Master Thesis

Redesign of a rehabilitation tool for hip patients based on patient profiling

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Industrial Design Engineering
MSc Integrated Product Design

Supervisory team
Chair: Dr. ir. Marijke Melles
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Mentor Reinier de Graaf Group: Dr. Stephan Vehmeijer
Mentor Zimmer Biomet: Msc. Hilbrand Bodewes

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Preface

The report in front of you includes the documentation of my final graduation project of the Master Integrated Product Design of the faculty of Industrial Design Engineering of the TU Delft.

With a mother with two new hips and a physiotherapist, an orthopedic surgeon and other medical professionals in my family, I was enthusiastic to work on this project about the rehabilitation of total hip replacement surgery for different patient profiles. Also because of a personal interest in psychology and personality types, it was a real pleasure to work on this last master piece of my TU Delft study.

Lisanne van Dijk
Delft, July 2018

Acknowledgments

I would like to thank Marijke and Bob, for the support and trust you gave me during the project.

Stephan, for the good feedback and positivity. And also for all the moments I could visit the hospital for research around hip surgery.

Hilbrand, for the good feedback and motivation.

Tessa, for your information about patient profiling.

My parents and brother, for being a big support to me.

All research participants and friends, especially Wouter, who supported me and were great sparring partners during the project. Also a special thanks to Jeroen, Samy and Maxim for your great support!

Executive Summary

This graduation project has been carried out in the context of the research project ‘Tailored Healthcare through Customer Profiling’ at the TU Delft, in collaboration with hospital Reinier de Graaf Group in Delft, and medical device company Zimmer Biomet. Together we focus in this project on the rehabilitation journey after total hip replacement (Total Hip Arthroplasty, THA).

Due to cuts in health care, physiotherapy is no longer reimbursed from the basic health insurance package. As a result, fewer patients have contact with a physiotherapist or other healthcare provider during their rehabilitation—and thus will no longer receive full aftercare and personal attention as before. This way, self-management becomes increasingly important; resulting in the fact that the responsibility of rehabilitation lies with the patient. Especially after hip surgery, patients benefit from sufficient exercises to increase their mobility and muscle strength. Therefore, supportive tools that help patients in self-managing their rehabilitation are desirable.

The central aim of this project has been to find out how different patient profiles benefit from different interaction features in the rehabilitation device ‘BioCoach’, to effectively support them in their rehabilitation process. The BioCoach is a wearable device for patients who are rehabilitating from hip replacement, and it monitors activity and exercises to improve mobility and muscle strength. However, there is currently only one general patient considered when designing healthcare products, contrary to consumer products, where products are designed for specific customer profiles. As such, research has shown that there is not one type of patient. Customer profiling techniques might be an effective way to design a tailored patient experience. Therefore, this project investigates how a tailored version of the BioCoach could meet the needs and wishes of the three different patient profiles: the ‘optimistic’ patient; the ‘managing’ patient; and the ‘modest’ patient.

Desk and field research have been conducted to gain a good understanding of these patient profiles and their context. In order to empathize with THA patients, a patient has been followed in the Reinier de Graaf hospital for a day to map the complete patient journey of a hip replacement. In addition, nine physiotherapists were questioned about their vision regarding the BioCoach. These insights outlined the foundation for potential roles for the BioCoach in coaching the patient during their rehabilitation journey, with the focus on the quality of physical exercise, walking and posture. Furthermore, with a statistic data analysis and a user test with 12 patients from the three different patient profiles, the three patient profiles are thoroughly analyzed to make assumptions for their needs and wishes concerning their rehabilitation. Based on the analysis insights, design guidelines are established per patient profile.
This analysis shows that the ‘modest’ patient needs the most guidance in self-management and can make the biggest improvement in health outcomes. Finally, a design vision has been formulated based on these findings and conclusions as a base for the ideation and conceptualization phase.

In the conceptualization phase, different idea generation methods have been used, such as brainstorming, analogies and a morphological chart, to generate a variety of ideas. By means of iterative design cycles these design directions have been developed to a concept level. Using predefined design criteria, the most promising concept was selected, called the ‘Biobuddy’. The Biobuddy is a product-service system that supports modest patients in self-management during their THA rehabilitation, intended to enhance the patient’s engagement, motivation and adherence to have a positive THA experience and successful outcome.
The product consists of two parts. The monitoring part, which is a sensing plaster, will be worn on the pelvis and upper leg of the patient. The plaster could recognize and measure exercise for muscle strength and mobility.These monitoring data will be transmitted to the Biobuddy: a booklet including a touchscreen with an application, which is tailored made for the modest patient profile.

A successful rehabilitation starts with a good preparation. The Biobuddy helps with goal-setting and process visualization. After surgery, the app will coach the patient by providing video explanation, giving feedback on exercise performance and providing insights in progression. Besides this, information about pain and medication is available.

The Biobuddy concept has been developed into an interactive prototype to be able to evaluate it with ‘modest’ users. The user interface (UI) of this digital application focuses on the feedback with regard to the patient’s progression and performance during rehabilitation, in an intuitive way.

A user test has been conducted with 5 elderly patients, to gain insights in the user experience and usability of the Biobuddy. The key insights gained through this user test show a positive relationship between the embedded interaction qualities - such as familiar, emphatic, playful and reassuring - and the patient’s motivation to self-manage their rehabilitation process with the aid of the Biobuddy.
The Biobuddy has taken the first steps in guiding patients to self-manage their rehabilitation process after hip replacement. Therefore, this graduation project might be of great interest for other medical designers and design research in general for supportive rehabilitation tools.

Reader’s guide

The icons below are shown at the beginning of the chapters to clarify the categorization of the content.

SCOPE REFINEMENT

LITERATURE RESEARCH

FIELD RESEARCH

DESIGN INPUT

PERSONAL VISION & REFLECTION

SYNTHESE

EMBODIMENT

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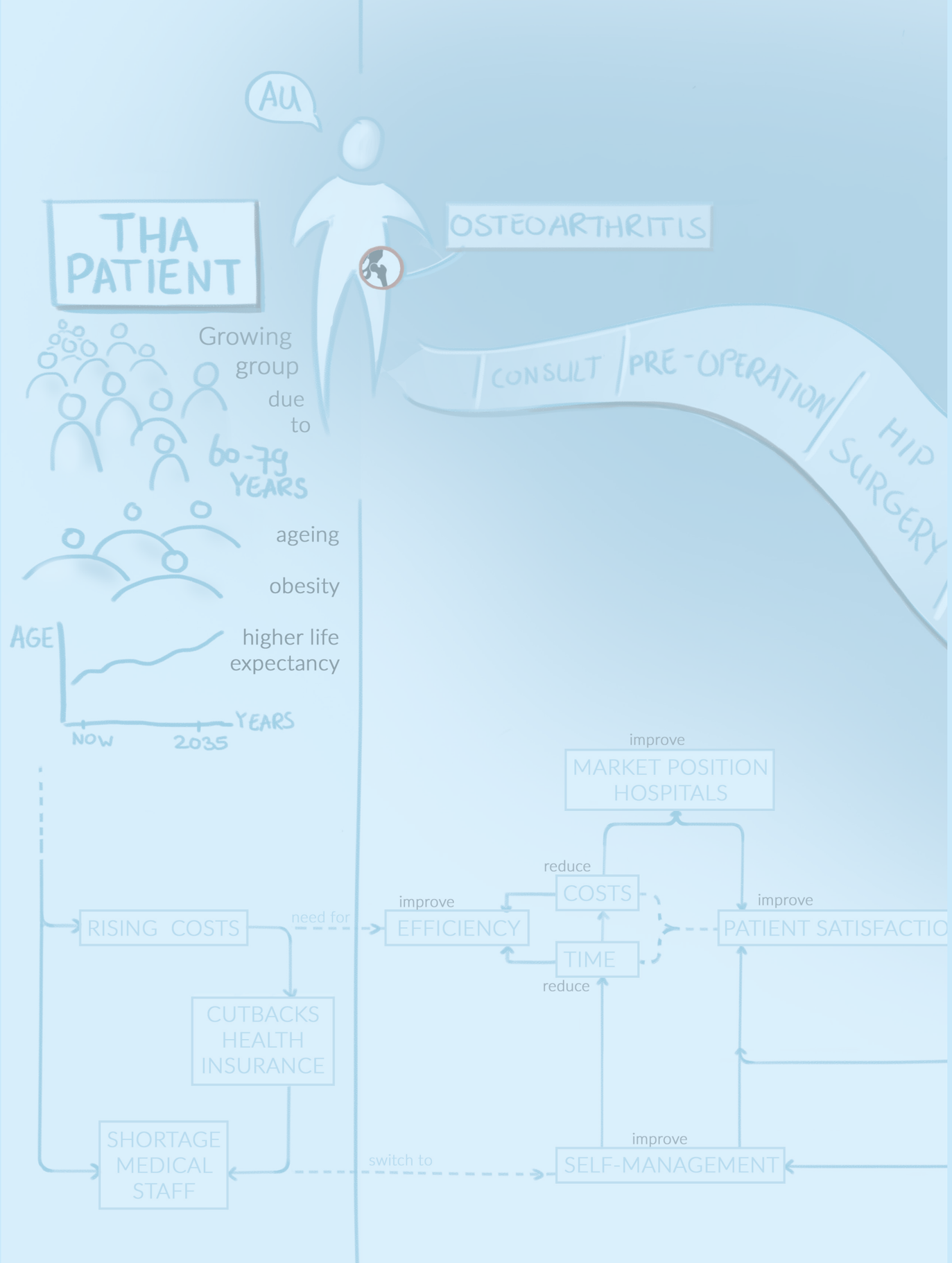


Chapter 1

Introduction

In this chapter, the assignment of this project will be introduced and motivated, starting with sketching a background picture of the existing situation in paragraph 1.1. Relevant trends and developments in total hip replacement rehabilitation will be described here, followed by an introduction on the rehabilitation product the BioCoach. Furthermore, the link to tailoring healthcare products by using patient profiling techniques will be discussed. In paragraph 1.2 the project partners will be introduced and the role of each partner will be explained. Finally the project scope and assignment will be defined in paragraph 1.3, followed by the approach in paragraph 1.4.

1.1 Background

In the Netherlands, more than 24.000 people receive a total hip replacement (Total Hip Arthroplasty, THA) each year. This number is expected to rise to 32.000 in 2030, an increase of 53%, because of the ageing society and rising life-expectancy (LROI, 2016); the increase in overweight people; better long-term results of operations and the more active lifestyle of the elderly patient (Otten et al, 2010). As a result, medical costs will rise (Van der Horst et al, 2011).

The rehabilitation phase

This project focuses on the rehabilitation phase after total hip replacement. After hip surgery, exercise is needed to increase mobility, to improve muscle strength and to reduce pain. At home, exercise needs to be continued; the physical therapist gives instructions about proper home care and may continue to work with the patient. However, due to cutbacks in health care, physiotherapy is not part of the 'basispakket' (basic package of health insurance) anymore since 2012. Physiotherapy will be reimbursed just partly or for a limited amount of treatments, depending on your health insurance. As a result, less patients will have contact with a physiotherapist or other healthcare providers during their rehabilitation and do no longer get the full aftercare and personal attention as before.

Self-management

Because of the reasons above, the need for active patient participation in their care is becoming more important. In other words, the focus of the post-operative phase switches more to self-management; resulting in the fact that the responsibility of rehabilitation lies with the patient. However, not every patient is equally capable of doing that, due to for instance a lack of knowledge, available information, motivation or self-confidence (Rademakers, 2016).

BioCoach

Therefore, supportive tools that help patients during their treatment are desirable, of which the BioCoach is a good product example (Kraak, 2013). The BioCoach is a wearable system that registers exercise in THA rehabilitation and transmits information to both the patient and physiotherapist—to provide advice and feedback in a meaningful way. The BioCoach consists of an exercise tracker worn around the leg and is connected to an application.

The BioCoach concept idea is developed at the faculty of IDE TU Delft during the Exploring Interaction course by Andriy Yasynetskyy and is further developed during one semester in the AED course (Advanced Embodiment Design). The client is Zimmer Biomet who has patented the design.

Tailored patient experience

At this moment, rehabilitation is in its basis a one-size-fits-all treatment; a standard programme of exercises will be followed, which is tailored for patients in difficulty by a physiotherapist, depending on the patient's condition. In healthcare products, just one 'general patient' is considered, in contrast to consumer products, where products are designed for specific customer profiles. Some patients probably don't fit in this 'general patient picture'; they don't feel heard or understood, and medical products don't fit their lifestyle and needs. According to research, a tailored patient experience may increase efficiency in healthcare (Berwick et al, 2008), enhance competitive advantage for hospitals (Wolf et al, 2014), improve patient satisfaction and health-related outcomes (Manary et al, 2013). Customer profiling techniques might be a way to effectively design a tailored patient experience. This project will investigate how tailored versions of the BioCoach could meet the needs and wishes of different types of patients.

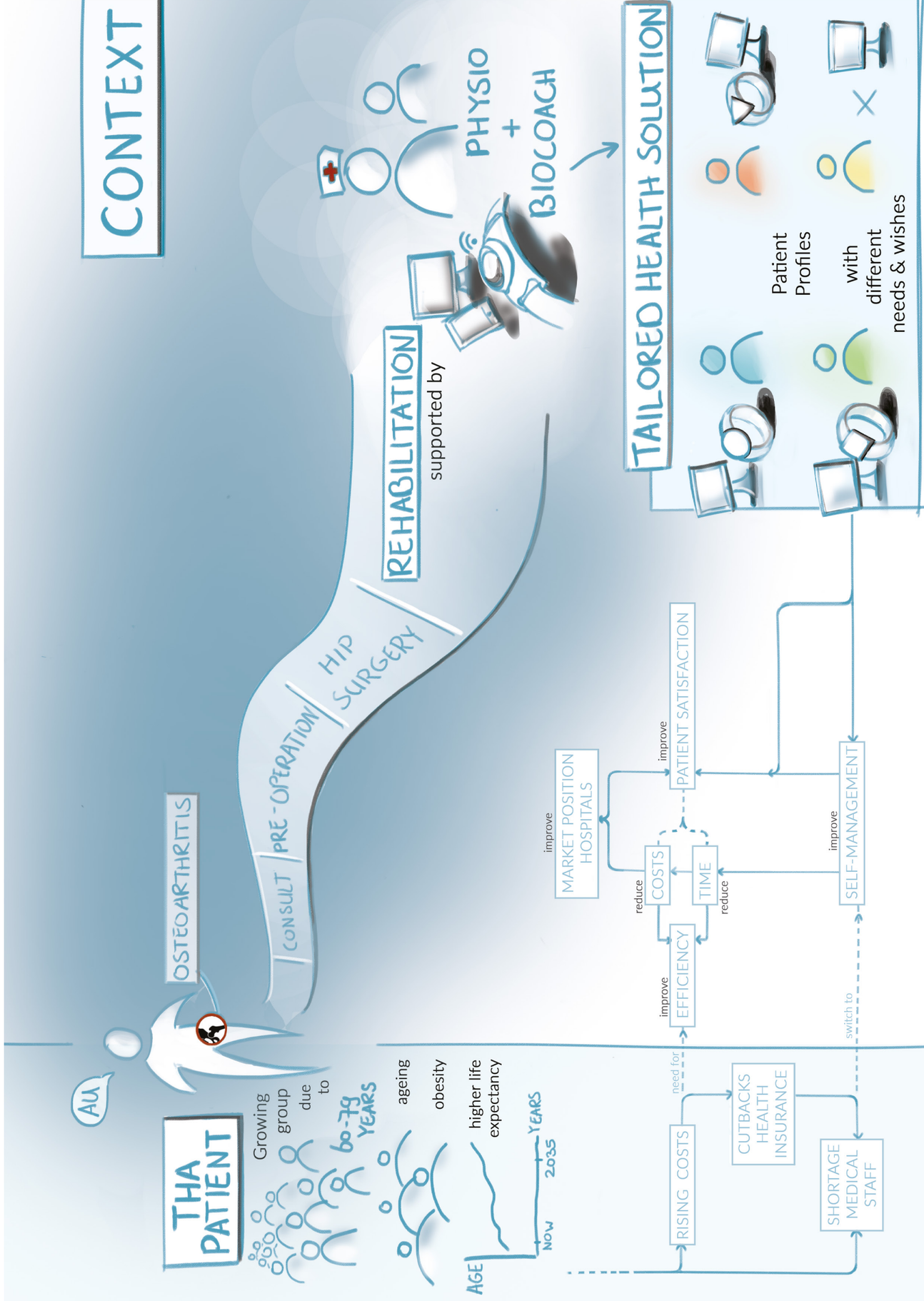


Figure 1-1 Background overview of tailored healthcare solutions in THA rehabilitation by using patient profiling techniques >

1.2 Project partners

To increase patient satisfaction, research at TU Delft is ongoing on patient profiling and tailoring healthcare in orthopaedics. The aim of this research is to define a set of validated design-oriented patient profiles and to test the effectiveness of integrating these patient profiles in medical product-service systems. This graduation project is part of this research programme, called 'Tailored Healthcare through Customer Profiling' (Melles et al., 2014) and contributes to this research by translating research insights into design proposals for personalized rehabilitation for hip patients.

A consortium of Delft University of Technology and partners from design agencies (Panton and Vanberlo), healthcare (Reinier de Graaf Group) and industry (Zimmer Biomet) is set up to explore the potential of customer profiling in designing a tailored THA patient experience.

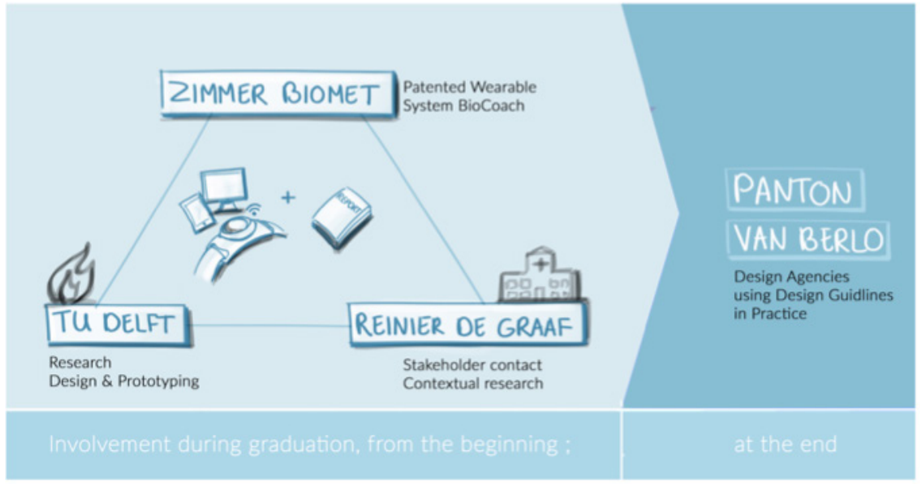


Figure 1-2 Overview and role of the project partners

TU DELFT

This graduation project forms the final project of the master Integrated Product Design (IPD) from the faculty of Industrial Design Engineering (IDE). The project is part of the Medisign specialization and contributes to the IDE healthcare research programme.

The starting point of this project is the report developed during the IPD master course Advanced Embodiment Design (AED) about the BioCoach and scientific input of different patient clusters as developed by IDE researchers Groeneveld and Dekkers (Groeneveld, n.d.; Dekkers, n.d.).

Role in this project:

The TU Delft supervisors provide support and coaching during the research and design process from an academic education perspective.

As a designer, you have the skills to analyze complex situations and come up with innovative solutions by doing creative sessions in combination with user research.

REINIER DE GRAAF GROUP

The Reinier de Graaf Group includes various hospitals in the Dutch Haaglanden region with Delft as its main location. This broad basic hospital has been providing care for almost eight centuries and is the oldest hospital in the Netherlands.

Role in this project:

Reinier de Graaf hospital will help in facilitating stakeholder contact and contextual research.

Their goal is to improve care and especially the patient experience during the entire care process, in which design could play a positive role. Therefore they work together with the TU Delft, especially with the Industrial Design faculty, to conduct research and design projects.

Healthcare professionals help in this traject by providing feedback during field research and testing, from a healthcare provider's perspective.

ZIMMER BIOMET

Zimmer Biomet is a world leading medical device company that designs, develops, manufactures and markets orthopedic products. The company has been based in Warsaw since it was founded in 1927 and has nowadays operations in more than 25 countries around the world and sells products in more that 100 countries (Simon, 2009). The portfolio of Zimmer Biomet consists of reconstructive products for hips, knees and shoulders, fixation devices, orthopedic support devices, dental implants, spinal implants and operating room supplies. Their purpose is to restore mobility, alleviate pain and improve the quality of life for patients around the world. Zimmer Biomet's aim is to reinvent the entire journey of a patient undergoing a joint replacement operation.

Rapid Recovery Programme

This graduation project is in line with the philosophy of the Rapid Recovery programme of Zimmer Biomet, in which they aim to support healthcare professionals in orthopedics to optimise the care they provide to patients, to help hospitals to achieve best possible clinical outcomes, create a superior patient experience, optimise length of stay, improve efficiency of care and increase professional satisfaction.

Role in this project:

Zimmer Biomet is the owner of the patented BioCoach design and is the advisor from a business perspective. The company will determine the added value of the research outcomes for the healthcare industry.

PANTON AND VANBERLO

Panton is a design studio for health care, based in Deventer since 2005. Their aim is to make healthcare more effective and intuitive by means of design.

VanBerlo is a design consultant agency based in Eindhoven since 1982. VanBerlo has experience in a wide range of product fields. In recent years they also work on projects for healthcare.

Role in this project:

Panton and VanBerlo will evaluate the usefulness and usability of the research outcomes that can lead to design guidelines for different patient profiles, which can be used during product development of medical devices in the creative industry.

1.3 Project scope & Assignment

Scope of the project
The assignment is a research-through-design project. Since this project doesn't start from scratch, the design direction, including insights into different patient profiles as well as a concept, is known (see chapter 2.1). A problem definition can be defined and we can focus on the product level.

Problem definition
The knowledge gap in this project is defined as: do patients with different patient profiles benefit from different interaction features in healthcare products and if so, what are these differences?
To investigate this, we need to know what is important to different patient groups. How can research insights of patient profiles be translated into needs and wishes of patients? Also, needs of other stakeholders such as the physiotherapist, surgeon and informal caregivers should be taken into account. For example, the role of the patient's caregiver could be supported or even changed by the product. As such, a preferable role of the BioCoach in the rehabilitation journey needs to be defined. What will be a right moment to introduce the BioCoach in the patient journey and how will this change the role of all stakeholders and their teamwork in the future?

This project explores the potential of BioCoach product proposals and required data
that should be collected to meet different patient's needs.
Perhaps there are similarities in product feature needs between different profiles. During testing, we need to know which patient profile fits the patient best. Also we need to think of the possibility that one patient could change between profiles over time. Probably not every patient needs both the physical BioCoach product and the application. A function analysis of the different parts of the BioCoach will be executed to investigate this.

Aim
The aim of this project is to show the differences in design of the BioCoach for different patient profiles and to validate that specific adaptations does work for one patient profile and less or not at all for another profile.

The expected results are design guidelines for these identified profiles.

Assignment
"Develop three interaction variants of the BioCoach (a THA rehabilitation tool) based on the different patient clusters as developed by IDE researchers Groeneveld and Dekkers (n.d.). Obtain feedback through user tests by prototyping the designs. Based on the insights, design guidelines will be defined for a tailored rehabilitation product-service."

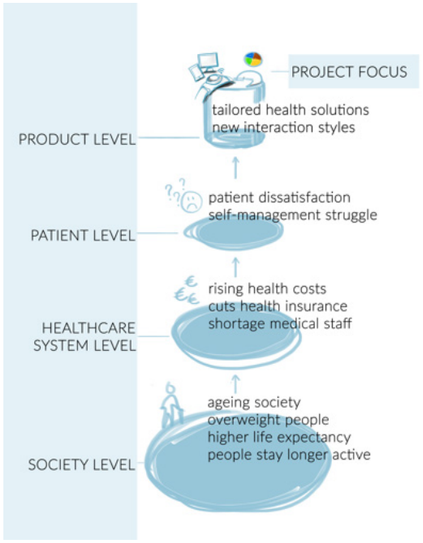


Figure 1-3 The project focus is on the product level

1.4 Approach

The systematic design approach of Roozenburg and Eekels (1998) will be used during the project, to create structure and tackle the complexity of this assignment in iterative design cycles.

Analysis Phase
This phase starts with a preliminary literature research to gain a good base of knowledge and understanding of different patient profiles in THA.
• What are the needs and wishes of different patient profiles? These insights can be gained in the parallel research of Tessa Dekker on 'Patiëntervaring op maat' (Tailored patient experience) and additional literature.
• What are the needs of the involved healthcare professionals and what information do they need? A rehabilitation journey will be made to map all stakeholders and their tasks and needs.
• Context analysis: background information on THA and the post-operative phase; how does treatment look like?
• Company information Zimmer Biomet
• Product function analysis of the BioCoach and similar or competitive products.

