (such as pain, function, and life quality), and how motion data from smartphones can change behaviour and facilitate rehabilitation.

Our contribution to the existing project is to create a suggestion for the user interface of the application, specifically the version for the caregivers, which includes the patients' self-tracking visualisations. Caregivers comprise healthcare workers involved in the patient's care, both pre and post-arthroplasty, typically including clinicians and physiotherapists. The purpose of the smartphone application is to collect self-tracking data via Apple Health [10] from iPhones and applicable smartwatches. Based on the data, the interface should be able to visualise the patients' rehabilitation progression and activity levels to facilitate dialogue and understanding of the surgical outcome. In the main project, the application will be developed in two versions, one for the caregiver and one for the patient. However, this Master's thesis will explore the caregivers' perspective when designing the prototype interface. Both versions will have the functionality of showcasing the self-tracking data in simple visualisations to ease the complexity of the different parameters. Since the visualisations are a core functionality, they should be suitable for both caregivers and patients. However, there will be slightly differing functionalities between the two versions, such as the caregivers being able to explore all patients' self-tracking data. In contrast, the patient will solely see their own. The design of the application and data visualisations will not implement actual patient data due to the intention of having the interface serve as a suggestion for further development. Additionally, the application's design will be limited to an iPhone format because the self-tracking data collection will be derived from Apple Health.

1.1 Aim & Goal

The Master's thesis aims to build an understanding of the current needs of caregivers and how a digital solution can facilitate communication and dialogue between patients and caregivers. Therefore the goal of the project is to create a prototype of an iPhone application that considers self-tracking data pre- and post-arthroplasty. It will be designed so that caregivers can understand a patient's rehabilitation process, mobility patterns and surgical outcomes. The design that will be developed will cater to the caregivers, but elements from it should be possible to implement in the patients' version in the future.

1.2 Research Questions

To be able to create a design that is suitable for the caregivers, there must be an understanding of what the needs are within the field, as well as what features in a design can help fill a gap in the sector. Therefore, the Master's thesis aims to answer the following research questions:

1. What are the caregivers' needs for the design of the suggested application?
2. What features can be applied in the design of the application to fill the caregivers' needs?

2

Background

Self-tracking within caregiving is relatively unexplored in Sweden due to regulations and long implementation times. To understand the field, possibilities, and challenges, this chapter will describe arthroplasty and the concept of person-centred care and its implementation in Sweden. Furthermore, the chapter will explore digitalisation within health care, mHealth tools, technical skills amongst seniors who are the primary group undergoing arthroplasty, and health literacy. A comparative analysis of similar examples of smartphone health applications and related products will be examined to finalise the background chapter.

2.1 Arthroplasty

The definition of arthroplasty is "*The surgical reconstruction of a joint to relieve pain or restore motion*" [11]. In the context of arthroplasty, the primary stakeholders are categorised as caregivers and patients. Caregivers comprise healthcare workers involved in the patient's care, both pre- and post-arthroplasty, typically including physicians and physiotherapists. Given that the average age for arthroplasty patients is approximately 65 years old [3], [12], [13], the term 'seniors' refers to individuals 65 years old or above. This age group represents the most common demographic for arthroplasty. In Sweden, approximately 25,000-30,000 knee and hip replacement surgeries are performed. It is the most common surgery for patients with osteoarthritis in the knee- or hip joints [14]. Osteoarthritis is a degenerative disease, considered one of the most common diseases of the locomotor system (the musculoskeletal system), and is primarily prevalent among middle-aged adults and seniors [2]. Osteoarthritis can lead to clinical signs of pain, walking difficulties, stiffness and progressive loss of movement. There is currently no cure for osteoarthritis. Hence, the treatments focus on controlling the pain and improving functionality, where physiotherapy is one of these treatments [2]. If the patient's condition does not improve through physiotherapy, total hip arthroplasty (THA) or total knee arthroplasty (TKA) is the surgical procedure of choice [2]. Physiotherapy is traditionally a routine component in the rehabilitation post-surgery. However, it is known that impairments and functional limitations remain up to a year after the surgery [15]. The efficiency of physiotherapy has therefore been questioned [15].

Arthroplasty is the surgical procedure of restoring joint function, with a focus on hips and knees. The joints can be restored by resurfacing the bones or using artificial joint prostheses. The artificial prosthesis for TKA is made out of metal and plastic parts and is attached to the femur (thighbone) and tibia (shinbone), and the back surface of the patella (kneecap) [16]. Regarding THA, the prosthesis consists of two parts: the joint capsule, a group of soft tissue ligaments surrounding the joint, and a socket for the joint capsule. The joint capsule is usually manufactured in metal and is attached to the femur, while the socket is made in plastic and attached to the pelvis [17].

Arthroplasty Rehabilitation

TKA requires both preoperative and postoperative rehabilitation. When preparing for the surgery, stair climbing tests have shown to be associated with better postoperative results [18]. Furthermore, timed up-and-go tests have also shown an association with greater outcomes. Although there is an association between preoperative exercise and postoperative results, Chesham et al. [19] conducted a systematic review of ten randomised controlled trials, resulting in insufficient preoperative physiotherapy evidence. Regarding postoperative rehabilitation for TKA, the aim is to improve physical function, particularly in daily living activities, walking, and knee range of movement. There is a focus on mobilising the patients as soon as possible post-surgery to regain lower limb function, and typically, the patients should be able to walk after their return from the hospital. After discharge from the hospital, the patients are expected to continue with a home exercise program [20].

Similarly to pre- and post-TKA, THA also requires pre- and postoperative rehabilitation [21]. Preoperative rehabilitation, which includes strengthening exercises, stretching, and aerobic activity, has shown beneficial effects, although the intensity and frequency of the rehabilitation should be customised and personalised to the individual patient. Hoogeboom et al. [22] conducted a review that counteracted the assumption of additional benefits and effectiveness of preoperative exercises, however, they emphasise that the review may be flawed due to the therapeutic validity in the individual studies, and may not have included high-risk patients for delayed postoperative recovery. After surgery, the patient is expected to follow a rehabilitation program, including bed exercises, strengthening exercises, walking training as well as practising weight-bearing [21]. A general problem when having undergone arthroplasty is that the patient may be dissatisfied with the final result due to unrealistic expectations for future mobility [21]. Therefore, education, as well as psychological preparation, is important.

2.1.1 Post-operative Behaviour

A common problem amongst arthroplasty patients is the potential of unwillingness to change their sedentary behaviour after surgery, even if they experience pain relief and an overall improvement in quality of life. Moellenbeck et al. [23] compared patient behaviour before and 9 months after THA and found that sedentary behaviour does not necessarily change over this period. They analysed factors such as the number of steps taken, time spent in moderate to vigorous physical activity, energy expenditure during physical activity, and time spent sitting, categorised into periods of 10, 20, 30 and 60 minutes. While the primary goal of arthroplasty is to restore joint mobility and relieve pain - outcomes that are often achieved - it is important to recognise that additional interventions may be needed to promote changes in sedentary behaviour. Excessive sedentary behaviour in seniors is associated with cardiovascular disease and a decline in daily functioning, so exploring ways to promote a more active lifestyle is essential even after THA [23]. However, the trial only included 16 patients, which may have affected the results, even if the patient's age, BMI and activity levels aligned with related studies. Similar results have been shown in TKA patients. Hodges et al. [24] point out that excessive sedentary behaviour was prevalent in 45 % of the study participants 12 months after surgery. In addition to the excessive sedentary behaviour of total joint arthroplasty (TJA) patients, there is the overarching problem of seniors being the most sedentary age group. Intrinsic and extrinsic factors work together to create barriers preventing seniors from moving away from a sedentary lifestyle. For example, seniors tend to participate less in leisure activities, which can be attributed to their physical health but also to their economic status, social attitudes towards seniors, lack of motivation and lack of awareness of different health programs [25]. Even though senior arthroplasty patients may experience reduced physical pain post-surgery, they still face obstacles that could prevent them from adopting a more active lifestyle.

2.2 Person-centred Care

Person-centred care (PCC) revolves around the process of ensuring that the patient receives personalised care tailored to their needs and health beliefs [26]. Another belief of PCC is to refer to the person receiving care as a person rather than a patient. Reducing the person receiving care to only a patient can lead to unwanted treatment and support. Instead, it is important to ensure that the person receiving care has more freedom of choice and can customise their care, resulting in better care overall [27]. Although, there are no clear guidelines for implementing it in practice. Currently, the European Union (EU) only provides its members with patient participation guidelines, intended to serve as a standard for patient involvement [28]. However, patient participation is only one part of PCC and does not cover all aspects of PCC. In Sweden, 13 of the 21 county councils have established initiatives and conditions to promote PCC, but the county councils in Sweden still see a need for national guidelines [29]. In addition, PCC has been shown to have advantages over more standardised care in the arthroplasty setting. PCC can reduce the length of stay following THA, even if the patient has, for example, severe kinesiophobia - the fear of movement [30], [31]. PCC allows you to meet patients' needs better than more standardised care, creating a better care experience, even if you have special needs. One way of enabling PCC could be through the inclusion of self-tracking. As mentioned in the introduction, self-tracking has been shown to increase the possibility of personalised care [9].

2.2.1 Person-centered Care within Physiotherapy

One aspect of PCC in physiotherapy that could positively impact the patients' rehabilitation is person-centred goal-setting, as discussed by Melin et al. [32]. Melin et al. [32] presented an early framework of how person-centred goal-setting can be formulated and implemented in physiotherapy. Firstly, the goal must be closely linked to the patient's personal context rather than based on what the physiotherapist thinks is best for the patient. For example, patients are more likely to set goals related to their physical activity and the social aspects of their lives, rather than medical outcomes such as pain, strength, or range of motion. Furthermore, collaboration between the physiotherapist and the patient is necessary when defining the goal. The patient must be involved early in the process of defining a goal, which also requires the physiotherapist to be more aware of the patient's needs and possibilities, committed, and transparent with the patient [32]. It could therefore be fruitful to investigate how a digital tool for arthroplasty patients can be used to enable person-centred goal-setting, by expanding the basis of decision-making for the physiotherapist.

2.2.2 Self-tracking

The concept of self-tracking refers to gathering data about oneself, the individual, regularly [33]. By recording and analysing the collected data, the production of statistics and other data which relate to regular habits and behaviours are visualised. Self-tracking today generally takes form in a vast array of digital technologies [34]. Devices such as sensors, smartphones and smartwatches can help individuals gain insights into different physical aspects of their lives [35]. Keeping track of our lives and daily activity has been ongoing for decades, and the new technologies combined with the increasing possibility of sharing data has resulted in more people finding it useful to quantify their lives [35].

Quantified Self

The term quantified self (QS) refers to any individual who is engaged in self-tracking, whether it be biological, physical, behavioural or environmental information [36]. The phenomenon of monitoring oneself has increased, and self-tracking tools allow the individual to track for example activity, sleep quality, and emotions through different self-tools such as applications, which in turn offers the opportunity for the individual to understand their body, mind and daily life [37]. The main goal of QS is to gain self-knowledge about one's habits through self-tracking, and is often focused on quantifiable data and objective metrics [36].

Lifelogging

Another concept within self-tracking that overlaps QS is lifelogging. Dodge & Kitchin [38] defined life-logging as "a form of pervasive computing consisting of a unified digital record of the totality of an individual's experiences, captured multimodally through digital sensors and stored permanently as a personal multimedia archive". Lifelogging considers both quantitative and qualitative data, intending to provide a record of every experience of an individual's life [38]. In the context of seniors, life-logging could be beneficial in receiving the insights necessary to stall the decline in the cognitive and motor skills, that many seniors experience [39]. Another study suggested that the platform of self-recorded data can be used as a basis for healthcare to provide personalised health advice to the patient when combined with medical platforms [40].

2.2.3 Apple Health

The project will collect self-tracking data through *Apple Health*, with a focus on step count and other factors of one's gait. Apple describes Apple Health as an application that gathers health data from devices such as iPhone, iPad, and Apple Watch as well as other health tracking applications already in use [10]. Apple Health automatically counts the user's activity, such as steps per day, walking and running distances as well as other measurements such as sleep tracking, menstrual cycles and breathing rhythm. Through the application, the user can see differences in activity over time. For the project, the following self-tracking data points will be of relevance, with their descriptions from Apple Health:

- **Steps** measures the number of steps the user has taken throughout each day [41].
- **Walking asymmetry** is defined as "*the per cent of the time that a user's steps with one foot are faster or slower than the other foot*" [42].
- **Walking speed** represents how quickly the user walks on flat ground [43]. The system records 10-30 speed samples per day.
- **Step length** refers to the distance between the user's front foot and back foot when the individual walks [44].

Apple uses line and bar charts to visualise the above self-tracking data. Munzner [45] explains how line charts and bar charts are used for a value attribute and a key attribute with a linear spatial layout. Apple's self-tracking data often includes a quantitative value attribute, such as the number of steps taken, and a key attribute, which in all cases is a selected period of time. Line charts are good at showing trends because they draw a relationship between the item along the key attribute axis, making it easy to see progress or decline. Bar charts can also show trends by arranging the key attributes on the horizontal spatial axis according to their respective quantitative value [45].

The reliability of health data provided by an iPhone was found to be good, especially for adults and seniors. Werner et al. [46] compared the gait data measured by an iPhone with a reference standard, in this case, the APDM Mobility Lab, which has proven results. After a 6-minute walk test, the result showed that both gait speed and stride length had good reliability and great consistency [46].

2.2.4 Biofeedback

A concept previously used in the medical context to monitor various aspects of movement and physical activity is biofeedback. Biofeedback is the technique of taking otherwise unknown biological data and presenting it to the patient. Typically used in rehabilitation, biofeedback can enable both patients and caregivers to gain insight into information beyond what is naturally available [47]. In biofeedback, devices (including wearables) have been created that analyse the individual's movement patterns.

Biofeedback in Arthroplasty

The use of biofeedback in post-arthroplasty rehabilitation has previously been explored, with positive results [7], [8]. Raaben [7] proposed the SensiStep system, a sandal with an in-sole sensor made for patients who underwent total hip arthroplasty. It was made to measure the average peak load, average loading rate, and average cadence, then visualise this data with the help of a tablet [7]. Furthermore, Castellarin [8] presented a discreet insole that carried weight sensors with real-time force feedback, aimed to provide steady monitoring for patients who underwent TKA [8]. Both studies had clear positive results, showing that biofeedback efficiently accelerates recovery. Meanwhile, the real-time force feedback insole improved therapy compliance and provided a better means for assessment for the caregiver. However, these studies revolved around using tangible and dedicated devices to enable biofeedback. While dedicated devices often have the advantage of delivering precise data, they have the problem of availability and accessibility. A problem with dedicated devices also stems from the inability, reluctance or lack of acceptance to use the device, often in the older adult population [48]. These devices are used for therapy and rehabilitation, which is why they need to be used sufficiently.

Instead of using a dedicated device to enable biofeedback for therapy and rehabilitation of arthroplasty patients, it would be interesting and valuable to explore how the self-tracking function in an iPhone could be used for biofeedback. This could lead to better therapy compliance and faster recovery. With a smartphone, patients can receive continuous updates on their rehabilitation progress without the need to communicate with their caregiver, and the caregiver can monitor the patient's rehabilitation more extensively [49]. The ability to gain continuous insights into one's rehabilitation has long been considered motivating for patients as they can observe their progress, which can lead to an increased degree of optimism in the post-arthroplasty patient [50]. While we are designing a prototype aimed to be primarily used by the caregiver, we are also considering how the patient can easily digest the visualised data to make it possible to interpret one's rehabilitation progress. Ramkumar et al. [49] presented a solution for patients undergoing TKA that consisted of a mHealth application (see Section 2.3.1) connected to a knee sleeve fitted with sensors that could record the range of motion during various exercises, as well as using the smartphone's native sensors. The data was presented on a dashboard designed for the caregiver and via the patients' smartphones. Positive effects were observed for both patients and caregivers. The system enabled remote patient monitoring, which helped to provide continuous insight into the patient's rehabilitation. The system also engaged patients through a user-friendly interface, visualisation of daily progress, encouraging notifications and using avatar-based feedback on joint movement, which led to higher compliance. In addition, because patients knew they were being monitored, they were more likely to perform the prescribed exercises [49].

2.3 Digitalisation within Caregiving

Digitalisation has several definitions, and according to Brennen & Kreiss [51], digitalisation refers to the process, such as rebuilding a media infrastructure, building a digital profile, or creating new channels for information and knowledge production. Digitalisation is often immaterial, whereas digitisation, which is often used interchangeably with digitalisation, is more material, such as transforming an analogue piece of paper into a digital file. Arguably, digitalisation has changed how society operates on a macro level, where it has become noticeable in almost every aspect of one's life [51].

Digitalisation in healthcare has contributed to the emergence of new care concepts, creating new opportunities for personalised care and more available information for the caregiver. One of these care concepts is eHealth (Electronic health). EHealth refers to health information technologies that open up an increased stream of available information for both the care receiver and caregiver, which can be used to support decision-making, tailor health programs and make electronic records more accessible [52]. Access to medical records has been shown to increase perceived control and, in some cases, reduce anxiety. This relationship has been seen with both paper-based and electronic medical records [53]. However, electronic health records have advantages that improve clinical outcomes, such as quality of care and reduction of medical errors [54].

When implementing digital solutions within health care, it is important to consider potential inequalities and inequities that may follow [55]. Although digital solutions can provide improved access to healthcare, the access may be affected by either supply factors or demand factors. The supply factors include geographical location, availability, and cost, while demand factors include the burden of disease, attitudes and skills [55]. Majcherak et al. [55] mention previous research from the United Kingdom, which demonstrated that the availability of health services is not proportional to the needs of the population, by exemplifying how individuals with disabilities encounter barriers regarding access due to unaccommodating physical environment, prejudiced beliefs and attitudes [55], [56].

Data Visualisation in Healthcare

In healthcare, data visualisations are often used to present complex data in a way that helps both the care receiver and caregiver to understand, draw conclusions and make decisions. As data visualisation is a tool for decision-making, visualisations need to be well-designed and not cause cognitive overload. While it is possible to make the decision-making process more efficient by increasing the amount of information presented without increasing the cognitive load, it is also important to recognise the negative effects that data visualisation can have. Data visualisation is designed to reduce cognitive load, however, if you offer interactivity, you also need to consider how the interactivity is being used, as it has been shown that it may introduce a high cognitive burden [57]. Furthermore, visualisations can also be distrusted, and the level of trust affects how well the information is integrated into the decision-making process [58]. Visualisations have more use cases than just displaying large datasets; they can also be used to increase compliance by providing real-time feedback on the rehabilitation of the care receiver.

2.3.1 mHealth

A concept within eHealth is mobile health (mHealth). mHealth focuses on how health services can be delivered and supported using mobile devices. Over 2.5 billion people worldwide own a smartphone. The accessibility of smartphones holds promise in the healthcare sector. There is great interest in mHealth services since they may potentially create accessible healthcare services for patients and caregivers. One way in which mHealth can be beneficial is by providing a platform to enable behaviour change. mHealth applications, often with the help from wearables, can allow you to track your physiological progress, set goals, compare results with others and counteract forgetfulness. These features have been shown to increase therapy compliance. mHealth applications can also serve as a medium for medical education. Access to educational information about one's disease or condition has anecdotally been shown to improve communication between care receivers and caregivers, enabling better-shared decision-making [59]. While there is reason to believe that the implementation of mHealth applications can improve certain aspects of healthcare, it is also important to consider the current problem areas, such as health illiteracy, discussed in section 2.3.3, and usability barriers, discussed in section 2.3.2.

Visualisation and Design in mHealth applications

When users initially download a mHealth application, they come with specific expectations regarding the features it should offer and the characteristics these features should possess. In a study, Lazard et al. [60] categorised these expectations into functional, flashy, and essential features, all contributing to the application's likelihood of being adopted by the user. Functional features include fundamental elements like menus, settings, and search functions placed in areas anticipated by the user. These basic functions are important in minimising cognitive load, particularly during the application's initial usage. Flashy features can be important, as they may grab the user's attention and create a positive first impression. This can include unique design elements or illustrations. In addition, flashy features have been shown to highlight certain features and increase perceived affordances. Essential features are those that users expect to use and help achieve the application's purpose. Depending on the application's purpose, these features may vary. For instance, a calorie tracker may be unnecessary for a post-arthroplasty application, while a graph displaying steps over time may be useful. However, it is worth considering that the study by Lazard et al. [60] included participants with a mean age of 35. Furthermore, when evaluating mHealth applications, it was found that high-fidelity prototypes were more attractive in all aspects. This highlights the importance of designing a high-fidelity prototype [60].

2.3.2 Seniors and mHealth

While the proposed design will target caregivers, it is still necessary to understand how seniors typically interact with mHealth applications. This perspective is considered for two reasons: First, it could be valuable if the caregiver could show important information from the application to the patient without providing an explicit explanation. The patient should be able to interpret the visual information as well. Secondly, if the application is designed with seniors in mind, integrating a potential patient version will be more seamless without requiring any major changes.

Between 2020 and 2022, there has been a noticeable increase in the use of digital health services among seniors. Digital health services can include searching for health-related information online, booking appointments with doctors or dentists, accessing personal health records online and using other digital health services, such as receiving prescriptions or consultations online. For example, the use of personal health records online increased from 25 % to 41 % for the 65-74 age group and from 15% to 32% for those aged 75-85 [61]. Even though the adoption of digital health services among seniors is not as widespread as in other age groups, there remains a positive attitude towards these technologies. Fowe et al. [62] explored seniors' attitudes towards technologies designed to predict cognitive decline, assist with adherence to healthy activities, and collect self-reported data on current and future health states. Among these, the technology enabling the collection of self-reported data for current and future health states through a smartphone was viewed as most positive in potential adoption.

It is also worth noting that how well a senior adopts a technology largely depends on personal characteristics. It is easy to think of older people as a homogeneous group without recognising the diversity within older communities. Researchers have failed to capture this diversity when studying older people's attitudes to technology. In addition, previous studies on the adoption of technology by older people have largely focused on women and people of high socio-economic status. These people are often among those who are open to adopting and using technology. This is important to consider as it may have created a false relationship between older people and technology [63]. Previous research suggests that older people often have positive attitudes towards technology and that there is reason to believe that technology can benefit them in their everyday lives. However, it is important to remember that previous studies may have failed to capture the diversity of older people's communities, so it is important to look at them from a critical perspective and question whether the findings can be generalised to the older community as a whole.

As the target group of arthroplasty is primarily seniors, implementing digital health services must be adapted to the age group. While current technologies and services can help seniors remain more independent, there appear to be barriers that prevent older people from taking full advantage of these technologies and services. For example, smartphone usage has positively affected self-rated health levels among seniors [64]. mHealth applications, which could positively influence the lives of seniors, remain relatively unutilised by adults over 65. One possible explanation could be usability barriers. With increasing age, the risk of cognitive decline, motor impairment, and vision and hearing problems also increases [65]. Complex interfaces, small fonts, lack of contrast and precise movements have therefore been identified as usability barriers and are thought to be related to the impairments that many older people have [66]. Another potential usability barrier could be that many seniors have limited health literacy. This limitation may render them unable to interpret and act on the information available in an mHealth application [67].

2.3.3 Health Literacy

Health literacy is the ability to perceive, interpret and act on health information. The inability to understand one's health information can lead to overall poorer health [68]. Chohan et al. [69] argue that mHealth applications are mainly for people with high health literacy, which is problematic as those with health illiteracy tend to have worse health status than those with adequate health literacy. In contrast, Lin & Lou [70] argue that the use of mHealth applications can instead improve health literacy, especially among those with low education and health literacy. Furthermore, by co-designing the mHealth application with the intended end-user, you can achieve better adoption because you are meeting the user's needs regarding their health literacy level [71]. In Sweden, 49% of the seniors, in this case, seniors that are 77, have limited health literacy. The level of health literacy amongst senior Swedes is strongly associated with age, education level, vision and cognitive ability [67]. It is therefore important to consider these factors when making design choices for a mHealth application and to ensure that their health literacy level does not get in the way of understanding the information displayed.

Guidelines for Designing mHealth applications for Patients with Low Health Literacy

Studies have been done on smartphone applications for THA and TKA, then focusing specifically on readability. Bahadori et al. [72] reviewed 15 applications for TKA and THA using readability assessment frameworks. Of the 15 applications that met the inclusion criteria, only one met the readability standards. The problems identified were long sentences and complex language. The fact that medical information is written in an unreadable way is worrying, as a large proportion of the patient population suffers from low health literacy. This calls for making medical information more accessible by avoiding complex medical vocabulary and shortening sentences. The authors also call for greater patient involvement in the development of applications, recognising that the target group may have special needs. They also recommend that applications should be evaluated through readability frameworks, such as the Gunning Fog Index, Flesch Reading Score and Flesch-Kincaid Grade Level, to ensure that they meet readability standards. Finally, the authors suggest that developers should be aware of the potential need to improve readability after implementation [72]

Emerson et al. [71] conducted a literature review of 57 articles addressing health literacy in mHealth applications. The result was six categories, *What we know*, *Write*, *Display*, *Organize*, *Engage* and *Test* consisting of respective recommendations;

1. **What we know**: The application should be designed for the target group. Considering if the target group has cognitive disabilities, memory issues, motor impairments, etc.
2. **Write**: The language used in the application needs to be digestible and provide a digestible explanation of scientific concepts.
3. **Display**: Use short sentences, use an interface with larger visuals with shorter labels, and provide media forms that resonate culturally with the user.
4. **Organise**: Provide a clear navigational structure to reduce cognitive load and modify interface elements to better meet older people's expectations.
5. **Engage**: This could include features such as speech-to-text and text-to-speech, customisation options, and interactive elements such as games and videos. The aim is to increase user engagement.
6. **Test**: Involve patients in the development of the mHealth application to get feedback on usability and accessibility in the early stages of implementation.

2.3.4 Examples of mHealth Applications

In order to develop a valuable assessment tool for caregivers, it is important to look at previous applications in the field of osteoarthritis and arthroplasty. Previous products and innovations have been analysed, and their benefits and shortcomings have been identified and are discussed in the following sections, see sections 2.3.4 and 2.3.4. Understanding the current market can provide the necessary information to develop and design a product that stands out in the market.

MyMobility

MyMobility, created by *Zimmer Biomet* [73], is a smartphone application for patients who have undergone arthroplasty with features similar to the proposed application design developed during this thesis. MyMobility collects activity data via the iPhone and Apple Watch, with a preference for the latter. MyMobility has several functionalities, such as in-app videos on physiotherapeutic exercises, direct messages to the care team, and physiological tracking that provides the caregiver's insights regarding the patientt́s recovery [73]. See the smartphone application and smartphone interface of MyMobility in Figure 2.1.

Joint Academy

Joint Academy is a digital clinic offering personalised and convenient treatment for chronic joint and back pain. It gives users access to professional physiotherapists who guide them through exercises and education tailored to their specific needs related to knee, hand and hip osteoarthritis. The service is available anytime, anywhere via

Figure 2.1: User Interface of MyMobility on iPhone and Apple Watch

an app, making it accessible to people recently diagnosed with osteoarthritis, who have been living with the disease for a long time and who are trying to avoid joint replacement surgery [74]. See the smartphone application and interface of Joint Academy in Figure 2.2.

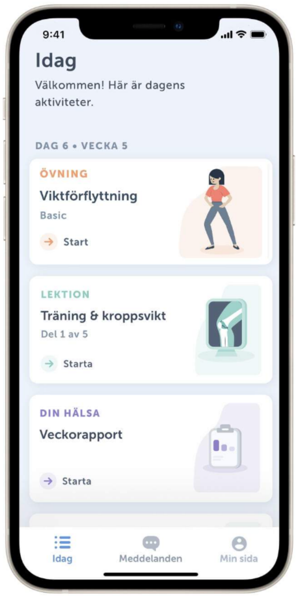


Figure 2.2: Screenshot of the Joint Academy application [75]

Clinical trials have demonstrated that a six-week Joint Academy program reduces patient-reported pain levels, walking difficulties and improves health-related quality of life [76]. However, while Joint Academy could be of value to patients who have undergone arthroplasty, it is important to consider that it mainly focuses on the rehabilitation of osteoarthritis and other injuries.

3

Theoretical Frameworks

Based on the background and the complexities of designing a smartphone application for the healthcare sector, different frameworks need to be taken into consideration. Due to the task of designing for the caregivers, it is a requirement to understand the field and what needs are important to consider.

This project is part of the field of interaction design, which is an interdisciplinary area drawing from various disciplines such as psychology, user experience, human-computer interaction, and design principles. Interaction design focuses on creating products and services that meet user needs and preferences, emphasising creating meaningful interaction between the user and the product. The goal is to ensure intuitive and efficient user experiences through user research, prototyping, usability testing, and iterative design processes [77]. Different design frameworks will be applied to facilitate caregivers' daily work lives. The primary design framework that will be applied during the design process is design thinking since it has previously been used to design mHealth applications due to its focus on empathy [78]. *Design thinking* is a non-linear framework that allows for an iterative design process. Additionally, *human-centered design* will also be considered due to its priority from the user's perspective.

This chapter will describe the above-mentioned design frameworks, including usability and accessibility, since the design's target group will be a heterogeneous group of caregivers with differing technical skills. Implementing visual elements in the patient's version of the application underscores the importance of usability and accessibility. This enhances the application's appeal and broadens its potential to cater to a wider target group.

3.1 Wicked Problems

When designing a product or artefact, the process is usually not linear, and the designer may face different issues along the way. A concept that emphasises how problems may be devious and symptoms of other issues is *Wicked Problems*.

Wicked problems as a concept was first mentioned by Rittel and Webber in 1973 [79]. The authors described wicked problems in comparison to tame problems, where an exhaustive formulation can be stated that contains the information needed for the problem-solver to actually solve the problem. Wicked problems are, in their nature, more deceitful, and the information needed to understand the problem depends on the idea of how to solve it [79]. Rittel & Webber [79] meant that the problem-solver needs an extensive inventory of all imaginable solutions ahead of time to describe a wicked problem in sufficient detail. Hence, wicked problems are, for example, ill-defined and ambiguous [80]. Wicked problems need to be taken into consideration when designing since they require an exploratory approach that is not linear.

Wicked problems need to be considered during the Master's thesis since there are several ways to produce and present visual data and design an application like the one proposed. Different interaction design frameworks will be considered to manage these potential problems.

3.2 Design Thinking

Design Thinking, as described by Brown [81], is an approach that refers to innovations being powered and built from thorough understanding through direct observations of what people want and need in their lives. It is a human-centred approach which involves empathising with the user through understanding, defining the insights to frame a clear problem statement, generating ideas without judgment to address the problem, prototyping to refine the previous ideas, as well as testing the idea through feedback to be able to iterate the design process [81]. Design thinking involves determining the fundamental issue that needs to be addressed and not searching for a final solution until the actual problem is defined. Therefore, exploring potential solutions is important before converging on a final idea [82]. Design thinking consists of two major phases: identifying the problem and solving the problem (See Figure 3.1) [83]. The *Identify* phase consists of two modes: *Discover* and *Define*. Discover involves an open exploration to understand the user's needs, especially the undiscovered needs that may be difficult to fully articulate [83]. Luchs et al. [83] further describe that during the Discover mode, it is important to gain empathy with the users, which refers to understanding their context, experiences, and behaviours. The authors further highlight that the Discover mode is built on an iterative process. Define, the second mode within identifying, is described as distilling the insights from the Discover mode and framing them to well-defined problems [83]. For further advancements, the main challenge is to identify which needs and insights are most important to pursue by converging the problem statements. The second phase, the solve phase, consists of two modes: *Create* and *Evaluate*. Luchs et al. [83] means that the purpose of the create mode is to develop a concept and prototypes that can be shared with the target group for feedback and, through iteration, can be further improved. The first step in the Create mode is to generate different ideas while considering the needs of the user, as well as desirability, feasibility and viability [83]. After having filtered the ideas, prototyping is the next step. By creating low-fidelity prototypes, the designers can explore the different ideas, and further converge and develop a high-fidelity prototype to present to the user for feedback [83]. The last mode within the design thinking framework is to evaluate and get feedback on the prototypes and the ideas. Through evaluation, the iterative process can continue from the feedback to further improve the prototype. The evaluation serves as a learning mechanism, rather than only validating [83].

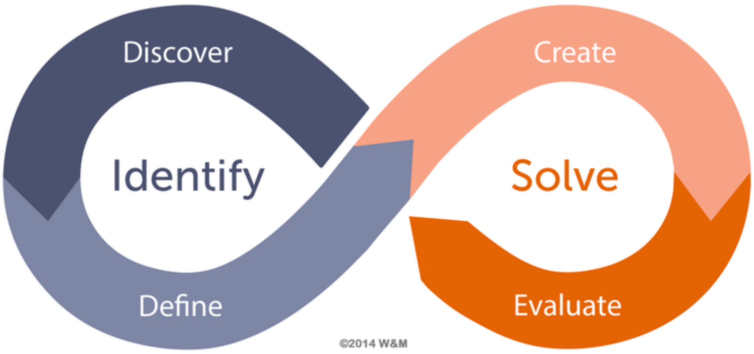


Figure 3.1: Design Thinking framework [83]

Design thinking has been applied previously within mHealth apps and has shown positive results. Farao et al. [78] argue that Design Thinking is well-suited for mHealth apps because the Discover phase focuses on empathy, thereby strengthening the emphasis on the needs of both the caregiver and patient. This will be carefully considered during the design process for this Master's Thesis.

3.3 Human-centered Design

Human-centred Design (HCD), a design philosophy proposed by Don Norman [82] is the process that ensures that the design matches the needs and capabilities of the users for whom it is intended by involving the end-user in the development stage in the design process [82], [84]. The importance of understanding the user stems from people tending to be unaware of their actual needs. Through observation, the designer can better understand the potential requirements for an artefact to cater to the user. The design should accommodate the user's needs and requires communication between the artefact and to the individual.

Norman [82] describes four stages within the human-centred design process.

- **Observation:** Referring to the initial research done to understand the nature of the problem.
- **Idea generation:** Also called ideation, is described as the generation of potential solutions.
- **Prototyping:** The creation of low- and high-fidelity prototypes ensures the problem is well understood.
- **Testing:** Having a group that corresponds to the target population using the prototype in an as casual manner as possible.

Norman [82] further describes the fundamental principles of interaction within human-centred design, which includes affordances, signifiers, constraints, mappings and feedback, whereas all the mentioned affect how accommodating the artefact is to the user [82]:

- **Affordances** refer to the relationship between an object and the individual, including interactions with agents, animals, humans or even robots. Affordances are the relationship between the properties and the agent's capabilities that determine how the object could be used.
- Norman [82] describes that many people find affordances challenging to understand due to being relationships rather than properties. Therefore, the design should also include **signifiers** communicating where an action should occur.
- **Constraints** limit what can be done and guide the user regarding the actions available.
- **Mapping** is a concept within the design and layout of different controls and displays. For example, mapping can use spatial correspondence between the layout and the control when a device is being controlled. Natural mapping refers to taking advantage of spatial analogies.
- **Feedback** means communicating the results of an action. Norman [82] underlines that feedback must be immediate because if the delay is too long, people tend to give up on their efforts. It is important to have a balance with the feedback since too much feedback can lead to annoyance or it can be inappropriate and distracting.

For the suggested project, it is important to understand the user's perspective and needs, whereas HCD allows for observation and understanding of the underlying problems.

3.4 Usability & Utility

Usability refers to how easy an interface is to use. According to Nielsen Norman Group [85], usability has five components:

1. **Learnability:** The user should be able to perform basic tasks even during initial usage.
2. **Efficiency:** How easily the user performs the task.
3. **Memorability:** The ease with which a user can remember the system after a period of not using it.
4. **Errors:** What is the frequency of user errors, how significant are these errors, and how can the user recover from them?
5. **Satisfaction:** The pleasure a user gets from using the product.

Utility, on the other hand, revolves more around the functionality of the design, if the design can fulfil the user's need. When designing, you have to consider both utility and usability. Otherwise, you will end up with a design that is either too difficult to use or doesn't do what you want. Therefore, a system's usefulness is determined by its utility and usability. If you cannot achieve usability or utility, there is a risk that the potential user will ignore the system. [85].

3.5 Accessibility

Accessibility usually refers to the use of different interactive products and systems by people with special needs, particularly those with disabilities and older people [86]. Accessibility is a form of quality concept that can be interpreted differently depending on the design approach used during the development of a product [87]. Persson et al. [87] mention that there is a lack of consensus regarding the definition of accessibility, which may hinder the adoption of accessibility on a wider scale, limiting the potential benefits. A significant challenge described by Persson et al. [87] is that the term accessibility is used in several varied contexts, which may lead to different interpretations and, even within the same context, be ambiguous. Regarding healthcare and accessibility, it is important not to view healthcare workers as one homogeneous group. Healthcare workers are diverse in terms of race, age, and expertise, which can have implications for design. The challenge lies in making our design accessible to all healthcare workers within the orthopaedic section. In addition, while the focus is on creating a prototype designed for caregivers, we also consider how patients, typically seniors, can use and benefit from our prototype. Designing for seniors presents several challenges, mainly because they are a group that suffers from conditions such as cognitive decline, motor impairments, and visual and hearing impairments, all of which affect how they interact with an interface [65].

3.5.1 Universal Design

Universal design is a similar framework within accessibility, with the goal of designing products that everyone can use to the greatest extent possible without any need for adaptations or specialised design [88]. Within universal design, seven fundamental principles are deemed necessary to ensure the accessibility of the product [87], [88]:

1. **Equitable use:** Meaning that the design is useful and marketable to people with varying abilities
2. **Flexibility in use:** The design should accommodate a wide range of individual preferences and abilities.
3. **Simple and intuitive:** The design should be easy to understand regardless of the user's previous experience or knowledge.
4. **Perceptible information:** The design should communicate the necessary information effectively to the user.
5. **Tolerance for error:** The design should minimize hazards and adverse consequences of unintended actions.
6. **Low physical effort:** The design should be able to be used efficiently and comfortably with a minimum of fatigue.
7. **Size and space for approach and use:** Referring to appropriate size and space are provided for approach, reach and manipulation.

3.6 Information and Data Visualisation

To create visualisations that meet usability and accessibility criteria, basic principles for data and information visualisation must be applied. Data visualisation is the process of taking data and creating a graphic representation of it to make a presentable result, which can be used as a body for analysis and conclusion. Researchers make the distinction between presentation graphics and exploratory graphics. Presentation graphics are often used to display proof of numbers, with clear figure explanations and captions, but without a real explanation of how the result was achieved. Exploratory graphics instead focus on finding the actual result, meaning they can exist without captions and legends and are supposed to be fast and informative [89].

To build a good foundation, you need to choose the right marks and channels. A mark is a graphical element in the visualisation that depicts an item in the dataset. Channels help to adjust the mark depending on the characteristics of the item in the data set. Visual channels could include size, position, shape and colour. When it comes to channels, there are two principles that one should follow to create a visualisation that is in line with our perceptual system: *Expressiveness* and *Effectiveness*. Expressiveness revolves around visualising ordered data, so it intuitively appears as such and making sure the visual encoding is limited to the attributes of the information of the dataset. Effectiveness, on the other hand, involves using the right channel to portray a specific attribute. An important attribute should use the most effective channel and vice versa. Visual channels can be broken down into two categories: ordered and categorical data. Ordered data refers to data variables that have a predefined order or values that follow a specific order. Ordered data uses magnitude channels, with the most effective being aligned spatial position followed by, in order, unaligned spatial position, length, angle, area, depth, luminance and saturation, curvature and volume. Categorical data instead follows no numerical order and can be classified into discrete groups or labels. An example could be gender, ethnicity or binary variables. Categorical data uses identity channels and is encoded using spatial region, colour hue, motion and shaping, ranging from most effective to least effective. Following these principles creates a visual encoding that our perception system can interpret intuitively [45].

3.7 Technology Acceptance Model

The *Technology Acceptance Model* (TAM) was presented in 1989 by Davis [90] to introduce a scale of perceived usefulness and perceived ease of use of novel information technology systems. Perceived usefulness is, in this circumstance, defined as *"the degree to which a person believes that using a particular system would enhance his or her job performance"* [90], meaning that the context of the term is in a professional setting, with a focus on the use-performance relationship. Contrasting, perceived ease of use refers to *"the degree to which a person believes that using a particular system would be free of effort"* [90], whereas the author claims that an application that is perceived to be easy to use is more likely to be accepted by its end-term users.

TAM is a common model to analyse digital systems and technologies within health care in regard to technology acceptance analyses [91]. The model predicts the user's intentions to perform particular behaviours and analyses the user's acceptance or rejection of a particular system. According to a literature review conducted by Garavand et al. [91], TAM is a common model used within health care and has shown a high ability to demonstrate the technology adoption amongst clinicians.

Even though TAM is used frequently within the healthcare sector, there are also challenges with the model that need to be considered. According to a literature review conducted by Legris et al. [92], a limitation of TAM and its use throughout the research is how it tends to measure the variance in self-reported use instead of system use. According to the authors, this is not a precise measurement but should serve as a relative indicator. Hence, assessing whether an application or technology has high acceptance when measured through TAM is a rather subjective form of evaluation that may not be possible to generalise to the greater masses.

4

Methodology

The following chapter presents the proposed methods and tools that will be used, with consideration of the design thinking framework. The target group refers to the caregivers, however, the patients will also be considered when designing the application so that the design is understandable for a wider demography. The application will be designed from the caregivers' perspective but the goal is to be able to implement the visualisations of the self-tracking data in the patients' version of the application as well. Therefore we need to consider that the data visualisations should be understandable from both a caregiver's and patient's point of view.

4.1 Methods in the Discover Phase

The initial step in the discover phase is to conduct a literature search revolving around the topic and the healthcare field, including the target group. To get an elaborate view of the users' needs for the design, semi-structured interviews will take place and serve as a pre-study, where affinity diagrams will be the main method of analysing the responses. The reason to conduct semi-structured interviews early in the design process is to understand the users' needs and root issues, to then define the problems in consideration of design thinking.

Literature Search

Finding relevant literature is a continuous process throughout the research but with an emphasis during the initial stages. It provides guidance for the study, helping to identify relevant methodologies and study designs, and enabling evidence-based decision-making. However, given the abundance of articles available on various platforms, systematically searching for articles becomes necessary to filter out irrelevant ones. This process involves translating your research question into keywords that can be used on platforms such as Google Scholar, Scopus, PubMed, and others. Searching with these keywords can offer an initial glimpse into the literature, providing relevant articles that can then serve as a basis for refining search terms. Filtering your search is also an aspect of finding relevant articles. This involves narrowing down the search results based on specific criteria such as time span, journals, citation count, and article type [93].

Semi-structured Interviews

Semi-structured interviews are a qualitative data collection method, where the interviewers have a set of questions prepared, with open endings so that the respondent can expand on their ideas and opinions. Semi-structured interviews involve balancing the mentioned set of questions, but allowing the participant to expand and delve deeper into certain issues [94]. Galletta & Cross describes how a semi-structured interview tends to be constructed [94]:

- **Opening segment:** The interview should begin with a statement of the purpose of the research, as well as informed consent to establish a level of comfort and ensure the participant's understanding of their rights. Furthermore, the interview should continue with broader questions to create openings for the participant to speak from their experience. If needed, the interviewer should support the flow of the interview with probes to guide the interview in the desired direction.
- **Middle segment:** In the middle segment of the interview, the interviewer should attend to the nuances in the narrative that in turn explores the complexity of the topic. During this segment, it is relevant to shift to more specific questions that relate to the research questions.
- **Concluding segment:** In the concluding segment, the interviewers should ask questions that may reflect theoretical considerations, as well as returning to experiences that may need further exploration, as well as additional thoughts regarding the topic.

Compared to surveys, interviews allow you to gain insight from body language, facial expressions and tone of voice. These aspects can carry information that could be of value to your study. Interviews are efficient at capturing small nuances that would otherwise be lost. While it is possible to capture these nuances in an online interview, it is preferable to conduct them in person [95]. However, due to the busy schedules of caregivers, some interviews with caregivers may be conducted online. The aim is to conduct as many interviews as possible in person to capture all the nuances.

To gain knowledge from the target group's perspective, semi-structured interviews will be conducted to fully understand the needs of the design, as well as get insights into the research questions from the caregivers' perspective.

Affinity Diagram

Based on the semi-structured interviews, an affinity diagram will be created. An affinity diagram consists of a large amount of data that is categorised and organised in groups or themes based on their relationships [96]. Affinity diagrams help with the process of making sense and organising the ideas for the designated project.

The creation of an affinity diagram involves gathering data, writing down observations and then organising the notes with data into thematic groups.

The first step is to write pieces of data, such as facts, drawings, quotes, observations and ideas on separate Post-it notes. It is important to have one piece of data per note. The process continues to put the notes up on a wall or spread them out across a table. The usage of Post-it notes makes it easier for the design team to categorise and move the data pieces into clusters [96]. The categories constructed from the affinity diagram allow for further analysis and help the group find key themes of importance based on insights and quotes from interviewees.

4.2 Methods in the Define Phase

When having understood the problem or problems in depth from the discovery phase, the group will start with defining the problem space, and ideate regarding potential solutions. Through ideation, all of the previous research done can be compiled into specific ideas and further understanding of the actual problems as well as ideas on how the design should look and which functionalities are of importance.

How Might We?

How Might We (HMW) is a method that precedes brainstorming, which can help rephrase the problem [95]. Usually, the steps in the HMW method follow the sequence [95]:

1. Specifying the materials to be explored, such as the problem statements, insights from research, and a design brief
2. Reframing the problems or insights into "How might we" statements until finding consensus on the right one.
3. Brainstorming solutions in response to the HMW statement.
4. Prioritising the different ideas, as well as recognising them as a step towards further exploration and the iterative development of concepts.

Hanington & Martins [95] describe that HMW statements both narrow and broaden the design direction, since they require careful and iterative wording, and enable a vast possibility for exploration. Therefore, the HMW method encourages open-mindedness, a collaborative approach as well as a user-centric thinking which are imperative for generating both innovative and effective solutions. This method is suitable to define the problem space and what factors are important when creating the design, to then be able to answer the research questions, see 1.2

Mind Mapping

Mind mapping is a tool that allows for visual thinking that can help idea generation and development when the relationships between several pieces of information are difficult to define. By extracting the team's ideas onto a paper, different relationships can be drawn in a non-linear manner. When creating a mind map, the limit should be one side of the paper to reduce the feeling of being overwhelmed [95].

The purpose of creating a mind map is to find associations between the different functionalities and needs of the target group, to better understand how everything is connected and what is to be prioritised during the creation of the prototype.

Brain Writing

Based on the semi-structured interviews, the affinity diagram, and the *How Might We* method, a brainwriting session will be performed to delve deeper into what information is important to visualise, as well as solutions of how the design may cater to the caregivers' needs. Differing from a classic brainstorming session where everyone in the group verbally expresses their ideas, the participants in a brain writing session write down a set amount of ideas during a limited time frame which are then passed on to the next individual in the group. The core of a brainwriting session is to expand the ideas from the participants and to aim for a wide solution space to then narrow it down.