Field research (interview and observations) will be done to gain understanding of the context and patient needs.

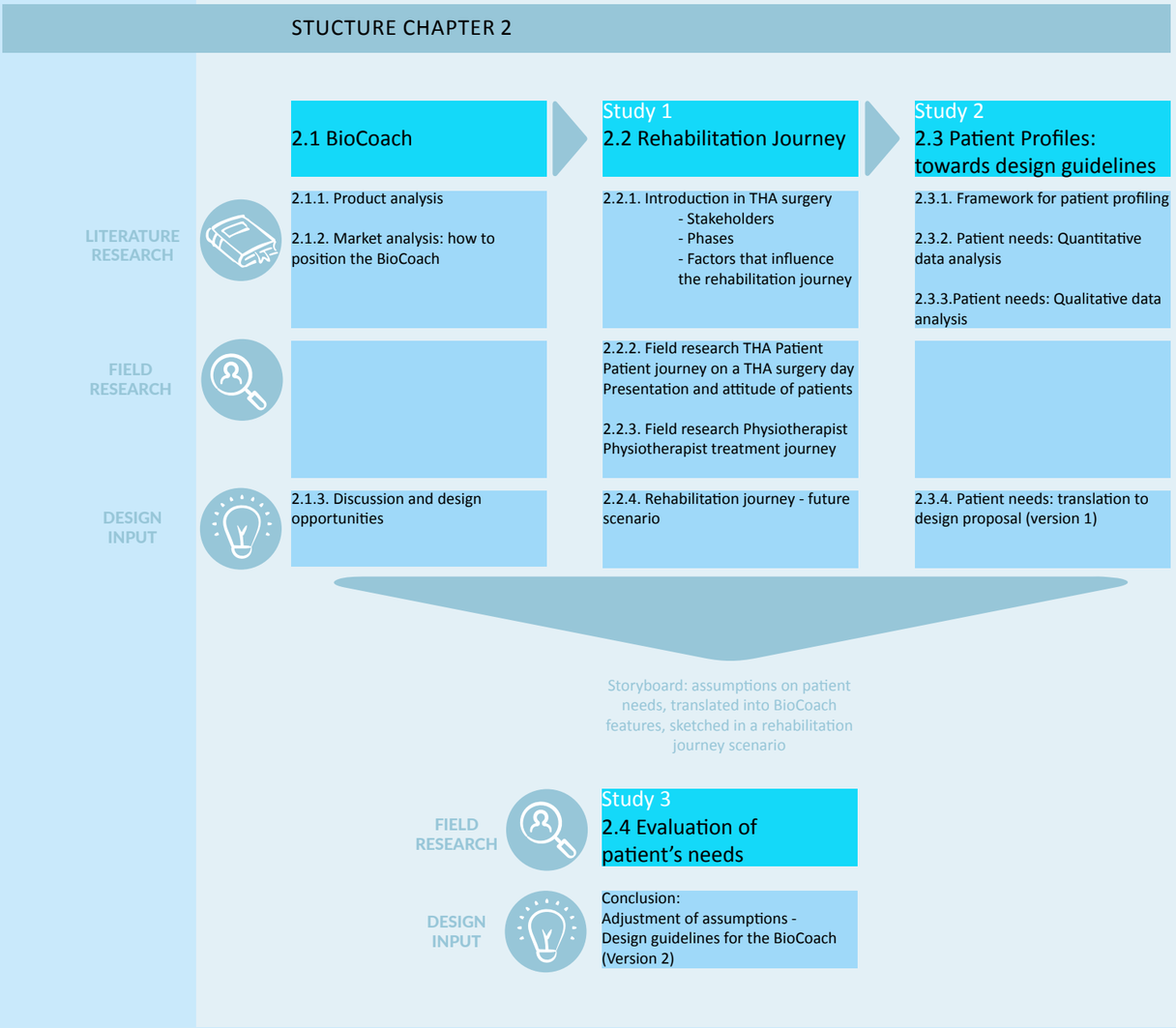
After this analysis phase, a first version of design guidelines for three different patient profiles will be established, based on the analysis insights.
Then, conclusions are drawn in the form of a design vision and a list of requirements and wishes, as described by Roozenburg, N.F.M. and Eekels, J. (1998).

Synthesis - Design & Test Phase
In this phase, prototype-based research will take place to investigate the effect of embedding the patient profiles in design. It will start with ideation and conceptualization. How can all findings be translated into design? Different idea generation methods will be used, such as brainstorming, how-to's, analogies and a morphological chart.
In this phase, iteration loops will be made. A prototype is made of the final concept and a user test with patients is done to evaluate the product.
The results and findings of the user tests in this synthesis phase will be translated into a product proposal for Zimmer Biomet.

Embodiment Phase- Final design
The final product proposal will be elaborated and optimized on ergonomic, aesthetic, technical and financial level.

Evaluation Phase
In this final phase, the product and process is evaluated and discussed, and conclusions are drawn by looking back to the list of requirements and wishes.
Recommendations are written about the BioCoach product development for Zimmer Biomet.
Also, design guidelines are written about for different patient profiles. These guidelines can be communicated to design agencies (Panton and Vanberlo) and used for other desing project for healthcare. Finally, recommendations will be made according to further research for the TU Delft research program and hospitals.

Reflection
During the entire project, feedback loops will be regularly used to evaluate on the process and progress. The insights are used to (re) define direction and to make this project come to a successful end.



Chapter 2

Analysis: the potential of patient profiling in rehabilitation

In this chapter, desk research has been conducted to gain a good understanding of the subject and to be able to formulate a design vision as a base for the conceptualization phase to generate new variants of the BioCoach.

This chapter is divided into three blocks. Firstly, the BioCoach product has been analyzed in paragraph 2.1. Then, in paragraph 2.2, we zoom in on the rehabilitation journey: how does THA rehabilitation look like, which stakeholders are involved and what is their role? Thirdly, patient profiling is discussed in paragraph 2.3. What do we already know about patient profiling and how could these insights be used to create design guidelines for different patient groups? By analyzing existing research data, assumptions are made on the patient's needs and wishes for supportive tools in their rehabilitation process. This is done by both a quantitative data analysis (paragraph 2.3.2) and a qualitative data analysis (paragraph 2.3.3), based on research of B. Groeneveld and T. Dekkers (n.d.).

The assumptions on the patient's needs and wished for supportive tools are translated into product ideas for the BioCoach. In the last paragraph 2.4, this test is described and discussed.

Every paragraph starts with an introduction of the subject and a discussion on what is relevant to this project and what questions need to be answered. Then, existing information gathered from literature will be discussed. In case questions are not totally answered now, the subject analysis is supplemented with field research.

2.1 BioCoach

The starting point of this project is the report developed during the IPD master course Advanced Embodiment Design (AED) about the BioCoach and scientific input of different patient clusters as developed by IDE researchers Groeneveld and Dekkers (n.d.).
The AED report was a follow up on a project by Andriy Yasynetskyy, which explored the option of developing a rapid recovery device for Biomet, defined in terms of interactions and elaborated on a system-level. During the AED course, the concept is during one semester further developed, with a focus on the product-level and embodiment design.
An overview of the current state of the BioCoach concept will be given in this paragraph.

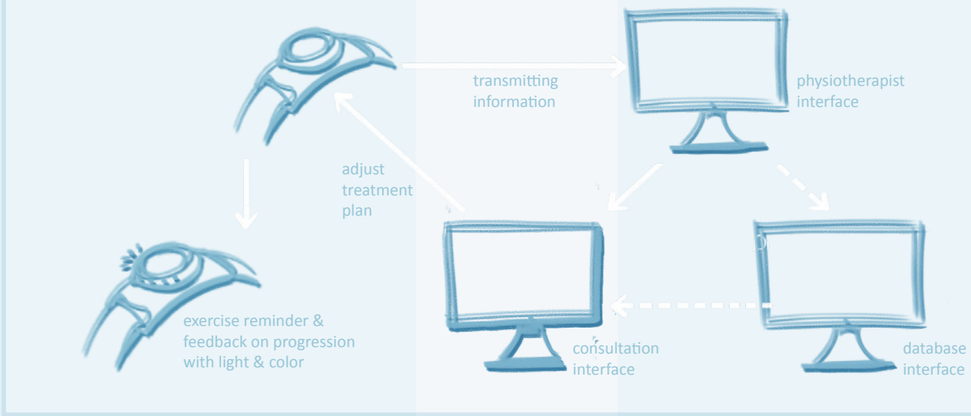
2.1.1. PRODUCT ANALYSIS

What is the BioCoach?
Quoting prof. Goossens: “During revalidation, the physiotherapist will often not know which exercises the patient is doing. Conversely, the patient often does not know if he is performing the exercises that he has been given in the correct way.” The BioCoach is a guide for patients who are rehabilitating from a knee or hip replacement while doing their exercises as instructed by their physiotherapist. The device records the movements of patients as well as their pain level during the day. The combination of monitoring the activity and pain level of the patient provides relevant information for the physiotherapist, to tailor the treatment plan during the process of recovery and to give appropriate advice to the patient in a much more efficient manner.
Patients wear the physical BioCoach device on their upper leg - over the clothes - and it registers their exertions (Figure 2-1). The BioCoach tells the patient if he or she is performing the exercises in the correct way. Beside this, the product transmits information to the physiotherapist, to know which exercises the patient is doing. In this way, the BioCoach creates a better connection between the patient and the physiotherapist.

Figure 2-1

Product function analysis
The BioCoach is a wearable device with an additional application for desktop and mobile devices. Both have their own function and usage, as can be seen in Figure 2-2. The monitoring device is used by the patient. The application is intended for the physiotherapist’s use and has three interface types.
Based on the results of interviews by the AED team with both patients and physiotherapists about device characteristics, a functional morphological map is made that shows which functions are found most important according to the different stakeholders. A component morphological chart represents functional solutions for a certain concept (Kraak, 2013, page 24-28). The final concept of the BioCoach is based on product function solutions coming forth of these two morphological charts.

Technology
The BioCoach sensor unit includes an accelerometer and gyroscope to measure the movements of the patient. A button for the patient is placed on the device to give input on their experienced effort of the exercises on a VAS-scale.
The device uses a rechargeable battery as power source. An USB-port supports both charging and the transfer of data. The USB-port allows for data upload (exercise data set) and download. The BioCoach has a memory that is able to store two months of exercise data (for buffering purposes). The software analyses the data and registers this onto a SD card. The Integrated Circuit (IC) has sufficient processing capacity for the BioCoach.



	BioCoach device		Biocoach application
User	The physical Biocoach band is worn by the patient.		The application is only used by the physiotherapist
Function	• Monitoring activity and exercises to improve mobility and muscle strength • Monitoring perceived difficulty or pain level • Providing feedback to the patient through LED signals • Transmitting information to BioCoach application	Transfer of information & adjustment of treatmentplan	• Providing insights in the patient’s activity and pain level • Receiving information from BioCoach device
Function in depth	**Exercise monitoring and feedback on progress** When the user does his exercises with the BioCoach, the device will record the type of exercise, time and repetitions the exercise is performed. During the exercises, the BioCoach will show the current completion of the progression bar and blinking the next LEDs to stimulate the user to keep exercising. When the exercise is completed, the blinking LED will be turned on permanently, and all LEDs will shut down after a few seconds. **Exercise Reminder**: And the LEDs will start to glow if the patients have not done their exercises for a long time, but also other activities, such as walking or taking the stairs. **Indicate User Pain** During or after a certain exercise, but also on other moments of the day (e.g. after walking some stairs), the user has the possibility to indicate a level of effort. To do this, a button is turned until the experienced effort level is reached, indicated on a scale from 1 to 10 by the LED of the progression bar. When the user is satisfied about the effort level, the button is pressed to record the data on the internal memory. The data will be stored on the device and it can be transferred to the physiotherapist at the meetings. The physiotherapist will interpret the input from the patient together with the measured data and can use it to optimize the rehabilitation program of the patient.	The ‘activity goal’ is set by the physiotherapist, and can therefore be adjusted during the rehabilitation process. The physiotherapists have to be able to input their personal philosophy on the rehabilitation process via this product, so they can implement the BioCoach in their way of work. In the same spirit, it is also said that physiotherapists should be free to create their own methods and exercise programs in order to optimise the patients’ recovery.	**Physiotherapist interface** • Provide an overview of his patients that are using the BioCoach • Allow him to see the individual progress of patients • See the average completion percentage & VAS scale for him to work on • Upload his own exercises to be added to the database **Database interface** • Show the complete database with all exercises that can be done for rapid recovery • Allows the physiotherapist to select exercises on parameters -hip / knee / shoulder & on -strength / flexibility / stability • Get community help about usage of the BioCoach or posting of questions • Contact Biomet directly for more specific help **Consultation interface** • Shows the progression (exercises) of the user since the last consultation • Shows the exercises that were completed poorly • Shows the exercises with whom the patient experienced pain • Allows to upload a different set of exercises and a practice sheet of these exercises to the BioCoach • Serves as a discussion facilitator between the patient and the physiotherapist.
User experience	The users need to trust the BioCoach and feel supported when exercising.		

Figure 2-2

2.1.2. MARKET ANALYSIS: HOW TO POSITION THE BIOCOACH

Healthcare and technology trends and developments

With the availability of new technologies, healthcare can be provided in different ways, and could be more integrated in the user's life. Currently, *digitalization* of care systems is taking place. More than 75% of all patients expect to use digital healthcare services in the future, as long as those services meet their needs and provide the level of quality they expect. Existing services often don't meet the patient's needs or are of poor quality (Biesdorf, 2014).

Digital (healthcare) service use is expected to increase across all age groups, so not only in younger generations (Biesdorf, 2014). Older patients prefer traditional digital channels such as websites and e-mail (Figure 2-3).

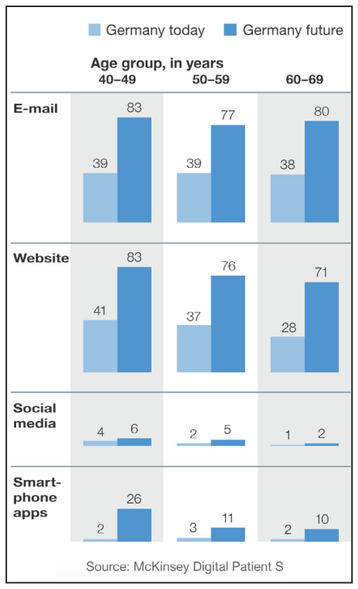


Figure 2-3 Digital interaction with health system (at least 1 interaction), % per age group from 40 till 69 years.

Short-term developments

Short-term developments that respond to the digitalization can be seen in health monitoring devices that become connected and digital solutions that enable the collection and analysis of the collected data. Also, *robotization* is a big trend: automation of physical work and the intelligent interaction with the environment. With the ongoing robotization, the question is which tasks we want to leave to people, and which tasks we want to give to robots (Went, 2015).

Long-term developments

In a conversation with the client appeared that long-term developments include integration of sensor technology within the prosthesis itself (chip in the hip). Still a lot of research and development needs to be done before these products can be introduced on the market, which could take 10 years. In the far future, the focus will be on prevention of hip arthrosis, so that no surgery will be needed anymore (H. Bodewes, personal communication, January 26, 2018).

Also, care is becoming more patient centered, in which for instance the patient's role is more active and the care has more focus on quality-of-life, health and behavior rather than on the disease (RVZ, 2010). This requires a different approach in the care process and a different conversation with the patient. Growing numbers of consumers will expect health products and services to improve their quality of life, rather than merely treating illnesses and ailments.

Beside this, patients become more and more empowered and have higher expectations of the quality of the care that they receive. This is because patients have increasingly access to more information about diseases and disorders, treatment options and quality of care (CWZ, 2013).

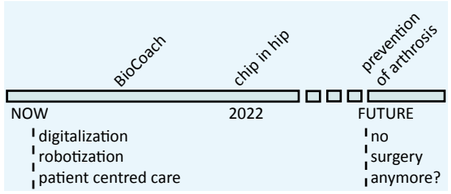


Figure 2-4 Short- and long-term developments in THA support

Competitive products

As concluded by the AED design team: "A product such as the BioCoach would be a disruption in the current product portfolio of Zimmer Biomet, but also offers great opportunity to cover the complete patient journey of joint replacement. More importantly the competitor analysis shows that none of them have a rehabilitation device in their product line-up. Similar products that are currently on the market focus on mainstream consumer products and never on medical applications."

Currently, there are some physical and digital products on the market, within the domain of rehabilitation coaching for better self-management for THA or TKA patients. Examples are mapped out in Figure 2-5.

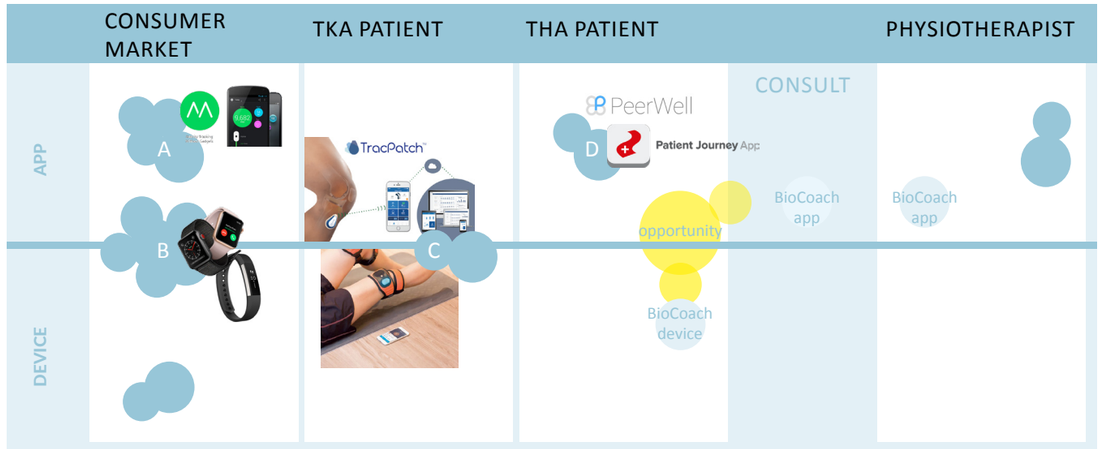


Figure 2-5 Examples of existing products within the domain of (rehabilitation) physical activity coaching for better self-management. The opportunity area of the BioCoach (yellow spot) is a product- service combination with relevant measurement and analysis functions combined with a suitable interface for total hip patients.

Displayed product examples:

<u>A) Activity tracking applications</u>
- Moves: The app Moves automatically records any physical activity like walking and cycling by keeping a smart phone in your pocket or bag. Insights are given in e.g. distance, duration and steps for each activity. The app is always on, so there's no need to start and stop it. Source: https://www.moves-app.com

<u>B) Combi device & app for consumer market</u>
- Apple watch: A line of smart watches, which incorporates fitness tracking and health-oriented capabilities with integration with iOS and other Apple products and services. Apple Watch relies on a wirelessly connected iPhone to perform many of its default functions. Source: https://www.apple.com/nl/watch/close-your-rings/
- Fitbit: a line of wearable fitness trackers. Source: https://www.fitbit.com/home

<u>C) Combi device & app for TKA patients</u>
- TracPatch: a wearable device that remotely monitors a patient's post-surgical activities by continuously sending activity data, including range of motion, ambulation, exercise compliance, and wound site temperature. It enables the healthcare provider to collectively and continuously monitor their patient's progress. Source: http://www.tracpatch.com/
- Kneesup: A knee rehabilitation system integrating smart wearable devices and mobile application. The product aims to help the user improving osteoarthritis from early rehabilitation to future long-term knee health care. Source: https://www.red-dot.sg/en/kneesup/

<u>D) App for (THA) patients</u>
- PeerWell: PeerWell helps THA and TKA patients optimize their health before surgery to recover faster. Leveraging evidence-based health science, the PeerWell app delivers customized daily lessons that are proven to better the results of hip or knee replacement surgery e.g. Source: https://www.peerwell.co
- Patient Journey App: An app with which a healthcare institution informs patients and family members about the treatment, by providing dosed, structured and interactive information to the patient at different time stages. Source: https://patientjourneyapp.nl

The medical applications are mostly designed to help patients with their self-management. These apps could facilitate in information and coping behavior. Also platforms exist that connect peers and companions in online communities.
The applications are made for patients or for healthcare professionals, but never for both and don't stimulate their teamwork, in contrast to the BioCoach.
Looking to medical devices that measure and analyze movement, some interesting knee and gait analysis products exist, that show functionalities that are relevant for hip patients. Though, a gap exists in a product-service combination with relevant measurement and analysis functions combined with a suitable interface for total hip patients (yellow spot in Figure 2-5).
A consumer product such as the Applewatch could replace many health care products in functionality, since it has good sensors, excellent battery and a link with telephone. However, there can be an overload of functions and options. In the BioCoach, the intended interface and usage are different; it is made user-friendly for the elderly without an overload of functions. This adds value to the BioCoach.

2.1.3 DISCUSSION AND DESIGN OPPORTUNITIES

DESIGN INPUT

(1) Physical coach
The choices of the AED design team about exercises and pain monitoring are based on the input of a small group of physiotherapists that were interviewed. The participating physiotherapists all prescribed specific exercises and were open to innovative products.
However, not every physiotherapist or orthopedic surgeon has the same vision on the utility of these exercises during rehabilitation. It is relevant to find out if every hip patient benefits from these exercises and how patients can be physically optimal supported. How is the development of treatment in the future and does these exercises cover the whole package of physical rehabilitation? In chapter 2.2 an answer will be found on this question.

(2) Placing of the device
The BioCoach will be worn over the pants, which is not pleasant for patients that are used to wear long skirts. Possibilities for other, more comfortable places can be explored.

(3) Application facilitating patient's needs
The current BioCoach application is only available for the physiotherapist, because of the main target group of the BioCoach: elderly, who are often not familiar with smart devices. So a choice was made to limit the interaction between the patient and the BioCoach with the physical band.
However, in the future more and more elderly will have affinity with applications on smart devices. This will create a lot of new opportunities in support during rehabilitation, for instance by providing information, showing insights and creating awareness and certainty. Therefore, the possibility of a product-service combination for the patient will be incorporated during the analysis and design phase.
The first step, to create a successful digital service, is to understand what patients really want (Biesdorf, 2014). In chapter 2.3 and 2.4 these patients' needs will be explored.

2.2 Rehabilitation Journey

This project is about rehabilitation of patients with a total hip replacement. However, the preparation for rehabilitation starts already before the surgery. So in this chapter, the whole THA patient journey starting from pre-operation till rehabilitation aftermath will be explored.

Goal of this chapter is to find out:
- how the THA rehabilitation process looks like;
- who is involved in this process and what their roles are;
- what important factors are that could influence the rehabilitation process, for instance in duration and heaviness

Beside this, it is relevant to know what role the BioCoach could play for different stakeholders. The product could be beneficial for patients in their rehabilitation, but perhaps also for the involved (informal) caregivers. During field research, the experiences and possible needs of physiotherapists during THA treatment is investigated. Also, field research is done in the hospital during a THA surgery day, to create a good understanding of the patient's experience of the hospitalization phase before going home and starting with the rehabilitation process.
After both literature and field research, the chapter concludes with a rehabilitation journey of the desired future situation, in which different insights of the analysis are integrated.

2.2.1. INTRODUTION IN THA SURGERY

LITERATURE RESEARCH

Hip replacement surgery is a surgical procedure in which the hip joint is replaced by an artificial joint, that is, a hip prosthesis. In the Netherlands, several different total hip replacement surgery approaches are used. The posterior approach, direct lateral approach, and direct anterior approach are by far the most common across the globe (Moretti, 2017).

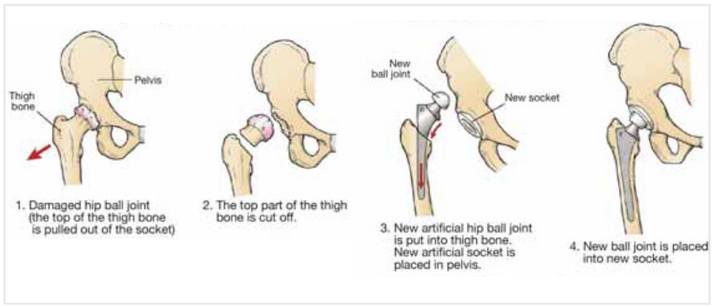


Figure 2-6 Procedure of Total Hip Replacement

The different surgery approaches result in different rehabilitation journeys, mainly in duration. The posterior approach is the conventional and most commonly used method. Because the muscles that holding the new hip were cut, this approach requires a longer recovery time and several movement restrictions to prevent dislocation of the new joint while the muscles heal.
In the anterior approach, the surgeon moves muscles aside rather than cutting through them. Advantages of this surgery are that the risk of dislocation after surgery is lower, so the postsurgical movement restrictions may not be necessary and recovery times are faster (Driggers, 2012).