Generally, a brainwriting session is divided into different phases. The first stage is to define the problem, by starting with a clear and concise problem statement which helps the participants to focus on a certain issue during the idea generation. The idea generation then starts, where each participant writes down different ideas individually on a paper. The ideas are then passed on to the next person, whose task is to read through the ideas and expand on them, creating a chain of collective creativity [97].

Dot voting

Dot voting is a democratic method where each group member is assigned a set amount of votes, e.g. dots or icons, that the members use to vote on their favourite ideas [98]. It is a simple tool to use to prioritise different ideas within a group setting. To apply the dot voting tool, there is a need to gather material, such as different options or ideas written down on paper or sticky notes. When having gathered the material, voting constraints are specified. This includes how many votes each participant is allowed to place and specifying the purpose of the vote. The participants should then place their votes, without any discussion. The conversation and discussion should continue after the dots are placed, and the votes are calculated [98].

4.3 Methods in the Create Phase

During the Create phase, the focus will be on sketching and prototyping the design into a functional interface through iteration. Sketching and prototyping help to conceptualise and visualise the ideas constructed in the previous phases.

Sketching

Sketching as an ideation method allows the designer to propose and explore ideas that can be communicated to either colleagues or stakeholders. It is a fast and cheap way to create and iterate ideas. Sketching is a way to start the design process, and to understand what problems may appear when creating the design as well as what are good parts of a design [99].

Sketching is a method that has a distinctive role when developing design since it allows for flexibility since it can easily be modified and discarded. Repeating and iterating the sketching process allows for ideas to grow and become more refined before continuing to build low- and high-fidelity prototypes [99]

Prototyping

Prototyping is an important phase within the *Design thinking 3.2* process, where the concepts and understandings from the discovery phase are realised and considered to create the desired prototype. When prototyping, the fidelity varies from low to high. When designing a prototype of an application, it is important to create wireframes before fidelity is added to the prototyping. Wireframing is the process of creating mockups which aim to plan and define the information hierarchy, structure and flow of your application. The process will continue by selecting a colour theme and typography for the application as well as creating a design system. After having done the mentioned steps, the process of creating a high-fidelity prototype with interactions for the usability tests will be done.

The primary software that will be used when prototyping is Figma [100]. The reason for working in Figma is due to its user-friendly interface, rich possibilities to create interactions, and the possibility to collaborate within the project.

4.4 Methods in the Evaluation Phase

For the evaluation of the design, there is a need to test the usability and accessibility of the design which will be done through a usability test according to the Think-Aloud (TA) protocol, questions following the TA-protocol, and a questionnaire according to the Technology Acceptance Model (TAM).

Usability Test

Due to the proposed task of developing a design for an iPhone application that stores self-tracking data from patients who have undergone arthroplasty surgery, the application needs usability tests to understand if the application seems intuitive and usable for caregivers. Usability tests involve testing a design, by having a group of representatives, in our case the caregivers which corresponds to the primary target group, conducting different tasks with the prototype [101]. Usability testing is a form of evaluation which allows the team to identify how the interface works and if there are elements that frustrate or confuse the users [95].

Usability tests usually follow the format of the TA protocol, where the user gets to explain every action with words and verbalise their thoughts throughout the test [95]. By conducting usability tests, an increased understanding of how the typical end user would use and interact with the design takes shape [95].

Usability tests tend to be analysed through qualitative means, such as interviews, observations, and further thematic analyses. However, when analysing a digital prototype, quantitative measures such as the amount of clicks or time spent searching for a way to conduct a task, may also be of interest for comparative analysis. Since the goal of the application is to serve as an asset for research at Sahlgrenska University Hospital, the evaluation of the design is important to find potential challenges and errors to then, be able to implement it.

As of now, relevant issues that need to be evaluated include accessibility as well as the user interface in regards to the information visualisation of the self-tracking. Therefore, the primary evaluation method will be usability tests where a group of individuals who are representative of the target group, caregivers, gets to perform a certain amount of tasks within the prototype in a controlled environment. Insights from the users are required to understand potential problems with the prototype and how well the key functionalities are highlighted.

Technology Acceptance Model Questionnaire

Based on the Technology Acceptance Model, a questionnaire consisting of twelve items, 6 concerning perceived usefulness, and 6 regarding perceived ease of use, is planned to be used. The purpose of the questionnaire is to quantify the mentioned aspects through a seven-pointed Likert scale with the anchors being likely and unlikely, ranging from: Extremely; Quite; Slightly; Neither; Slightly; Quite; and Extremely [90].

Through the questionnaire, the aim is to gain an understanding if the participants have a similar impression of the applications and concept's usefulness as well as if it is easy to use.

5

Design Process & Execution

The following chapter will explain the execution and process of the development of the design based on the design thinking framework, including the phases of *Discover*, *Define*, *Create* and *Evaluate*. To follow the design process, a time plan was made according to the framework, see Appendix A. The four phases and how different methods were used throughout the design process are described in the chapter, as well as the reasoning behind each step. Figure 5.1 was made to visualise how the process is planned, and which steps will be followed during the execution.

5.1 Phase 1: Research & Discover

The first step in the discovery phase was a literature review. This initial step served as an open-ended phase, allowing for exploration without a clear goal in mind. As the discovery phase progressed and more information was digested, underlying issues related to the problem area could be identified. To further explore the problem area and gain perspectives not identified in the literature review, 10 semi-structured interviews were conducted with healthcare professionals experienced in dealing with arthroplasty patients. The interviews served as a pre-study to understand the need and context. Finally, an affinity diagram was created based on the interviews to structure and organise the findings from the interviews.

5.1.1 Literature Search

A thorough literature search was conducted to understand the problem space. Google Scholar and Chalmers Library were used as the primary platforms for finding relevant articles. Due to the different related areas of the thesis, it was necessary to have different sets of keywords depending on the area being researched. Initially, previous studies that revolved around topics such as mHealth, self-tracking, and digitalisation in healthcare were dissected. Keywords used were: Person-centred Care; Seniors and Technology; Seniors and self-tracking; Digitalisation in healthcare; Usability mHealth apps; Accessibility; Biofeedback in Arthroplasty. Using these papers, further references and keywords could be found by looking at which papers were referenced in the selected papers, creating a snowball effect. As arthroplasty, healthcare, and self-tracking were unexplored topics for the group, the literature search began broad, focusing on finding overview articles such as meta-reviews and systematic reviews to provide a foundational understanding of the subject matter.

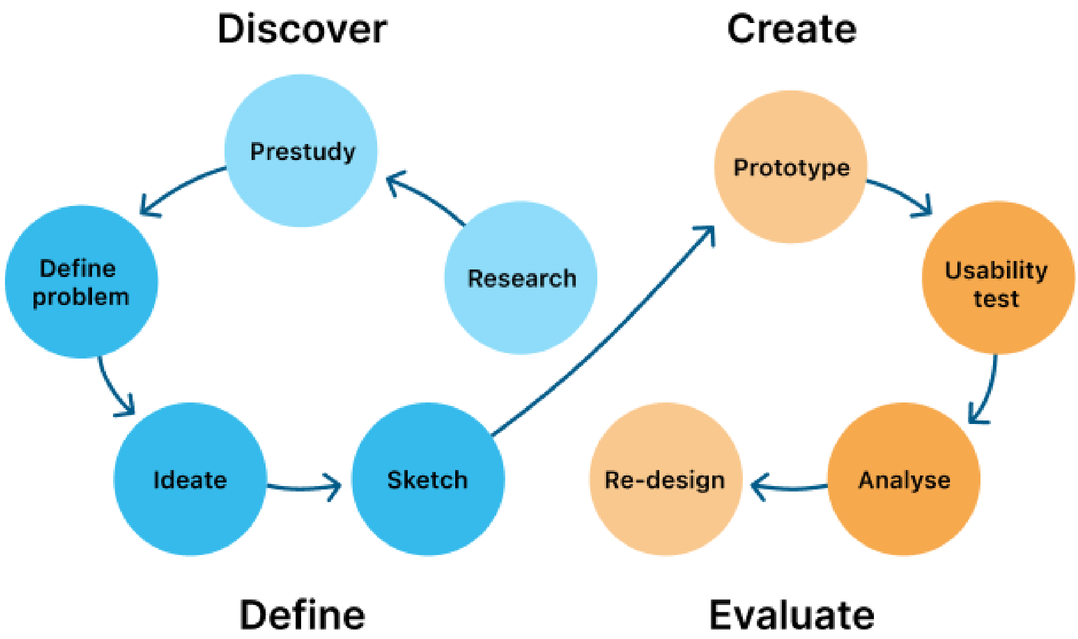


Figure 5.1: Model of the planned steps in the design process according to the *Design Thinking* framework

As we gained a better understanding of the relevant topics, we shifted our focus to more specific articles. These articles were relevant for understanding the problem area and helped the group identify potential methodologies for the study. Furthermore, an in-depth literature search identified a research gap: using self-tracking through smartphones to assess the outcome of arthroplasty. The findings from the literature search also partially formed the basis of the interview questions and helped to understand medical terms used within arthroplasty.

5.1.2 Semi-structured Interviews

10 semi-structured interviews were carried out to gain a better understanding of the users and their current contexts. These interviews aimed to gain insight into the current practices in Sweden and understand the communication between caregivers and patients. The interviewees were professionals in orthopaedics or physiotherapy due to their expertise in the areas of arthroplasty and osteoarthritis. Including several physiotherapists was particularly important during this phase because of their speciality in rehabilitation and the patient's movement patterns, making them the primary caregivers patients encounter more consistently post-arthroplasty.

Pilot Interviews

Before conducting the semi-structured interviews, two pilot interviews were conducted with one orthopaedic surgeon and one resident doctor/PhD student to gain a deeper understanding of the topic holistically and understand which interview questions were relevant. The pilot interviews took approximately 40 minutes. There were several insights from the pilot interviews. However, some of the questions were too similar, confusing the participants. Furthermore, some of the questions had no answers due to overestimating how much technology and data visualisations are used in healthcare and physiotherapy.

Through the insights from the pilot interviews, the questions were revised to give the interview a better flow and make the questions more concise. See Appendix B for the revised interview questions that were used to guide the semi-structured interviews.

Participant Selection

The participant selection was made by contacting hospital departments that specialise in orthopaedics and physiotherapy clinics, with the additional help of the orthopaedic surgeon who was a part of the pilot interviews. The decision to interview physiotherapists primarily during this stage was due to the need to understand current communication between caregivers and care receivers and get insight into their specialisation within movement patterns. The interviewees' occupations and years of experience are listed in table 5.1.

Table 5.1: Table of demographic measurements for the interviews

Participant	Current practice	Years of experience
1	Researcher in OA	25
2	PhD student	7
3	Physiotherapist	13
4	Physiotherapist	5
5	Physiotherapist	21
6	PhD Physiotherapist	15
7	Physiotherapist	17
8	Physiotherapist	9

Revised Interviews

The interviews were conducted in Swedish because all interviewees were native Swedish speakers. The purpose of conducting the interviews in Swedish was to decrease the potential of a language barrier. Eight interviews were conducted and took approximately 25 minutes, including giving information about the project and the interviewees giving consent through a consent form (see Appendix D). The location of the interviews was online, via either Microsoft Teams or Zoom, due to the interviewees working in different cities in Sweden. All the interviews used the same structure of questions, but because the interviews were semi-structured, some participants were asked additional questions to prompt discussion, while others had questions removed due to time constraints or their lack of relevance to their work.

The interviews followed the following structure: Current practice within arthroplasty, digitalisation within health care, the caregivers' needs, evaluation of the patient's movement patterns, and the general attitude towards implementing digital tools and self-tracking in the healthcare landscape. The questions varied from open to more specific, depending on the topic. Open and speculative questions were necessary to get a detailed perspective of the interviewees' thoughts and opinions on digitalisation within physiotherapy. After conducting the interviews, they were transcribed automatically using Microsoft Teams or Microsoft Word if conducted over Zoom and then manually corrected.

Affinity Diagram

Based on the answers from semi-structured interviews, an affinity diagram was created. Creating the affinity diagram started with reviewing the transcribed material from the interviews. Valuable information from the transcribed material was translated into keywords and topics that were written down. Both group members completed this process to ensure intercoder reliability. The keywords and topics were written down as digital notes in *Figma*. Keywords and insights were discussed and then categorised according to the topics and questions the interviews revolved around. After categorising the insights and answers from the interviewees, recurring themes were identified. To add substance to the recurring themes, the transcribed material was reviewed further to find relevant quotes that touched on the specific theme.

The themes and categories found through the affinity diagram were derived from insights, keywords and citations. The themes are summarised in 5.2, and further described in chapter 6. The citations were translated from Swedish to English for a better report flow, and the original quotes can be received on request. URL to the Affinity Diagram can be found in appendix E.

Table 5.2: Table of themes found from the Affinity Diagram, based on the semi-structured interviews during the discovery phase

Themes
Current Practice
Subjective Evaluation
Assumptions regarding patients
Lack of information
Digitalisation within health care
Objective evaluation
Validity
Individual goal-setting
Accessibility
Lifestyle factors

5.2 Phase 2: Define the problem

The discover phase consisted of different methodologies that gave the group insight into arthroplasty in Sweden's healthcare landscape. Understanding caregivers' practices in rehabilitating arthroplasty patients also revealed their needs and expectations for rehabilitation. To organise the material collected and consider it during the design process, the define phase consisted of different tools and methods to specify caregivers' needs. The caregivers' needs were defined based on the problem statement. Filtering out needs and expectations deemed unrelated or implausible was important for maintaining focus on the research questions. To begin the *Define* process, we created "How Might We" statements to recognise the needs that are to be considered. Further, we created personas based on the semi-structured interviews to understand generalised archetypes of the users.

The *Define* phase then continued through ideation, where different brainstorming techniques were applied to generate different ideas based on the problem area.

5.2.1 How Might We?

To define the problem space around the research questions, the group employed the How Might We method, described in Section 4.2. Creating questions based on the collected data allowed for guidance during the design process.

- How might we create a design that visualises the patients' self-tracking data to understand the surgery outcome while making it accessible to the caregivers?
- How might we create visualisations that are accessible to both the caregivers and the patient?

The how might we questions allowed us to narrow the problem space down to accessibility and usability to focus on the visualisations considered the application's main component.

5.2.2 Mind Mapping

Based on the information from the discover phase, and to start the ideation process, we created a mind map with different requirements to consider when designing the interface of the application (see Figure 5.2). The mind map was created to outline the necessary components for the application and to find inspiration for its features. The mind map allowed us to explore which factors were connected to one another and to get a starting point for which functionalities were important and needed to be considered. The main components that were considered during the mind mapping procedure were the *caregivers* and *patients*, as well as *data visualisations* and *functionalities*. We realised commonalities between factors, such as the target groups (caregivers and patients) being both heterogeneous groups. Therefore, we emphasised the focus on accessibility to make the application as simple as possible. Additionally, the simplicity of descriptions in the design was important to reduce the medical language barrier. Furthermore, the functionalities of the caregivers' version need additions, such as comparisons to analyse the surgical success and the possibility of filtering based on different needs.

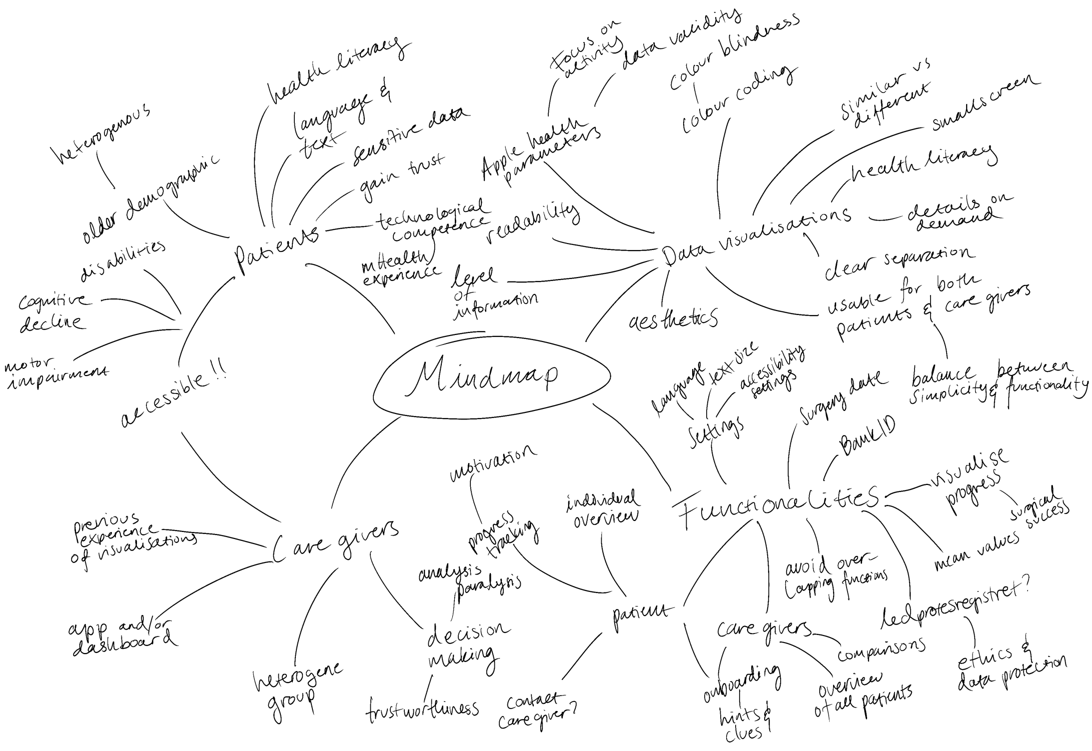


Figure 5.2: Mindmap that was created during the define phase

5.2.3 Brain Writing

After creating the mind map based on the interviews, a second ideation method was conducted - brain writing. This method was used to explore the solution space based on the mind map and to get different ideas for visualising the self-tracking data. The session was divided into 4 sets of 5 minutes, where both group members began by writing down 3-4 different ideas during 5 minutes, which were then built upon with either descriptions or quick sketches (see Appendix C).

Dot Voting

Dot voting was used to prioritise the ideas of the brain writing session. Each group member placed 3 votes on their favourite ideas to decide which ideas were preferred, see Appendix C) Dot voting was also used to raise discussion regarding the options most relevant to the prior findings from the literature review, semi-structured interviews, and problem statement.

The results of the brain writing and dot voting were the prioritisation of highlighting the surgery date and the possibility of sorting the patients according to when they had the surgery done in combination with additional filtering features. Furthermore, the idea of seeing a compressed version of the patient's activity levels was emphasised. Additionally, comparing a patient's self-tracking data with the mean value of all the other patients was considered, both for the potential of motivation from the patient's perspective and for the caregivers to compare the patients' progress.

5.3 Phase 3: Create

The information and insight gained from the previous phases made it possible to start concretising and visualising the ideas. This phase marked a transition from abstract concepts to the design of a high-fidelity (hi-fi) prototype. Through sketching, wireframing, and prototyping, the fidelity of the designs increased while the level of abstraction decreased, resulting in a tangible product that potential users could evaluate.

5.3.1 Sketching

Sketching was done throughout the design process and was not limited to the beginning of the design process, but rather used as a tool throughout the design phase. It started with sketches that helped to generate early concepts and low-fidelity (lo-fi) prototypes, and then as the process progressed, the sketches became more specific, helping to refine ideas into something tangible (See Figure 5.3). This was useful when generating ideas for different data visualisations and the interface's structure. To exemplify, explaining a specific data visualisation can be difficult and lead to confusion and misinterpretation. Therefore, the sketches improved communication so that the ideas were interpreted correctly. Sketching was done both physically on paper and digitally on tablets.

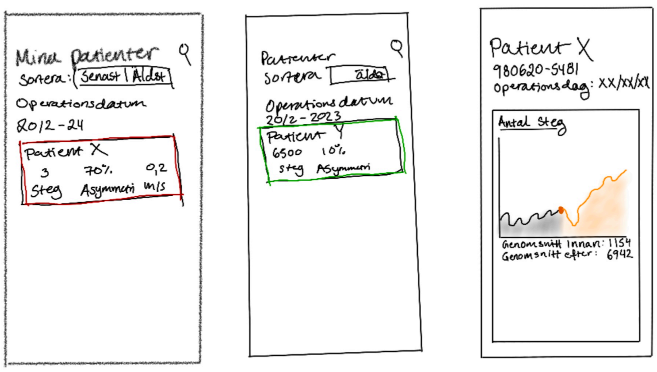


Figure 5.3: Early sketches of the prototype

5.3.2 Wireframes

The wireframes were primarily based on the results from sketches, mind mapping and brain writing. Figma was used as the tool for the wireframes and helped to understand how the information hierarchy could look in an application of this nature. Several wireframes were created, with different layouts and structures to fit the different visualisations (see Figure 5.4 for examples of the wireframes created). As the structure, flow and information hierarchy got more refined and polished, aspects such as pixel-specific layouts and actual data visualisations could be added. Including mock-ups of the data visualisations in the wireframes was important as it provided insight and guidance on what size they needed to be readable and interpretable. The wireframes were discussed with our supervisor to ensure the right decisions were made and to gain an extra perspective on the design choices.

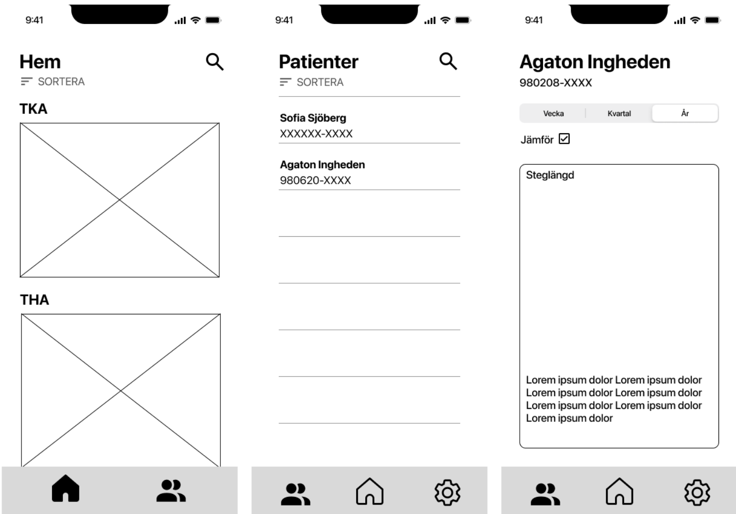


Figure 5.4: Early wireframes of the home screen, patient list view and detailed patient view

5.3.3 Prototype

With a clear understanding of the structure, flow and information hierarchy, the hi-fi prototype began to take shape. Similar to the wireframes, Figma was used as a platform for designing the prototype. In addition, various icons were designed during this phase using Adobe Illustrator and Procreate. Beyond icons, a library of UI components was also created, containing design elements such as navigation bars, switches, segmented controls, headers and more. Creating a component library in *Figma* helps maintain consistency throughout your design. The data visualisations required numerous iterations due to the complexity of designing the combination of colour, placement, type of visualisation, use of legends and labels, size and accessibility considerations. Furthermore, as the visualisations developed, the pixel-specific layout required minor adjustments. This was necessary because it was difficult to predict what the wireframes would look like with hi-fi data visualisations, including labels and grids. To create the data visualisations, one *Figma* plugin, *Random Linechart*, was used for the line graphs. The plugin offered customisability to fit our variables and requirements and the ability to generate several different visualisations quickly. With the quick generation of data visualisations, it became easy to see what worked in our prototype and what did not. Also, the lines and graph were generated as vectors, allowing for customisation in Figma, an advantage over using a static image.