According to orthopedic surgeon S. Vehmeijer, the variation in approaches will remain in the coming years (personal communication, February 1, 2018). The BioCoach is suitable for all total hip replacement patients, independent of the used surgery technique.

Nowadays, day treatments become more common. Nevertheless, the patient journeys visualized in this chapter, are based on a patient that stays in the hospital for 3 days.

Phases
A total hip replacement surgery includes different phases, starting with the first consult with a general practitioner (GP) and ending with the rehabilitation at home and the aftermath. In Figure 2-9, the current rehabilitation journey with all involved people and their role is visualized. This is done by looking into the information map of the THA patient (Figure 2-7) and by talking to a physiotherapist (W. van Dijk, personal communication, September, 2017) and an orthopedic surgeon (S. Vehmeijer, personal communication, October, 2017).

Figure 2-7 Information map for THA patients

The journey zooms in on the phases that relevant to rehabilitation, namely the pre-operative phase, post-operative phase and rehabilitation phase.

During the pre-operative phase, the patient receives a lot of information from the hospital about the surgery and usually there is a briefing with companions.
The THA surgery will be followed by the post-operative phase, in which the patient will see a physiotherapist and practise walking with the new hip for the first time.
After hospitalization, the patient is going home; most of the time a relative could drive the patient home. Then, the rehabilitation phase will start.

Stakeholders
The target group of the BioCoach consists of patients who received hip replacement surgery and their involved medical professionals (physiotherapists and orthopedic surgeon).
The relation between the different stakeholders, as described by the AED team (2013), can be found in Figure 2-8. In Figure 2-9, the roles of all involved people are mapped out.

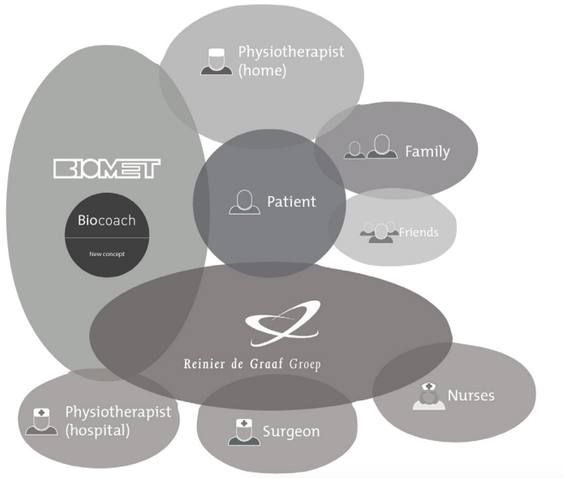


Figure 2-8 Stakeholders (AED team, 2013)

Rehabilitation Journey - current situation

Total Hip Arthroplasty (THA)

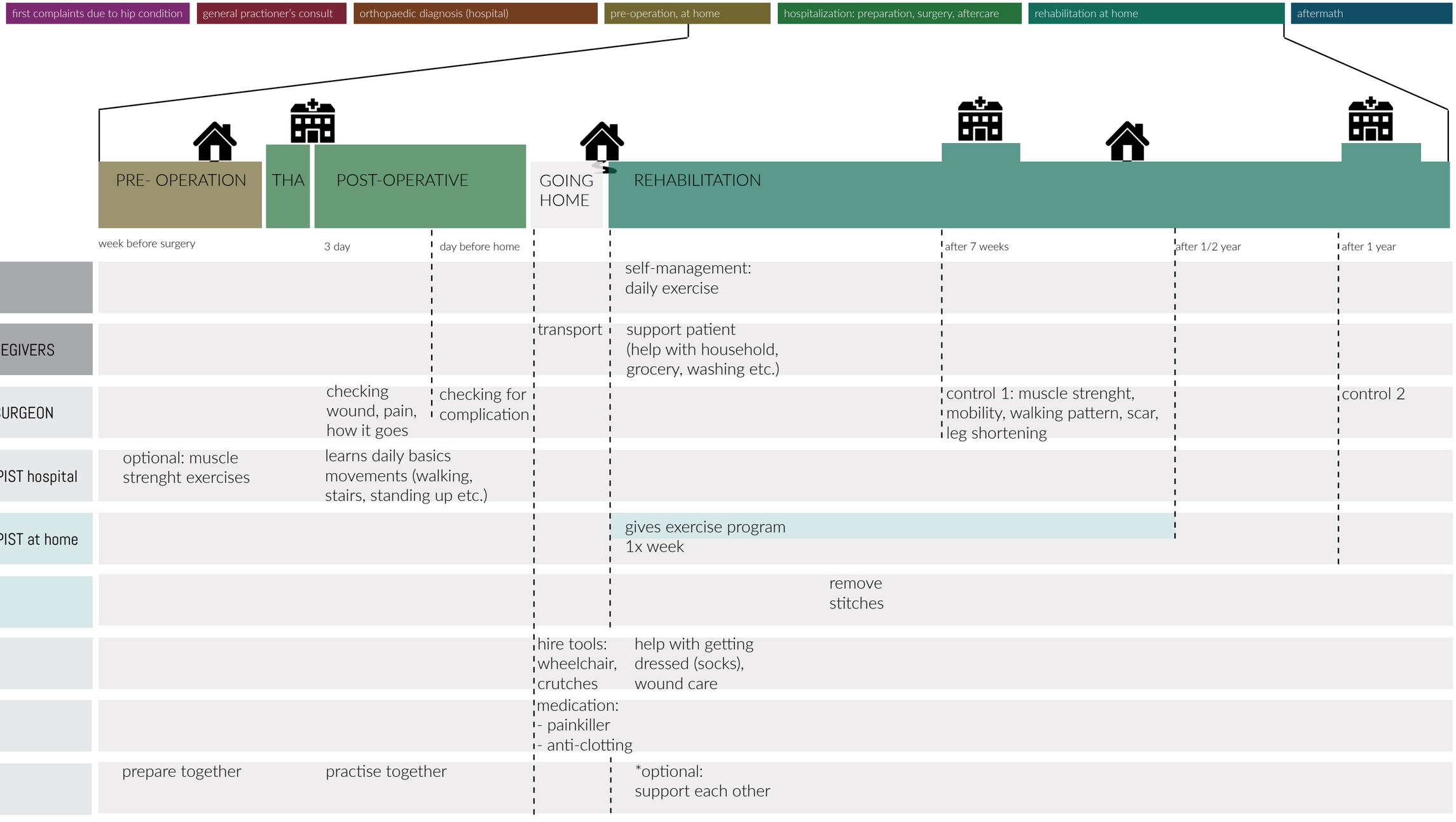


Figure 2-9 Current situation of the general THA rehabilitation journey

LITERATURE RESEARCH

Factors that influence the rehabilitation journey

Different factors could influence the rehabilitation process, for instance in duration and heaviness. A literature research is done to create an overview of factors that must be taken into account while designing for THA patients. Also several factors are pointed out by healthcare professionals in the previous field researches and during talks with physiotherapists and orthopedic surgeons. Most important factors will be discussed in this chapter, including physical health (body condition, mobility, muscle strength, pain, complications), mental health, self-management (coping behavior, adherence), home situation and surgery techniques.


Physical health


Mental health


Self-management


Surgery techniques


Home situation

Physical health

Postoperative

After hip surgery, postoperative physiotherapy is recommended. Preferably strength and functional exercises to increase mobility, improve muscle strength and reduce pain. According to the 'Koninklijk Nederlands Genootschap voor Fysiotherapie' (KNGF, 2010) exercise therapy has been proven to be effective to reduce pain and improve physical functioning in the short term and must be done under supervision. Depending on the body condition, the physical therapist gives instructions about physical exercise and may continue to work with the patient. The content and intensity of the exercise program should be adapted for each patient to individual objectives at the level of their limitations in activities or participation.

Nevertheless, the effect of exercises in long term has not been proven, tells orthopedic surgeon Stephan Vehmeijer. Also, some physiotherapists are not like-minded about exercises and prefer to prescribe just walk training, as could be concluded from the interviews with physiotherapists in chapter 2.2.3.

However, some people benefit from postoperative muscle strengthening exercises, for example if the muscle strength is greatly reduced by prolonged pain and arthritis. So, two groups of patients can be distinguished here:

1) Patients that benefit from walking training supplemented with muscle strengthening exercises;
2) Patients that rehabilitate with only walking training.

Preoperative

Based on the current evidence, preoperative physiotherapy is not recommended by the KNGF (2010), but it can be considered for individuals if there are many functional limitations preoperatively. According to Sharma (2009), preoperative physiotherapy may facilitate faster postoperative functional recovery, but multicenter and well-designed prospective randomized studies with outcome measures are necessary to confirm its efficacy. The KNGF does not recommend preoperative information for patients to shorten hospital stay, improve pain, adherence after surgery, patient satisfaction, ROM, mobility or prevent thrombosis, but it can be considered if there is fear of the operation and the post-treatment (See Appendix 2).

Orthopedic surgeon Stephan Vehmeijer explains that preventive physiotherapy may prevent surgery; strong muscles could reduce osteoarthritis, and also reduces pain.

Pain

Pain is a signal from the body to indicate that something is wrong; therefore it is of vital importance for the maintenance of healthy tissue. But living with pain is counterproductive to the recovery. According to Sharma (2009), postoperative pain may influence the patient's ability to participate in rehabilitation. Pain can interfere with both rest and exercise after surgery. Also, pain is the biggest reason that patients stay longer in the hospital. When pain is reducing, patients dare to go home earlier.

Pain can be partly reduced with exercising and with painkillers. However, taking in lots of medicines can cause unpleasant side effects, so it is preferable to take painkillers as little as possible. Of course, this would also save lots of money. Most painkillers in the world is used in the USA. Quoting J. Avila (2011):

"It is unclear if Americans are suffering from more pain than ever, but they are definitely getting more prescriptions for it. [..] Experts say most of those prescriptions are unnecessary. The United States makes up only 4.6 percent of the world's population, but consumes 80 percent of its opioids."

Designing something to manage pain and the usage of pain medication could be valuable for the patients themselves and interesting from a business point of view. This idea suits Zimmer Biomet's focus on rapid recovery and preparing patients to go home quickly.

Mental health

Several psychological aspects influence recovery after total hip arthroplasty, such as depression, anxiety, resilience, and personality traits (Benditz, 2016). THA patients with low depression and anxiety levels have significantly better outcomes with respect to early hip functionality. Elderly persons with depression symptoms tend to underrate their self-report activities of daily living, so the association between depression and functional recovery may be a bit inflated (Jelicic, 1996). A wearable monitoring device, such as BioCoach, could give a more reliable view on this relation.

Self-management

As stated in the introduction background chapter (1.1), the need for active patient participation in care is becoming more important and increasingly expected from the government and society. The focus of the postoperative phase switches more to self-management, resulting in the fact that the responsibility of rehabilitation lies with the patient.

However, not every patient is equally capable of doing that, due to for instance a lack of knowledge, available information, motivation or self-confidence (Rademakers 2016).

Three in ten Dutch adults experience difficulty in finding, understanding and applying health information. Higher levels of self-efficacy results in lower postsurgery depression scores (Hartley, 2008). In terms of self-direction, 48% of Dutch people struggle to manage their health, illness and care by themselves. This lower health literacy is related to poorer health (Rademakers, 2014).

Also, in the Netherlands, 13 percent of the population is low literate. They have difficulty with reading, writing and often also with arithmetic. Technically they can read a text such as "two pills twice a day", but they cannot apply it properly, according to research. Care providers often overestimate the ability of patients to live healthier lives, but low-literate people often miss the 'doing ability, as the WRR pointed out. This problem with low-literate people is increasing (Huijbregts, 2017).

Adherence

Poor adherence to the physiotherapy home program is a problem with up to 65% of patients. Approximately 10% of patients fail to complete their prescribed physiotherapy treatment (Bassett, 2003). If adherence is proven to be less than desirable, an effective solution to the problem can only be sought when its underlying reasons have been identified (Bassett, 2003). In a study of Jack et al. (2010), strong evidence for barriers to treatment adherence were found, namely low levels of physical activity at baseline or in previous weeks, low in-treatment adherence with exercise, low self-efficacy, depression, anxiety, helplessness, poor social support or activity, greater perceived number of barriers

to exercise and increased pain levels during exercise (Appendix 3).
The findings of a systematic review of Essery et al. (2015) indicate that greater self-efficacy, self-motivation, social support, intentions and previous adherence to physical therapies predict higher adherence to self-managed, home-based physical therapy.
So, interventions to support patients' self-managed physical rehabilitation should include elements designed to enhance patients' self-efficacy, self-motivation and social support.

Home situation
The home situation could influence the duration of hospitalization after surgery and the type of aftercare at home. For instance living without a partner or children at home will require more preparation and thinking ahead to deal with situation that are hard to carry out by the patient in the period after surgery, such as doing groceries and the household.
Home care can play a role here. But also getting some mental support and a feeling of security.

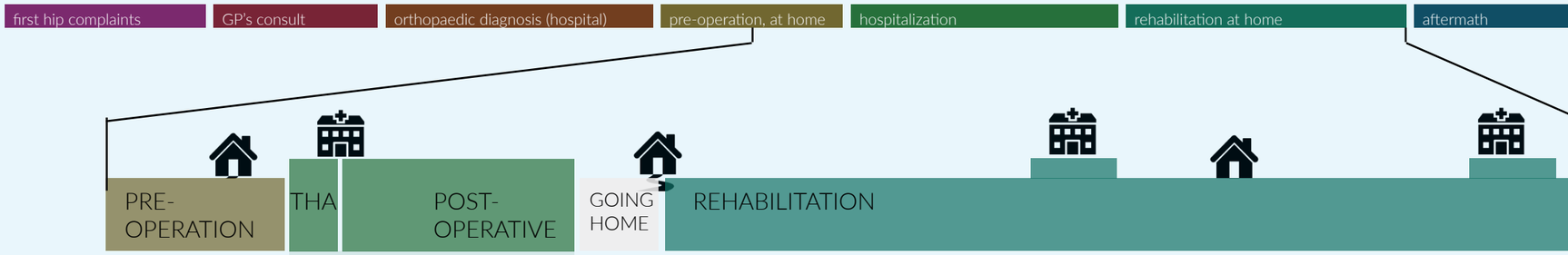
Surgery techniques
As discussed in chapter 2.3.1, different surgical techniques could influence the duration of rehabilitation.

The 5 factors discussed above could change per patient. In chapter 2.3, there will be analyzed if there are groups of patients who have significant similarities in these factors, so that patient's profiles could be defined to be able to tailor healthcare products.

2.2.2. FIELD RESEARCH THA PATIENT

FIELD RESEARCH

Patient journey on a THA surgery day
During one day, a patient is followed in the Reinier de Graaf hospital from the moment before surgery till an hour before going home. The patient (Patient B) is a Dutch man (70+) who got an 'ASI THA surgery' at his right hip, due to osteoarthritis of the hip bullet joint. He was experiencing worsening pain that started ten years ago. Last year, his women received the same type of hip surgery, which resulted in a successful and satisfying outcome. The patient is getting a day treatment, so he can go home the same evening. During surgery, no special conditions need to be taken into account, such as allergies.
An overview of the day will be given.



Pre-operative phase (06.30 -08.15)
Before surgery, the patient lies in an anaesthesia room. The state of mind of the patient is serene: he seems to be relaxed and has a very positive and realistic attitude regarding the surgery. He explains: "Preferably you don't have a surgery of course, but if it is necessary, it's great that this opportunity exists and I'm very grateful for all the good care and all friendly, involved caregivers here. It is useless to worry about things you don't have an influence on, I trust the surgeon and nurses for doing the right job."

Surgery phase (08.30-09.20)
The patient goes to the Operating Room (OR). Before falling asleep because of total anaesthesia, the patient can choose the background music, which also will be played during awaking after surgery. He appreciates this opportunity very much. Later he indicates the importance of music in his life; it is an expression of your emotional state.
The surgery is going well, no complications take place (such as extreme blood loss or leg length discrepancy). If complications would have appeared during surgery, it would not have a big influence on the rehabilitation process. Total duration of his operation is 38 minutes.

Post-operative phase (09.20-19.00)
09.20 Directly after surgery, when the wound is sutured in the OR, the anaesthesia stops working and the patient is awaking. He is not dazed and is therefore immediately approachable. While still lying in the OR, he directly could call his woman, to say that everything went well.

(09.30- 09.50)
The patient is being transferred to another room, the recovery room. Some vital checks are done, such as heart rate and blood sugar. The patient is feeling well and is able to talk about some of his experiences.

(09.55 – 19.00)
After 20 minutes, the patient goes to a personal room in the orthopedics department. Here, the patient stays for the rest of the day. During this time, the patient can rest and can receive visitors such as family. During the day, the patient is feeling good and likes to talk about experiences. He is not experiencing lots of pain, but feels the wound. He is immediately able to walk quite well, using crutches. He doesn't have the feeling that he got a surgery at all.

Some essential moments in the department:
-Nurse is checking vitals, such as blood pressure and sugar. The patient's conditions are good.
-Nurse is helping the patient with getting dressed.
-Patient gets food from the nurse (in the morning, lunchtime and diner)
-Physiotherapist is visiting the patient two times during the day. She gives exercise advice and will practice with walking with crutches. The patient directly can put his full weight on his right leg. This is possible for all hip patients. Although in the past, patients were more cautious about the advice on loadability. The treatment basically consists of walking and just some basic movements in the morning to stretch the body muscles. Everyone has another start level with walking, so the right amount of steps is a bit based on trial and error. It is better going too slow than going too fast!
The patient emphasizes during walking, that he is not feeling at all that he got surgery.
-Around 16.00, the orthopedic surgeon is visiting the patient to ask how it is going and gives a last advice and a hand.

Going home…
At home, there will be taken care of the patient by his women and probably neighbors and friends. A good friend, who is physiotherapist, will coach the patient in his walking pattern, when needed, so no additional physiotherapy treatment is desired. The patient emphasizes that it is a privilege to have good people around you, who you can trust.
The patient has a map from the hospital with information about the THA phases, but thinks he will not need it. "It's all about common sense, accepting the situation and listening to your body while practicing with walking." "Listening to advises and looking to science is useful, but finally you need to make your own choices and considerations, seeing things in the right perspective and be open to do compromises. There is not just one good road."
But the patient can imagine that if people are experiencing fear to walk again or for instance people who are living alone, support could be desirable.

** The patient wrote a letter about his experiences of his surgery day. This letter can be found in Appendix 4.*

Figure 2-11 Photos of the THA surgery day

After 1 day (17-10)
"Ongelofelijk, maar ik loop weer vrijwel normaal door mijn huis: heerlijk
Was gisteren een perfecte dag met alle begeleiding van alle vriendelijke mensen. Ik zou Dr Vehmeijer nog even een mailtje willen sturen om hem te informeren over het perfecte verloop in het post operatieve traject.
Vanmorgen was de fysio-therapeut hier bij me. De pijn is betrekkelijk gering, maar dat zal ook wel te danken zijn aan de pijnstillers."
"Voor de operatie vroeg ik of het infuus wat hoger kon. Dat was het meest traumatisch van de hele operatie, oftewel het viel dus enórm mee."

Eigen initiatief infuus

After 5 days (21-10)
"Ik kan je mededelen, dat ik maandagavond van mijn vriend Ton(de fysio) bij thuiskomst onmiddellijk mijn krukken moest opbergen en dat ik dientengevolge direct zonder enig support door het huis wandelde, tot grote verbazing van mij en mijn kinderen en kleinkinderen. De nacht heel goed geslapen, waarschijnlijk door de kracht van de pijnstillers en de andere ochtend met mijn echtgenote opgestaan om in het huis de normale bezigheden te doen: ontbijt, ochtendblad en achter mijn PC.
In de middag 3 uur heerlijk geslapen. Dinsdag voor het eerst weer naar buiten het blokje rond. Kostte wel wat energie -enkele stops in moeten lassen- maar verliep toch heel bevredigend. Van Ton wat oefeningen opgekregen die ik dagelijks uitvoer, met name om de spieren weer aan een normaal patroon te laten wennen. Nu iedere dag een klein beetje beter.
Samenvattend: van de nieuwe heup geen enkele last. De enige beperking is de wond -pijnlijk- en het herstel van de spieren, hetwelk volgens Ton in totaal wel 4 tot 6 weken kan gaan duren. In totaliteit een ongelofelijk positieve ervaring m.b.t. de Nederlandse gezondheidszorg!!"

22-10
"Alles gaat nog steeds voorspoedig en de operatie lijkt veel langer dan nog maar een week geleden."

After 8 days (24-10)
"Alles gaat goed hier. Vanmiddag belde Stephan nog even: sympathiek!"

Gemist in traject:
Ze zeiden 'denk eraan er kan een terugslag komen'. Na 14 dagen opgezwollen been met vocht: daar heeft niemand iets over gezegd van tevoren. Niet op voorbereid. Opgelost met een steunkous van mijn vrouw en massages.

Eigen oplossing

After 2 weeks (30-10)
"Vandaag ter controle van de wond in het ziekenhuis geweest. Geen bijzonderheden, zij het dat de wond nog behoorlijk gezwollen is -bloeduitstortingen en vocht- en mijn rechter been in totaliteit nog dik is. De bloeduitstortingen worden inmiddels minder. Het totaalbeeld blijft gelukkig positief, Vrijwel geen pijn meer en steeds mobieler."
"Minpunt bij de wondcontrole: assistent zei 'ze hebben spieren & zenuw doorgesneden'. Dit klopte niet.."

After 6 weeks (27-11)
"Met mij gaat alles goed en wij hadden een heerlijke tijd in Frankrijk. Iedere dag heerlijk nazomerweer goed genoeg om buiten te zijn en te **zwemmen**."

"Ik ken geen pijn van de heupoperatie. Vanaf 16e jeugdreuma, dus weet wat pijn is. "

Geen pijn, voorspoedig herstel

Conclusion, from a designer's perspective
Looking at the three defined patient clusters defined by T. Dekkers (explained in chapter 2.3), it seems that this patient definitely belongs to the 'optimists' group, based on this first day experience. Because of his positive, grateful and realistic attitude, intrinsic motivation and informal caregivers around him (family, friends, neighbors), it seems that no supportive tools are needed for a successful recovery. However, the question is whether he remains an 'optimist' during the rehabilitation. Perhaps he is a good bluffer or the aches and complaints come a few days after the operation. Who knows, his profile may change. It would be interesting to see how the rehabilitation process is going after a few days and weeks.

PRESENTATION AND ATTITUDE OF PATIENTS

Presentation of patients - nothing is what it seems to be
For patients, it is sometimes difficult to communicate what they actually feel or want. It may be difficult for the patient's environment and healthcare providers to know how the patient's story should be interpreted and what the patient really needs.
It can happen that something will be exaggerated, such as pain catastrophizing; or something is minimized or completely disregarded, for example in camouflage behavior by a person with a proud, positive, modest or independent attitude. Also, information could be not reported, because it is forgotten or not noticed by the patients themselves, e.g. due to ignorance, tension or no experience with the context. Or, extra or irrelevant information is made up, for example lying about medication use or because they want to get more attention (van Duijn, 2014).

This makes the collaboration between patient and caregiver - and thus an effective rehabilitation treatment - more difficult. The BioCoach could potentially play a major role in finding out the underlying needs in the presentation of the patient.

Optimists vs. pessimists - Case study patient B
Patient B (see previous paragraph) seemed very relaxed, but afterwards it turned out he was nervous and had the feeling that he would die on the operating table, according to his physiotherapist. Patient B was delighted that someone was sitting next to him on his surgery day; since he had all day personal attention, support, security and reassurance. As if he could hold a hand all the time. The patient's concerns were definitely not turned out on the surgery day itself. His physiotherapist stated that Patient B is brilliant in hiding his unpleasant emotions. He has a high IQ and EQ.
These patients create, sometimes unconsciously, a certain picture of how they would like to be seen by the outside world. They do not want to be seen as weak and pathetic. Also, many patients find it difficult to ask for help. Therefore, they prefer to seek help in their inner circles. Towards caregivers, you could encounter a pattern: "I can do it all by myself, I do not need help". In this way, healthcare providers in the hospital can be informed wrongly by the patient and are unaware of the patients' actual feelings and needs. This does not have to be unwillingness of the patient. Judging too quickly by care providers what a patient means or needs can lead to wrong decisions or poor care.

Hiding your feelings for the doctor could be named as 'camouflage behavior'. This camouflage behaviour is commonly seen among intelligent people. They are stars in not showing that they actually find the surgery traject scary and they present the situation as positive. It can be discussed if this camouflage behaviour is smart behaviour. According to Singh et al. (2016), a positive atmosphere and attitude gives beneficial outcomes after total hip arthroplasty. In their study they concluded that a pessimistic explanatory style before surgery was associated with significantly less favourable improvement in function, activity limitation after primary THA and possibly higher risk of pain. In a study of Ferreira (2007) with individuals with osteoarthritis, greater optimism and support were significantly related to both greater life satisfaction and lower depressive symptoms. Furthermore, optimism partially mediated the relationship of pain to life satisfaction, while support partially mediated the role of pain in depressive symptoms.
So concluding, a positive attitude and fooling yourself and your environment a bit with camouflage behaviour around the surgery seems smart.

Nevertheless, it is important that patients get the treatment and support they need and deserve.
In the case of patient B, the patient is also smart enough to arrange good aftercare by (informal) caregivers. A strong and empathetic environment is important to deal with mental issues as anxiety. Good information and empathic behaviour of both relatives and caregivers in any form is very valuable.
But what if the patient has few family or friends, not a stable home situation or found it difficult to ask for help to both caregivers and relatives and be a burden to someone? This could be the case with people who have a proud, modesty, tough or strong attitude who don't want to whine and want to solve everything themselves. In this case the patients could deprive themselves of sufficient care.

Offering support in a very low-threshold, non-obligatory way (with 'velvet gloves') may help. The BioCoach can respond to this. For instance in naming 'mental or psychological help' something more down to earth such as 'having a little conversation'. Also, communication with a product feels more anonymous, there is no pressure of seeing a healthcare professional, which could create limitations in sharing feelings and thoughts. Beside this, the BioCoach could facilitate a positive environment and play a role in stimulating a positive attitude among patients.

2.2.3. FIELD RESEARCH PHYSIOTHERAPIST

FIELD RESEARCH

For a designer, it is desirable to be able to empathize with your target group, to understand their needs and get more feeling with the situation. Therefore, talking with the target group is helpful (Stappers, 2012).
Beside this, different questions arised that are not yet answered during the target group analysis with existing literature and reports. So a field research is set up and will be explained here.

As mentioned in chapter 2.1, the AED design team already did some interviews with physiotherapists during their project in 2013. Their research goal was to define an optimal feedback system for the patient through identifying their needs and requirements. They firstly asked general questions about the consultation, for instance about the duration and frequency. Then, they asked about the content of the home exercising program.
Questions about the needs of the physiotherapists themselves and their vision on their role in the future are not incorporated. At this point the situation of physiotherapy treatments may have changed, due to improved surgical techniques and cuts in healthcare. Also, it would be interesting to know if the BioCoach could play a beneficial role in other fields of rehabilitation, beside a physical treatment coach. Perhaps it could fulfill other needs of the physiotherapist themselves, that are probably not identified yet.

Aim
The main question of this field research is:
How could the BioCoach play a beneficial role in the perspective of the physiotherapist?

Eight sub-questions are formulated:

- Are there differences in approach of the treatment per physiotherapists? So how does their THA treatment look like and what is happening during one consult in tasks and time?
- How do they experience the administration tasks?
- How often do they see complications or difficult situations in patients and how do they deal with this?
- Do patients get fewer consults nowadays because of cuts by the health insurance? If so, how can a patient recover well, how is this captured?
- How is the teamwork and involvement of other stakeholders, such as the specialist, informal caregivers or home care?
- What does the future of physiotherapy look like? Would the role of the physiotherapist change in the future? How?
- What does their ideal physiotherapist treatment look like?
- How do they think of supportive products or a technical tool, which could help the patient in recovering at home? What could a role of such a tool be like?

Method
Semi-structured interviews were conducted face-to-face or via telephone with 9 physiotherapists, working in the South-West of the Netherlands. During the interview, the function of interviewee and stenographer have been both done by myself.
All physiotherapists had experience with hip patients and worked in private clinics, since most hip patients are going there and they are most nearby the patients home. Physiotherapists in a nursing or rehabilitation center are most times working with patients with more complications.
To analyze the content of the interviews, a *qualitative content analysis* is done in order to identify main themes that emerge from the responses.

Results
The total transcript of the interviews can be found in Appendix 1. Here, the outcome will be summarized, clustered into main themes: treatment approach; administration; teamwork and complicated care; support tools; future role of physiotherapist and differences between patients.

Treatment approach

There are differences in approach of the treatment per physiotherapists. All physiotherapists are using treatment guidelines of the KNFG, but their vision on duration and exercises of the treatment plan is different. Some are more focusing on separate exercises; others are focusing on posture and daily movements, especially walking. According to P5: "*The best exercise is walking. The quality of walking is essential.*"
Also, the posture is fundamental. P8 indicated: "*The head needs a reference system, the motor skills work best with orientation on the horizon. Imaging affects upright walking*."
According to the interviews, we can conclude that relevant points in rehabilitation are:
1) Work on a good posture (head balance). Mirror yourself, so you see what you're doing and be aware how you walk. Imagine the process of rehabilitation.
2) Work on muscle strength, mobility, when needed
3) Work on walking training (first in a bridge or with crutches and then independent)

Administration

All physiotherapists indicated that the amount of administration is not realistic for the short time of a treatment consult and results in less time for the patient or unpaid extra work for the physiotherapist. So, two solutions could be: more available time for one consult or less administration. The first solution could only be solved by the government or healthcare insurance. In the second solution, the BioCoach could play a positive role.

Teamwork and complicated care

Teamwork between physiotherapist and other caregivers doesn't occur often.
In situation of complex care with psychological aspects or when complications take place, a multidisciplinary approach could be beneficial. Nowadays, the different professionals don't have time and a medium to have contact with each other in their work. It could be unclear for patients which healthcare professional they need to approach and care professionals can give contradicting advices to patients. Beside professional care providers, it is pleasurable to involve informal caregivers in the process.

Support tools

Different roles of support tools during rehabilitation treatment that are suggested by the physiotherapist are: motivator; monitoring of activity, mobility and pain; explaining the content and frequency of the treatment plan; providing good information and preparation.
Good information and preparation gives support and security that can prevent anxiety.
Beside this, P7 stated: "*You can measure mobility and pain, but probably not your own walking pattern and posture, which is the most essential. You need to observe this. Counting steps says nothing about the quality of walking, while this is what matters most*."
They call such a tool as an addition on the physiotherapy treatment that could lower down the amount of consults. They don't see support tools as a total replacement of the physiotherapist, since they value human contact.

Future role of physiotherapists and differences between patients

All physiotherapists indicate their role is changing into coaching and prevention.
Multiple physiotherapists indicate that nowadays more THA patients rehabilitate independently, without the coaching of a physiotherapist. They think that less THA patients will need physiotherapy in the future, for instance because of better surgery techniques. Especially active people, for instance athletes who overloaded their joint, hardly need coaching. Also due to cutbacks, patients try to exercise by themselves, which is not always good. Some indicate patients are responsible for their own health, not the care provider, which is a switch in mindset compared to a few years ago. So, physiotherapy is desirable for everyone but not necessary for everyone; then you would deliver unnecessary care.
They also indicate that there will always be a group of patients who prefer to see a physiotherapist. The added value of a physiotherapist here is mostly the interpersonal contact; it is valuable to touch, communicate and reassure in fear, keep someone moving and motivate patients. Also, patients must regain the confidence in the hip area; it requires human hands to let people experience that they can load the hip again. These are in particular patients with fear of movement, and elderly, who often have multiple health problems. The biggest group of patients needs motivation.

Discussion
Since I asked the questions and notulated the answers by myself, the results could be influenced by my personal experience and interpretation. However, I tried to stay objective during the conversations and the interpretations of the results and tried not to influence the physiotherapists.

Some physiotherapists were more willing to talk extensively about their profession and took the time for the interview. Others were short-spoken. The sub-questions were used as a guideline during the interview, but sometimes questions are not answered. This resulted in nine different interviews, which have not an equivalent outcome in quantity of information, so some themes cannot be easily compared between the participants.
However, all physiotherapists had something interesting to add and the total amount of interviews gives a good feeling and idea of how physiotherapists experience and think of the THA treatment. New insights in the rehabilitation process of THA patients are gained and it is possible to draw some general conclusions.

Conclusion
After a rich collection of answers that physiotherapists gave - about their treatment approach, the administrative part, the added value and future role of physiotherapists, supportive products and noticed differences between patients - our main question can be answered: 'what could be potential roles of the BioCoach, which are beneficial for the THA process from the perspective of the physiotherapist?' These potential roles of the BioCoach could be further explored during the design process.

DESIGN INPUT

BioCoach role in physical treatment: posture and quality of walking
As mentioned by the physiotherapists, a good posture is important for balance and coordination; a slanted head and walking leaned forward can cause bad load on your joints. But also vice versa, an upright position of the head can correct the body posture. Without a good posture, people could waggle and rehabilitate badly. This can be confirmed in literature [Bobath Theory + Staarink, 2011).
The current BioCoach gives feedback on the quality of exercises, in contrast to many other activity trackers, which focus only on quantity. Beside this, it would be valuable if the BioCoach could coach on the quality of the posture of the body during walking and **imaging** this posture before walking.

BioCoach role in administration: automation in administration
Big part of the administration is about reporting the progress and conditions of the patient (Figure 2-10). These data could be measured with the BioCoach and automatically be processed in an administrative report. This need can be confirmed by S. Biesdorf (2014), who states that a commonly cited need for healthcare professionals includes support for repetitive administrative tasks.

BioCoach role in complicated situations and teamwork: creating a platform
The BioCoach application could provide a communication platform to connect healthcare professionals with each other during complex care, for instance a GP, physiotherapist and psychologist. Also informal caregivers could be involved. Complex care will increase coming years, due to the combination of more (chronic) diseases and an increase in multimorbidity (RIVM, 2014). By 2030, a sixth of all Dutch people have multiple disorders.

BioCoach role in support and preparation: providing individual information
Current folders and stencils with information are for lots of patients too extensive and too general. Informing and preparing someone individually and carefully in advance and knowing exactly what to expect, is much more effective. Also, translating the specialist's info to the patients in their own language is helpful. This can be done for instance in the form of text, images or video.

PHYSIOTHERAPIST TREATMENT JOURNEY
In Figure 2-10, the current physiotherpy treatment journey of THA patients and their physiotherapist is visualised and zooms in on a consult and the role of the physiotherapist.
Beside the journey, potential roles of the BioCoach are indicated, based on the input of the physiotherpists that participated during the field research.

Establishment of treatment plan
Currently, the physiotherapist is establishing a treatment plan based on the anamneses during a first consult with the patient.

A monitoring device, such as the BioCoach, could play a major role in establishing the treatment plan in frequency and heaviness of exercises, based on monitored activity.
However, this will not be further investigated in this project, because of the limited time span.

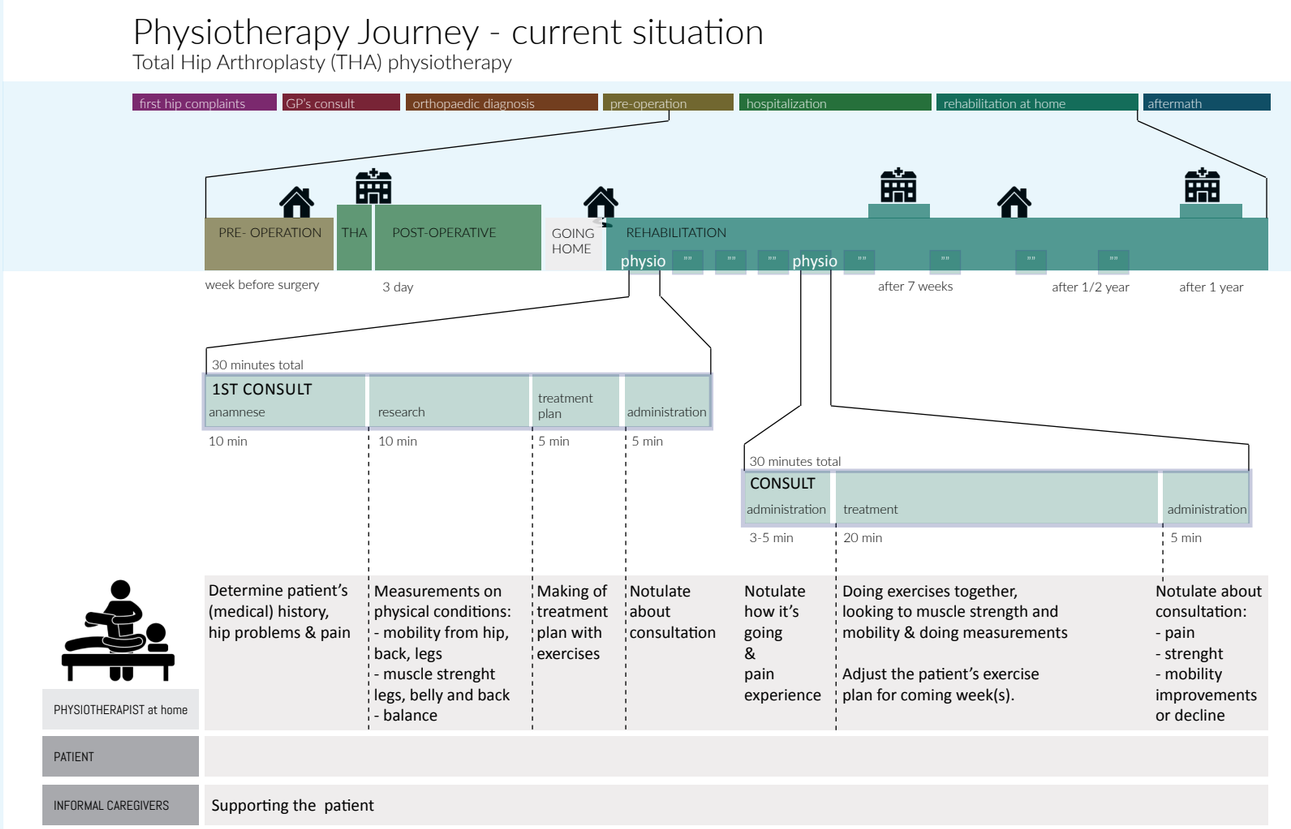


Figure 2-10 Current situation of the physiotherapy treatment

Rehabilitation Journey - future scenario with BioCoach role

Total Hip Arthroplasty (THA)

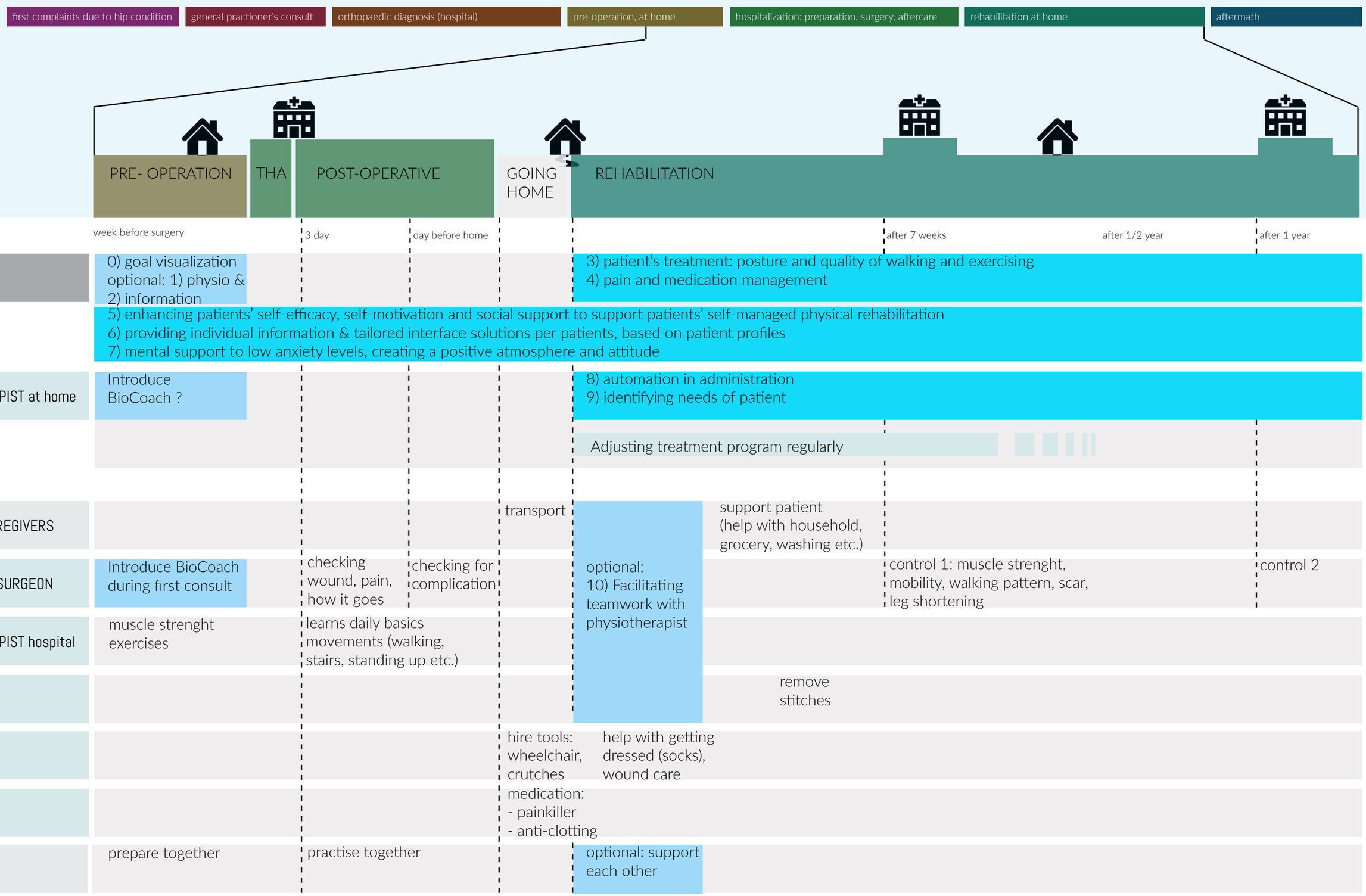


Figure 2-12 Future situation of the THA rehabilitation journey with portential BioCoach roles

2.2.4. CONCLUSION: REHABILITATION JOURNEY – FUTURE SCENARIO

DESIGN INPUT

To conclude this rehabilitation journey chapter, all design implications of this chapter are collected and translated into potential roles of the BioCoach. On the previous page, these BioCoach roles are visualized in the rehabilitation journey overview. Here, the roles are listed with the corresponding paragraphs between brackets.

Patient

Preoperative

• BioCoach's role in visualizing the end goal and movement after surgery [2.2.3]
• BioCoach's role in preoperative physiotherapy for individuals with many functional limitations preoperatively [2.2.1]
• BioCoach's role in preoperative information for individuals with fear of the operation and the post-treatment [2.2.1]

Postoperative

• BioCoach's role in patient's treatment: posture and quality of walking [2.2.3]
• BioCoach's role in postoperative exercise and walking training [2.2.1]
• BioCoach's role in pain and medication management [2.2.1]

Complete journey

• Introduction of BioCoach application for patients to support in self-management [2.1]
• BioCoach's role in patient's preparation: providing individual information [2.2.3]
• BioCoach's role in creating a positive atmosphere and attitude [2.2.3]
• BioCoach's role in mental support to low anxiety levels [2.2.1]
• BioCoach's role in enhancing patients' self-efficacy, self-motivation and social support to support patients' self-managed physical rehabilitation [2.2.1]

Physiotherapist & caregivers

• BioCoach's role in supporting physiotherapist's administration: automation in administration [2.2.3]
• BioCoach's role in identifying underlying needs in their way of presentation of the patient. [2.2.2]

Teamwork

• BioCoach's role in complicated situations and physiotherapist's teamwork: creating a communication platform [2.2.3]

Other

• BioCoach's role in researching the relation of depression and anxiety levels and functional recovery [2.2.1]

2.3 Patient Profiling: towards design guidelines

As discussed in Chapter 1, currently only one general patient is considered when designing healthcare products, unlike consumer products, where products are designed for specific customer profiles. How can a healthcare product, and in this case - a rehabilitation tool in THA - become more tailored? In this chapter, possibilities of patient profiling are explored.

Paragraph 2.3.1 discusses current knowledge of patient profiling. Furthermore, three patient profiles are chosen to further investigate throughout this project.

When designing a product for a specific group of patients, you need to know the needs and wishes of its user. The needs of the three defined patient profiles have not been established yet. So, in paragraph 2.3.2 and 2.3.3 information is gathered to make assumptions on needs during rehabilitation after a total hip replacement, for the three patient profiles. Both a quantitative and a qualitative data analysis are conducted. Herein a new research methodology is described and this method will be evaluated in a discussion. A definition of evaluation that is appropriate here:

> *Evaluation is a process of ascertaining the decision areas of concern selecting appropriate information, and collecting and analyzing information in order to report summary data useful to decision makers in selecting among alternatives (Alkin and Solomon, 1983: 14).*

Finally, the assumptions on needs of the different patient profiles are translated into a first set of design proposals for the BioCoach (2.3.4).

2.3.1. FRAMEWORK FOR PATIENT PROFILING

LITERATURE RESEARCH

What is customer profiling and why do we use it?

Customer profiling is a way to create a portrait of a group of customers, that helps to make design decisions concerning a service system. Patient customer profiling focuses on personal preferences, such as outcome expectancies and coping behavior. As stated in the introduction, by tailoring healthcare products, healthcare can become more efficient (Berwick, 2008), patient satisfaction and health-related outcomes may improve (Manary, 2013) and the market position of hospitals improves (Wolf, 2014).

How can customer profiling techniques be applied on patients?

When we think about characteristics of patients who got a total hip replacement, we know just one common thing for sure: their THA surgery. Colleagues in a company for instance, do often have the same level of education and interest in a specific work sector, but patients can differ in any conceivable area, such as character, personality type, intelligence, education level, interests, culture, origin, home situation, gender, age, appearance, health properties...

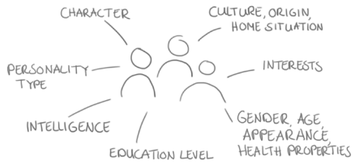


Figure 2-13

By designing tailored made healthcare products, it is not realistic to develop hundreds of different versions, tailored in function and user experiences regarding different patients. So if we want to design tailored healthcare products that meet specific patients' needs, similarities have to be found to be able to distinguish various, smart patient groups.

Looking at common factors, values are identified as stable factors that are applicable to different patient profiles— with the advantage that they do not change in a short time. As such, PhD researcher B.Groeneveld is exploring the potential of value themes (Schwartz, 2012) in patient profiling. A generative, quantitative study is done with THA and TKA patients, who have shared their experiences about their care process. Transcripts of these patients are clustered based on value theme, so that a value circle could be made of all each of these patients (Groeneveld, n.d.). The assumption is made that patients with equivalent value circles can be clustered and then profiles can be made from these clusters.

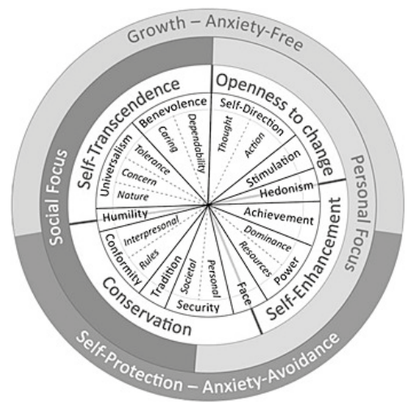


Figure 2-14 Value themes (Schwartz, 2012)

PhD researcher T.Dekkers is trying to find a set of validated patient profiles by doing quantitative studies (Dekkers n.d.). Main goal of this study is to formulate groups of patients that significantly distinguish themselves from each another. THA patients will be clustered based on relevant communication preferences and characteristics in segments. Satisfaction and clinical outcomes will be predicted for each segment. In this quantitative research study with almost 200* THA and TKA patients, characteristics of these patients are explored by using a questionnaire. The participants filled in a questionnaire, with questions about how they experience their health, what preferences are in communicating with healthcare professionals, sociodemographics and coping behavior for managing pain and stress. This questionnaire is based on Brief COPE (Carver, 1997).
Based on the questionnaire outcomes, a statistic data analysis is done and three patient profiles are defined. As a result of this, three tables with data per cluster are formed (Appendix 5).

3 patient profiles

The three clusters will be used in my research on designing tailored solutions in rehabilitation for different types of patients.

**the study started with 500 participants. Finally 190 participants filled in the form sufficiently to be able to contribute in the analysis.*

DESIGN INPUT

Design choices

Naming of patient profiles
To communicate about different profiles, it's easy to give the profiles a name to recognize them quickly. At this moment, three patient roles are used to indicate the profile: optimistic, managing and modest.