One of Figma's advantages is the possibility of mirroring the prototype from your computer to your mobile device. This feature was used throughout the process because the visualisation medium can influence your perception of the data. Furthermore, Figma allows for collaboration within the team, which is important for testing ideas and working simultaneously. The last prototyping step was to add interactions between the components and the views. Since the flow and structure of the application were already mapped out from the wireframing, there was an idea of how the interactions would function, simplifying the implementation. After adding the interactions, the group reviewed the design several times to identify inconsistencies. Some inconsistencies were found, primarily related to differences in margins and visualisations. By addressing these inconsistencies and refining the interactions, we created a prototype with a level of fidelity suitable for evaluation.

5.4 Phase 4: Evaluate

To evaluate the prototype, usability tests were conducted with a total of seven participants. The first usability test was a pilot test with a student from the Interaction Design & Technologies Master's program to revise the think-aloud protocol and find any confusing tasks. After evaluating the usability test based on the pilot test, six usability tests were conducted with healthcare professionals within orthopaedics and physiotherapy.

5.4.1 Usability test

The usability tests were conducted in the participants' respective work environments, either in their offices or a secluded group room. The participants involved agreed to have their voices recorded and screen recorded by signing a consent form, which also included descriptions of how the data would be used. Choosing their natural work environment was done for two reasons. First, the artefact is designed to be used in the caregivers' work environment, making it relevant to test it there. Secondly, due to the caregivers' schedules, it was easier to meet them at their workplace. The entire evaluation took approximately 20 minutes, whereas the TA protocol took 8 to 10 minutes, the reflective questions took approximately 8 to 10 minutes, and the TAM questionnaire took around two minutes.

Think-Aloud Protocol

The usability tests followed a TA protocol where the participants were given certain tasks to perform within the prototype. Before the TA protocol, participants were presented with a photograph of a painting and encouraged to talk about it. They were advised to mention anything they felt, saw, or experienced with the painting, with the understanding that there were no right or wrong responses. This served as an exercise for the participants for the TA protocol to acclimate them to verbalise their thoughts. No time limit was set for this exercise; it ended when the participants felt they had finished. Following this initial exercise, participants were given a smartphone with an active screen and voice recording containing the design prototype and a paper with written instructions. They followed these instructions and completed the assigned tasks, verbalising their thoughts consistently. Throughout the TA protocol, the participants were advised not to ask questions to the test leaders to prevent potential bias or hints. However, the test leaders were present throughout the TA protocol to address any bugs or errors that could arise. In such instances, the test leaders were able to assist. The usability test ended when the participant finished the last instruction.

Reflective Questions

Once the participants had completed the TA protocol, they were asked open-ended questions covering aspects such as design, data visualisations, accessibility, and overall impressions. Furthermore, if the participants faced problems during the TA protocol, the different specific challenges were discussed to reflect on potential issues.

Technology Acceptance Model Questionnaire

A technology acceptance model (TAM) questionnaire (see Appendix F) was used at the end of the usability test to get an indication of whether the tool was perceived to be useful in different expertise areas within caregiving. The questionnaire is a seven-pointed scale divided into two parts, the first being perceived usefulness and the second being perceived ease of use. The participants subjectively rated how useful the product was and how easy they thought it as how easy they thought the product was to use. The questionnaire's purpose was to give the participants the possibility to think about whether the application concept could be useful and implemented within their occupation and if it was simple to understand.

The responses from the questionnaire were inverted, meaning that extremely likely corresponded to 7, while extremely unlikely corresponded to 1. To calculate the mean value of the responses and standard deviation, *Microsoft Excel* was used. Due to the low number of participants in the usability test, the results from the TAM questionnaire served as indications of the perceived usefulness and ease of use.

5.4.2 Affinity Diagram

An affinity diagram was created to structure the findings from the evaluation. This affinity diagram followed the same workflow as the affinity diagram done during the Discover phase for the semi-structured interviews. The process started with transcribing the voice recordings from the usability testing and the associated semi-structured interviews. After transcribing, the material was translated into keywords and topics, which were written down as digital notes in Figma. Quotes that highlighted a specific keyword or topic were also added. To create an initial structure, the keywords and topic were first divided into positive and negative. Beyond creating an initial structure, dividing it into positives and negatives also made it easier to see patterns in aspects that invoked specific emotions or experiences. The positives and negatives could then be further broken down into themes and categories.

Every process in creating the affinity diagram was done in collaboration and was highly iterative. The themes and categories were constantly discussed and adjusted to reflect the findings from the usability test.

6

Results

Based on the design process and findings from the semi-structured interviews conducted during the research phase, a high-fidelity prototype was designed of the suggested smartphone application *Hur går det?*. The findings and insights from the semi-structured interviews, design solution, results from the qualitative evaluation and the suggested re-design are described in this chapter.

6.1 Findings from Semi-structured Interviews

At the beginning of the project, semi-structured interviews were conducted to gain broader insight into the context of caregiving and the needs of the caregivers. The findings will be structured based on the themes identified in the Affinity Diagram, see Section 5.1.2, while the URL for the Affinity Diagram in Figma can be found in the Appendix E.

Current Practice

In the caregivers' current practice, several stakeholders are involved, including doctors in primary care, orthopaedic doctors, nurses, and physiotherapists. The main purpose of arthroplasty is pain relief. A functional examination of the patient's movement patterns uses ocular inspection to assess whether a patient is a candidate for surgery. Currently, analogue measurement tools such as a goniometer (an angle measurement tool for knees) are utilised. After the surgery, patients are encouraged to move as soon as possible with walking aids and are given rehabilitation exercises from physiotherapists to do at home. Patients also revisit physiotherapists for further assessment of the rehabilitation process a time after the surgery (approximately 4-6 weeks). If needed, the patients continue to see a physiotherapist after the surgery to increase joint functionality. An important consideration is that the patient usually meets different caregivers on each visit. Participant 8 highlighted this "*The difficult part is that you don't follow the same patient. It is different persons who meet them during the enlistment, different who meet them in the hospital, and different people who meet them after four weeks. So the most of them [patients], you only meet on one occasion. And then it is quite hard to know how they have been before*".

Subjective Evaluation

Currently, assessing the patient's movement patterns and rehabilitation relies on subjective observations by the caregiver and the patient's self-reported experiences. Participant 4 said, "*The amount of information is what I collect myself. And the amount of information is how much, how many times, I assess or look at a patient. I don't really get any information except for when a patient says that they for example limps (...). You don't get an objective evaluation of the patient's gait, it becomes an assessment*". Furthermore, Participant 1 said, "*It is easy that one [the patient] is overshadowed by the pain that has been, which makes it difficult to get a fair before- and after view of yourself as a patient*".

Assumptions Regarding Patients

Due to the subjective nature of the current assessment tools, there seems to be a relatively low trust towards the patients from the caregivers' perspective. Participant 2 mentioned, "*There is a big risk or weakness in what the patient tells me. I am fully aware that what the patient says does not have to match with the reality. I need to make an evaluation of what the patient says to then interpret it somehow*". Similarly, Participant 3 said "*You don't always trust what the patient says. Because we nag a lot about how important it is that they move and do their exercises. But you usually get a feeling that they say that they've done more than what they actually have*". This insight was further related to general behaviours and trends, where Participant 1 added "*Unfortunately we see that there is a trend for a lot of people where they don't move as much, and that they don't always pick it up after [surgery], so you have changed your behaviour and needs to work on a behaviour change*".

Lack of Information

Since the assessment of a patient's movement patterns is done subjectively, indicating a lack of information regarding movement patterns in general. Participant 5 said "*I believe that it [information] is not very objective. (...). I see how the patient walks and moves when they visit the rehab, when they are exercising [at the rehab gym], and when they walk short distances. But how they move when they are out on a longer walk or how many stairs they actually walk in, I don't really know more than the patient's subjective story*". Additionally, Participant 2 mentioned that "*The need is to help nuance what the patient tells me. To help with giving concrete information. (...) As mentioned there is a big risk that the patient remembers incorrectly or overinterprets some things, or even consciously doesn't tell me exactly the truth due to different reasons. (...) Concrete information could either verify what the patient says, or the opposite which could help me understand if there is something I don't get regarding what the patient says and what I see in front of me*".

Digitalisation within Healthcare

While there has been a move towards digitalisation in healthcare, the interviewees suggest that the sector is falling behind, often hindered by various factors. Participant 2 said "*There are those who have started to introduce digital aids. But I would* *say that generally speaking, it is unusual for us to use it in the care of our prosthetic patients."*". When Participant 1 received the question "How do you see the use of such apps, for example in healthcare?", they responded " *"I believe that we need more. We use digital data too little in healthcare in general. We don't take advantage of the opportunities that exist to visualise for the patient, changes and conduct the dialogue based on having something in front of you and discussing it."*"

Digital Tools within Healthcare

The usage of digital tools within healthcare was shown from the interviews to be very low. The digital tools that were mentioned were Joint Academy, Operationskollen, Physiotools and Platform24. However, none of the tools offered visualisation of movement patterns, even if there was a wish to implement this type of digital tool. Participant 1 mentioned the possible advantages of a digital self-tracking tool designed for arthroplasty patients. "*(...) You get a fantastic real-time basis and to have the app in dialogue with the individual patient regarding their progress and improvement and change*". Because of the nature of healthcare being governed by laws, regulations and procurements, there also seems to be a slowness in implementing digital tools. Participant 2 said *"I feel that there is a slowness in adopting this type of tool. Now I work in public care, and there is a lot governed by procurement and laws and regulations, which means that I feel that it can take quite a long time before you can successfully implement tools, such as what we are discussing right now"*. Participant 5 highlighted their concerns revolved around less tech-savvy seniors being left out when using a digital tool. *"Some [patients] have a very good grasp and are very good at this. But I think it also excludes some people who are not as comfortable using it."* when they received a question regarding general opinions or thoughts about the proposed concept.

Objective Evaluation

Given the current practice of subjective assessment and patient reports, participants highlighted the potential value of objective data. Participant 2 said "*Patients that are around 50 to early 60 years old, they quite commonly and spontaneously use their step counter in their phones (...). I usually experience that this is very valuable. Then there is something objective and concrete to discuss and value together*". Furthermore, participant 1 mentioned the possibilities of objective comparisons "*(...) It also gets easier to visualise to the patient through some sort of form of you [patient] with the larger mass (...)*". Participant 3 said *"It could be great to really get it black on white"* and added "*We need more evaluation tools, especially if they can be easily integrated with the medical records (...)*".

Validity

When discussing data and self-tracking, validity was a prominent theme. The trustworthiness of the data was highlighted by two participants. The data must be reliable, otherwise, it risks not being utilised in caregivers' practice. Participant 4 said "*I like data and numbers. I like it more when I can get an actual value on some-*

thing, so I would say that I am quite positive towards it. But it needs to be sufficient, it needs to be specific enough or trustworthy to make one feel that you can and want to use it". Participant 6 spoke about a research project, using self-tracking "*We have had weird data when people had ridden or sat on a field lawnmower*". Participant 6 further mentioned "*(...) there is a good deal of limitations in the measurements. How reliable it is and so on. So maybe not the most advanced measurements*".

Individual Goal-setting

When physiotherapists are working with patients, they try to tailor the care to fit that specific patient. Participant 4 mentioned that it is like a craft "*Much (...) within physiotherapy is like a small craft. And it's often you make an assessment then adjust depending on the assessment*". This individualistic approach also applies to the goal-setting. Goal-setting is important when it comes to the communication between physiotherapists and the arthroplasty patient. The process of formulating a goal is done in collaboration between the two. The patient can speak about their goals, what they would like to achieve and what activities they wish to return to. Participant 6 said the following about goal-setting "*It is usually at the first visit that you might ask what kind of activities they usually do and what they want to go back to. Is it reasonable and so on? Maybe the upcoming golf season and so on. Then you try to talk about when in time it might be reasonable and what do we need to do to get there?*". Participant 6 also spoke about goal-setting "*Yes, I want to say always, but we don't always do that. But usually we try to start from what the patient wants to be able to do*". So, there is an aspiration to work toward patient-related goals, but this is not always possible. Different motivations also drive the patients, affecting the goal's definition. Participant 7 added "*And the motivation of each patient is also very different. And the expectations they have of the operation and what they want to be able to do after the operation also differ greatly. Some are satisfied that it just doesn't hurt, and some have very high demands that they want to get started and become more active again*".

Accessibility

The participants mentioned their concerns regarding the accessibility of the digital tool. While the caregivers were informed that the project revolved around designing a digital tool for them, there was a common theme among the participants to consider the patient's perspective on accessibility. Participant 2 reflected on the language in the application, "*(...) Different languages, different versions. I see a problem with the material we are currently using in healthcare. Swedish is the language of choice. But the society does not really look like that. There is a large portion of patients that need the material in other languages*". Participant 2 also mentioned their wishes that the interface should be user-friendly for the patient and informative for the caregiver "*(...) user-friendly, of course, and that it is user-friendly for the patient and informative for the carer*". This topic was also touched upon by Participant 5 who emphasised that the patients, usually seniors, don't always have technical expertise. Participant 5 said "*What can be difficult is that the age group that often needs these operations is a bit older. Maybe between 70 and 80 years old,* *some even older. Not all of them are technically skilled or find it easy to use the technology*".

Lifestyle factors

Many factors contribute towards the rehabilitation post-arthroplasty. Your current life situation, your attitude towards pain and your daily habits were all discussed during the interviews. Participant 1 mentioned an interesting aspect of walking aids "*Sometimes we see people releasing their walking aids too early. They choose to walk and limp instead*". Participant 6 mentioned that patients tend to move more after surgery when they are no longer in pain, but without having seen any empirical evidence of it. "*(...) But gradually, when they are no longer in pain, they usually move too. But that's more from my experience. It's not like I have a lot of statistics on what it looks like. In the beginning, they move considerably less. Because they are in a lot of pain and need to do the rehabilitation*". Participant 3 said that they would like the movement patterns throughout the day, as the walking habits among patients differ "*(...) Whether they get up and move around or just lie on the sofa all day. Those who are up and moving may be those who move almost too much. But then you perhaps can also see it in the app in that case. That you have actually moved too much. And then it often means that, for example, the knee swells and they get more pain. So then you might have to restrict those patients*".

6.2 Design Solution

Based on the insights from the semi-structured interviews, the design and aesthetic choices of the application *Hur Går Det?* were made. The results from the interviews indicated a desire for simplicity and minimalism. The colours used are according to *Region Västra Götalands* standard, and the colour library was downloaded from their official design system. The blue colour shades are associated with healthcare in the region, where the colours were used consistently throughout the design, with the addition of complementary colours according to the design system on icons and in the data visualisations. The font used throughout the design was a sans serif, named SF Pro Display, due to its similarities to the official font for Region Västra Götaland.

6.2.1 Login Screen

On the login screen, the user can log in using BankID or another login method, along with the ability to change the language. Although the login options lack functionality in the prototype, they contribute to realism, which proved beneficial during usability testing.

6.2.2 Overview

The home page of the application design acts as an overview of all arthroplasty patients. This overview presents the mean percentage value of how many patients

Figure 6.1: Mockup of Login screen

move more or less after arthroplasty, visualised in two bar charts. The bar charts represent respectively THA or TKA and are intended to give users insight into the patients' activity levels. This overview aims to provide caregivers with an immediate estimation of the patients' recovery. A higher activity level indicates successful surgery and rehabilitation, serving as a deductive indication

Figure 6.2: Mockup of Overview page

6.2.3 List/Grid View

To access the patient information and their self-tracking data, the user goes into the tab "Patienter" (eng: Patients), where they are presented with a list view of all their patients. To search for a patient, the user can either use the search bar and search on the patient's personal identification number, according to the standard within healthcare, or scroll through the list vertically. Furthermore, the user can use the filtering function to sort the patients either in alphabetical order (default) or by surgery date. The filtering function also enables users to filter patients who have undergone a hip replacement or knee replacement, as well as those who are more or less active after surgery. The list view displays the patient's name, personal identification number, surgery date, and an icon indicating the operated joint. Users can access a detailed view of the patient by selecting the desired patient.

If the user prefers a more visual overview of the patients, the user can go to the grid view, where the same functionalities, such as searching and filtering, are present. Information about the patient is presented in the list view with the addition of a bar chart presenting the number of steps the patient has taken during the past seven days, as well as a mean value of the number of steps taken. Hence, the user can decide whether they prefer to see an overview of the patient's steps when scrolling through the patients or whether they prefer to see the patients organised in a list.

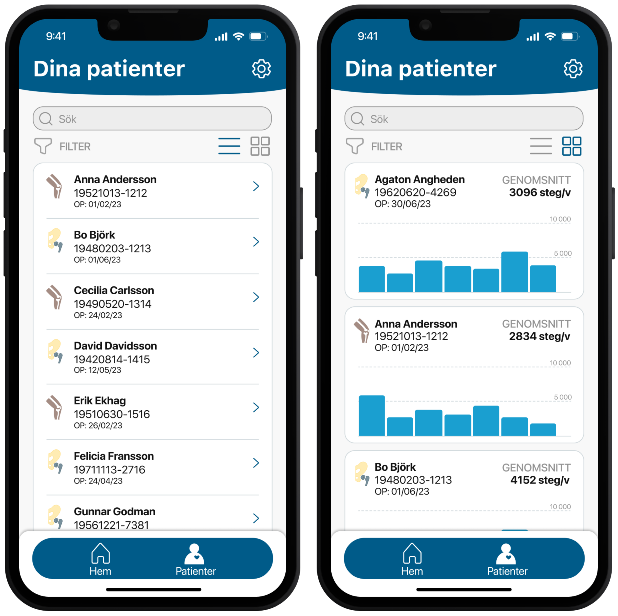


Figure 6.3: Mock up of List (left) and grid (right) view

6.2.4 Patient View

Once a patient has been selected, the user is presented with a detailed view of the patient. This view displays all movement parameters. In the header, users can choose the desired period and compare the selected patient with other arthroplasty patients. An info button is also available, providing necessary information about the time span and "compare with others". Turning on the comparison function overlays a mean value of other patients on top of the visualisation. This feature enables the user to compare how one specific patient is doing compared to other patients. Personal information from the list view is also shown in the header to prevent confusion about the viewed patient. The patient view comprises visualisations of the movement parameters presented in a scrollable body. Each visualisation is accompanied by an info button that explains the movement parameter and details how and how often it is collected.

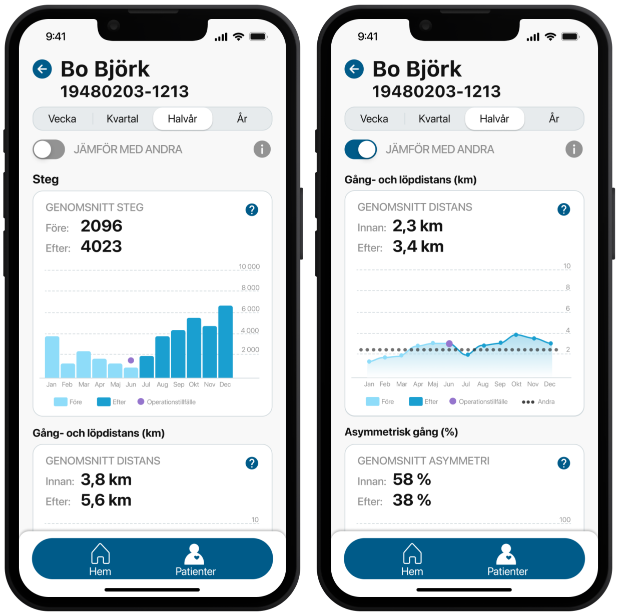


Figure 6.4: Mock up of patient view

Visualisations in the Application

The variable step count is visualised with a bar chart, while the other variables are visualised as line charts. While it may seem inconsistent not to stick to one type of visualisation, using a bar chart for the step count was done for the following reason: Step count is highly dependent on external factors such as season, weather, and access to transport. A patient may show an increase in steps in the summer as they spend more time outdoors, but as it gets cooler, they may reduce their activity regardless of their pain level, making it difficult to see clear trends. Line charts highlight trends as they show a relation between data points, which is why line charts were chosen for the other variables, as they are not as dependent on external factors as step count, except walking and running distance. However, with the colour scheme depicting before and after surgery, accompanied by the numbers, the bar chart can show general trends in activity levels.

Depending on the chosen period, explanations of the marks are displayed alongside the visualisations. The marks used for months use two different colours, depending on whether they are before or after the date of surgery. The colour difference clarifies the movement patterns before and after surgery, potentially providing valuable insights into the patient's progress. Furthermore, the visualisations are designed to be interactive, with the ability to trigger a tooltip displaying the exact value for a specific day by tapping on a mark, such as a bar representing a specific day.

6.2.5 Settings

The settings menu holds functions that regard account, accessibility, language, integrity and basic information about the application. The settings page was constructed to give the usability test participants a more real-life experience, although only switching the language to English was functional. See Figure 6.5 for a mock-up of the settings.

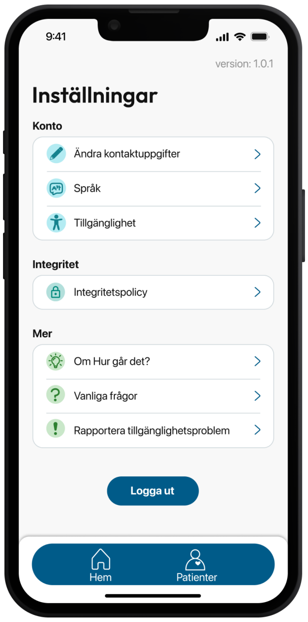


Figure 6.5: Mock up of settings page

6.3 Evaluation

A usability test was conducted according to the think-aloud protocol to evaluate the hi-fi prototype. Following the TA protocol, the participants were interviewed with open-ended questions about the design. Concluding the usability test, the participants filled in a questionnaire according to the Technology Acceptance Model, where they subjectively rated the usefulness of the concept and design and the perceived ease of use.

6.3.1 Usability Test

The usability tests were conducted at the respective participants' workplaces and held in meeting rooms or personal offices. The decision to conduct the usability test at the participants' workplaces was due to the intended environment where they would use the smartphone application when implemented. Six participants were recruited for the usability test, all specialising in orthopaedics, working either in a hospital or at a physiotherapy clinic. The participants were found through the contact persons of the project that the thesis is a sub-project within, contacts from the orthopaedic department at Mölndals Hospital, and from the semi-structured interviews (P5, and P6). Table 6.1 shows the participants' occupations and how many years they have had their current occupational roles.

Table 6.1: Table of demographic measurements for the Usability Tests

Participant	Current practice	Years of experience
$P1$	Orthopaedic engineer, Researcher	30
$P2$	Orthopaedic specialist	1
$P3$	Orthopaedic speciality trainee	2
$P4$	Orthopaedic nurse	15
$P5$	Physiotherapist	17
$P6$	Physiotherapist	21

6.3.2 Results of the Think-aloud protocol

The primary tasks the participants were assigned included analysing the overview, navigating to their patients, and exploring a patient's movement patterns. The affinity diagram, based on the result from the TA protocol, can be found in Appendix H.

Overview

The first page they were asked to analyse was the home page, which consisted of an overview of how many patients moved more or less after the surgery, based on their step count data (See Figure 6.2).