By using a name, it's not desirable to create a specific, prejudiced picture around a profile beforehand, especially when this is a negative picture. Options to refer a name to the role of a patient or the role of an interaction can be explored.
Another option could be a number or letter. However, than ranking may arise. A color might be suitable, since it could create a feeling about a profile, but just in a subtle way. A choice need to be made what a suitable solution will be in naming.

Determination of profiles
At this moment, determination of patient profiles is done beforehand, by using a questionnaire. Another option is to determine

the profile during usage of a product, in a less obtrusive way. For instance patients could choose several options and based on their preferences, a profile can be formed. This second method is done for instance on Facebook or Spotify.

Adaptation of profiles
After determination of the profile of a patient, this profile will be used during the care process. However, it could be possible that this patient will have another profile in different situations. For example, when a patient experiences a surgery for the first time, the profile could be different than when the same patient will undergo another healthcare intervention for a second time. The level of anxiety, communication needs or pain and coping could for instance differ.
According to Street et al. (2012), preferences might change after a certain experience in the care process. So a switch of profile must be possible for the same patient.

Beside a change in preferences after care processes, people's values can change over time, for instance because of traumatic or life-changing events.

We can also think of a change in coping and communication preferences because of skill development and life experience (becoming more assertive, increasing self-confidence or gaining empathy).
Another point is the knowledge of healthcare jargon: this can be learned over time or people forget about it due to age (eg. Alzheimer disease).

However, most patients who got a total hip replacement are elderly. Knowing this, their skills and values are likely not to change over the years. Most change will happen in younger years, except the forgetfulness.
Also, a change in people's values, coping and communication preferences and knowledge of healthcare jargon are for the longer term, they will not change from one day to the next. So it depends on the duration of a specific healthcare treatment if the option for adaptation must be available during the care process or between different care processes.
Since we are talking about a THA journey of a maximum of 1 year, we don't have to take this possible change into account within one THA journey, so during this project's design process.

How to design for these patient profiles
Once we have properly identified the patient profiles, we can find out what the different patients could benefit from during their rehabilitation. For this, we need to delve into the profiles and the interactions that these patients have with their healthcare professionals.
Patients' needs could be translated into design guidelines for support tools, such as the BioCoach.

In the next paragraphs, the patient's needs have been researched by analyzing both quantitative and qualitative data about the three patient profiles.

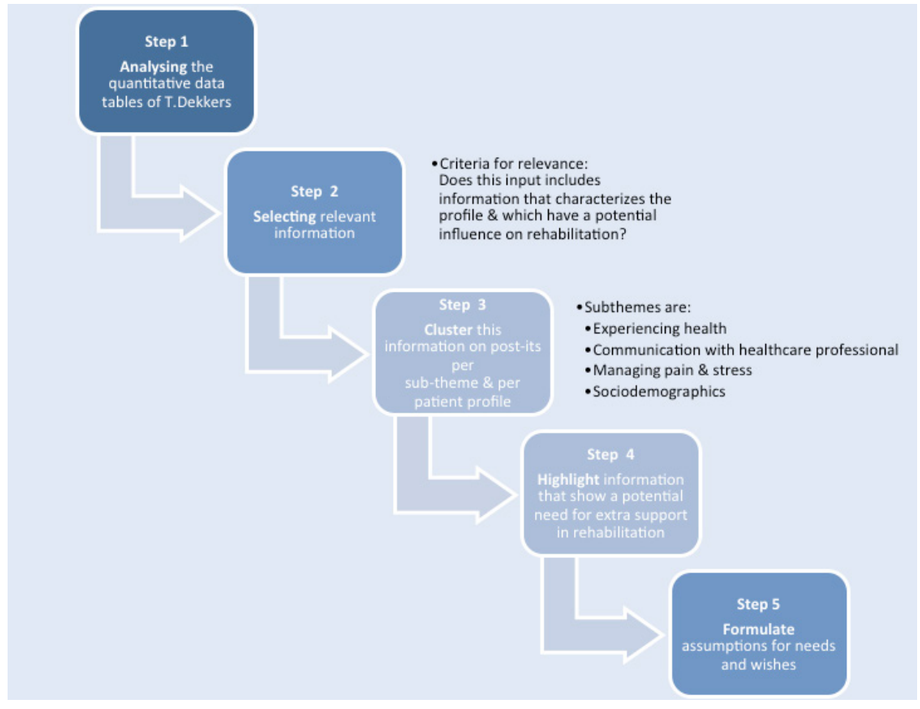
2.3.2. PATIENT NEEDS: QUANTITATIVE DATA ANALYSIS

Intro
When designing a product for a specific group of patients, you need to know the needs and wishes of the user. The needs of the three defined patient profiles have not been established yet.
By analyzing the available information about the three patient profiles, we can try to make assumptions on needs during rehabilitation after a total hip replacement. In this paragraph, quantitative data of the study conducted by T.Dekkers has been analyzed and interpreted for the situation of the patient during rehabilitation after a total hip replacement surgery.

Method
As mentioned in the previous paragraph, a statistic data analysis of the quantitative study is done. Three patient profiles - of which three tables with data per patient profile - are formed (Appendix 5). These tables were the input for this project and formed a starting point to indicate assumptions for needs and wishes in rehabilitation. This is done in five steps, visualized in the figure beneath.

Data outcomes that seemed relevant, according to factors that could have an influence on supportive needs in rehabilitation, are selected and presented in a results scheme. Important factors in rehabilitation were already discussed in paragraph 2.3.2.

The selected data outcomes will be clustered in four subthemes: experiencing health; communication with healthcare professional; managing pain and stress; sociodemographics. These subthemes were also used in the study of Dekkers (n.d.) and can be seen as the variables of this test.



Results
Step 3 till 5 of the method are digitalized into the scheme on the next page. The highlighted information shows a potential need for extra support in rehabilitation

Relevant characteristics of patient profiles

	Profile - OPTIMISTIC	Profile - MANAGING	Profile - Modest
Outcomes	-highest satisfaction -experiencing least pain after surgery	highest decrease in pain after surgery	-'self-reported health' decreases after 3 months -lowest decrease in pain after surgery
Experiencing health	Physical: -highest self-rated health score + quality of life -least pain Mental: -least anxiety	Physical: -lowest self-rated health score + quality of life -most pain Mental: -medium anxiety	Physical: -medium self-rated health score + quality of life -medium pain Mental: -highest anxiety
Communicating with healthcare professional	Preferences: -lowest in emotional support, discussing personal circumstances & inhibition -medium openness & participation Medium competences & self-efficacy	Preferences: -highest in participation, openness, emotional support, inhibition, discussing personal circumstances Competences: -most coherent, critical, personal, active -highest self-efficacy for health info	Preferences: -lowest in participation, openness. -medium in emotional support Competences: -least coherent, critical, personal, active -lowest self-efficacy for health info
Managing pain & stress	-lowest pain catastrophizing Coping style: -least active coping, planning positive reframing, religion, use of emotional & instrumental support, self-distraction, denial, venting, substance use, behavioural disengagement, self-blame -medium acceptance & humor* **the underlined text is their most used coping style.*	-high pain catastrophizing Coping style: -most active coping, planning, positive reframing, acceptance, humor, use of emotional & instrumental support, self-distraction, denial, venting, substance use, self-blame* **the underlined text is their most used coping style.*	-highest pain catastrophizing! Coping style: -most, religion + behavioural disengagement -least acceptance + humor -medium active coping, planning, positive reframing, self-distraction, acceptance* **the underlined text is their most used coping style.*
Sociodemographics	-most male (58%) -<65-59 years -mostly tertiary higher educated -50% retired, others employed, (self-) beneficiary -most are married (73%) -65% daily internet use, 13% never -support from partner (73%), child, 13% gets no support	-57% female -<65-75 years -higher educated -57% retired -65% married, 22% widowed -65% daily internet use, 16% never -support from partner (59%), child, neighbour, friends, 5% gets no support	-75% female -51% is 76+ years (elderly) -mostly lower educated -80% retired -68% married, 21% widowed -41% daily internet use, 26% never -support from partner (64%), child, family, 7% gets no support

Discussion

About the method

The results table is based on my interpretation of the data that seemed relevant to me to be able to make assumptions on patient's needs. So this is not the only possible outcome, but for my research this was the most practical.

During the exploration of the data, that can be found in Appendix 2, scores are compared between the profiles. Sometimes one profile scores the highest on one variable, but it is important to find out if this difference is significant between the groups, compared to the total number of points that can be scored. When the scores of all profiles are very close to each other on one variable, a highest or lowest score on that variable doesn't say a lot about a profile.

Also, I compared the scores to the highest possible score. Maybe a profile scores the lowest of all profiles, but is compared to the highest score, still very high and thus tells something relevant about that profile.

About the research outcome

The 'Optimistic' profile doesn't experience much pain and anxiety and give themselves the highest score in health and quality of life. In communication with healthcare professionals, they have the lowest preference for emotional support or discussing personal circumstances. Probably because they don't experience much trouble. Therefore, it is plausible that they score low in coping behavior too, since they simply don't feel a need or reasons to talk about their conditions. Also, most participants get support from a partner.

The 'managing' patients experience most pain and have the lowest score in self-rated health and quality of life. This could be a reason that they are very involved in their healthcare process and are most active in coping behavior, since they have a lot to cope with. They have the highest self-efficacy for health info and are mostly higher educated, which could mean that they are able to take initiative to manage themselves as good as possible.

After the surgery, the self-reported health is increasing the most, compared to the other patient groups.

In the 'modest' profile group, the self-reported health is increasing after 6 weeks (from 70,74 to 75,21) but strongly decreases after 3 months (69,10). It would be interesting to know if this decrease is a result of bad rehabilitation. In my opinion a point to highlight, since this could be relevant information for further research and show a potential need for extra support in rehabilitation. This group has the lowest self-efficacy for health info, is least coherent and active and is mostly lower educated, which could mean that self-management is not easy.

Size of patient profile groups

The distribution of the clusters in the entire population is 32% - 43% - 25%. Among the participants in the generative study, the distribution is 26% - 63% - 11%, so an oversampling of the managing profile and a submerging of the modest profile.

The oversampling of the managing patients could be expected, since that group is most involved in the process and for instance higher educated and more critical and active. You are less likely to encounter the modest patients in research. This could be relevant to be aware of during the design process.

Conclusion
The goal of this study was to collect relevant information for every patient group and make assumptions for needs and wishes in their rehabilitation, based on these results.

After interpreting the quantitative data per patient profile, a conclusion is drawn on needs for support during the rehabilitation phase. These conclusions can be found in the table below.

ASSUMPTIONS FOR NEEDS & WISHES IN THA REHABILITATION, BASED ON QUANTITATIVE RESEARCH

Profile - OPTIMISTIC

Since the optimists are experiencing least pain or health problems, they probably want to recover quickly. When not supported by (informal) caregivers, support in dosing exercises or advice for slowing down could be desirable, to prevent over exercising, which can cause injuries.

Profile - MANAGING

Because of their highest pain experience, lowest self-rated health score and high pain catastrophizing, support in pain management would be helpful and probably mental support for anxiety.

Facilitating a possibility for participation, openness, emotional support, inhibition, discussing personal circumstances, while communicating with healthcare professionals would be desirable.

Profile - Modest

Mental support for anxiety. Facilitate medium in emotional support while communicating with healthcare professionals.

Provide easy reachable clear information in simple language, because of lowest self-efficacy for health info and mostly lower education.

Design criteria:
- Solutions that are independent of internet usage (26% never uses internet)

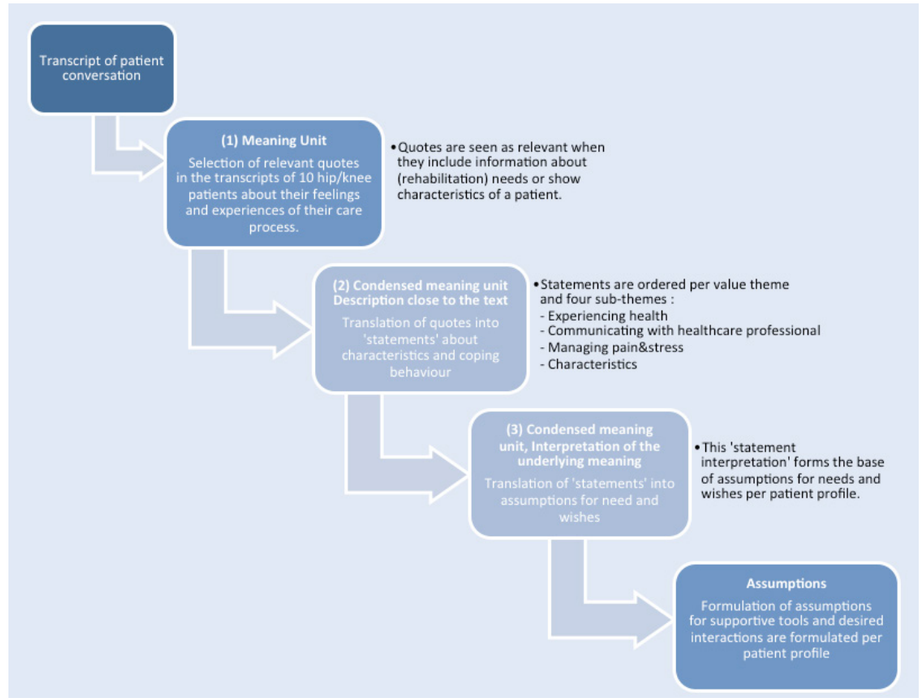
2.3.3. PATIENT NEEDS: QUALITATIVE DATA ANALYSIS

Introduction
In a qualitative study conducted by Groeneveld (n.d.), a subgroup of hip and knee patients has been interviewed to map out their experience regarding the provided care. These patients participated already in the previous, quantitative study conducted by Dekkers (n.d.), analyzed in paragraph 2.3.2. Through an analysis of the qualitative research data of these patients, assumptions are made on their needs and wishes during the rehabilitation process of hip surgery, for the three different patient profiles (see paragraph 2.3.1).

These assumptions on needs can be compared to the assumption in the previous paragraph, to get a more complete picture of all three patient groups. This will be done in the next paragraph.

Method
To create structure in this analysis process of the qualitative data, an approach is used based on the 'qualitative content analysis-methodology' described by Graneheim (2003). In the figure below, this approach is explained in the form of a diagram.

The quotes and their interpretations are ordered by ten value themes: power, achievement, hedonism, stimulation, self-direction, universalism, benevolence, conformity, tradition and security. Within these values themes, four sub-themes are distinguished: experiencing health, communicating with healthcare professionals, managing pain&stress, and characteristics. These four subthemes are defined to create a better overview of important topics that will help to formulate assumptions about the patients' needs and wishes for better care. These themes are similar to the subthemes of the quantitative study, for the reason that it will be easier to compare both studies. This could be useful to see if both analyses are equally practical and reliable, and if they can complement each other.



Results

In the tables below, a part of the findings from the qualitative data analysis are presented, gathered through the qualitative data using the 'qualitative content analysis-methodology'. In Appendix 6, the whole table with all quotes can be found.

Profile - OPTIMISTIC

Theme	Sub-theme	Meaning unit	Condensed meaning unit Description close to the text	Condensed meaning unit Interpretation of the underlying meaning
Power	Managing pain & stress	„'verpleegkundige natuurlijk bij me en alles [...] Dus ik zeg; 'Nou dat gaat een raar verhaal zijn, ik voel helemaal geen reet.' Hoe kan ik nou lopen als je niets voelt?'	**Laat duidelijk weten** dat hij na operatie lang gevoelloos blijft	Geeft duidelijk zijn toestand aan.
Achievement	Characteristic	'Aankleden de eerste dag, dat mocht niet van de verpleegster [...] Ik zeg; 'Ik moet toch naar huis?' *lacht* [...] En ik sta en ze zegt; 'Wat doe je?' Ik zeg; 'Ik doe mijn broek aan.' Ze zegt; 'En je schoenen?' Ik had sandalen meegenomen want het was nog in juli. [...] Kan ik gelijk ook instappen. // Ze zegt; 'Je moet niet met een kruk de trap op lopen.'Waarom niet? Ik heb toch een leuning en een kruk, dat gaat toch?''	Neemt **eigen initiatief** met aankleden, met krukken lopen op de trap.	**Eigenwijs,** wil **snel** gaan, handelt soms tegen advies van verpleegster in. Kan hiermee risico lopen. houding
Hedonism				
Stimulation				
Self-direction	Characteristic	'Al zeven man, zeggen; 'Ik zal u eens even optillen.' Dus ik zeg; 'Nee man, dat doe ik zelf wel'. Ik ben gewoon gaan zitten en ik ben heel sterk, vind ik. Dus ik heb mezelf opgetild en mezelf die brancard opgetild, mijn benen erop getild en mezelf, hup, zo erop.' //	Wil niet geholpen worden met iets wat hij zelf kan, vindt zichzelf sterk.	Wil **sterk overkomen**. Eigenwijs, sterke wil, **doorzetten,** maakt **eigen keuzes** (niet perse het advies van verpleegster), kan hiermee **risico** lopen om heup te overbelasten.
Universalism				
Benevolence				
Conformity				
Tradition				
Security	Experiencing health	'Ik doe een hoop dingen die ik niet vertrouw op mijn knieën. Een hoop dingen.'	Neemt risico in belasting heup. Doet veel dingen die hij niet vertrouwt op zijn knieën.	Trail and error, op een manier die **hij** verantwoord vindt.

Profile - MANAGING

Theme	Sub-theme	Meaning unit	Condensed meaning unit Description close to the text	Condensed meaning unit Interpretation of the underlying meaning
Power	Experiencing health	'Ik deed geen oog dicht eh 's nachts' // 'Ik had dus duidelijk wel pijn na mijn operatie. En ik krijg dus totaal helemaal niets. Ik heb zelfs om een paracetemolletje moeten vragen. En dan werkte dus helemaal voor geen meter bij mij, dus daar had ik niets aan.'	Kan niet slapen van de pijn. Had duidelijk pijn na operatie, maar kreeg geen **pijnmedicatie** van verpleegkundige. Moest hier zelf om vragen.	ervaart veel **pijn**
Self-direction	Characteristics	'ik heb haar alleen voor de avond even in huis gehaald en voor de ochtend [„] Zij sturen alleen een beetje bij. Zo heb ik het ook afgesproken.	Beslist zelf wanneer ze hulp wilt en spreekt dit met de zorgveleners af. Thuiszorg kijkt vooral wat wel/niet kan en stuurt bij.	Wil controle houden, eigen beslissing nemen, heft in eigen handen.
Security	Communicating with healthcare professional	'Ik ben dus alleen [„] daar werd eigenlijk geen notitie van genomen. [„] 'Is er al thuiszorg geregeld? Moet ik dat zelf doen?' // Dezelfde middag dat ik naar huis zou gaan, bleek er nog niets geregeld te zijn. Dat hoorde ik van de thuiszorgdame die 's avonds bij mij voor de deur stond, van; 'Ja, 's ochtends waren ze nog gebeld.' [...] Dat geeft toch een stukje stress.' 'Maar die zie je pas als je naar huis gaat. En dat geeft van tevoren heel veel onzekerheid [...]transferverpleegkundige. [...] 'Ja je wil dat van tevoren regelen. Als ik thuiskom wil ik het in orde hebben.' //	Het was niet duidelijk of alles geregeld was bij thuiskomst na operatie, zoals thuiszorg. Het bleek later dat dit dezelfde middag nog geregeld moest worden. Dit last-minute regelen veroorzaakt stress. Geeft van tevoren veel **onzekerheid** dat je in het ziekenhuis pas de transferverpleegkundige ziet als je naar huis gaat.	Wil graag ruim van tevoren geïnformeerd worden en dingen geregeld hebben, wil zekerheid: bespaart stress en zorgen. Goed rekening houden met de **persoonlijke situatie**. Wil graag (fysiek en mentaal) kunnen **voorbereiding**, zorgen dat alles in orde is, weten waar je aan toe bent.

Profile - Modest

Theme	Sub-theme	Meaning unit	Condensed meaning unit Description close to the text	Condensed meaning unit Interpretation of the underlying meaning
Power	Communicating with healthcare professional	'Ook de communicatie, niet luisteren.' 'Misverstanden, ja. Maar daarvoor ging het ook al niet, dat we elke keer terug moesten.' 'Ja het is allemaal genezen, ga maar fysiotherapie doen.' Ik zeg; 'Ja, ik kan niet op mijn been staan, het is net een stuiterballetje zo.' 'Ja wil je niet of kan je niet?' 'Ja, ik wil wel, maar ik kan niet.'	De hulpverleners **luisteren** niet goed volgens de patiënt, patiënt voelt zich niet gehoord of begrepen. Geen **inbreng** van de patiënt in beslissing, lijkt alsof ze het er niet mee eens is.	Communicatiefout, er wordt niet goed geluisterd of patiënt druk zich niet goed uit.
Achievement	Experiencing health	'Acht weken heeft dat in mijn hoofd gezeten; 'Nee, je kan niet opstaan.'	Onwennigheid, of je wel of niet meteen kunt opstaan.	Onwennigheid
Hedonism	Communicating with healthcare professional	Over informatievoorziening: 'Dat zal mij een worst wezen, als ik maar geholpen werd.' Over fysiotherpie: 'Ja, ze vinden het wel leuk als wij er zijn.' *lacht*. 'Ja positief, ja, je wordt gewoon een beetje lachen en dan is het weer serieus. 'Ja, ik heb er geen hekel aan om erheen te gaan, hoor.'	Niet geïnteresseert in achtergrondinfo, als ze maar geholpen wordt. Vriendschappelijke verstandhouding met fysio is positief	Legt **verantwoordelijkheid** voor een oplossing bij de zorgverlener. Fijn als het contact met zorgveleners niet te serieus is, grapjes tussendoor.
	Managing pain & stress	Andere patiënt: 'een nieuwe heup kan zolang meegaan, gezien het aantal km dat je wilt maken'... P1: 'Ja, dan blijf ik lekker zitten. Dan blijft ie nieuw.' 'Ah, toen moest ik, dus ik ging eigenlijk prettig ging ik in die operatie.'	Gebruikt **humor** om de 'pijn te verzachten', het minder serieus te maken. Geeft veel oordelen, iets was prettig of juist helemaal niet.	Gebruikt als coping humor & venting (emoties uiten)
Security	Managing pain & stress	'Ik moest een foto van die knie, weet je. Dat het niet klopte. Nee, ik moest een foto en dat duurde te lang. En toen is mijn man naar de huisarts geweest en die is heel boos geworden. ' [...] 'Ja, die stuurt je dan door'	Wordt boos als het te lang duurt, oftewel, **toont emoties** om de juiste zorg te krijgen.	Opkomen voor jezelf. Venting.

Discussion

About the method

By making the assumptions on needs and wishes, I tried to filter out the interpretations of the statements that are independent of the personal health circumstances or complications. This way, a clear general overview of a patient profile is formed—and not from one personal story.

How did I experience this new approach to analyse qualitative data?

This qualitative data analysis takes—compared to the quantitative data analysis—a lot of time and focus. It is plausible that the analysis would go quicker if you attended the interview, so that you could hear the intonations of sentences. I have read the original transcripts of the patients' conversation; this helped me to better understand the context and the feeling behind a quote, than if I only read a separate quote.

I often read the transcript aloud for myself; hearing the text works better for me than just reading it. Possibly, this may also be the case for others. Reading aloud the transcript to each other (possibly a role play) or using audio recordings could presumably help to have a quicker understanding of the quotes and to be able to extract the essence in there.

Qualitative analysis vs. quantitative analysis

Since we did both a quantitative and qualitative data analysis with the same goal, we can compare the results and see if they support or contradict each other. Assumptions are ordered per sub-theme, so they could be easily compared with the quantitative study.

We can see that the results are different but in line with each other—so they can enrich each other. The qualitative study shows more an in-depth view about a patient, which makes it easier to understand how someone thinks and where feelings are coming from. The quantitative study gives a good general overview on the profiles, which is useful to form quickly design guidelines.