During the TA protocol, the participants interpreted the overview of the patient's activity levels somewhat differently. P1 said while in the overview "*Ok, the hip prostheses activity after surgery, six months, knee prostheses based on the patients' amount of steps before and after arthroplasty. Yes, it is an overview and good.*", which was in line with the initial design. P5 sees a typo in the prototype immediately and said "*So 24 per cent of everyone who's had hip surgery moves less after surgery, and 77 per cent moves more. My first thought is that it does not add up to 100 per cent, is 77 + 24 one hundred, or am I bad at math?*", but continued to analyse the visualisation as intended and mentions "*so the overview is like a conclusion that most of the patients move more after the surgery which is positive since we want it that way*"

P3 similarly mentioned when looking at the overview "*Here we can see a clear increased activity 6 months after the surgery in comparison to before, for the hip* *prosthetic patients, and for the knee prostheses its also a significant difference, more than double*", with the notation that they believed it was a comparison between before and after surgery and not an overview of the patient's activity level solely after surgery which was the intention of the visualisations. P2 indicated some confusion regarding the time period (six months) "*77 per cent is more active, and 24 per cent moves less over 6 months. It sounds like some are having issues with the healing. (...) Now Im wondering if its including the time that is close to the surgery or if it is some kind of recent average. The day? It does not say anywhere, or the last week or anything like that. It just seems to be the number of steps before and after surgery*".

Based on the participants' interaction with the overview, there was a discrepancy regarding what the visualisations actually presented. Which in turn was followed up after the TA protocol.

List of patients

The participants were assigned to go to the list of patients to find a specific patient. All of the participants understood the personal identifiers in the list, such as the name of the patients', and surgery date. P3 mentioned specifically "*We can see a list with personal identification numbers, surgery date, and if it was a hip or a knee*". However, P4 did not realise that the icons represented the joints until the think-aloud protocol was finished, and mentioned afterwards "*Right, it is a hip or a knee that they had surgery on (icons). I did not think of that before, but I get it now*". Regarding the filtering function, P1 exhibited some trouble with finding the filter button in the list view, and tried to use the search bar instead. While trying to search, instead of filtering P1 mentioned "*To just see patients that have a hip prosthesis. Then we have to search. We want to write hip prosthetic*".

Grid view

When accessing the grid view, the additional bar charts display the number of steps taken over the last seven days. P3 mentioned "*You get a slightly better overview. You can see how many steps they [the patients] have taken*". P5 seemed to believe that the bar charts represented several weeks, instead of days "*(...) I see how much they have walked week per week, I guess that is the bars*".

Patient view

When the participants got to the detailed view of the patient, they were assigned to do a few specific tasks. These tasks revolved around finding out the specific amount of steps and the corresponding distance for a specific day, in this case, Tuesday. To find out the specific amount of steps or distance, the participants needed to hold down on the mark for Tuesday to activate a tooltip. While the participant realised that they needed to interact with the mark, the interaction seemed overall unintuitive based on their reactions. P4 said "*Yes, then he walked 3752 (steps). Oh, I have to hold it. Or it pops up very quickly*", while P1 said "*He took 3752 steps, but it does not stay when I touched it*". P6 also spoke on the matter, "*I can't seem* *to click on it, but it lights up when I press the bar?*". It was clear that some of the participants did not find the interaction intuitive, both with the step count and the walking distance. P2 seemed to confuse the numbers for the step count with the week the visualisation showed "*Week 41-52 does not sound like a real week number*".

The next step was to find walking asymmetry and find out how that variable was collected. All participants found the walking asymmetry with ease, and the question mark was used to find out more information about walking asymmetry. P2 showed an uncertainty after reading how the variable was collected, "*Okay so Ive seen the information how the data is collected, did it say that there? 10-30 samples daily, is that the information on how the data was collected, Ill assume it is*". What they said, in combination with their body language, indicated that they were unsure if that was the right information. However, P1 seemed to think it was an adequate amount of information, saying "*Then we have asymmetrical gait. We can see about 42 %, if we click on the question mark it says (...), the system logs 10 to 30 samples daily. Okay, good*".

The participants were then instructed to change the selected period and look at how Bo Björk's movement patterns have changed over time. P4 mention that they can see how the movement pattern has changed after the surgery date "*Yes, or he walks almost twice as much as he did before (surgery) approximately. The walking asymmetry is also less, so now he walks more evenly too*". P2 also was able to notice the change after the surgery "*Maybe a quarter of a year, The surgery was in June, then it increases (activity) significantly*". P3 expressed that it was good to be able to see the change visually "*And then we have the surgery date. You can compare it visually before and after surgery. That is good*". However, it was not clear if all the participants spotted the mark of the surgery date. P5 and P6 did not explicitly express whether they had spotted the surgery date. P5 only mentions the before and after numbers accompanying the visualisation. "*(...) Before and after the surgery then? That before the surgery he walked with 42 per cent asymmetry and after 27 per cent. I guess that is what you mean?*".

While dissecting and looking at Bo Björk's movement data, the participants needed to compare Bo Björk's data with other patients. Two of the participants struggled with finding the switch for "compare with others". P6 seemed uncertain of where to find this function, initially thinking it was seen in the grid view. "*Compare how Bo Björk compares to other patients on the different movement parameters. Then we will look at everyone. Maybe that's what you saw in the beginning there? No, it wasn't*". It was first when P6 received a hint they were able to find "compare with others". P4 had an idea of navigating to another patient to be able to compare them: "*Compare with other patients. Then I have to go to another patient, I think. Going in on David here then? No, it wasn't*". However, P4 was able to find it by themselves without receiving a hint after navigating around. There was also some confusion regarding the mean value of other patients. For example, there was some confusion as to why the mean value of other patients was shown as a straight line and not a line with different data points. P5 said " *But, I don't really understand who the others are. That the others' average is a straight line?*". But after finding the information button, P5 understood what the straight line meant. P2 expressed his confusion as to who the mean value was referring to "*So this is some form of mean value of how the others are walking, other prosthesis wearers then? Or could it be other healthy individuals as well? Or other individuals before and after surgery? I don't really know*".

6.3.3 Reflective Questions

When having completed the TA protocol, the participants were asked reflective questions (See Appendix G) that regarded the design and visualisations in general, as well as questions concerning potential challenges they faced. The reflective questions were open-ended so that the participants could freely discuss their opinions on their design and bring light to potential issues. During the follow-up question, the participants were allowed and encouraged to revisit the prototype. The answers to the questions were transcribed and coded, where themes regarding the design were defined. The themes identified during the follow-up questions included: Importance of tracking movement; Ease of use and navigation; Design and aesthetics; Accessibility; and Desired additions. The affinity diagram, on which the result from the think-aloud protocol is based, can be found in Appendix H.

Importance of Tracking Movement

A focus during the follow-up questions was the importance of tracking movement from a patient's and the caregiver's perspectives. P3 mentioned "*For the patients, it's important for them to know how much they move, and if it has been a change in the movement pattern, I believe. You can clearly see how it was worse before the surgery and a clear improvement after*". P1 further stated "*(...) it fills the need I can imagine exists if I was in this situation as a patient, to see my activity and how it has been over time. I want to see the relationship between others, and what you could say is expected by the interface*". P2 discussed the caregiver's point of view by stating, "*We do have a lot of gait analysis we conduct here [hospital]. But this is also an advantage. I mean we do the surgery here so that they [patients] can have a casual life outside, so it allows for not only measuring these parameters in a hospital*". P2 continued discussing the implementation of the application "*It's a good pseudo marker to be able to see how far the patients are able to walk after a surgery (...). I thought it was a good overview and quite easy to switch between them (pages) and navigate. Then the question is what to use it for or how to implement it in your clinical workday*". P2 also brought up the relevance of the data from both the patients' and caregivers perspective "*Somewhere it is like daily activity, or how much pain they have, or how much they want to work or how much you [patient] want to be able to move (...). All of that is relevant for what we are doing, so being able to register how people manage their daily life I think is good.*". The mentioned statements indicated the need to understand the patient's movement patterns, which applies both to the patients and the caregivers. The patients would be able to see if their movement patterns and activity levels are improving, and the caregivers expressed the need to see the patient's rehabilitation progress continuously in real-time.

P5 exemplified how self-tracking data further can nuance the dialogue "*(...) But how much of this is outdoors? Are you with me? But of course, it's difficult to see if they only walk indoors. You want them [patients] to go outside. Because if it was like, I've walked quite a lot, but I haven't been outside more than 500 steps or whatever. Why aren't you? Is it because you're afraid of falling or is it because? Has there been a snow storm or that you can start that discussion.*". This would allow for a new communicative mean which can create a new dimension of the dialogue between the patient and caregiver. Furthermore, P4 mentioned the different time spans "*It's really good to be able to see different time periods to compare. (...) Because I assume that the patients also can see that?*", indicating the possibility of getting a better overview of the rehabilitation process for both the caregivers and patients.

Simplicity in Data Visualisation and Recognisability

A key feature of the design is the simplicity of the data visualisations. This feature was mediated to the participants successfully, as shown during the reflective questions. A recurring theme in the participants answers was the recognisability of the visualisations. As it became clear during the discovery phase that caregivers, especially physiotherapists, were not used to data visualisation in their clinic, it was important to make the data visualisation as legible as possible. Several interviewees commented that the design was similar to other activity apps, which created a sense of familiarity. P4 said "*I recognised it a bit from the health app, so that feels quite comfortable since you know what it is about*" and P1 said "*(...) I work with an activity app normally, so I kind of know how much I walk and such, so I am familiar with the interface and functionalities*". P6 and P5, who in the pre-study expressed their lack of experience with data visualisation in their work, both found the design easy to use and understand. P6 commented, "*No, but it was a fairly simple design and quite like this; So, you kind of understand what you have to do like other (apps). So it was an easy design and easy to find and so on*". Similarly, P5 noted the aspect of legibility "*But as I said, I'm not very used to reading tables and diagrams and graphs and so on, but I still thought it was easy to understand*". Despite P5 and P6's unfamiliarity with data visualisations in their practice, they found the visualisations legible, possibly because they recognised elements from other activity applications.

The data visualisation was not designed specifically for caregivers but was designed also to be implemented in the patient version of the application, hence the simplicity. This was partly implemented to ensure transparency between the caregiver and the patient so that both see the same things. In addition to transparency, the simplicity of the data visualisations can reduce cognitive load and save time, even for caregivers with a high level of experience with data visualisation. Achieving simplicity and legibility in the data visualisations was done by following the basic principles of data visualisation, as presented in Section 2.3.

Ease of Use and Navigation

Since this was a prototype done in design software, there were a few situations where the interactions did not work as planned. For example, the pressable area of a button was sometimes too small, rendering it difficult to press. This was noticeable during the think-aloud protocol and was also spotted in the screen recordings. However, the participants were aware of the faults that may come with it being a prototype and were not mentioned later during the follow-up interview as an interfering element.

The number of views needed to contain all of the necessary information was held to a minimum to avoid unnecessary navigation. Navigating the application was deemed easy, with many of the participants commenting on the ease of use. P3 spoke on the matter, saying "*Its a very easy application, you just press some things back and forth*". P2 also mentions the navigation while adding to the possibility to delve deeper: "*It is quite navigable, and a plus is that it is easy to delve deeper if you become interested in something specific. (...) But that you both can zoom out and then, (zoom) in a bit on what interests you*". The ability to focus on individual interests is important because each patient is unique. Some patients may take many steps per day, but if they have a short stride length, it could indicate cautious walking. The artefact enables caregivers to identify inconsistencies in movement patterns and provide advice based on these observations, complementing current practice. However, P5 mentioned their uncertainty about whether the application was easy to use because of the design or it was because of the accompanying TA protocol. P5 commented "*I don't know how it would have gone if I'd just sat down here and tried it myself. (...) Now it was like because I was given some, how shall we say, clues, like what to look for and when I got it, it was no problem, like it was very easy to find*". While none of the other participants mentioned the possible influence of the TA protocol, it is worth considering if it may have influenced the perceived ease of use.

Three participants had some minor problems with the "compare with other" function. Two of the participants did not find the function during the TA protocol, suggesting that the placement of the switch was not intuitive. P4 stated that "*The only thing was to find 'compare with others'. It was very easy once I saw it, but I didnt at first and thought I needed to go back*". Another factor that could have contributed to the perception of "compare with others" is the unfamiliarity of using such a function. P4 added "*It was very new to me (...), so Im not used to it. But it felt very snazzy to be able to do that*". P5 had some minor confusion regarding the dotted line, which could be attributed to them activating the "compare with others" function before receiving the instruction in the think-aloud protocol. After opening the information overlay, they understood what the dotted line meant, later commenting " *(...) I didn't realise that the dots were the others. Now that I know about it, it's very clear, but I didn't realise it from the beginning*".

Design and Aesthetics

The participants further commented on the aesthetic choices and how the visualisations were designed. P1 mentioned, "*There's no weird colours, nothing like that, it is according to the standard at VGR (Västra Götalandsregionen*". P3 stated "*I like that it's stylish/clean, and not too cluttered. Everything is uniform regarding colours, and those parts, it looks professional (...)*", and P6 similarly mentioned "*But I thought it was clear and good, concise, manageable and clear pictures with hips and knees*

(...). P2 said "*It's a pleasant background with blue and white. (...) It looks pretty serious with the fonts and titles*". P5 further discussed how the blue hues affected their impressions of the visualisations "*Also that everything is all blue, which means that you don't get the feeling that something is worse than something else. If it's red and green, it's very easy to think the reds are negative and green is something positive. Here it felt kind of neutral*". Based on the responses from the participants, the indication that the blue hues used gave a sense of neutrality and simplicity. In the case of activity levels, the colour scheme can be seen as an advantage since every patient has different starting points and goals after the surgery.

Accessibility

Creating sufficient data visualisations for a mobile application can be difficult as you are dealing with limited screen space. There were a few concerns initially that the text size for some of the small elements in visualisations would be too small for the caregivers to read. However, readability was good, according to the interviewees, as text size and information were deemed sufficient. A common theme throughout the usability test was that the caregivers tended to think from the patient's point of view. Comments that were made regarding accessibility mostly touched on what problems patients, often seniors, would encounter if they were to use the application. P3 commented "*It might be a little too small for some elders (...). On the important parts its a good size, like the before and after, which is the important part.*" and was complemented with "*Maybe you could write in text if it is a hip or knee, instead of the pictures, even if it looks nice. But some older people may not see them as good as young people*". One of the initial prototypes had a setting where one could change the text size. However, as it is an application for an iPhone, you are recommended to change the system settings instead of changing them in the application. This is so that the different settings will not multiply each other.

Desired Additions

During the follow-up questions, some of the participants also began discussing what additional variables could be of value. P1 asked "*Is there a connection to the medical side and the doctor's point of view? For example where I can register data, corresponding to the journal, maybe that would be good*". Furthermore, P3 mentioned "*Maybe an addition would be something like a pain diary, or how many times they've seen a physiotherapist, so you can see if the pain and movement patterns correlate*" and P4 mentioned, "*A thing that is valuable to add would be pain. (...) To get that perspective (...), we work with the VAS scale to see the pain decrease*". Adding the possibility of self-report data, such as experienced pain or a diary for exercising, would allow objective and subjective data to be intertwined and analysed in the same medium.

6.3.4 Results from Technology Acceptance Model

Concluding the qualitative analysis, the participants completed a questionnaire according to the Technology Acceptance Model (See Appendix F). The questionnaire was divided into two parts: perceived usefulness and perceived ease of use. The questionnaire is built on a Likert scale of 1 to 7, where 1 represents Extremely Unlikely and 7 represents Extremely Likely. The responses' mean value and standard deviation were calculated as a complementary analysis to the TA protocol and questions to understand if the participants had similar impressions regarding the perceived ease of use (See Table 6.2), and if it was easy to use (See Table 6.3).

Table 6.2: Table of mean (M) and standard deviation (SD) regarding perceived usefulness

Question	Mean (M)	Standard deviation (SD)
1	5.5	1.22
2	5.5	1.22
3	5.33	1.03
4	5	0.89
5	5.83	1.17
6	6	1.1

Table 6.3: Table of mean (M) and standard deviation (SD) regarding perceived ease of use

Question	Mean (M)	Standard deviation (SD)
7	6.5	0.55
8	6.33	0.52
9	6.5	0.55
10	6.67	0.52
11	6.67	0.52
12	6.83	0.41

Due to the amount of participants, the results from the questionnaire served solely as an indication or pseudo-marker for evaluating the concept and design. Regarding perceived usefulness, question number 4 had the lowest mean, being "Using *Hur går det?* would enhance my effectiveness on the job", M=5, SD=0.89. Question number 6 had the highest mean, "I would find *Hur går det?* useful in my job", with M=6, SD=1.1. Regarding perceived ease of use, question 8 had the lowest mean, corresponding to the question "I would find it easy to get *Hur går det?* to do what I want it to do", with M=6.33, SD=0.52. Furthermore, question 12 "I would find *Hur går det?* easy to use", had the highest mean value M=6.83, SD=0.41.

6.4 Suggested Re-design

The application was designed through an iterative design process, where suggested changes were made based on challenges seen during the usability tests. As the feedback from the participants was fairly sparse, the design did not see any major changes. All the feedback was considered and deemed legitimate. Minor changes are included in the list below, while the changes made to the visualisations are presented in Section 6.4.1.

- **Overview/Home page:** Added the option to change between quarter, six months and year. Minor wording changes were made to clarify what the visualisation presents and to avoid tautology (See Figure 6.6).
- **Grid view:** Added labels for the different days in the visualisation to avoid confusing it with different weeks. Additionally, the knee icon was changed to be in line stylistically with the hip icon (See Figure 6.7).
- **Login screen:** Changed the login option from BankID to SITHS eID, as it is the main verification method for caregivers in Sweden (See Figure 6.8).

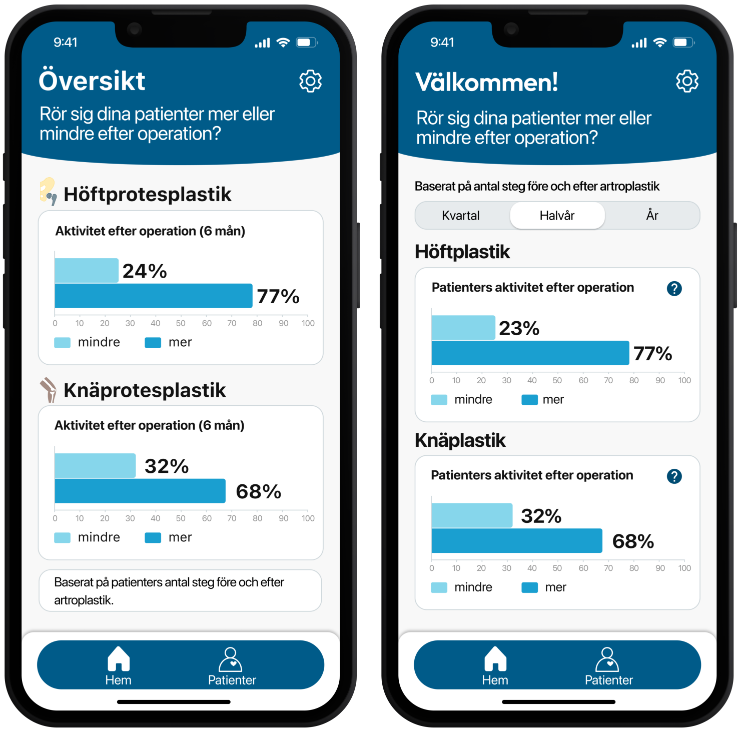


Figure 6.6: Visualisations for the grid view, previous design (left) revised design (right)

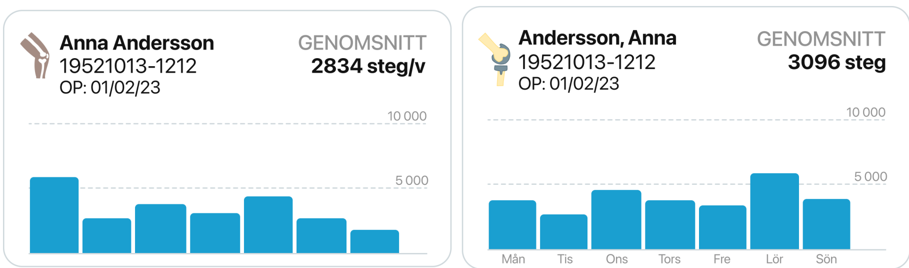


Figure 6.7: Mock up of the grid view, previous design (left) revised design (right)

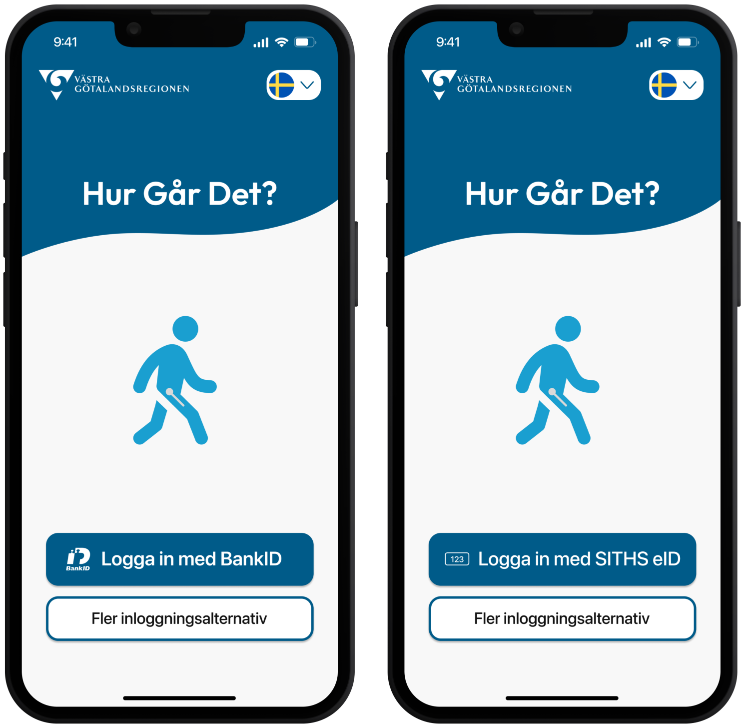


Figure 6.8: Mock up of the login screen, previous design (left) revised design (right)

6.4.1 Visualisation Design

The visualisation of the movement variables was modified based on feedback from usability testing. Although minor, these changes were considered significant and contributed to the final design. Participants P3, P4 and P5 all noted that the visual analogue scale (VAS) was a valuable addition for assessing patient pain levels over time. Caregivers can now view the patient's pain level within the same tooltip that is displayed when selecting a particular day in the visualisation (See Figure 6.10). This improvement allows carers to see, for example, whether extensive walking on one day correlates with increased pain levels the following day. The interaction for the tooltip was also adjusted as participants demonstrated a sense of confusion while interacting with it. Instead of requiring a press and hold on one of the marks, the tooltip is now displayed by a simple tap, as this appeared to be the most intuitive option according to our test subjects.

It has been revised to be a curved line to address participant confusion about the straight mean line for other patients. This adjustment better highlights potential changes in movement before and after surgery. The curved line makes it easier to compare surgical outcomes for individual patients with the collective group (See Figure 6.9).

Another adjustment was to change the colour of the surgery date marker to orange. Feedback indicated that the original colour scheme made it difficult to locate the surgery date in the visualisation. By using orange, a complementary colour to blue, the surgery date marker now stands out more (See Figure 6.9).