Assumptions on characteristics & needs in THA rehabilitation, based on qualitative research

Profile - OPTIMISTIC	Profile - MANAGING	Profile - Modest
Experiencing health Quick recovery. Pain is not too bad. Not giving up in advance (in case of complications or heavy work), doing what is possible. Difficulty in changing. Active hobbies, continues after surgery.	Experiencing health Experience lots of preoperative pain and mostly also postoperative pain, which is difficult. Often multiple diseases. Less mobile after surgery, more dependent on others, but would like to be independent.	Experiencing health Experience a lot of pain, share this with the doctor. Pain catastrophizing. Unease.
Communicating with healthcare professional Appreciate explanation, (extensive) info, clarity, honesty and involvement of caregivers. Want relevant feedback and a physio that understands you exactly and put you on the right track. Value good advice, guidance and confirmation of the physio. Appreciate personal contact, benevolence. Have a sense of responsibility. Not afraid to ask questions. Want to know what a realistic expectation is in terms of recovery time.	Communicating with healthcare professional Appreciate it if caregivers will listen better. Would like to be informed and arranged things well in advance. Want to have assurance to saves stress and concerns. Would like to be able to prepare (physically and mentally) and to ensure that everything is alright. Want to know what to expect. Want clarity and certainty about what is or is not possible.	Communicating with healthcare professional Communication errors occur: people do not listen carefully or the patient does not express themselve well. Contradictions: Patient finds clarity and understanding what is going to happen important, but is not interested in background information. Patient lays the responsibility for a solution with the other. Low acceptance and frustration for a caregiver's fault, but respects care providers who do their best. Prefer if contact with caregivers is not too serious, jokes in between.
Managing pain & stress Clearly indicate their state. Think ahead, look for solutions to cope with situations. Willing to use tools when needed. Help in acceptance and a realistic image is desirable. They have a clear day program in which the patients care for themselves consciously.	Managing pain & stress Is open to therapy, experiment with what is possible. Like to make own choices. Value privacy and their own network (feels safe and familiar). Prefer to choose their own caregivers. Would like to be independent. Finds external help often unnecessary. Preparation, information and positive messages ensures that the patient can handle the process easier and less heavy. Patients ensure that they understand what is important in the recovery, what to look out for and what to arrange.	Managing pain & stress Use humor. Shows emotions (venting). Tries to keep doing nice things together.
Characteristics Motivated, positive, active lifestyle, independent, assertive, critical, down-to-earth attitude, pride, stubborn, perseverance. Want to get the best out of their body. Want to be seen as strong, want to go fast. Take own initiative (not necessarily according the advice of nurse), take risk to overload hip. Do not want to waste anything. Think practical, looking for creative solutions.	Characteristics Involved attitude. Assertive, communicate complaints clearly. Was active and would like to be active again. Want to be in control, make own decision, Is not used to be a burden to others and does not want to be so.	Characteristics Judge quickly, something is right or wrong. Passive attitude, although they do stand up for themselves or protest when they think something is not OK. Show emotions and share their opinion.

The quantitative study took less time for me to analyze. But probably the research itself, with approaching a big group of patients with questionnaires and doing the first statistic data analysis, takes more time than qualitative generic sessions with small groups. This could be a consideration in future research, what the most effective and efficient way will be to make assumptions based on qualitative or quantitative research.
The assumptions could also be ordered per value theme instead of sub-theme, when it would be interesting to see what different value profiles are per patient profile. In the results table, all quotes are already clustered per value theme, so it would be easy to collect all assumptions per value theme.

Size of patient profile group
As said in the quantitative data analysis discussion, the distribution of the profiles in the entire population is 32% - 43% - 25% (optimistic - managing - modest). Among the participants that are analyzed in this qualitative study, most participants had the managing profile and just one participant is analyzed with the modest profile. So, results from the modest profile are least reliable. However, the assumptions of this profile give a good example of how a modest patient could deal with the rehabilitation process.

Conclusion
The key findings coming forth from the qualitative data analysis show the differences in the patients' needs and wishes during the rehabilitation process. In the table on the left, the concluding assumptions are summarized per patient profile. We can see clear differences between the profiles.
One thing that stands out in the results, is that the modest patient does not seem very anxious, despite the outcome of the quantitative analysis, which states that this profile experiences the highest level of anxiety. The other conclusions of this qualitative data analysis, which can be read in the table above, seem something that could have been expected after seeing the quantitative analysis results.

DESIGN INPUT

2.3.4. PATIENT NEEDS: TRANSLATION TO DESIGN PROPOSAL

In the previous paragraphs, assumptions on needs and wishes during THA rehabilitation are formulated, based on a quantitative and qualitative data analysis, for the three patient profiles.

These assumptions can be compared and combined, to make the patient profile needs assumptions as complete as possible and has a higher validity, reliability and thoroughness. Next step is to translate these assumptions to design proposals for the BioCoach. How can the assumptions lead to design criteria for the Biocach and what does it mean to desirable moments of interaction?

Question is if the BioCoach is the right medium to meet all needs. Probably the BioCoach is just suitable to meet part of the needs and another medium, such as a (informal) caregiver, is more suitable to fulfill the other needs. This could be explored in a user test. However, in the table on the right, every assumed need is captured in a possible BioCoach function.
For every patient profile, the advice for supportive tools is divided in four possible functions:

- Physical coach: what role could the BioCoach have in physical coaching?
- Pain management: what role could the BioCoach have in pain management, for instance advice on medication?
- Communication: what role could the BioCoach have in communication with (informal) caregivers or companions?
- Mental coach: what role could the BioCoach have in mental support?

Also, an advice on the information level is given, which will describe the way how patients could be approached, for instance in simple language or rather with thorough, scientific substantiation.

Below the functions, the desired moment of interaction and interaction qualities are described, which are also based on both the quantitative and qualitative data analysis.

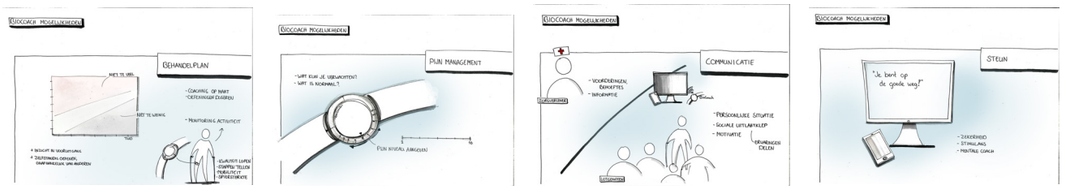


Figure 2-15 Possible Biocoach functions

After this analysis, the assumptions are shared and tested with patients, in the context of the 'BioCoach' by using a storyboard (Figure 2-15), to see whether the assumptions correspond to the needs and wishes of all three patient profiles. This first user test is discussed in the next paragraph.

ADVICE FOR SUPPORTIVE TOOLS, BASED ON PATIENT NEEDS ANALYSIS (VERSION 1)

	Profile - OPTIMISTIC	Profile - MANAGING	Profile - Modest
Information level	Providing a realistic view on rehabilitation time and recovery of the body	Providing enough, carefully formulated, individual information to be able to be good prepared on the process and to feel in control to limit possible feelings of anxiety.	Providing clear, easy reachable information in simple language and guidance.
Physical coach	Dosing exercises or advice for slowing down, to prevent over-exercising, which can cause injuries.	Creating the possibility to exercise independently of others. Providing insight into treatment plan and progress, to give a feeling of certainty and clarity. Coaching in dosing exercises; must be slowed down rather than motivated.	Providing motivation to take responsibility in the rehabilitation process; to be active enough and search for solutions when needed.
Pain management	An advice to lower down medication when not experiencing pain.	Preparing patients for the pain experience and showing what is a 'normal' pain level.	Preparing the patient for pain experience.
Communication	/	Facilitating a possibility for participation, openness, emotional support, inhibition and discussing personal circumstances in communication with caregivers.	Possibility to share experiences, express emotions.
Mental coach	Helping in acceptation that rehabilitation takes time.	Building trust. Give confirmation and assurance whether the patient is on the right track, positive messages to limit feelings of uncertainty. Showing positive stories or affirmations to make the process more pleasant and light.	Providing a feeling of security to limit feelings of anxiety.
Moment of Interaction	My desired interaction of the physical BioCoach band focuses on the moment of exercising (walking) during the rehabilitation, especially to prevent over-exercising. My desired interaction experience of the BioCoach application focuses firstly on the moment of providing information before surgery, about activity and pain expectation during rehabilitation, to help the patient with imagining the process. Secondly, the interaction experience focuses on the moment during rehabilitation when patients need a realistic view about their activity level and progress.	My desired interaction of the physical BioCoach band focuses on the moment of exercising (walking) during the rehabilitation, especially to prevent over-exercising. My desired interaction experience of the BioCoach application focuses firstly on the moment of providing information before surgery, about activity and pain expectation during rehabilitation, to help the patient with imagining the process. Secondly, the interaction experience focuses on the moment during rehabilitation when patients need security about their activity level, progress and pain level or need motivation and support to go on and feel better.	My desired interaction of the physical BioCoach band focuses on the moment of exercising (walking) during the rehabilitation, especially to motivate them and confirm if they are doing well. My desired interaction experience of the BioCoach application focuses firstly on the moment of providing simple information before surgery, about activity and pain expectation during rehabilitation, to help the patient with imagining the process. Secondly, the interaction experience focuses on the moment during rehabilitation when patients need security, certainty about their activity level, progress and pain level or need motivation and support to go on and feel better.
Interaction qualities of the product	realistic, down to earth, practical, positive, involved	controlled, focused, friendly, honest, involved, open-minded, warm	Being consistent, stable, convincing, emphatic, a listening ear, guiding, careful, committed, joyous, respectful, simple
Other design comments	Probably, these patients could help themselves without extra supportive tools, especially when they have good (informal) caregivers around them. Nevertheless, a supportive tool could make the process more pleasurable		Create solutions that are independent of internet usage (26% never uses internet)

2.4 User test: Evaluation of patient needs

FIELD RESEARCH

After analyzing data of THA patients from both quantitative and qualitative research in the previous paragraphs, different assumptions are formulated for needs and wishes for these patients during the rehabilitation process. These needs are translated into different functions for the BioCoach. In a user test, these design proposals will be evaluated with former THA and TKA patients with different patient profiles.
The goal of this test is to have a good starting point of needs and wishes of patients of different profiles, to create suitable concepts of the BioCoach product and interface.

Introduction
It is relevant to figure out if patients from different patient profiles recognize themselves in the assumptions on needs and wishes in rehabilitation (see paragraph 2.3). A user test is set up to evaluate all assumptions, related to possible BioCoach functions.
When insights about patient's needs are gathered, it would be possible to validate or adjust the drafted assumptions. Taking this in mind, the main question of this test can be formulated.

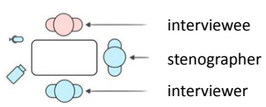
Research question:
From what functions and interactions could patients of the three different patient profiles benefit in their rehabilitation process?
Sub-questions:
1) Are there similarities or differences in needs between patients of the same patient profile?
2)Are there similarities or differences in needs between the three different patient profiles?
3)Are there needs that are specific for one patient profile?

Hypothesis
The hypothesis of this study is equal to the assumptions on 'Advice for supportive tools', based on the patient needs analysis, which can be found in the table on the previous page.

Method
Interviews with (former) patients were done to understand their experience about their whole surgery journey and to understand where coping behavior and needs in rehabilitation are coming from.
A storyboard is made of the THA-process in which all assumptions of chapter 2.3 on patient's needs are integrated, to use as a conversation tool with the (former) patient. This storyboard explains the different parts of THA and introduces the BioCoach product in the patient's journey. Per storyboard slide, several questions are asked to the participant, which can be found on page 55-56.

Participants
A total of 12 patients were interviewed, both THA and TKA patients. These TKA patients were included, as this would result in a higher and appropriate response rate within the restricted time. TKA patients have a similar treatment and rehabilitation path as THA patients have.
These patients participated in the earlier qualitative study of Groeneveld (n.d.) that is analyzed in paragraph 2.3.3, except of one patient: the THA patient that was observed (paragraph 2.2.4) also participated. This patient was in his 7th week of rehabilitation, the others were over 6 months in their rehabilitation.

Procedure
This test was done simultaneously with a user test of PhD candidate Groeneveld, which included an evaluation of his previous qualitative study and a different product scenario test. After one test, we could switch the role of interviewer and stenographer.



Both scenario tests took around 25 minutes each. The duration of the whole session was 90 minutes.
The scenario tests were introduced by showing the participant the rehabilitation journey map (figure 2-9). This created an overview of the whole process and showed the participant the moments of interaction with the product in the journey.

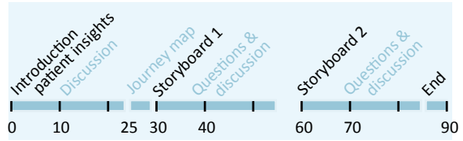


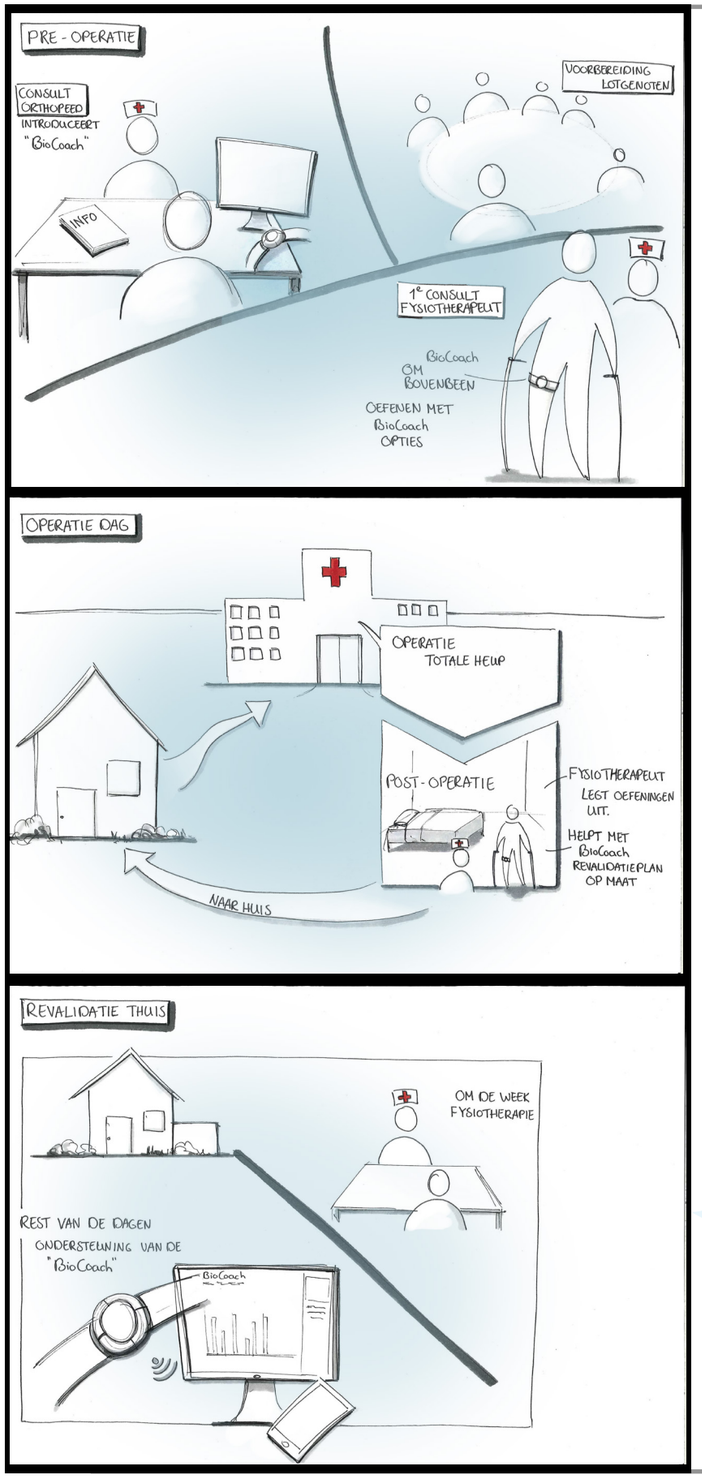
Figure 2-16 Timeline of procedure

The BioCoach storyboard includes the slides on the next pages.

Figure 2-17 Photo impression of the test procedure

Analysis
The notes taken during the interview were structured in sub-categories and analyzed afterwards. The sub-categories are based on the different BioCoach functions (physical coach, pain management, communication and mental coach), the information level and other comments about for instance physiotherapy and the pre-operative phase. These sub-categories make it easier to compare the results with the hypothesis of the different patient groups and to compare these groups with each other. Finally, we want to see what the similarities and differences are between patients of the same profile and between the different patient profile groups.

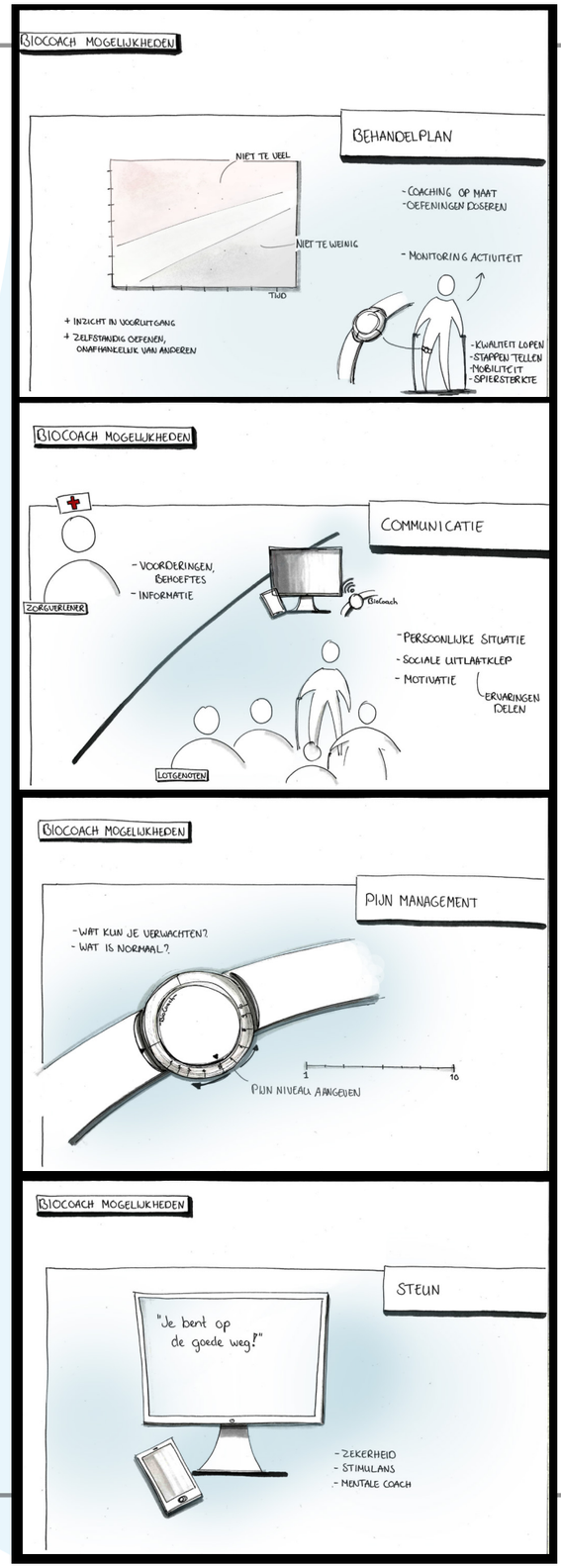
Results
The results are presented in a table. The twelve patients are juxtaposed, clustered by patient profile. Relevant comments on the different categories are listed. The product function categories are rated with a plus or minus, which indicates if the participant would like to use this function. The complete data can be found in Appendix 7.



1) Pre-operation:
Before surgery, the patient has a consult with the orthopedic surgeon, a preparation with peers and possibly a first physio consult. The BioCoach will be introduced.

2) THA + Post-operative phase:
after surgery, the patient gets his own room in the department. A physio visits the patient and will give an explanation about exercising and the BioCoach.

3) Rehabilitation at home:
a. Every two weeks, the patient is going to a physiotherapist, who will adjust the treatment plan and provide coaching.
b. The moments in between consults, the patient must manage himself. He will use the BioCoach. This product provides support in:
i.Monitoring: creating insight in activity and progression;
ii.Coaching: exercises, pain, support to practice independently;
iii.Communication with peers or caregivers.



4) BioCoach product proposals, four possible functions:

4a. Physical coach:
dosing exercises: not too much, not too little;

4b.Pain management:
what to expect, what is normal

4c. Communication:
opportunity to digital communication with fellow sufferers or with caregivers (to discuss personal situation, progression and needs, provide motivation);

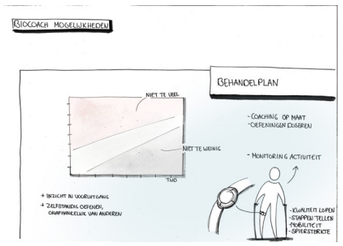
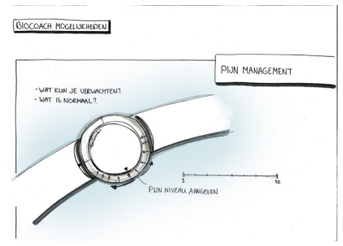
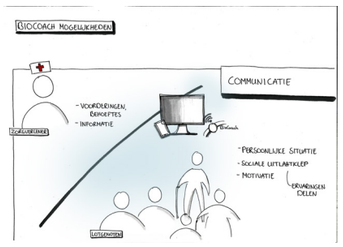
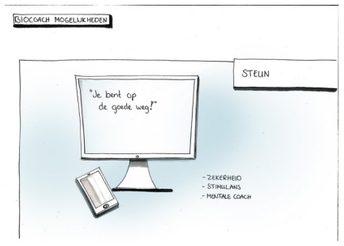
4d. Mental coach:
positive messages, indicating that someone is doing well.

Figure 2-18 Storyboard slides with corresponding introduction text

User Test results

Feedback on BioCoach functions of THA and TKA patients with different patients profiles

= deviation on hypothesis

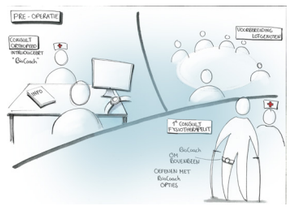
	Profile - OPTIMISTIC				Profile - MANAGING						Profile - Modest	
	Participant A1 TKA m	Participant A2 THA Getouwd m	Participant A3 TKA Getouwd v	Participant A4 THA Partner m	Participant B1 THA Alleenstaand v	Participant B2 THA Alleenstaand v	Participant B3 THA Alleenstaand v	Participant B4 THA v	Participant B5 TKA Getouwd m	Participant B6 THA Weduwnaar m	Participant C1 Broken hip Getrouwd v	Participant C2 TKA Alleenstaand v
	+	+	+	+	+	+	+	+	+	+	+	+
	**Motiverend**	**Progressie** zien, positieve vergelijking t.o.v. anderen. Het geeft **steun**.	**Motiverend**, weten dat je het goed doet en wat je moet doen Idee van '**Politie-agentje**' prettig. Kwaliteit van lopen & spiersterkte meting zijn goed. Neemt ook **onzekerheid** weg.	Zowel **motivatie** als **afremming** fijn, betere balans vinden (zit zowel in rode als grijze gebied). Je maakt het inzichtelijk, 'stok achter de deur' En fysio kan je op je donder geven. Wilde wel snel vooruit, maar wilde er niet per se heel veel voor doen.	**Afremming** bij teveel bewegen goed, onafhankelijk kunnen oefenen is fijn, inzicht in wat je precies gedaan hebt goed.	Zelf te ijverig, dus zou fijn zijn als het apparaat '**indamt**'. Waarschuwing-slampje tijdens activiteit, preventief. Houd het intrinsiek; **eigen verbetering** zien. Ook: Wat is gewoon, wat niet >> uitschieters signaleren.	"Is dit onderzocht?" Belangrijk waar het op gebaseerd is. **Motiverend**, biedt houvast. Complimentje achteraf. **Positieve dingen** erin zetten, dat helpt mensen het meeste verder! kan **onzekerheid** weg halen, kan deels artscontact vervangen.	Bij oefenen thuis **weet je niet goed** [of je genoeg doet of het goed doet] **inzichtelijk** maken, dat je weet wat er bij komt kijken, dat je ziet dat het **tijd en geduld** vergt. Fijn om voorderingen te zien	**Motiverend**, stok achter de deur. [...] Dan heb je een beetje **houvast**. Voor mij was het een beetje zwemmen. Product voegt toe: Zwart op wit.	Heb wel eens dat je een beetje **teveel doet**. Geeft iets van idee van of er vooruitgang in zit.	Je staat oefeningen te doen en denkt, **doe ik het wel goed**? Gelijk duidelijke info: Nee! Hakken tenen! Wel **ALTIJD oefeningen gedaan**, ondanks pijn. Later: **soms te moe ervoor** >> ter plaatse info geven, visueel. Zou daardoor fysio misschien minder vaak kunnen zien.	Deed niet per se **teveel**; hooguit 's avonds als ze niet kon slapen. Nuttig dat je kan zien dat bewegingen **goed zijn** en dat je **vorderingen** zien.
	-	-	+	-	+	-	+/-	-	+	-	+	+
	Minder relevant voor patient. Medicate kan misschien verminderd worden bij weinig pijn; is nu vrij zwaar in de orthopedie!	Voelde geen pijn, niet relevant voor patient. Maar goede product optie als je wel pijn ervaart. "Als je weet dat pijn erbij hoort, is het niet erg."	Goed om beetje idee te hebben welk pijn niveau normaal is. Pijn was **teleurstellend** en had **invloed op oefeningen.** "Ik **snap niet waarom** je nog zoveel pijn moet ervaren tegenwoordig. Er is toch zoveel mogelijk?"	Geen meerwaarde, had niet veel moeite met pijn.	Pijn: iedere dag grenzen uitproberen, maar wel voorzichtig. Medicatie: je wilt **weten wat je krijgt**, je wilt weten **waar de grens** ligt voor medicatie.	Cijfers aan pijn geven ook heel lasting, vindt zichzelf specifiek geval	Ik had **niet** zoveel pijn achteraf. **Wel** medicatie genomen.	ik ben niet klein-zielig. [...] zal ook niet gauw medicatie gebruiken; kan redelijk goed tegen pijn. kwestie van acceptatie.	[Kan] inzichtelijk maken, wat ben ik aan het doen	Pijnmanagement bij hem ging vanzelf wel.	Had liever niet geweten hoe heftig/ pijnlijk het zou worden. Pijn was na 2 dagen wel minder. "Ik schijn hoge pijn-grens te hebben." Vond dat ik **te veel medicatie** meekreeg, maakte hier geen gebruik van, had ik dit allemaal wel nodig?	Ging oefeningen doen om van pijn af te komen. **Pijn na operatie = 10**. Pijnbeleving werd niet serieus genomen. Je krijgt al **zoveel tabletten, je weet niet wat normaal** is qua pijn. Moest overgeven van de vele medicatie.
	+	-	+	-	+	+/-	+/-	+	+/-	-	+	+
	Tijdens proces coachend contact met fysio: veel praten. Later **lotgenoten** contact om ervaringen te delen. **positive comparison**	Contact met onbekenden lotgenoten geen behoefte aan. Kan ik me iets bij voorstellen, dat fysio gegevens uitleest.	Lotgenotencontact? **Ja**, als je elkaar kan helpen. **Bekenden of onbekenden maakt niet uit:** je kan van iedereen leren. **Elkaar motiveren/ opbeuren, ideeen opdoen**, kijken hoe je dingen evt. anders kan doen.	hoeft van mij allemaal niet per se.	**Lotgenotencontact**, ervaringen delen is fijn	**Samenwerkings-verband met fysio** Lotgenotencontact motiveert niet als je slechter presteert WEL: Realistisch beeld geven. Vergelijking met andere patient heeft (in haar ogen) GEEN zin	Goed om motivatie te geven. Vergelijking met jezelf zien i.p.v. vergelijking met een ander. Gegevens delen **met arts en een vast iemand in ziekenhuis**. Inzicht in data voor sociale kring gaat te ver.	**Tussentijds fysio contact** om oefening aan te passen handig. Lotgenotencontact geen behoefte aan. Iedereen heeft altijd allerlei adviezen klaar. Niet altijd prettig. Hoef niet te weten hoe het met andere patient gaat, want **iedereen is individueel anders**.	Heeft al genoeg lotgenotencontact opties. Is bij iedereen anders. Eerder **contact met chirurg** dat hij weet dat ik er zoveel last van heb zou fijn zijn.	Lotgenotencontact kan ook via Facebook. Contact zorgverleners wordt misschien juist meer: overvloed van gegevens, je weet niet wat je ermee moet.	**Fysio** op scherm thuis. Lekker makkelijk, doen wanneer je het wilt, meerdere keren. Feedback op oefeningen: Duimpje "A la Toon!" Lotgenoten vergelijking is niet prettig, mensen die het aandikken. Tenzij ze niet opscheppen.	Advies **zorg-professionals** kan digitaal. Lotgenoten liever face2face. Fijn om verhalen van anderen te horen of lezen. Automatisch doorsturen van info mag, maar moet dan bij consulten achteraf besproken worden.
	-	-	+	-	+	+	+	-	-	-	+	+/-
	Daarvoor heb ik mezelf en fysiotherapeut, **wil niet zonder fysio,** hij geeft volledig plaatje.		Afleidingsfunctie kan fijn zijn. Motiverend effect lotgenoten-contact waarsch fijn. In haar normaal **dagelijks contact vaak weinig ruimte** om het te bespreken.	Dat is ook niet helemaal voor mij van toepassing.	Fijn als je voelt dat er **begrip** is voor je situatie. Steun is hard nodig. **Nuchter verhaal** over dat het waarschijnlijk wel **goed** zal gaan zou fijn zijn	kan **belonings-systeem** zijn; kijken naar statistieken tov. jezelf.	In het begin geeft het **angst** dat het toch faliekant mis gaat. doet geestelijk iets. Heup neemt grote **emotionele ruimte in beslag**, loop tegen barrières aan, ben (deels) emotioneel uit balans, het geeft onzekerheid.	Wel goed om te horen **dat het goed gaat**, maar niet essentieel.	Heeft hier **familie** voor. Ik accepteer het zoals het is, ik wou dat ik er iets aan kon veranderen, maar er is niks. [...] Probeer te accepteren dat het niet meer gaat [...] Je moet het zelf verwerken.	Ben wel eens **onzeker**, maar dan vraag ik het aan de fysio. Praten is veel directer, beter beeld van gesprekspartner. Computers geef ik opdrachten, met mensen praat ik. Positieve berichten zijn fijn, maar vooral als ze van een naaste komen.	**Duimpje omhoog**, haha! **Duimpje omlaag**. Zou mental coach kunnen zijn Had veel pijn (en **stress**)	**Steun ervaren** zou goed zijn. Lezen van verhalen leuk, maar minder effect dan wanneer je gaat praten met bijv. buurman. Laatste geeft betere beeldvorming van gesprekspartners. **Elkaar ZIEN** is belangrijk.

User Test results

Feedback on rehabilitation and information level of THA and TKA patients with different patients profiles

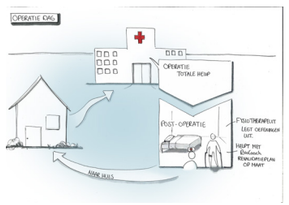
= deviation on hypothesis

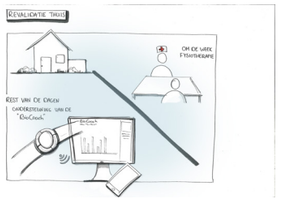
Information level



Profile - OPTIMISTIC				Profile - MANAGING						Profile - Modest	
Participant A1 TKA m	Participant A2 THA Getouwd m	Participant A3 TKA Getouwd v	Participant A4 THA Partner m	Participant B1 THA Alleenstaand v	Participant B2 THA Alleenstaand v	Participant B3 THA Alleenstaand v	Participant B4 THA v	Participant B5 TKA Getouwd m	Participant B6 THA Weduwnaar m	Participant C1 Broken hip Getrouwd v	Participant C2 TKA Alleenstaand v
Vond patientenmeeting achteraf nazorg	**Niet te veel, niet te weinig**; Gevaar van gebrek aan communicatie even groot als een teveel aan communicatie: “**Focus** op wat voor jou belangrijk is” **Positieve verhalen** voor de operatie graag van **professionals**. “Ik realiseer me dat het wel eens mis kan gaan.” Ervaring van chirurg (via mond op mond reclame) belangrijk. **Geen gebruik gemaakt** van informatiebijeenkomst vooraf: “Had het al gehad [bij vrouw, toen zij heupoperatie had gehad]”. Ook geen info gehad op consult.	Informatie: PA (na operatie) het beste. Daarvoor: Iedereen valt eigenlijk in **herhaling**. Bijv. consulenten. “Had wel **boeiender** gekund.” Bijeenkomsten voegden weinig toe. “Van anderen ben ik niks wijzer geworden.”	Info vooraf: Weet niet meer of het een map was. Info bijeenkomst voor operatie: Ben wel geweest, maar ook **niet per se nuttig**.	Veel informatie uit ziekenhuis **te algemeen**, “Je denkt: Het zal wel”. **Band opbouwen** met zorgverlener is belangrijk; kent je achtergrond, en is mentale steun. Weten bij wie je moet zijn. Mensen die **duidelijk** zijn en **klaarstaan**.	Je wilt weten **wat je kunt verwachten**: enkel Physician Assistant (PA) legt dit goed uit. Graag **goed geinformeerd** zijn, goed **voorbereiden**. Visualiseer implicaties. Mbt. ervaringen zijn testimonials prettig. Revalidatie = zoektocht. Ze moeten het niet te mooi voorstellen. Je wordt **in het diepe gegooid** na de operatie; hier een programma voor maken als ziekenhuis, dan krijgen artsen ook minder vragen. Focus op preventie. **Gebruiksvriendelijkheid** belangrijk, informatie moet nuttig zijn om beslissing mee te kunnen maken. Herstel gaat 2x sneller als je gemotiveerd bent	Patiënt zou graag **meer advies** van arts krijgen voor extra zekerheid Maakt nu ook al lijstjes ter **voorbereiding**. Leuk om **positieve verbetering** te zien. “Geneeskunde is geen wetenschap; maar wel belangrijk: Wat is de **onderbouwing**? Belangrijk dat het gebaseerd is op gegrond **professioneel advies**.” Ook weer niet TEVEEL info ophopen. Lotegenotencontact vooraf WEL fijn; want: heupprothese vasthouden, uitleg over operatie.	Vindt het de **verantwoordelijkheid** van patiënt dat je zelf dingen regelt, bijv. bedenken wat je thuis nodig hebt. Belangrijk dat patiënt ook **kritisch** is, niet blindelings de arts volgen, ook zelf denken/ meekijken, kunnen mogelijk fouten mee voorkomen worden. Eigen operatie: ze zijn bedillerig over je, niet fijn. Bijv over pillen: “ik ga niet zomaar iets innemen, **wil weten wat ik neem**. Hier was geen tijd voor, dus nam het maar, maar daar ergerde ik me wel aan.” Zou contact willen met iemand op mijn **eigen niveau**. Duur revalidatie mogen ze beter zeggen, dat het een lange weg is, en dat het waarschijnlijk wel goed komt (ook niet altijd). Dit maakt je nu **onzeker**. Voorbespreking: sommige mensen wijden wel heel erg uit.. Maar: “Ik weet dat het gewoon moet/hoort. [...] Je denkt misschien dat je alles weet maar ...”	Gehoorprobleem Lotgenotencontact vooraf WEL gewaardeerd: Prettiger dan veel info. “Heel **concreet**.”	**Bereidt zich goed voor** en is goed op de hoogte van de situatie. Keek van tevoren zelf op **internet**; info over operatie etc. Lotgenotencontact vooraf: Niet heel nuttig.	Informatie vooraf **niet gelezen**: “ Dat ik denk, laat maar. [...] Ja, ik **gaf m’n eigen eraan over** eigenlijk.” Oefeningen wel trouw gedaan: “Anders kwam ik m’n dag niet door” **Visualisaties** kunnen verhelderend zijn i.p.v. een map met veel tekst. Zegt dat ze niet zo goed in schrijven is. Liever **vooropgestelde opties** aan kunnen vinken dan zelf antwoorden moeten bedenken. Graag **simpele, korte uitleg**. **Humor** toevoegen (lachen) is altijd goed, moet niet te serieus worden. Over de lotgenoten-bijeenkomst: zowel het horen van ervaringen als het delen van eigen ervaring is fijn. Dat je ziet **dat je niet de enige bent**. Echtgenoot: ik vind onszelf beneden gemiddeld van iets duidelijk kunnen omschrijven. Mevrouw vindt ze gemiddeld hierin. Vond groepsvoolichting goed; mensen hebben toch veel verschillende vragen.	“Ben zelf [door de pijn] een **zeurderige patient** geworden.”

Other insights





Dit product **helpt** vooral bij het **traject na de operatie**; orthopedie richt zich nu vooral op de voorbereiding, maar **je hebt geen controle over de revalidatie**, ookal leggen ze het je vaak uit.	Wel **veel contact met fysio**, ook aan huis-- tevens een goede vriend. Kwam in het begin iedere dag: Normaal misschien 1/2x per week. Voortraject is het ergst. Iedereen heeft ook een mening. Product kan voor **algemene kostenbesparing** zorgen. Bezoek aan **spreekuur** van pt **kost ook veel tijd**; hierdoor wordt spreekuur ook minder belast. Het is **acceleratie** van informatieuitwisseling. Kan ook **overbezorgheid wegnemen** (bij sommige mensen)	Fysio voor de operatie: “Nee, nee... **was me niet verteld**.” Nu (bij 2e knie) wel; weten dus nu ook meer over wat waarsch goed werkt. Dag v. operatie: “Kreeg je een ijsje, was ook het **enige wat ik me kon herinneren**!” Begeleiding fysio in ziekenhuis: Heel miniem. Is een nacht langer gebleven: **Heel veel pijn**. Moeten **soebatten** om oxycodon oid. “Bijzonder hoe erop werd gereageerd, van nou, is dat nou nodig...” > Niet echt comfortabel met terugkeer naar huis: “1e 2 dagen probeerde ik **oefeningen uit boekje** van ziekenhuis te doen, maar dat **kon eigenlijk helemaal niet** want spieren waren verlamd. **Daarna** fysio: Beviel WEL goed. Zelf gevonden, geen hulp bij nodig.	Kan contact met fysio minder? Nee, voordoen/ **beoordelen van oefeningen** wel belangrijk + het **sociale** [aspect; het is een] reden om de deur uit te gaan.” Algemeen: Voornamelijk functie 1 handig, toch eventueel dan met [contact?] fysiotherapeut achter de hand (functie 3). Weet niet of het in het algemeen verschil gemaakt zou hebben voor herstel, maar zou het wel prettig gevonden hebben. Misschien was het nog wel **sneller gegaan**, als hij was **gecorrigeerd** op bijv. waggelen; hoorde hij nu van vrouw. Fysiotherapie voor operatie? “Bij kijkoperaties wel fysio, maar niet specifiek voor deze operatie.” 1x p.w. fysio, in 1e 3 mnd (okt-nov-dec)	Na operatie val je in een soort **zwart gat qua begeleiding**; Dit is een praktisch voorstel hiervoor. Zou kunnen leiden tot **minder** fysiotherapie. **Menselijk contact** moet blijven, maar kan vanuit fysio OF vanuit partner/ sociale omgeving. MAAR: die hebben minder verstand van zaken, dus BEVESTIGING van info vanuit Coach is heel prettig Band dragen = geen punt Monitoring = geen punt, je hebt er immers voor toestemming gegeven Patient heeft rustige, nuchtere houding, **zoekt naar oplossing**; goed voor zichzelf zorgend. **voorbereid** op proces Revalideren = **trial & error**.	Mensen kunnen rust & **veiligheid** ervaren. Dit apparaat **haalt het tobberige** er een beetje vanaf” Eigen **voortgangsproces** = interessant en **motiverend**: “Moet je nou eens vergelijken met een half jaar geleden!”	Contact fysio: zelfs als apparaat dit kan meten blijft **mens-tot-mens contact** belangrijk. Contact zou wel iets **minder** kunnen. “Het is gewoon fijn om soms gewoon iemand te zien” >> Fysiotherapeut CHECKT. “Fysiotherapeut zou me altijd toch nog **meer geruststelling** geven dan feedback van een apparaat.” Zit het wel prettig op huid die ‘veranderd’ is? “Sleutels bijvoorbeeld zitten absoluut niet lekker in z’n broekzak nu.” Bij adviezen in computerprogramma: “Ik **bel toch** eigenlijk **altijd even**.” Want vaak toch net niet wat je gevraagd hebt/ situatie net anders.	De band moet geen belemmering zijn op je been: moet niet afzakken, ook niet te strak zitten. Fysio: vantevoren besproken en nagebeld; toch gedoe op moment zelf en toegewezen therapeut leek er weinig verstand van te hebben. Vervelend. **Contact met fysio** moet misschien toch al **vantevoren geregeld** worden.. keertje langsgaan, misschien vast wat oefeningen doen. Ziekenhuis mag ‘goede’ fysio’s aanraden. “Goede fysio vind ik toch wel winst.” Fysio was niet op de hoogte wat voor ingreep ik had. Advies **huisarts** en **fysio sloot niet op elkaar aan.**	Zat wel erg weinig tijd tussen consult & operatie. Contact fysio: eerste dagen thuis, daarna 1x per week. “**Vond het eigenlijk genoeg maar dacht ‘Laat ik maar gaan**...’ [Fysio] zegt gewoon, als je ‘t niet doet ga je misschien verstijven. “Hij zegt: je hebt recht om hier te komen.” Had liever hydrotherapie gehad, maar dat was te duur. **Was niet gegaan als fysio niet vergoed werd.** Probeerde zoveel mogelijk te fietsen. Deed niet per se oefeningen (wel op hometrainer). Wandelen wel **soms te pijnlijk**, moest dan onderweg stoppen.	Weet niet of het iets toevoegt: “Als alles goed gaat heb je zo’n apparaat eigenlijk **niet nodig**.” Vooral **vooruitgang** in 1e 6-12 maanden, dat zou handig kunnen zijn. “Is leuk om te weten” [Maar niet echt nodig zo lijkt het]. 2 Dagen in ziekenhuis geweest: fysio bij hem langsgekomen 1x. Over fysio: wat hij deed **kan ik zelf ook**. Na afloop 3-4x bij fysio langsgeweest; daarna **zelf naar fitnesscentrum**, daar lopen ook fysio’s rond. Veel goedkoper, 3x per week → eigen initiatief. Algemeen: Bewustzijn **kostenaspect**?	TV feedback misschien? Of direct op app? Echtgenoot over fysiotherapie: vindt het **niet erg** om er naartoe te gaan. Ik ga er zeker weer heen **als ik van de verzekering vergoeding krijg**.	Zou het wel willen gebruiken. Algemeen: apparaat kan zaken bijhouden & helpen doorgeven hoe het herstel verloopt (**voortgang** zien & **communicatie**) Had **alles geregeld** wat geregeld moest worden. Mis tijdens revalidatie: Orthopeed weet niet wat fysio doet/opmerkt. Is meerdere keren terug gegaan naar ziekenhuis. Advies van arts kwam niet overeen met fysio (qua oefeningen). **Fysio verslag terugkoppelen aan arts**. Dit zou automatisch kunnen gebeuren, dat de arts weet hoe je aan het revalideren bent. Had **geen fysio voor operatie**. Fysio minder zien in huidige situatie? Als product kan aangeven dat je goed bezig bent misschien wel. Helemaal zonder fysio? Nee; toestellen heb ik niet in huis, hij kan ook masseren.

The results of participants with the same patient profile have been compared. Equalities and differences in needs can be noticed. These findings are discussed below.

Optimistic profile

Information level

Assumption: Providing a realistic view on rehabilitation time and recovery of the body

The optimistic patients would like to get the right amount of individual information: not too little and not too much, so only what is important for them to know and no overload.

General information meetings or the general information map is not necessary for them.

Physical coach

Assumption: Dosing exercises or advice for slowing down, to prevent over-exercising, which can cause injuries.

All patients are positive about the physical coach function, but their reason differs from the assumption; three of the four patients needed motivation instead of the advice to slow down.

Pain management

Assumption: Advice to lower down medication when not experiencing pain

Most optimistic patients found the pain management option not relevant, since they experienced little pain. However, one patient was disappointed in her heavy pain experience, which affected her exercises (A3).

Communication

Although the assumption that the optimistic profile would not have a need to communicate with peers, two out of four participants liked the option to communicate with both known and unknown peers. For instance to see a positive comparison with other patients, to share their experience and to motivate and help each other (A1, A3).

Mental coaching

Assumption: Helping in acceptation that rehabilitation takes time.

Just one optimistic patient preferred to have a mental coaching option, since the option to talk about her situation in her normal life didn't appear often (A3).

Managing profile

Information level

Assumption: Providing enough, carefully formulated, individual information to be able to be good prepared on the process and to feel in control to limit possible feelings of anxiety.

Bonding and building trust, having a care provider who knows your background. Individual, useful and user friendly information, not too general. They want to have certainty, professional advice and know the sources. All prepare themselves well.

Physical coach

Assumption: Creating the possibility to exercise, independently of others. Providing insight into treatment plan and progress, to give a feeling of certainty and clarity. Coaching in dosing exercises; must be slowed down rather than motivated.

The assumption of the physical coach matches the needs of the managers well: All managing patients are positive about this function.

Pain management

Assumption: Preparing patients for the pain experience and showing what is a 'normal' pain level.

Pain differs per patient. According to data (Dekker, n.d.), the managing profile experiences most pain, but in this test, several managing patients had little pain (B3, B4), so a pain management tool seems not patient profile specific.

Communication

Assumption: Facilitating a possibility for participation, openness, emotional support, inhibition and discussing personal circumstances in communication (with healthcare professionals). Building trust.

Two-thirds of the managing patients indicated that they like to have a digital connection or intermediate contact with a healthcare professional, such as the physiotherapist, the surgeon or someone in the hospital. Just one managing patient preferred to have contact with peers, to share experiences. Most didn't like to see the comparison with peers since everyone's situation is different and it doesn't feel pleasant if you see that your progress is worse than other patients. They just want to see their own progression.

Mental coaching

Assumption: Give confirmation and assurance whether the patient is on the right track, positive messages to limit feelings of uncertainty. Showing positive stories or affirmations to make the process more pleasant and light.

Most managing patients experienced some level of fear or uncertainty. Mental support is desirable, but this can often be accomplished by family or relatives. Human contact is preferred. However, they indicated that also positive messages are helpful and reassuring.

Other comments:

Rehabilitation is a quest. Confirmation of the product is pleasant.

Modest profile

Information level

Assumption: Providing clear, easy reachable information in simple language and guidance.

The assumption about information level is matching the modest patients' preference: providing guidance and clear, easy reachable information in simple language.

Physical coach

Assumption: Providing motivation to take responsibility in the rehabilitation process; to be active enough and search for solutions when needed.

The most important function of the physical coach for this patient group is to provide feedback on their correctness of exercise performance.

The results do not show that the patients always need motivation. One patient indicated that she always did her exercise, but later she indicated that she was sometimes too tired to do it, which is contradicting (C1). It seems, the patient sometimes forgot how she performed over the weeks.

Also, it seems the patients are following the advice of the caregiver, but often don't exactly know why they have to do something, so the underlying goal is not clear. Because of this, the execution of exercises could be done wrongly.

Pain management

Assumption: Preparing the patient for pain experience.

The modest patients experienced a lot of pain. This was not taken seriously by the caregivers at first sight. C2 indicated a pain level 10, which is extreme. The other noticed she had SOO MUCH pain, but this actually lasted only 2 to 3 days (C1). So pain catastrophizing seems happening here.

The patients indicated that they got lots of medication. They didn't know if it was normal or too much. One patient got sick of all medication. The other patient didn't take everything. Medication management might be helpful for this profile.

Communication

Assumption: Possibility to share experiences, express emotions.

They liked the idea that the advice of healthcare professionals can be given digitally, so that it is possible to watch the advice several times whenever you want in your own home. It sounds easy and nice to them.

One modest patient liked to talk with peers, but had a preference for face to face contact.

Mental coaching

Assumption: Providing a feeling of security to limit feelings of anxiety.

Positive icons when you're doing well are preferred. Mental support is good, but human contact for support is the best in their opinion.

Other comments:

This group is the least self-sufficient. They have difficulty with intervening if something doesn't go according the plan.

After analyzing the participants with the same patient profile, the matching needs of each profile can be compared between the profiles. Then, possible similarities in needs between profiles could be noticed and needs that seems specific for a profile can be indicated. This is done in the conclusion section.

Discussion

About the method

The visualizations in the storyboard seemed to be an effective tool to support the conversation; it triggered the thoughts of the participants to talk about several subjects.

Size of patient profile groups

The distribution among the different patient profiles is not equal. As with the previous study, most participants had the managing profile and just two modest. This makes the modest profile results least reliable, but still useful to draw general conclusions.

Patients on the edge

Looking to the results, several participants differ a bit from the assumptions, but generally they fit the profile picture well.

However, three patients stand out in deviating from the assumptions. Their quotes fit quite well to another profile. Therefore I assume that they are on the boundary of two profiles.

***A3**: Optimist-Modest:*
The patient is smart and resolute, but shows modest behavior and a layed-back attitude.
***B5**: Manager-Modest:*
The patient gives manager answers but has modest behavior.
***C2**: Modest-Manager:*
The patient comes across as a modest patient - not resolute - but she has sorted out everything, like a manager would do.

Looking to data of Dekkers (Figure 2-19), it can be confirmed that B5 and C2 are 'boundary patients'. A3 is far from a boundary, but seems a managing patient instead of an optimistic patient! What to do with patients that are at the boundary of two profiles or deviate from the assumptions? This is an important question to answers during the design process.

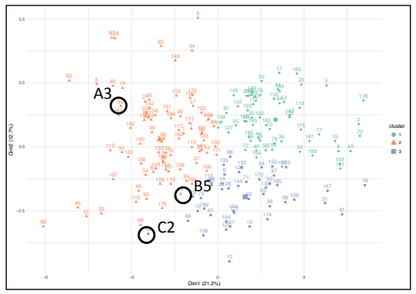


Figure 2-19 - Plot of participants, distributed over the profiles (Dekkers, n.d.)