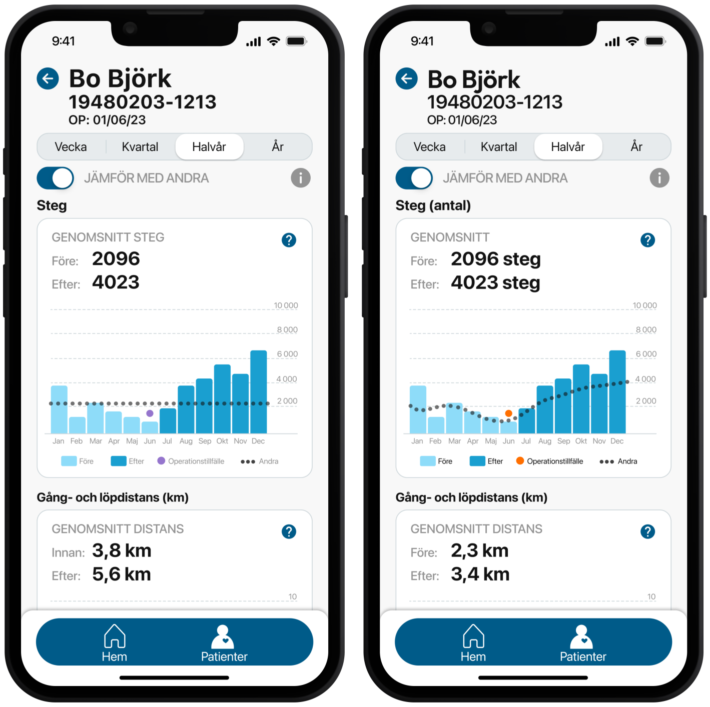


Figure 6.9: Mock up of the patient view, previous design (left) revised design (right)

Finally, the text within the visualisation has been revised to clarify that the number shown represents the average steps for the week rather than a week number, as one participant initially thought (See Figure 6.10).

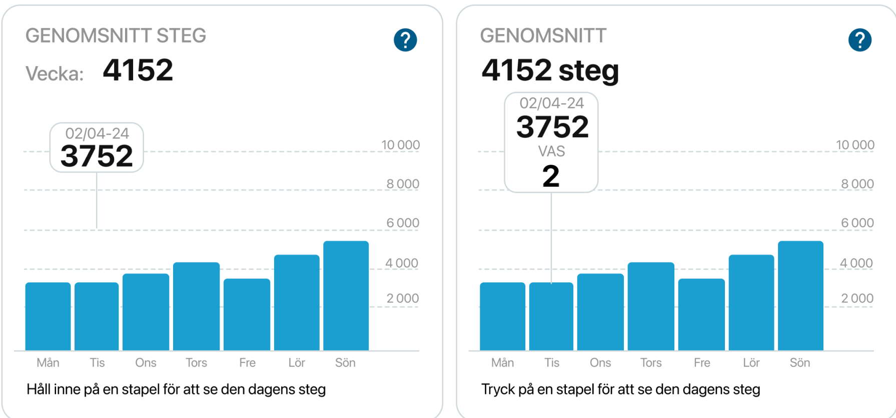


Figure 6.10: Visualisation for step count on a weekly basis, previous design (left) revised design (right)

6.5 Summary

The results from the usability test indicated the need for digital tools within the industry to evaluate surgical outcomes and personalise care for individual patients.

Challenges that were present for the participants when using the application included the placement of buttons as well as ambiguity and differing interpretations regarding what the visualisations presented. Based on the TAM questionnaire, the application had high perceived ease of use ratings. Most participants could also see the application's usefulness and its potential implementation in the field. Based on the evaluation of the design solution, a re-design was made with adjustments according to the insights and challenges the participants faced.

7

Discussion

The implementation of digital solutions in healthcare, such as self-tracking applications, presents both opportunities and challenges for improving patient care. This discussion chapter explores the reflections and insights gained from developing and evaluating *Hur går det?*, a self-tracking application designed to monitor movement patterns and rehabilitation progress in arthroplasty patients. Through an iterative design process driven by Design Thinking principles, *Hur går det?* was conceptualised to meet the diverse needs of caregivers within the orthopaedic healthcare sector. The final concept, including the most valuable variables according to the caregivers, based on the user research and evaluation, was objective activity data over differing time spans, as well as patient-reported pain levels (see Section 6.4). The iterative nature of Design Thinking also provided the foundation necessary to answer our research questions:
What are the caregivers' needs for the design of the suggested application?
What features can be applied in the design of the application to fill the caregivers' needs?. The research questions will be answered in the conclusion; see chapter 8.

Furthermore, the chapter will also discuss the challenges related to the evaluation and implementation of digital healthcare solutions. This includes ethical considerations, technical constraints, and the necessity for comprehensive usability testing. The discussion emphasises the importance of balancing the advantages of self-tracking with ethical implications, such as data privacy and patient autonomy.

Looking ahead, we outline future research directions, including creating a patient version of *Hur går det?*, broader usability testing, and exploring its applicability across different healthcare domains. The discussion highlights the importance of using a user-centred approach that empathises with the end-users when creating and designing a digital tool for the healthcare sector. By exploring this approach, we aim to contribute to the ongoing advancement of person-centred care through innovative digital solutions.

7.1 Reflection on Concept

Digitalisation within health care has increased over the past years, creating new opportunities for person-centred care with increasing customisation. With the description: *the process of ensuring that the patient receives personalised care, tailored to their needs and health beliefs*, person-centred care (Section 2.2) revolves around customising the care towards the patient. *Hur går det?* allows the caregivers to get insight into the patient's movement patterns, which can lead to the patients that have access to *Hur går det?* getting more personalised care in comparison to the patients not owning for example an iPhone. The goal of promoting PCC in Sweden could, therefore, entail that patients have the same base to receive personalised care. Thus, the different digital tools are encouraged to be adapted so that a broader group can access them.

Biofeedback

By utilising the health data collected by an iPhone, an accessible form of biofeedback has been created. Biofeedback within arthroplasty has previously been explored with positive results, but with dedicated devices, it also focuses on fewer variables than the proposed application. Positive outcomes include increased therapy compliance and improved means of assessment for caregivers [7], [8], [49]. Compared to dedicated devices, which can be affected by reluctance to use and lack of acceptance [48], carrying around a smartphone at all times is more likely, even though seniors may have different technological habits compared to younger individuals. While not all seniors in Sweden own an iPhone, it is assumed that it is a frequently used device among them. Using a smartphone as a means for biofeedback to track movement patterns before and after arthroplasty has not been explored previously, and this proposed solution has investigated the potential advantages of such an application. Due to the lack of ethical approval for involving real patients, evaluating the clinical results of *Hur går det?* was not possible. However, usability tests provided insights into how *Hur går det?* could create a better assessment platform for caregivers. Leveraging the advantages of biofeedback using a smartphone also relates to PCC, as it could enable and improve the process of person-centred goal-setting.

Relation to Person-centred Care

Person-centred goal-setting is another important aspect of PCC [32]. By providing caregivers with *Hur går det?*, caregivers now have access to objective information, which previously, to some degree, has been unavailable or unknown. Our goal is that this objective information can serve as a platform for dialogue with the patient, which could facilitate the collaboration necessary to enable person-centred goal-setting. We also hope to influence the post-operative behaviour of arthroplasty patients, see section 2.1.1. *Hur går det?* cannot address all the intrinsic and extrinsic factors influencing the sedentary lifestyle of seniors. However, *Hur går det?* could enhance patients' motivation by formulating goals that align with their wishes, needs, and capabilities and providing them with continuous insights into their rehabilitation progress. Increasing their motivation by having a clear goal and better insight into their rehabilitation could be the first step to breaking them out from a sedentary lifestyle. While *Hur går det?* has its potential advantages, you can not ignore the ethical implications it would bring. Further stakeholders, for example, VGR, Inspektion för vård och omsorg (IVO), and Inera (SITHS provider), need to be involved to ensure that the continuous stream of sensitive data between the patient and the caregiver remains protected and ethically sound. Beyond the ethical implications, you also need to consider that digital solutions within healthcare are governed by laws, regulations, and procurements, which adds further complexities. As shown, implementing self-tracking tools in healthcare may have a high potential of making care more personalised, but it is important to remain critical and question the feasibility of it.

Design Implications

While *Hur går det?* was designed with caregivers as the primary user, a question was encountered: Who is the primary target group within the caregiving sector? Different occupational roles within healthcare have different needs and uses of the data. For example, surgeons and doctors were interested in connecting the data further to the medical side, such as the patient's medical records, surgery and prosthesis type. Physiotherapists, on the other hand, would rather see patient-recorded outcomes as well, such as diaries and logged exercises. The surgeons and doctors can, therefore, use the data as a form of evaluation tool of how successful the surgery was, while physiotherapists are the caregivers with the most contact after the surgery and facilitate the patient's rehabilitation. In addition, the patients' should also gain information about their movement patterns. Hence, the design was also adjusted to suit the patients. The patients within arthroplasty are typically seniors, which has its design implications. One design implication was that health illiteracy was considered, to account for the large portion of seniors in Sweden with health illiteracy. To make the application accessible for seniors with low health literacy, the visualisations were made without using complex medical terms and lengthy sentences, which Bahadori et al. [72] emphasise should be avoided in mHealth applications. If the user finds a variable difficult to understand, they are provided with an explanation of the concept in a suitable language. Other design aspects taken into account to address health illiteracy included a clear navigation structure to avoid cognitive load, the use of large visuals with shorter labels, and the inclusion of customisation options such as voice synthesis and colour-blind options, all of which [102] explains have a counteracting effect on health illiteracy.

Beyond adjusting the application for health illiterate patients, the design also followed more general guidelines of mHealth applications to increase the enjoyment and engagement of the user. Following the recommendations of [60], to include functional, flashy and essential features, we designed an mHealth application that resonates with the user. Firstly, menus, settings, and other functional functions were designed and placed in areas anticipated by the user to accommodate the user's expectations and minimise cognitive load, especially during the initial usage. Half of the participants in the usability test explicitly mentioned the application as being navigable and easy to use, with no negative remarks from the rest, only suggestions for possible improvements. However, the initial usage may have been influenced by the presence of the TA protocol, as observed by P5.

Flashy features are made to grab the user's attention and create a positive impression with the help of design elements and illustrations. They have also been shown to highlight certain features and increase the perceived affordance [60]. Currently, this is not a consumer application but instead revolves around the caregiver's use. Therefore, our focus was on functionality and simplicity rather than aesthetics. Although, we received positive remarks about the aesthetics and affordances during usability testing. With the colour difference in the visualisation, we could create a clear affordance of before and after surgery. This was evident in the usability testing, where 4 out of 6 participants explicitly mentioned that they could observe the change in movement patterns before and after surgery. Another example of how affordance was created is through the hip and knee icons, which added an aesthetic element to the list/grid view while still serving an important function.

Functional features are those that users expect and enable the application to fulfil its purpose. By visualising different movement variables, the application achieves its goal of providing caregivers with a visual representation of changes in movement before and after arthroplasty. However, during the usability tests, it became clear that the addition of the VAS scale would be valuable and further enhance the application's ability to fulfil its purpose. An important consideration is that the pain variable introduces a subjective metric that is patient-reported. This requires the patient to continuously report their experienced pain for the caregiver to be able to see potential correlations. This further leads to the discussion point regarding pain thresholds, and that every person experiences pain differently. Therefore, the functionality becomes up for interpretation and can solely be seen as an indication. During the user research (See Section 6.1), one of the participants highlighted that patients are often overshadowed by the pain that has been, even if it was solely occasional, which in turn can affect when they were to input their pain level. Therefore, the patient's pain would need to be logged consistently to be valuable for the caregivers.

Equity in Care

As previously mentioned in Section 2.3, implementing digital solutions within health care may lead to potential inequalities and inequities. The concept of *Hur går det?* would only be available for iPhone users due to its self-tracking system which currently measures more mobility parameters such as step asymmetry and step length in comparison to Android devices. These gait parameters can facilitate the assessment of potential complications such as if the patient is limping or has trouble walking after surgery. Therefore, the caregivers can get a more holistic view of the patients' movement patterns than just being able to see the number of steps that the patient has taken. Hence, the possible end-users would most likely be a smaller group of individuals, both since the primary group that undergoes arthroplasty is seniors as mentioned in Section 2.1, and seniors being the group with the lowest smartphone usage in Sweden according to Internetbanken [103], and the iPhone is associated with a higher price point. Therefore, solely catering the application to iPhone users can lead to inequity regarding personalised care due to caregivers not having access to every patient's data. While the validity of the activity data from an iPhone has been proven to be reliable [46], a further technical challenge is how the seniors' smartphone habits look. The previous statement includes whether they carry their devices in an appropriate placement and at all times of movement. For the self-tracking data to have increased validity, the device should be placed in a pocket close to the centre of the body mass. If not, the data may be unreliable. In addition, activities that do not revolve around walking, such as cycling, may be considered gait-based activities. It is, therefore, important for the caregiver to remind the patient to keep the smartphone as close to their body as possible, preferably in a pocket.

7.2 Reflection on Process

Throughout the project, different design frameworks were applied to serve as guidelines to create the design of the interface for the application. The design framework that primarily was used throughout the process was Design Thinking, due to its emphasis on empathising with the users, which was essential when designing for healthcare. Furthermore, the design framework has been applied previously when creating mHealth applications, as mentioned in Section 3.2. While Design Thinking served as a baseline for the process and execution, other frameworks such as Human-Centered Design and Universal Design have guidelines that were considered especially when creating the prototype. The former design framework was applied in a manner to understand if the design was easy to interact with and if the affordances and constraints were appropriate for the aimed target group. The latter, Universal Design, is a framework for accessibility, to create designs that are suitable for a great extent of people regardless of their abilities. The framework has seven principles, as mentioned in Section 3.5.1, that were used as guidelines when designing the interface. These included factors such as sizing and colouring, as well as using both text and visualisations to accommodate as many people as possible. Furthermore, there was a high focus on making the design as simple as possible, with few functionalities to decrease the potential of over-complicating the information presented. The infusions of principles and guidelines from other design approaches than Design Thinking, allowed us to consider further factors important to the users and the design's accessibility, where the latter was especially highlighted during the user research and evaluation.

7.2.1 Reflection on Evaluation

When recruiting the participants for the usability tests, the goal was to have a diverse pool of caregivers to understand if several occupational roles could benefit from the concept. All of the participants specialised in either orthopaedics or physiotherapy. However, none of the participants worked exclusively with patients who had undergone arthroplasty. Therefore, further evaluations need to be conducted with participants who are specialists in arthroplasty for further studies.

During the usability test, the participants were very positive towards the concept and design of the application in general. Although, the positive feedback may be a product of the need for digital solutions within health care. In this case, the opportunities to follow the patients' rehabilitation progress are not utilised. Hence, there is a possibility that the design in itself is not adequate, but rather the concept being appreciated since it fills a void within the industry. As the lack of digital solutions within healthcare is prevalent, caregivers may be unable to compare *Hur går det?* with another existing product, rendering it difficult to give feedback. It remains unclear if the positive feedback would stand if the caregivers had more digital solutions to compare *Hur går det?* to. Although the usability test participants found the readability of the application to be good, it is important to note that readability was not assessed using a standardised tool such as the Gunning Fog Index, Flesch Reading Score or Flesch-Kincaid Grade Level. Smartphone applications around TKA and THA have been known to have poor readability, especially affecting those with poor health literacy, so it could be valuable to evaluate *Hur går det?* using a standardised method [72]. Another important aspect was that the usability tests included healthcare professionals, a group with high health literacy. A sentence that is understandable to them may seem complex to another person without medical expertise. In the context of designing for health literacy, both [102] and [72] call for the inclusion of patients in the development to account for health illiteracy. This was not achieved, primarily due to the lack of ethical approval for involving patients and the design tailored to caregivers. Therefore, we could only obtain secondary information about the needs of patients from the caregivers.

Think-aloud Protocol

Furthermore, the questions following the TA protocol followed the same structure, however, some of the participants elaborated more on certain questions than others and discussed different challenges that they faced during the TA protocol. Therefore, some of the discussions after the test had differing outcomes, which may lead to an inconsistency in how elaborately the participants discussed the design and concept. Throughout the reflective questions, there was a tendency for the participants to drift away from the core discussion and start to talk about the aspects that were not a part of the evaluation. For example, it was a recurring pattern that the participants discussed the design from a patient standpoint, for example, by mentioning that patients may have eyesight impairments, a low level of technical knowledge, but also specific functions that could be valuable in the patients' version. While important insights, they were not a part of the actual evaluation and may have hindered other insights that could potentially be implemented in the re-design, as time was a limiting factor.

Technology Acceptance Model

The TAM questionnaire was used to gain an understanding of the concept of the application and was met with acceptance in different occupational roles within orthopaedics and physiotherapy, as well as if the design itself was easy to use. It is important to consider that only six participants participated in the evaluation, meaning that the results from the questionnaire are solely seen as trends and are insufficient for calculating statistical significance. However, the participants had similar responses, especially regarding perceived ease of use, indicating a consensus that the design was intuitive for the participants to use. Also, neither the reflective questions nor TAM took into consideration implementation. Implementation when it comes to digital solutions within healthcare is a difficult aspect, as laws, regulations, and procurements govern the healthcare. In the usability test, only the design and the concept were evaluated. If the plausibility of implementation of *Hur går det?* were to be evaluated, it may have shifted the positive results as caregivers could see the implementation of *Hur går det?* as implausible or unrealistic. During the follow-up questions of the usability test, where the participants were encouraged to speak their minds, the unlikeliness of implementation was not brought up. However, it is not expected that the caregivers would have extensive knowledge of current legislation, as it is a different realm of expertise.

7.3 Ethical Considerations

The application's primary purpose is to conduct research and analyse the success rate of arthroplasty, as well as understand how the patient's rehabilitation is progressing. Therefore, several stakeholders will have use of the application. The primary stakeholders are researchers, caregivers specialised in arthroplasty and physiotherapy, and the patients. First, the researchers with access to the application can evaluate and assess the results of arthroplasty and how different variables and parameters are affected. Furthermore, the application allows for the evaluation of both a group and individual dimension for research. Second, the caregivers who work hands-on with patients can use the application to understand whether a patient is progressing with their rehabilitation as expected or if there are any issues arising over time. The caregivers can further get information about previous movement patterns, which can help with understanding what the patient's starting point was, and how their movement patterns are affected by arthroplasty. Third, the patients can follow their progression and see whether their rehabilitation improves as desired or if their data has deviant patterns. The stakeholders are a diverse group of people who have different backgrounds and purposes for using the application. To present the data of interest it needed to have a balance and structure that both novices and experts in the medical field could understand.

The design process revolved around creating an application to manage personal, sensitive patient data, addressing ethical issues and ensuring transparency. Using self-tracking data retrieved from the patients as an assessment tool can lead to further ethical concerns regarding how it is used and presented. Information on how the data was collected and if it was done continuously throughout the day or through samples was added, even if the data used in the prototype was imaginary, to increase transparency. This further leads to the question of privacy-related issues, including who can access the data and request information about a patient. Stakeholders involved in the application's development and usage include the caregivers, researchers, patients, and the developers of *Hur Går Det?*. An important question to consider is who holds the key to the patient's information in *Hur går det?*. There are many caregivers involved in the rehabilitation of arthroplasty patients. Should everyone participating in the rehabilitation process have access to the patient's information, similar to access to medical records, or should it be limited to the caregivers who meet the patients on multiple occasions? This aspect also ties in with the patient's consent, specifically whether the patient grants consent to an individual caregiver or to an entire care unit. Ethical issues may arise when giving consent to an entire care unit, as the patient may be unaware of who has access to their data. At the current stage, the patient's information will be limited to researchers. However, a possible future implementation in the orthopaedic sector would raise the question of which caregivers should have access to the patient's sensitive movement data.

Pushed Self-tracking

Another aspect of self-tracking worth considering is the concept of dataveillance. While dataveillance can have many definitions, Lupton [104] described dataveillance as the following: "The watching of people using technologies that generate data". Lupton [104] further describes a form of dataveillance called *pushed self-tracking*, which revolves around self-tracking that is being encouraged or advocated by an external stakeholder instead of being solely an individual initiative. It is often used within healthcare to nudge patients towards a more preferred state of health by tracking variables such as blood sugar, blood pressure or physical activity. In this case, behavioural changes do not always stem from a positive place; rather, they can arise from feelings such as fear, guilt, or shame, which could be induced when the patient is not reaching a goal. While the patients' participation in *Hur går det?* will be voluntary, the caregiver needs to be aware that the patient's change in activity might not come from their motivation but rather the fear of not reaching a desired outcome. During the semi-structured interviews, it was revealed that caregivers have a suspicion that patients may occasionally withhold information regarding the extent of their physical activity. As *Hur går det?* provides a quantifiable measure of the patient's movement, it becomes more challenging for the patient to withhold the truth regarding the extent of their physical activity. This could potentially create friction between the caregiver and patient, as the caregiver may begin questioning the patient about why their activity levels are not at a preferred level, possibly inducing feelings of guilt and shame in the patient. However, the enhanced dialogue facilitated by *Hur går det?* may provide the insights necessary to increase understanding of the patient, countering the guilt- and shame-inducing aspects of pushed self-tracking.

7.4 Future Work

The primary aspect of future work involves creating a patient version of the application and implementing the visualisations for further evaluation to assess their suitability for patients. Creating both versions of the application would allow for further ethnographic studies, such as observations of the usage of the application as a communicative means between the caregiver and patient. Beyond the evaluation of visualisation, a potential patient version would also need to be evaluated in terms of user perception. Clinical results of using *Hur går det?* need to be explored to provide a quantifiable outcome. Clinical outcomes could include compliance with rehabilitation and receiving a more holistic view of the arthroplasty outcome. While the validity of the gait data from an iPhone has previously been shown to be good [46], further determination is required to ensure if this validity is sufficient for use in a clinical setting. A future study involving patients could include a comparison between the gait data from the iPhone and a dedicated accelerometer such as the Axivity AX6, which offers raw data logging in six axes [105], unlike the iPhone's three axes, providing data with higher resolution. The Axivity AX6 is small enough to be worn in a wristband, making it easy to wear in everyday life. Comparing the results from the dedicated accelerometer and the gait data from the iPhone would enable researchers to evaluate the validity further.

Despite the limited number of participants in the usability test, which consisted of only six individuals, there are indications that the results may be applicable beyond this specific group. This potential for generalisability is supported by insights gathered during the pre-study phase, which involved interviews with caregivers from different regions across Sweden. The caregivers consistently emphasised the necessity for increased access to objective information and digital tools in orthopaedic healthcare. Although the participants in our study expressed positive attitudes towards integrating digital tools in healthcare, it remains uncertain whether this perspective is universally shared among the diverse array of orthopaedic professionals. To ensure the effective and inclusive implementation of *Hur går det?* in a clinical setting, further extensive usability testing with additional caregivers is necessary. This broader approach would help ensure that all stakeholders' perspectives within the orthopaedic sector are adequately represented, thereby enhancing the generalisability of the findings.

Suggested future work of the caregivers' version includes testing and evaluating the application through different methods, such as observation in a natural context, to see how the application and its information would be applied in the caregivers' work environment. Further evaluations would potentially find other obstacles the application may promote in general use cases instead of solely focusing on the visual design. This would allow for further evaluation of the overall user experience, not only the ease of use. Furthermore, a participant in the usability test mentioned that he would rather use a dashboard or similar. Hence, the application should be available in other formats as well, such as tablets and computers, so the caregivers can use their preferred medium. The hospitals the group visited had different devices that they used. Hence, the application should ideally be possible to implement on different devices without the need to invest in specific units to access the data provided by *Hur går det?*.

It is suggested that the application's readability should be tested through further standardised methods and with a larger participant pool of varying demographics. Testing the readability of different age groups, educational backgrounds, and people with varying impairments would allow for further evaluation of usability functionalities and whether the readability is adequate. Using a standardised method, such as Gunning Fog Index[106], Flesch Reading Score or Flesch-Kincaid Grade Level [107], with a larger participant pool would allow further evaluation of the application's language with individuals with lower health literacy.

For future work, *Hur går det?* should not only be seen as a single entity. Instead, it can be seen as a concept of how to utilise self-tracking within healthcare. The usage of self-tracking, in an appropriate manner, can be applied in a plethora of sectors within healthcare. During this project, the concept was applied solely to caregivers and patients in arthroplasty, but the possibility of implementing the concept within the orthopaedic sector in general has great potential. Furthermore, it can improve the physiotherapy sector, through the addition of continuously collected objective data that follows the patients' rehabilitation.

8 Conclusion

The goal of the project was to understand the needs within caregiving in arthroplasty and create a design of an iPhone application that visualizes self-tracking data pre- and post-arthroplasty. The project was made in collaboration with Sahlgrenska University Hospital and the University of Gothenburg to understand the caregivers' needs of the application and what it needs to include. Through utilising the Design Thinking Framework, the aim was to gain a deeper understanding of the caregivers' needs through the research questions:

- *What are the caregivers' needs for the design of the suggested application?*
- *What features can be applied in the design of the application to fill the caregivers' needs?*

It was found that differing occupational roles have different needs and potential use areas of the application, for example, the needs of doctors included being able to evaluate surgeries and medical outcomes, while physiotherapists saw the need for the addition of objective data to see the patient's rehabilitation progress continuously. However, similarities in functionalities could still be applied overall. It was found that the variables of most value to the groups of caregivers are the patient's movement patterns before and after arthroplasty throughout different time spans, in combination with self-reported pain from the patient. Through these variables, the caregivers can use the application in addition to existing mediums, such as medical records or exercise diaries. The application can, therefore, in this stage, work as a complement to gain more knowledge about the patient's movement patterns and how the surgery has affected their daily life along with subjective assessment.

Digital tools within healthcare have been relatively unutilised in Sweden, especially when it comes to the potential to customise care through patients' self-tracking data. While current subjective evaluation measures are still necessary, the utilisation of self-tracking data within arthroplasty can serve as a fulfilling complement to the current practices. The concept of *Hur går det?* has the possibility to provide objective information to caregivers which opens up a new platform for discussion with the patient. This form of a novel means of communication may facilitate the national goal of personalising care and can be implemented in further spaces than arthroplasty.

Bibliography

[1] World Health Organization, *Ageing and health*. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/ageing-and-health.

[2] C. S. Umpierres, T. A. Ribeiro, Â. E. Marchisio, *et al.*, "Rehabilitation following total hip arthroplasty evaluation over short follow-up time: Randomized clinical trial.," *Journal of Rehabilitation Research & Development*, vol. 51, no. 10, 2014.

[3] C. Seidlitz and M. Kip, *Introduction to the Indications and Procedures*, H. BleSS and M. Kip, Eds. Springer, 2018, ch. 1. DOI: 10.1007/978-3-662-55918-5_1. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK546138/.

[4] I. Shichman, M. A. Roof, N. Askew, *et al.*, "Projections and epidemiology of primary hip and knee arthroplasty in Medicare patients to 2040-2060," *JB & JS Open Access*, vol. 8, no. 1, Jan. 2023. DOI: 10.2106/jbjs.oa.22.00112. [Online]. Available: https://doi.org/10.2106/jbjs.oa.22.00112.

[5] C. Pabinger, H. Lothaller, N. Portner, and A. GeiSSler, "Projections of hip arthroplasty in OECD countries up to 2050," *HIP International*, vol. 28, no. 5, pp. 498–506, May 2018. DOI: 10.1177/1120700018757940. [Online]. Available: https://doi.org/10.1177/1120700018757940.

[6] EuroQol, *EQ-5D-5L | EuroQol*, Dec. 2023. [Online]. Available: https://euroqol.org/information-and-support/euroqol-instruments/eq-5d-5l/.

[7] M. Raaben, H. C. Vogely, and T. J. Blokhuis, "Real-time visual biofeedback to improve therapy compliance after total hip arthroplasty: A pilot randomized controlled trial," *Gait & Posture*, vol. 61, pp. 306–310, Mar. 2018, ISSN: 0966-6362. DOI: 10.1016/j.gaitpost.2018.01.038. [Online]. Available: http://dx.doi.org/10.1016/j.gaitpost.2018.01.038.

[8] G. Castellarin, M. Merlini, G. Bettinelli, R. Riso, E. Bori, and B. Innocenti, "Effect of an innovative biofeedback insole on patient rehabilitation after total knee arthroplasty," *Applied Sciences*, vol. 12, no. 5, 2022. DOI: 10.3390/app12052456. [Online]. Available: https://www.mdpi.com/2076-3417/12/5/2456.

[9] T. Sharon, "Self-Tracking for Health and the Quantified Self: Re-Articulating autonomy, Solidarity, and Authenticity in an age of Personalized Healthcare," *Philosophy & Technology*, vol. 30, no. 1, pp. 93–121, Apr. 2016. DOI: 10.1007/s13347-016-0215-5. [Online]. Available: https://doi.org/10.1007/s13347-016-0215-5.

[10] *Use the Health app Apple Support*, Jan. 2024. [Online]. Available: https://support.apple.com/en-us/104997.

[11] *Artroplastik | Svensk MESH.* [Online]. Available: https://mesh.kib.ki.se/term/D001178/arthroplasty.

[12] O. Rolfson, J. Kärrholm, L. E. Dahlberg, and G. Garellick, "Patient-reported outcomes in the swedish hip arthroplasty register: Results of a nationwide prospective observational study," *The Journal of Bone and Joint Surgery. British volume*, vol. 93-B, no. 7, pp. 867–875, Jul. 2011, ISSN: 2044-5377. DOI: 10.1302/0301-620x.93b7.25737. [Online]. Available: http://dx.doi.org/10.1302/0301-620X.93B7.25737.

[13] *Svenska Ledprotesregistrets årsrapport för 2022 är här - Sahlgrenska Universitetssjukhuset*, Oct. 2022. [Online]. Available: https://www.sahlgrenska.se/omraden/omrade-3/ortopedi/ledord-susa/svenska-ledprotesregistrets-arsrapport-for-2022-ar-har.

[14] *Artroplastik | Svensk MESH*, 2022. [Online]. Available: https://mesh.kib.ki.se/term/D001178/arthroplasty.

[15] C. Lowe, K. Barker, M. Dewey, and C. Sackley, "Effectiveness of physiotherapy exercise following hip arthroplasty for osteoarthritis: a systematic review of clinical trials," *BMC Musculoskeletal Disorders*, vol. 10, no. 1, Aug. 2009. DOI: 10.1186/1471-2474-10-98. [Online]. Available: https://doi.org/10.1186/1471-2474-10-98.

[16] *Knee replacement implants - OrthoInfo - AAOS*. [Online]. Available: https://orthoinfo.aaos.org/en/treatment/knee-replacement-implants/.

[17] *Höftprotes - Sahlgrenska universitetssjukhuset*, Feb. 2022. [Online]. Available: https://www.sahlgrenska.se/omraden/omrade-3/ortopedi/hoftprotes/.

[18] J. W. Leong and M. Reed, "Knee arthroplasty: Post-operative care, rehabilitation and follow-up," *Orthopaedics and Trauma*, vol. 35, no. 1, pp. 49–55, 2021.

[19] R. A. Chesham and S. Shanmugam, "Does preoperative physiotherapy improve postoperative, patient-based outcomes in older adults who have undergone total knee arthroplasty? A systematic review," *Physiotherapy Theory and Practice*, vol. 33, no. 1, pp. 9–30, Oct. 2016. DOI: 10.1080/09593985.2016.1230660. [Online]. Available: https://doi.org/10.1080/09593985.2016.1230660.

[20] *Knäprotes - Sahlgrenska universitetssjukhuset*, Feb. 2022. [Online]. Available: https://www.sahlgrenska.se/omraden/omrade-3/ortopedi/knaprotes/.

[21] V. Colibazzi, A. Coladonato, M. Zanazzo, and E. Romanini, "Evidence based rehabilitation after hip arthroplasty," *HIP International*, vol. 30, no. 2_suppl, pp. 20–29, Dec. 2020. DOI: 10.1177/1120700020971314. [Online]. Available: https://doi.org/10.1177/1120700020971314.

[22] T. J. Hoogeboom, E. Oosting, J. E. Vriezekolk, *et al.*, "Therapeutic Validity and Effectiveness of Preoperative Exercise on Functional Recovery after Joint Replacement: A Systematic Review and Meta-Analysis," *PLOS ONE*, vol. 7, no. 5, e38031, May 2012. DOI: 10.1371/journal.pone.0038031. [Online]. Available: https://doi.org/10.1371/journal.pone.0038031.

[23] B. Moellenbeck, F. Van Der Horst, G. Gosheger, C. Theil, L. Seeber, and T. Kalisch, "Sedentary Behavior in Older Patients before and after Total Hip Arthroplasty: A Prospective Cohort Study," *Healthcare*, vol. 8, no. 3, p. 346, Sep. 2020. DOI: 10.3390/healthcare8030346. [Online]. Available: https://doi.org/10.3390/healthcare8030346.

[24] A. Hodges, A. R. Harmer, S. Dennis, *et al.*, "Prevalence and determinants of physical activity and sedentary behaviour before and up to 12 months after total knee replacement: a longitudinal cohort study," *Clinical Rehabilitation*, vol. 32, no. 9, pp. 1271–1283, Apr. 2018. DOI: 10.1177/0269215518769986. [Online]. Available: https://doi.org/10.1177/0269215518769986.

[25] L. TamSeto, P. L. Weir, and S. Dogra, "Factors influencing sedentary behaviour in Older adults: An ecological approach," *AIMS public health*, vol. 3, no. 3, pp. 555–572, Jan. 2016. DOI: 10.3934/publichealth.2016.3.555. [Online]. Available: https://doi.org/10.3934/publichealth.2016.3.555.

[26] I. Ekman, Z. Ebrahimi, and P. Olaya Contreras, "Person-centred care: Looking back, looking forward," *European Journal of Cardiovascular Nursing*, vol. 20, no. 2, pp. 93–95, Feb. 2021, ISSN: 1873-1953. DOI: 10.1093/eurjcn/zvaa025. [Online]. Available: http://dx.doi.org/10.1093/eurjcn/zvaa025.

[27] N. Britten, L. Moore, D. Lydahl, O. Naldemirci, M. Elam, and A. Wolf, "Elaboration of the gothenburg model of personcentred care," *Health Expectations*, vol. 20, no. 3, pp. 407–418, May 2016, ISSN: 1369-7625. DOI: 10.1111/hex.12468. [Online]. Available: http://dx.doi.org/10.1111/hex.12468.

[28] T. U. of Gothenburg. "Innovative standard for patient participation in person-centred care." Accessed on: 30/1-24. (2022), [Online]. Available: https://www.gu.se/en/gpcc/innovative-standard-for-patient-participation-in-person-centred-care.

[29] SKR (Sveriges Kommuner och Regioner), *Personcentrerad vård i sverige*, 2018. [Online]. Available: https://skr.se/download/18.5627773817e39e979ef3837a/1642162020005/7585-631-5.pdf.

[30] L.-E. Olsson, J. Karlsson, U. Berg, J. Kärrholm, and E. Hansson, "Person-centred care compared with standardized care for patients undergoing total hip arthroplastya quasi-experimental study," *Journal of Orthopaedic Surgery and Research*, vol. 9, no. 1, Oct. 2014, ISSN: 1749-799X. DOI: 10.1186/s13018-014-0095-2. [Online]. Available: http://dx.doi.org/10.1186/s13018-014-0095-2.

[31] L.-E. Olsson, E. Hansson, and I. Ekman, "Evaluation of person-centred care after hip replacement-a controlled before and after study on the effects of fear of movement and self-efficacy compared to standard care," *BMC Nursing*, vol. 15, no. 1, Sep. 2016, ISSN: 1472-6955. DOI: 10.1186/s12912-016-0173-3. [Online]. Available: http://dx.doi.org/10.1186/s12912-016-0173-3.

[32] J. Melin, Å. Nordin, C. Feldthusen, and L. Danielsson, "Goal-setting in physiotherapy: exploring a person-centered perspective," *Physiotherapy Theory and Practice*, vol. 37, no. 8, pp. 863–880, Aug. 2019. DOI: 10.1080/09593985.

2019.1655822. [Online]. Available: https://doi.org/10.1080/09593985.2019.1655822.

[33] D. Lupton, "Self-tracking cultures: Towards a sociology of personal informatics," in *Proceedings of the 26th Australian computer-human interaction conference on designing futures: The future of design*, 2014, pp. 77–86.

[34] D. Lupton, *Self-tracking, health and medicine*, 2017.

[35] M. Riphagen, M. van Hout, D. Kritjnen, and G. Gootjes, "Learning tomorrow: Visualising student and staffs daily activities and reflect on it," *ICERIE2013*, 2013.

[36] M. Swan, "The quantified self: Fundamental disruption in big data science and biological discovery," *Big data*, vol. 1, no. 2, pp. 85–99, 2013.

[37] M. Ruckenstein and M. Pantzar, "Beyond the Quantified Self: Thematic exploration of a dataistic paradigm," *New Media & Society*, vol. 19, no. 3, pp. 401–418, Jul. 2016. DOI: 10.1177/1461444815609081. [Online]. Available: https://doi.org/10.1177/1461444815609081.

[38] M. Dodge and R. Kitchin, "Outlines of a World Coming into Existence: Pervasive Computing and the Ethics of Forgetting," *Environment and Planning B: Planning and Design*, vol. 34, no. 3, pp. 431–445, Jun. 2007. DOI: 10.1068/b32041t. [Online]. Available: https://doi.org/10.1068/b32041t.

[39] A. Ksibi, A. S. D. Alluhaidan, A. Salhi, and S. A. El-Rahman, "Overview of lifelogging: Current challenges and advances," *IEEE Access*, vol. 9, pp. 62 630–62 641, 2021. DOI: 10.1109/ACCESS.2021.3073469.

[40] K. Karako, Y. Chen, P. Song, and W. Tang, "Super-aged society: Constructing an integrated information platform of self-recording lifelogs and medical records to support health care in Japan," *BioScience Trends*, vol. 13, no. 3, pp. 276–278, Jun. 2019. DOI: 10.5582/bst.2019.01124. [Online]. Available: https://doi.org/10.5582/bst.2019.01124.

[41] *StepCount | Apple Developer Documentation*. [Online]. Available: https://developer.apple.com/documentation/healthkit/hkquantitytypeidentifier/1615548-stepcount.

[42] *HKQuantityTypeIdentifierWalkingAsymmetryPercentage | Apple Developer Documentation*. [Online]. Available: https://developer.apple.com/documentation/healthkit/hkquantitytypeidentifierwalkingasymmetrypercentage.

[43] *WalkingSpeed | Apple Developer Documentation*. [Online]. Available: https://developer.apple.com/documentation/healthkit/hkquantitytypeidentifier/3131040-walkingspeed.

[44] *WalkingStepLength | Apple Developer Documentation*. [Online]. Available: https://developer.apple.com/documentation/healthkit/hkquantitytypeidentifier/3552088-walkingsteplength.

[45] T. Munzner, *Visualization analysis and design*. Dec. 2014. DOI: 10.1201/b17511. [Online]. Available: https://doi.org/10.1201/b17511.

[46] C. Werner, N. Hezel, F. Dongus, *et al.*, "Validity and reliability of the Apple Health app on iPhone for measuring gait parameters in children, adults, and seniors," *Scientific Reports*, vol. 13, no. 1, Apr. 2023. DOI: 10.1038/s41598-023-32550-3. [Online]. Available: https://doi.org/10.1038/s41598-023-32550-3.

[47] O. M. Giggins, U. Persson, and B. Caulfield, "Biofeedback in rehabilitation," *Journal of NeuroEngineering and Rehabilitation*, vol. 10, no. 1, p. 60, 2013, ISSN: 1743-0003. DOI: 10.1186/1743-0003-10-60. [Online]. Available: http://dx.doi.org/10.1186/1743-0003-10-60.

[48] J. Mariano, S. Marques, M. R. Ramos, *et al.*, "Too old for technology? Stereotype threat and technology use by older adults," *Behavior & Information Technology*, vol. 41, no. 7, pp. 1503–1514, Feb. 2021. DOI: 10.1080/0144929x.2021.1882577. [Online]. Available: https://doi.org/10.1080/0144929x.2021.1882577.

[49] P. N. Ramkumar, H. S. Haeberle, D. Ramanathan, *et al.*, "Remote patient monitoring using mobile health for total knee arthroplasty: Validation of a wearable and machine learningbased surveillance platform," *The Journal of Arthroplasty*, vol. 34, no. 10, pp. 2253–2259, 2019, ISSN: 0883-5403. DOI: https://doi.org/10.1016/j.arth.2019.05.021. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0883540319304954.

[50] C. M. Herbert and G. E. Powell, "Insight and progress in rehabilitation," *Clinical Rehabilitation*, vol. 3, no. 2, pp. 125–130, May 1989, ISSN: 1477-0873. DOI: 10.1177/026921558900300207. [Online]. Available: http://dx.doi.org/10.1177/026921558900300207.

[51] J. S. Brennen and D. Kreiss, *Digitalization*, Oct. 2016. DOI: 10.1002/9781118766804.wbiect111. [Online]. Available: http://dx.doi.org/10.1002/9781118766804.wbiect111.

[52] G. L. Kreps and L. Neuhauser, "New directions in ehealth communication: Opportunities and challenges," *Patient Education and Counseling*, vol. 78, no. 3, pp. 329–336, Mar. 2010, ISSN: 0738-3991. DOI: 10.1016/j.pec.2010.01.013. [Online]. Available: http://dx.doi.org/10.1016/j.pec.2010.01.013.

[53] T. Davis Giardina, S. Menon, D. E. Parrish, D. F. Sittig, and H. Singh, "Patient access to medical records and healthcare outcomes: A systematic review," *Journal of the American Medical Informatics Association*, vol. 21, no. 4, pp. 737–741, Jul. 2014, ISSN: 1527-974X. DOI: 10.1136/amiajnl-2013-002239. [Online]. Available: http://dx.doi.org/10.1136/amiajnl-2013-002239.

[54] N. Menachemi and Collum, "Benefits and drawbacks of electronic health record systems," *Risk Management and Healthcare Policy*, p. 47, May 2011, ISSN: 1179-1594. DOI: 10.2147/rmhp.s12985. [Online]. Available: http://dx.doi.org/10.2147/RMHP.S12985.

[55] D. Majcherek, S. W. Hegerty, A. M. Kowalski, M. S. Lewandowska, and D. Dikova, "Opportunities for healthcare digitalization in Europe: comparative analysis of inequalities in access to medical services," *Health Policy*, vol. 139, p. 104 950, Jan. 2024. DOI: 10.1016/j.healthpol.2023.104950. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S016885102300235X#bib0024.

[56] G. Hashemi, M. Wickenden, T. Bright, and H. Kuper, "Barriers to accessing primary healthcare services for people with disabilities in low and middle-income countries, a Meta-synthesis of qualitative studies," *Disability and Re-*

habilitation, vol. 44, no. 8, pp. 1207–1220, Sep. 2020. DOI: `10.1080/09638288.2020.1817984`. [Online]. Available: `https://doi.org/10.1080/09638288.2020.1817984`.

[57] S. Park, B. Bekemeier, A. D. Flaxman, and M. Schultz, "Impact of data visualization on decision-making and its implications for public health practice: a systematic literature review," *Informatics for Health & Social Care*, vol. 47, no. 2, pp. 175–193, Sep. 2021. DOI: `10.1080/17538157.2021.1982949`. [Online]. Available: `https://doi.org/10.1080/17538157.2021.1982949`.

[58] H. Elhamdadi, A. Stefkovics, J. Beyer, *et al.*, "Vistrust: A multidimensional framework and empirical study of trust in data visualizations," *IEEE Transactions on Visualization and Computer Graphics*, pp. 1–11, 2023, ISSN: 2160-9306. DOI: `10.1109/tvcg.2023.3326579`. [Online]. Available: `http://dx.doi.org/10.1109/TVCG.2023.3326579`.

[59] S. P. Rowland, J. E. Fitzgerald, T. Holme, J. Powell, and A. McGregor, "What is the clinical value of mhealth for patients?" *npj Digital Medicine*, vol. 3, no. 1, Jan. 2020, ISSN: 2398-6352. DOI: `10.1038/s41746-019-0206-x`. [Online]. Available: `http://dx.doi.org/10.1038/s41746-019-0206-x`.

[60] A. J. Lazard, J. S. Brennen, and S. P. Belina, "App designs and interactive features to increase MHealth adoption: user expectation survey and experiment," *Jmir mhealth and uhealth*, vol. 9, no. 11, e29815, Nov. 2021. DOI: `10.2196/29815`. [Online]. Available: `https://doi.org/10.2196/29815`.

[61] Statistiska centralbyrån (SCB), *Befolkningens it-användning 2022*, `https://www.scb.se/hitta-statistik/statistik-efter-amne/levnadsforhallanden/levnadsforhallanden/befolkningens-it-anvandning/pong/statistiknyhet/befolkningens-it-anvandning-2022/`, Accessed: 3/14-24, 2022.

[62] I. E. Fowe and W. R. Boot, "Understanding older adults attitudes toward mobile and wearable technologies to support health and cognition," *Frontiers in Psychology*, vol. 13, Dec. 2022. DOI: `10.3389/fpsyg.2022.1036092`. [Online]. Available: `https://doi.org/10.3389/fpsyg.2022.1036092`.

[63] M. Zhang, "Older peoples attitudes towards emerging technologies: A systematic literature review," *Public Understanding of Science*, vol. 32, no. 8, pp. 948–968, May 2023, ISSN: 1361-6609. DOI: `10.1177/09636625231171677`. [Online]. Available: `http://dx.doi.org/10.1177/09636625231171677`.

[64] X. Liang, F. Xiong, and F. Xie, "The effect of smartphones on the self-rated health levels of the elderly," *BMC Public Health*, vol. 22, no. 1, Mar. 2022, ISSN: 1471-2458. DOI: `10.1186/s12889-022-12952-0`. [Online]. Available: `http://dx.doi.org/10.1186/s12889-022-12952-0`.

[65] H. Ramdowar, K. K. Khedo, and N. Chooramun, "A comprehensive review of mobile user interfaces in mhealth applications for elderly and the related ageing barriers," *Universal Access in the Information Society*, Jul. 2023, ISSN: 1615-5297. DOI: `10.1007/s10209-023-01011-z`. [Online]. Available: `http://dx.doi.org/10.1007/s10209-023-01011-z`.

[66] M. Awan, S. Ali, M. Ali, M. F. Abrar, H. Ullah, and D. Khan, "Usability barriers for elderly users in smartphone app usage: An analytical hierarchical process-based prioritization," *Scientific Programming*, vol. 2021, W. Nawaz,

Ed., pp. 1–14, Dec. 2021, ISSN: 1058-9244. DOI: 10.1155/2021/2780257. [Online]. Available: http://dx.doi.org/10.1155/2021/2780257.
[67] J. Wångdahl, J. Agerholm, A. Liljas, J. Heap, and C. Lennartsson, "Health literacy among older adults 77+ in sweden," *European Journal of Public Health*, vol. 32, no. 3, Oct. 2022, ISSN: 1464-360X. DOI: 10.1093/eurpub/ckac131.331. [Online]. Available: http://dx.doi.org/10.1093/eurpub/ckac131.331.
[68] M. R. Andrus and M. T. Roth, "Health literacy: A review," *Pharmacotherapy: The Journal of Human Pharmacology and Drug Therapy*, vol. 22, no. 3, pp. 282–302, Mar. 2002, ISSN: 1875-9114. DOI: 10.1592/phco.22.5.282.33191. [Online]. Available: http://dx.doi.org/10.1592/phco.22.5.282.33191.
[69] A. H. Chohan, H. Mohd Affandi, J. Awad, and A. I. Che-Ani, "A methodology to develop a mobile application model to appraise housing design quality," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 11, no. 6, p. 4, Nov. 2017, ISSN: 1865-7923. DOI: 10.3991/ijim.v11i6.6379. [Online]. Available: http://dx.doi.org/10.3991/ijim.v11i6.6379.
[70] Y. Lin and M. Lou, "Effects of mhealthbased interventions on health literacy and related factors: A systematic review," *Journal of Nursing Management*, vol. 29, no. 3, pp. 385–394, Nov. 2020, ISSN: 1365-2834. DOI: 10.1111/jonm.13175. [Online]. Available: http://dx.doi.org/10.1111/jonm.13175.
[71] M. R. Emerson, S. Buckland, M. A. Lawlor, *et al.*, "Addressing and evaluating health literacy in mhealth: A scoping review," *mHealth*, vol. 8, pp. 33–33, Oct. 2022, ISSN: 2306-9740. DOI: 10.21037/mhealth-22-11. [Online]. Available: http://dx.doi.org/10.21037/mhealth-22-11.
[72] S. Bahadori, T. Wainwright, and O. H. Ahmed, "Readability of information on smartphone apps for total hip replacement and total knee replacement surgery patients," *Journal of Patient Experience*, vol. 7, no. 3, pp. 395–398, Apr. 2019. DOI: 10.1177/2374373519844266. [Online]. Available: https://doi.org/10.1177/2374373519844266.
[73] *mymobilityő*. [Online]. Available: https://www.zimmerbiomet.lat/en/medical-professionals/zb-connect/mymobility.html.
[74] J. Academy, *About us | Joint Academy*, Nov. 2023. [Online]. Available: https://www.jointacademy.com/us/en/about/.
[75] *JOINT ACADEMY*. [Online]. Available: https://playformance.se/info/joint-academy.
[76] H. Nero, J. Dahlberg, and L. Dahlberg, "Joint academy a six-week online treatment program for osteoarthritis," *Osteoarthritis and Cartilage*, vol. 26, S315, Apr. 2018. DOI: 10.1016/j.joca.2018.02.632. [Online]. Available: https://doi.org/10.1016/j.joca.2018.02.632.
[77] T. Y. Siang, *What is Interaction Design?* May 2024. [Online]. Available: https://www.interaction-design.org/literature/article/what-is-interaction-design.
[78] J. Farao, B. Malila, N. Conrad, T. Mutsvangwa, M. X. Rangaka, and T. S. Douglas, "A user-centred design framework for mHealth," *PLOS ONE*, vol. 15,

no. 8, e0237910, Aug. 2020. DOI: 10.1371/journal.pone.0237910. [Online]. Available: https://doi.org/10.1371/journal.pone.0237910.

[79] H. W. Rittel and M. M. Webber, "Dilemmas in a general theory of planning," *Policy sciences*, vol. 4, no. 2, pp. 155–169, 1973.

[80] T. Ritchey, "Wicked problems," *Acta morphologica generalis*, vol. 2, no. 1, 2013.

[81] T. Brown, "Design thinking," *Harvard business review*, vol. 86, no. 6, p. 84, 2008.

[82] D. A. Norman, *The design of everyday things*. Jan. 1988. [Online]. Available: http://documents.irevues.inist.fr/bitstream/2042/30193/1/XX%5C_CNE-Prospective%5C_000738.pdf.

[83] M. G. Luchs, K. Swan, and A. Griffin, *Design Thinking: New Product Development Essentials from the PDMA*. Sep. 2015. [Online]. Available: http://dspace.vnbrims.org:13000/xmlui/handle/123456789/4867.

[84] C. Abras, D. Maloney-Krichmar, J. Preece, *et al.*, "User-centered design," *Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications*, vol. 37, no. 4, pp. 445–456, 2004.

[85] J. Nielsen, *Usability 101: Introduction to Usability*, Jan. 2012. [Online]. Available: https://www.nngroup.com/articles/usability-101-introduction-to-usability.

[86] H. Petrie and N. Bevan, "The evaluation of accessibility, usability, and user experience.," *The universal access handbook*, vol. 1, pp. 1–16, 2009.

[87] H. Persson, H. Åhman, A. A. Yngling, and J. Gulliksen, "Universal design, inclusive design, accessible design, design for all: Different conceptsone goal? on the concept of accessibilityhistorical, methodological and philosophical aspects," *Universal Access in the Information Society*, vol. 14, pp. 505–526, 2015.

[88] D. Rømen and D. Svanæs, "Validating wcag versions 1.0 and 2.0 through usability testing with disabled users," *Universal Access in the Information Society*, vol. 11, pp. 375–385, 2012.

[89] C.-h. Chen, W. Härdle, and A. Unwin, *Handbook of Data Visualization*. Springer Berlin Heidelberg, 2008, ISBN: 9783540330370. DOI: 10.1007/978-3-540-33037-0. [Online]. Available: http://dx.doi.org/10.1007/978-3-540-33037-0.

[90] F. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS Quarterly*, vol. 13, pp. 319–, Sep. 1989. DOI: 10.2307/249008.

[91] A. Garavand, M. Mohseni, H. Asadi, M. Etemadi, M. Moradi-Joo, and A. Moosavi, "Factors influencing the adoption of health information technologies: a systematic review," *Electronic Physician (Online)*, vol. 8, no. 8, pp. 2713–2718, Aug. 2016. DOI: 10.19082/2713.

[92] P. Legris, J. Ingham, and P. Collerette, "Why do people use information technology? A critical review of the technology acceptance model," *Information & management (Amsterdam)*, vol. 40, no. 3, pp. 191–204, Jan. 2003. DOI: 10.1016/s0378-7206(01)00143-4. [Online]. Available: https://doi.org/10.1016/s0378-7206(01)00143-4.

[93] A. Grewal, H. Kataria, and I. Dhawan, "Literature search for research planning and identification of research problem," *Indian Journal of Anaesthesia/Indian journal of anaesthesia*, vol. 60, no. 9, p. 635, Jan. 2016. DOI: 10.4103/0019-5049.190618. [Online]. Available: https://doi.org/10.4103/0019-5049.190618.

[94] A. Galletta and W. E. Cross, *Mastering the Semi-Structured interview and beyond*. Jun. 2020. DOI: 10.18574/nyu/9780814732939.001.0001. [Online]. Available: https://doi.org/10.18574/nyu/9780814732939.001.0001.

[95] B. Hanington and B. Martin, *Universal methods of design expanded and revised*. Rockport Publishers, Dec. 2019.

[96] T. Y. Siang, *Affinity Diagrams: How to Cluster Your Ideas and Reveal Insights — interaction-design.org*, https://www.interaction-design.org/literature/article/affinity-diagrams-learn-how-to-cluster-and-bundle-ideas-and-facts, [Accessed 30-01-2024].

[97] *What is Brainwriting? | Miro*. [Online]. Available: https://miro.com/brainstorming/what-is-brainwriting/.

[98] S. Gibbons, *Dot Voting: a simple Decision-Making and prioritizing technique in UX*, Feb. 2024. [Online]. Available: https://www.nngroup.com/articles/dot-voting/.

[99] J. Rojas, *Learn how to use sketching as an ideation method*, Feb. 2024. [Online]. Available: https://www.interaction-design.org/literature/article/etch-a-sketch-how-to-use-sketching-in-user-experience-design.

[100] *FigMa: The Collaborative Interface Design Tool*. [Online]. Available: https://www.figma.com/.

[101] Interaction Design Foundation - IxDF. "What is usability testing?" (Jun. 2016), [Online]. Available: https://www.interaction-design.org/literature/topics/usability-testing.

[102] M. R. Emerson, S. Buckland, M. A. Lawlor, *et al.*, "Addressing and evaluating health literacy in mHealth: a scoping review," *mHealth*, vol. 8, p. 33, Oct. 2022. DOI: 10.21037/mhealth-22-11. [Online]. Available: https://doi.org/10.21037/mhealth-22-11.

[103] *Mobilen är den digitala enhet som används mest | Svenskarna och internet*, Oct. 2021. [Online]. Available: https://svenskarnaochinternet.se/rapporter/svenskarna-och-internet-2021/internetanvandning-och-det-uppkopplade-hemmet/mobilen-ar-den-digitala-enhet-som-anvands-mest/.

[104] D. Lupton, "The diverse domains of quantified selves: self-tracking modes and dataveillance," *Economy and society/Economy and Society*, vol. 45, no. 1, pp. 101–122, Jan. 2016. DOI: 10.1080/03085147.2016.1143726. [Online]. Available: https://doi.org/10.1080/03085147.2016.1143726.

[105] *Axivity | Product*. [Online]. Available: https://axivity.com/product/ax6.

[106] *Gunning fog index*. [Online]. Available: http://gunning-fog-index.com/.

[107] *Flesch Reading Ease and the Flesch Kincaid Grade Level – Readable*, Mar. 2024. [Online]. Available: https://readable.com/readability/flesch-reading-ease-flesch-kincaid-grade-level/.

A

Planning

A.1 Time Plan

To structure the project, a time plan was made according to the *Design Thinking* Framework. The framework consists of four phases: Discover, Define, Create and Evaluate. The design thinking framework suits the project since it has a focus on empathy for the users, which is an important part when designing a mHealth application. The focus will be to understand the needs of the target group, as well as presenting the self-tracking data in a simple. The project will span over 20 weeks, and throughout the process there will be weekly supervision meetings with the group's supervisor with the aim to discuss the report and stick to the time plan (See Figure A.1).

A.2 Planned Results

The planned results of the project is to create a suggested design for the application *Hur går det?*, and data visualisations that will be implemented in both the caregivers' and then the patients' version. Furthermore, the results will include an analysis of the caregivers' needs within the field of orthopaedics and how the application may facilitate their work, as well as results from a usability test where the functionalities are tested and how the the target group perceives the data visualisations and the overall design of the application.

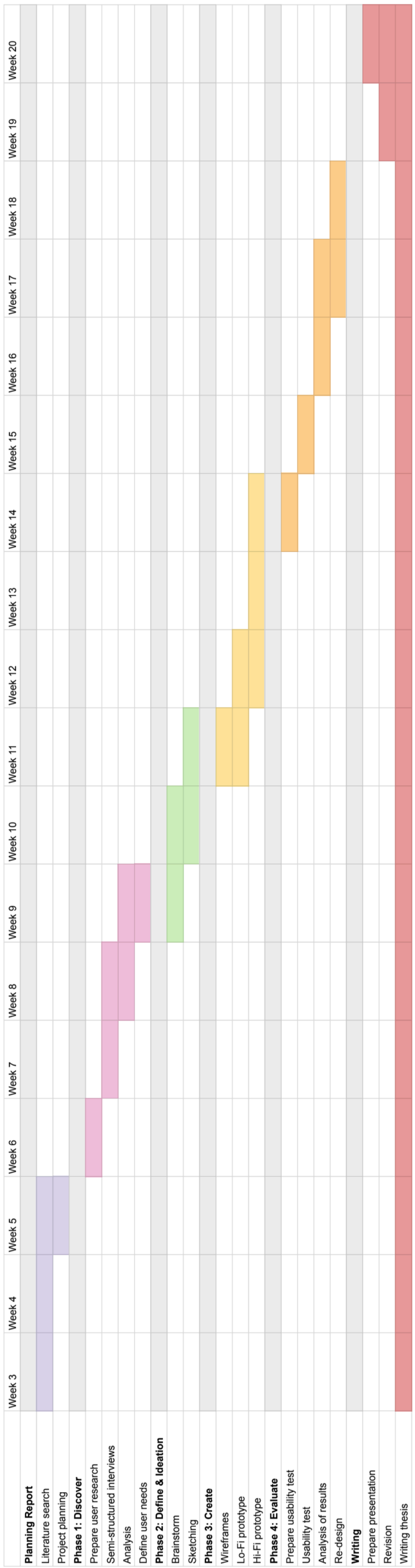


Figure A.1: GANTT chart of the proposed time plan

B

Semi-structured Interview Questions

Jobbar du med patienter som har gått igenom artroplastik, det vill säga patienter med knä eller höftproteser?

Generellt
Kan du beskriva din nuvarande process för att följa patientens framsteg (före och efter artroplastik)?

Använder du/ni digitala verktyg i din patientvård? I sådana fall: Hur integrerar du för närvarande den teknologin i din patientvård?

Får du tillgång till information om patientens rörelsemönster i dagsläget, från en annan källa som då inte är patienten själv? - Isåfall vilken?

I sådana fall: Hur ser du på mängden informationen som är tillgänglig om patientens rörelsemönster och rörelsekvalité?

Jobbar man med patientmål? Hur förs den dialogen isåfall?

Datavisualisering
Stöter du på olika typer av datavisualiseringar inom ditt yrke, det vill säga grafer eller annan visuell representation av data?

Ifall de stöter på datavisualiseringar gällande patienter: Vilken typ av datavisualisering finner du mest effektiv när du tolkar patientrapporterade resultat?

Applikation + Self-tracking
Känner du till begreppet self-tracking?

Hur ser du på implementationen av medicinska appar och self tracking i dagens vårdlandskap?

Vilka indikationer ger dig en snabb överblick över en patients framsteg och rehabilitering?

Hur skulle du helst vilja att en smartphone-app hjälper dig att se över dina patienters rehabilitering (efter artroplastik), till exempel funktioner eller specifik data? skippa

Feedback
Vilka behov tror du att en sådan app hade kunnat uppfylla inom fysioterapi, baserat

på dina erfarenheter?

Har du några generella åsikter eller specifika önskemål angående utvecklingen av en app som denna?

C

Brain Writing

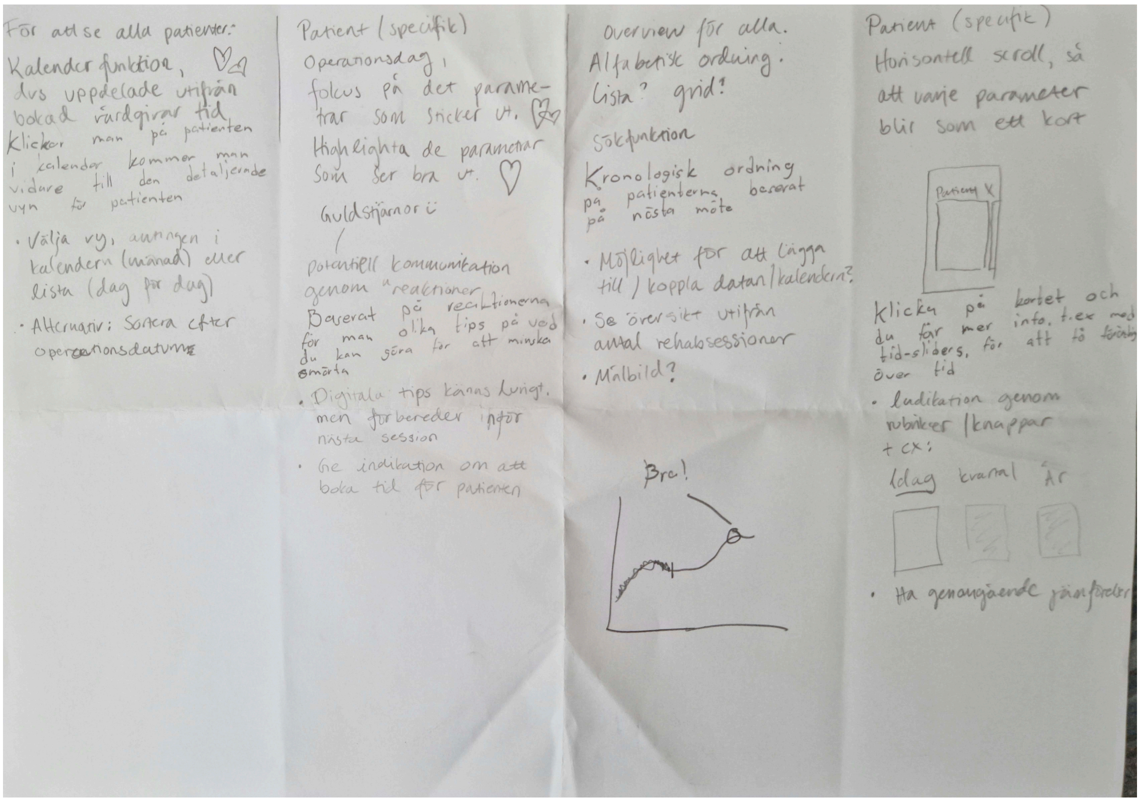


Figure C.1: Picture of the first brain writing results

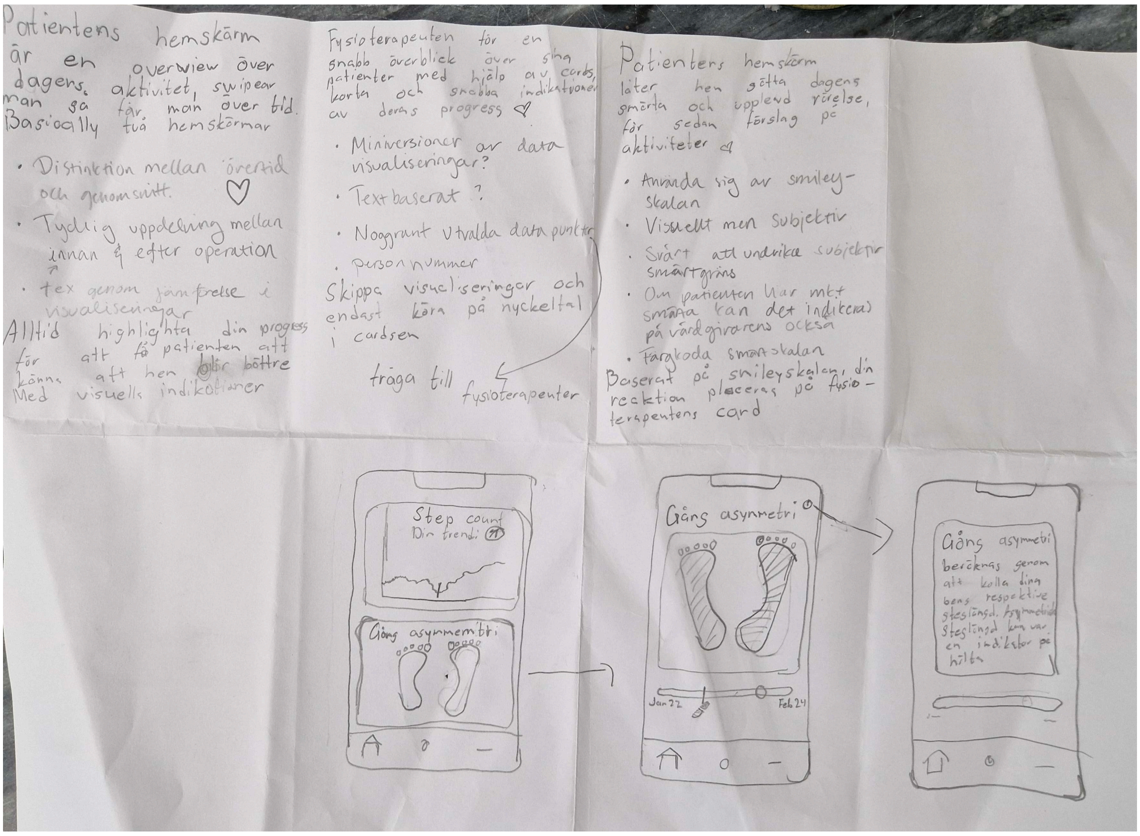


Figure C.2: Picture of the second brain writing results

D

Consent form Semi-structured interviews

CHALMERS

Consent and information about processing of personal data in student thesis

I agree to my personal data in the form of: age, gender, occupation as well as audio/video recording may be treated by Chalmers University of Technology for the study:

We are using the data from the interview to gain an understanding of current physiotherapist practices when working with patients with osteoarthritis. The aim is to use the data to develop an application that can be used by physiotherapists to gain insight into the patient's movement patterns before and after arthroplasty surgery.

Information

Your personal data will be handled as follows: Your interview data will be used solely for academic research purposes to gain understanding of the needs within the physiotherapy field. Digital recordings and data will be securely stored and accessible only to the research team until Sep 2024, after which they will be permanently deleted. Physical documents will be securely destroyed. Your information will be kept confidential, with data anonymized or pseudonymized. Identifiable information will not appear in any reports or publications.
Your consent is valid until further notice. You have the right to withdraw your consent at any time. You do this through contacting alexandra.weilenmann@ait.gu.se, ingheden@chalmers.se or sofsjob@student.chalmers.se.
If you withdraw your consent, we will cease processing personal data we have collected with the support of your consent. Some information may be saved due to Chalmers obligations under Swedish archive legislation.

Chalmers University of Technology, org. No. 556479-5598 is personal data controller. You can find Chalmers privacy policy at www.chalmers.se.
As a participant you have the right to receive information about how your personal data is processed. You have the right to have incorrect information corrected, redundant data deleted, request that processing shall be restricted and data transferred to another actor. You also have the right to submit a complaint to the Swedish Authority for Privacy Protection (Integritetsskyddsmyndigheten). Do you have any questions about Chalmers's processing of personal data contact Chalmers's data protection officer at dataskydd@chalmers.se.
I agree that Chalmers University of Technology processes personal data about me in accordance with the above.

Place:	Signature
Date:	Name clarification

Figure D.1: Consent form for the semi-structured interviews during the discovery phase

E

Affinity Diagram from the User Research

https://www.figma.com/board/H1OV9jxEQF08s5Zr16Z6Hn/Untitled?node-id=0%3A1&t=trejJjFKzXQPrlIQ-1

F

Technology Acceptance Model

Technology Acceptance Model

Perceived usefulness

	Likely						**Unlikely**
	Extremely	Quite	Slightly	Neither	Slightly	Quite	Extremely
1. Using *Hur går det?* in my job would enable me to accomplish tasks more quickly							
2. Using *Hur går det?* would improve my job performance							
3. Using *Hur går det?* in my job would increase my productivity							
4. Using *Hur går det?* would enhance my effectiveness on the job							
5. Using *Hur går det?* would make it easier to do my job							
6. I would find *Hur går det?* useful in my job							

Perceived Ease-of-Use

	Likely						**Unlikely**
	Extremely	Quite	Slightly	Neither	Slightly	Quite	Extremely
7. Learning to operate *Hur går det?* would be easy for me.							
8. I would find it easy to get *Hur går det?* to do what I want it to do.							
9. My interaction with *Hur går det?* would be clear and understandable.							
10. I would find *Hur går det?* would be clear and understandable.							
11. It would be easy for me to become skillful at using *Hur går det?*.							
12. I would find *Hur går det?* easy to use.							

Figure F.1: Picture of Technology Acceptance Model questionnaire including the questions

G

Follow Up Questions from Usability Test

Intervjufrågor:

Vad är dina generella åsikter/första intryck av designen?

Hur upplevde du datavisualiseringarna, var de oklara eller tydliga? Hade du velat ändra på något specifikt?

Hur upplevde du läsbarheten, inklusive textstorlek och färgval?

Vad fanns det för oklarheter i designen?

Vad uppskattade du i designen?

H

Affinity Diagram from the Usability Test

https://www.figma.com/board/nXGlIImdttJWgaCNhgVde8/Usability-test?node-id=0%3A1&t=a5YUp8mbKiUjtPfk-1