DESIGN INPUT

Conclusion

After analyzing the data of this user test, a new table is made with adjusted assumptions on needs of patients, translated to BioCoach proposals.

The hypothesis about rehabilitation needs corresponds with a large number of participants, but in every profile group, some participants deviate.
It can be seen that general design guidelines can be set up per profile, but it is not possible to distinguish needs that are specific for one group; all profiles have some overlap with each other's needs and have exceptions within the group. The need for several product functions seem patient-related instead of profile-related.
When a function is not relevant for all patients of that profile, it is indicated as optional in the table.

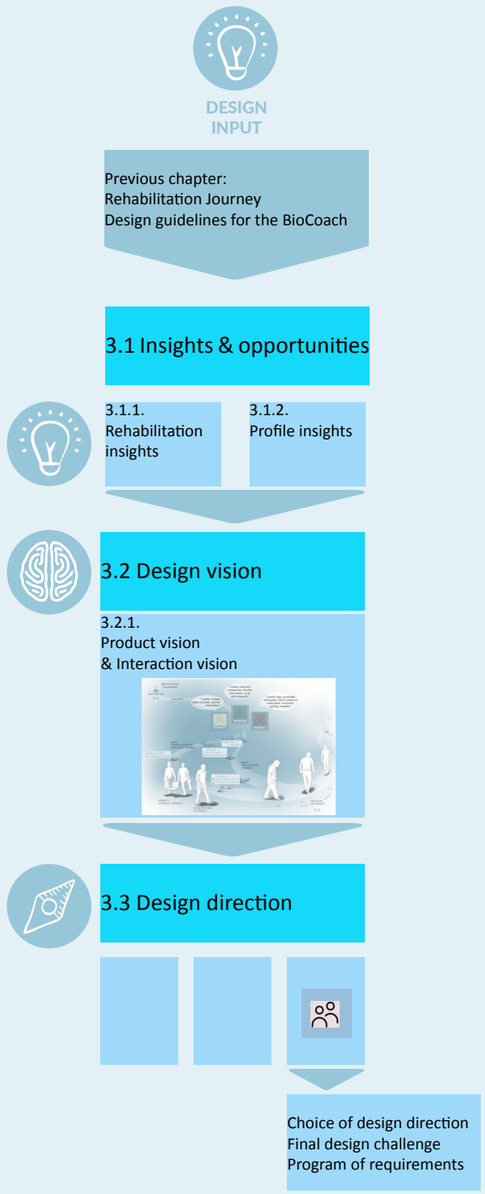
Some product proposals are desirable for all patients, but for different reasons. For instance getting insights in your progression could work both motivating, decelerating and give certainty. So when patients have different needs for instance in terms of being motivated or slowed down, it can be (partly) fulfilled by the same product function, as can be seen with the 'physical coach' function.

When we look to the information level, clear similarities within the patient profiles can be seen. Also, these information preferences differ per patient profile. Therefore we can validate guidelines for the presentation of information for different patient profiles, as can be seen in the right table in the 'information level' and 'interaction qualities'.

Concluding, rehabilitation needs seems patient-related, but the level of information and interaction is profile-related.

ADJUSTMENT OF ASSUMPTIONS - DESIGN GUIDELINES FOR THE BIOCOACH (VERSION 2)

	Profile - OPTIMISTIC	Profile - MANAGING	Profile - Modest
Information level	Getting the right amount of individual information: only what is important for them to know, no overload. Providing a realistic view on rehabilitation time and recovery of the body.	Providing enough, carefully & friendly formulated, individual information to be able to be good prepared on the process and to feel in control to limit uncertainty or feelings of anxiety.	Providing clear, easy reachable information in simple language and guidance.
Interaction qualities of the product	realistic, down to earth, practical, positive, involved	controlled, trustworthy, friendly, honest, involved, warm, supportive	Simple, consistent, convincing, emphatic, reassuring, guiding, committed, joyous, respectful
Physical coach	Creating **insights** in progression. Possibility to both motivate or slow down the patient in exercising.	Creating the possibility to exercise independently of others. Providing insight into treatment plan and progress, to give a feeling of certainty and clarity. Coaching in dosing exercises; possibility to be slowed down or be motivated.	Provide insights on progression and visual feedback on if they perform their exercises well. ***optional**: Providing motivation to take responsibility in the rehabilitation process; to be active enough and search for solutions when needed.*
Pain management	*optional: Pain info when experiencing pain. An advice to lower down medication when not experiencing pain.*	Give information about medication. ***optional**: Preparing patients for the pain experience and showing what is a 'normal' pain level.*	Medication management: give advice about medication use. Preparing the patient for pain experience (pain level and duration).
Communication	***optional:** Facilitating a possibility for contact with peers to share experiences*	Facilitating a possibility for a digital connection or intermediate contact with one specific care professional.	Digitalize the advice of the healthcare professional (e.g. physio), to be able to see it again. ***optional**: Possibility to share experiences, express emotions.*
Mental coach	Insights in progression gives support and certainty. Positive comparison with others is good for self confidence. ***optional**: Helping in acceptation that rehabilitation takes time.*	Building trust. Give confirmation and assurance whether the patient is on the right track. Showing positive stories or affirmations to make the process more pleasant *(passive).* ***optional**: send positive messages to limit feelings of uncertainty (active).*	Providing a feeling of support and security to limit feelings of anxiety or uncertainty. Seeing a face or otherwise positive icons.
Other design comments	These patients could help themselves without extra supportive tools, especially when they have good (informal) caregivers around them. Nevertheless, a supportive tool could make the process more pleasurable		Create solutions that are independent of internet usage (26% never uses internet) These patients are least self-reliance.



Chapter 3

Design Vision

In the previous chapter, an extensive analysis has been conducted concerning the BioCoach product in the context of the THA rehabilitation journey, for three different patient profiles. In this analysis, the needs of the target group—the three patient profiles and the physiotherapist—are discussed.
In this chapter a design vision has been formulated based on findings and conclusions from the analysis phase.

First, an overview will be given of all the insights and opportunities that have been collected in the analysis phase.
Then, a product vision will be drawn. In this product vision, the design statement will be defined.
An interaction vision is formulated about a desirable experience during usage of the product. As such, for every patient profile, specific interaction qualities are defined. The interaction vision and the interaction qualities form the basis for the user experience and will therefore also be applied in the conceptualization phase.
Finally, the design direction will be specified.

3.1 Insights & opportunities

First, all gathered opportunities for the BioCoach that could benefit the THA rehabilitation journey are listed. Then, important insights per patient profile are covered that could influence the rehabilitation process; they need to be taken into account in the design process.

3.1.1. REHABILITATION INSIGHTS

Insights in BioCoach's functions and opportunities during the rehabilitation journey

Patient
Preoperative
• BioCoach's role in visualizing the end goal and movement after surgery [2.2.3]
• BioCoach's role in preoperative physiotherapy for individuals with many functional limitations preoperatively [2.2.1]
• BioCoach's role in preoperative information for individuals with fear of the operation and the post-treatment [2.2.1]

Postoperative
• BioCoach's role in patient's treatment: posture and quality of walking [2.2.3]
• BioCoach's role in postoperative exercise and walking training [2.2.1]
• BioCoach's role in pain and medication management [2.2.1]

Complete journey
• Introduction of BioCoach application for patients to support in self-management [2.1]
• BioCoach's role in patient's support and preparation: providing individual information [2.2.3] & Provide tailored interface solutions per patients, based on patient profiles [2.4]
• BioCoach's role in creating a positive atmosphere and attitude [2.2.2]
• BioCoach's role in mental support to low anxiety levels [2.2.1]
• BioCoach's role in enhancing patients' self-efficacy, self-motivation and social support to support patients' self-managed physical rehabilitation [2.2.1]

Physiotherapist & caregivers
• BioCoach's role in supporting physiotherapist's administration: automation in administration [2.2.3]
• BioCoach's role in identifying underlying needs in their way of presentation of the patient. [2.2.2]

Teamwork
• BioCoach's role in complicated situations and physiotherapist's teamwork: creating a communication platform [2.2.3]

Others
• BioCoach's role in researching the relation of depression and anxiety levels and functional recovery [2.2.1]

3.1.2. PROFILE INSIGHTS

Insights into the three patient profiles (problem definition)

At the beginning of this project, several insights into different patient profiles were known, but the needs of the different profiles were not known. Since the different patient profiles have been analyzed (2.3.2. 2.3.3 & 2.4), insights into their needs can be shared per patient profile that could function as a base for the design phase. These needs could be found in the table on page 63.
The insights into the problem definition per profile, that are the base for these design guidelines, are summarized below.

1) Optimistic profile
• are self-reliant;
• not clear how they perform their exercises and how their walk quality and posture is;
• sometimes a lack of motivation, sometimes impatient and over-active: difficulty in finding the right activity balance: not too little, not too much.

2) Managing profile
• are self-reliant;
• not clear how they perform their exercises and how their walk quality and posture is;
• experience of pain and anxiety;
• sometimes a lack of motivation, sometimes over-active: difficulty in finding the right activity balance.

3) Modest profile
• are not self-reliant
    o difficulty in understanding the advice, feedback and information of healthcare professionals (it must be easy reachable, simple language, clear and not too much);
• goal is not clear, they don't understand why they are doing something;
    o hard to communicate their needs or feelings;
    o forget what they did or should do;
• not clear how they perform their exercises and how their walk quality and posture is;
• experience of pain and anxiety
    o not clear how much medication they need to take
    o pain-catastrophizing
• sometimes a lack of motivation: difficulty in finding the right activity balance; not too little, not too much;
• sometimes a lack of commitment, engagement, and involvement.

3.2 Design vision

3.2.1. PRODUCT VISION

After all insights have been collected, a product vision is formulated. This vision forms the basis for the interaction qualities of the intended design.

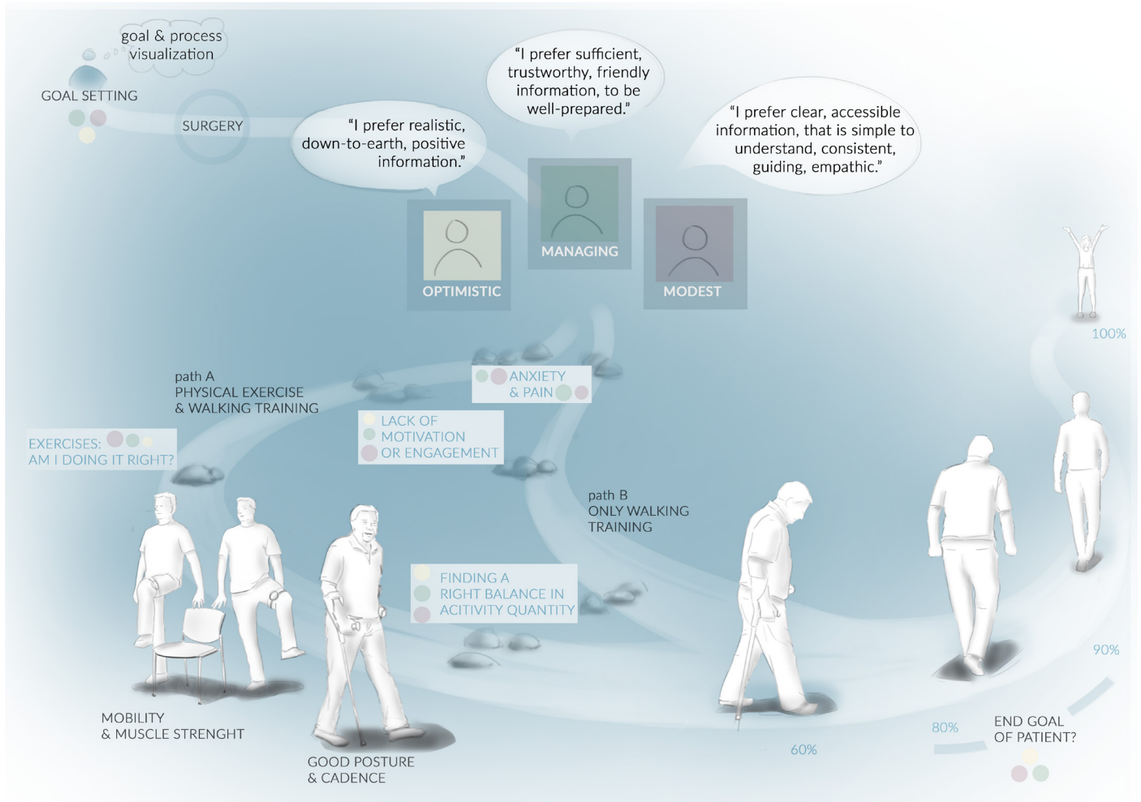


Figure 3-1 Vision on the THA rehabilitation journey for the three patient profiles.
Design direction: design for the modest patient profile, with the focus on Path A: doing physical exercise and walking training.

Design statement:

"Supporting patients in their self-management of physical activity during their first 6-8 weeks of THA rehabilitation, including the preparation of rehabilitation before surgery, by designing an integrated 'product-service system' that will take all aspects into account that could interfere with a positive rehabilitation journey, such as finding a right balance in the quantity of activity, and providing feedback on quality of posture, exercise and walking pattern - while creating a positive atmosphere around rehabilitation."

In the figure on the left, my vision as a designer on the rehabilitation journey for all patient profiles is visualized.
In this visual, difficulties are depicted as stones on the road (blue text) and important focus points are mentioned: the goal setting before surgery; the combination of physical exercise and walking training, or the shorter path of only walking training; and finally, the end goal of recovery, which might differ per patient.

Vision on the BioCoach's qualities
I envision the BioCoach as a physical coach: a tool that will coach patients on their physical activity during their rehabilitation.

The current version of the BioCoach focuses only on the physical exercises at home, not on walking training. However, my research shows that walking training is essential and therefore needs extra care and guidance; since the walking pattern is disturbed because of the patient's hip problems (pain, reduced muscle strength and mobility) before surgery.

Walking and exercising
Physical exercises are needed to improve muscle strength and mobility, before the patient is able to learn to walk correctly and independently. During walking, the muscle strength exercise and mobility exercise are practiced. By combining physical exercises and walking training, the patient learns to walk in the right way again (Figure 3-1, path A).
Some patients, who do not experience softened muscle strength or a decline in mobility, only focus on the walking part to recover (Figure 3-1, path B). Which path the patient will follow will differ per individual and is not dependent on their established patient profile, since the profiles don't include characteristics about physical conditions.
The quality and quantity of physical exercises and walking training influence each other. For example, if you are coached in doing the right amount of exercises, but then go out for a very long walk, you can still overload the body. So therefore, I would like to take the **>** total amount of physical activity of the patient

Figure 3-2 Vision on the BioCoach qualities

GENERAL INTERACTION VISION - for all profiles

The desired interaction of the BioCoach should stimulate a positive atmosphere and mindset. As concluded in the analysis chapter 2.2.3 (page 37), a positive atmosphere and attitude gives beneficial outcomes after total hip arthroplasty concerning function, activity limitation and risk of pain (Singh, 2016).
In the favorable case, patients will experience their rehabilitation and surgery procedure as something that enriches their life, instead of being a weakness.

Besides a positive experience of the rehabilitation process, the envisioned product experience is the feeling of wearing something valuable, such as jewelry.
So, the product itself feels like something positive to carry with you; something to be proud of instead of something you don't want to be seen with and feels as a burden, (such as an outboard bracket, wheelchair, sling, rollator or neck alarm).
Something that empowers the patient and gives a feeling of independency.

into account with the BioCoach, and monitor the quantity of walking and exercising during rehabilitation.

Desired feedback of the BioCoach
The current BioCoach is able to determine the correctness of the exercise and monitor the revalidation progress of the patient. This information is then recorded and stored in digital datasets. Afterwards, this information can be found in the online portal of the physiotherapist. This way, the physiotherapist is able to provide more informed feedback to the patient during the consult. On the other hand, the patients receive only feedback from the BioCoach on their progress and the amount of exercises, and thus not on the correctness of execution. However, in the user test of chapter 2.4, half of the patients (2/2 modest, 3/6 managers and 1/4 optimist) indicated that they would like to see if they performed their exercises well, preferably directly after performing their exercises at home. In the new BioCoach concept, it is desired mainly for the modest and managing patient profiles to get feedback on the correctness of their exercises and posture.

In addition to a physical coach, other aspects were researched during the analysis phase, such as mental support, pain management and social communication.
In my opinion, these other aspects will not be the main goal of the BioCoach, but they could be potential sub-goals that could be integrated into other stages of the human-product interaction. For example, when a patient from the modest profile receives feedback, it could be implemented in such a way that it has a beneficial effect on the patient's motivation, anxiety and pain experience.
Mind and body are connected and influence each other; a good physical performance and recovery by the patient will only be reached when the patient feels mentally fine. I think especially for mental support, human interaction is valuable. But in my opinion, the BioCoach can definitely play a beneficial role in mental support as well, by means of taking away fear and uncertainty.
The envisioned moment that I have in mind in which the BioCoach could play a beneficial role in here is the reassuring interactions—i.e., giving the right information at the right time and the goal setting before surgery and before doing activity, using motor imagery.

Vision on the BioCoach's user experience
It's often mentioned by patients that the rehabilitation phase is experienced as a quest. When using the BioCoach, the user experiences that he/she is not alone on this quest; you go on a journey and travel together. We can use this metaphor of going on a journey: you don't know exactly what to expect, but there is a clear end goal in mind. There could be (unexpected) obstacles on the road and different paths could be taken, but finally the journey will lead you to your final destination, with the help of your guide (the BioCoach).

Your buddy
The BioCoach could be seen as a supportive tool or guide during this journey—to make the journey more effective, efficient, pleasant, and satisfactory.
The BioCoach could be a reliable friend; an experienced travel buddy to share experiences with and who will support you in uncertain situations (see Figure 3-2, A). Or a professional travel guide that explains where things are coming from (Figure 3-2, B). Also, it can be a down-to-earth travel tool, such as a travel map or compass that just shows the right direction (Figure 3-2, C).

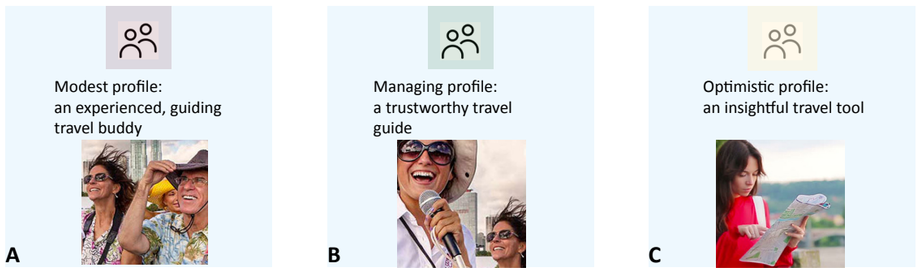


Figure 3-2 - Metaphor for the BioCoach during the rehabilitation journey for the three patient profiles >

Why do these three types of buddies fit with each profile?
These three metaphors for the patient profiles are based on the interaction qualities that are defined in the analysis phase and formulated in the design guidelines (chapter 2.4, page 59).

INTERACTION QUALITIES

Beside the general interaction vision that is desired for all patient profiles, explained on the previous page, every patient profile has its own, specific interaction qualities.
Since we will focus on the feedback of the User Interface of the BioCoach, the user experience, the interaction vision and qualities are relevant to generate ideas in the conceptualization phase.

An experienced travel buddy for the modest patients
The preferred interaction qualities of the modest profile are: simple, consistent, stable, convincing, emphatic, a listening ear, guiding, committed, joyous, respectful.
The modest patient profile prefers **understandable and easy reachable** information in **simple language** or **visuals**. They want someone who could **guide** them and take them by the hand, in short: someone they can rely on. The modest patient profile wants to be taken seriously, but the rehabilitation process itself should not be experienced as something too serious, but joyful and **playful** instead.
Since modest patients experience the most anxiety and pain, an interaction that is **reassuring** and **motivating** is desired.
In conclusion, the envisioned interaction for this patient profile is corresponding to an experienced travel buddy: a reliable friend who knows where to go, like a professional guide, and who feels familiar to share their own experiences with the patient. This way, the patient feels supported in uncertain situations to reduce anxiety.

A professional travel guide for the managing patients
The managing patient profile prefers **reliable**, **extensive**, **friendly** formulated information in a **supportive** and **involved** way, from someone they can trust. They want to stay in **control** by preparing themselves well and want to know the background information and the reason behind their tasks and actions. Information must be based on reliable sources, such as a doctor or scientific research.
In conclusion, a metaphor that portrays the envisioned product experience for this patient profile is a professional travel guide: a trustworthy guide who supports you on your journey and during difficult moments of pain or uncertainty, by explaining where things are coming from.

An insightful travel tool for the optimistic patients
The optimistic patient profile prefers **practical**, **down to earth** information and interactions in a **positive** and **involved** way. They want to get a **realistic** view on their rehabilitation process. They don't want an overload on background information, but just the things they need to know to recover well. Overall, this patient profile is in search for the **right balance** in the amount of physical exercises to stay on track.
As could be read in chapter 2.4, the optimists tend to figure things out by themselves and take risks during rehabilitation. To optimize their rehabilitation journey and recovery time, they just need a little tool to keep them on the right path by providing insights in their progression and activity level.
Therefore, the metaphor of a travel map or a compass is chosen: an insightful, accurate travel tool that just shows the right direction to stay on track.

3.3 Design direction

The initial design problem is rather broad and described as: ‘Do ‘the three profiles’ benefit from specific BioCoach interaction features during the THA rehabilitation?
Based on all insights (3.1), design directions can be specified, which makes the solution space smaller. For each patient profile, a design direction will be formulated.

Direction 1:
Design a BioCoach product variant for the optimistic patient profile

“Supporting optimistic patients during THA rehabilitation in finding a right balance in the quantity of physical activity and providing feedback on the quality of exercise in a positive, realistic, down-to-earth way. Enhance a good posture and walking cadence.”

Direction 2:
Design a BioCoach product variant for the managing patient profile

“Supporting managing patients during THA rehabilitation in finding a right balance in the quantity of physical activity and providing feedback on the quality of exercise in a positive, trustworthy, involved way. Enhance a good posture and walking cadence. Provide support in managing pain and anxiety. ”

Direction 3:
Design a BioCoach product variant for the modest patient profile

“Supporting modest patients during THA rehabilitation in finding a right balance in the quantity of physical activity and providing feedback on the quality of exercise in a simple, understanding, easy reachable, joyous way. Enhance a good posture and walking cadence. Provide support in managing pain and anxiety.”

Choice of design direction: Modest profile
In my opinion as an industrial designer, all patient profiles could benefit from using the BioCoach. But since this project has a limited time span, the decision is made to focus on only one of the patient profiles: the modest patients (design direction 3).

Why? Various reasons for this focus can be made:

• The modest group is the least in self-reliance, so this group could benefit from having additional support in their self-management;
• The modest group has the lowest decrease in pain after surgery and their ‘self-reported health’ decreases after 3 months after surgery. This could be due to the fact of inadequate rehabilitation, which means that this group can make the biggest improvement in ‘health outcomes’;
• The modest group has the most difficulties in understanding advice, feedback and information. So, I think that when a design is understandable and working well for this group, the other profiles will understand it too.
• The modest group is the most challenging for me personally; I didn’t work or have conducted user tests with this group before, so this will be an interesting new experience for me.

Optimists and managers could also manage themselves without extra support of a product like BioCoach; they are self-reliant. However, it could increase the quality of rehabilitation and could make the process more pleasant.

Narrow down the scope
To narrow down the scope of this graduation project further, the decision is made that the focus of the final design will be on the feedback of the BioCoach on the patient’s exercises during home rehabilitation. This focus is chosen, since it is a logical continuation on the insights obtained in the analysis phase, which shows that the differences per patient profile mostly lies in the way of presenting the feedback and information to the patient. This is done through the User Interface (UI) of the BioCoach.

Other directions that can be further developed through follow-up research are:

• *Focus on the physical activity measurement*, so the input of the BioCoach. Of course this part will be included in the final design, but no additional user research will be done about it.

• *Enhance a good posture and walking pattern.*
Besides coaching the patient on exercises, how could the BioCoach help the patients best in improving their posture and quality of walking? For example, is measuring the posture and walking gait and giving real-time feedback the most effective way to enhance a good walking quality, or is a reminder before going for a walk enough? Further research should answer these questions.

• *Creating a selection tool for ‘patient profile’ determination.*
With the insights gathered in paragraph 2.3 and 2.4 about patient profiles, an overview could be made with all possible patient needs that patients could have during rehabilitation. By selecting the desired options per patient, a tailored product could be shaped.

I will therefore recommend the above other directions for follow-up research.

Final design challenge:
“Design the feedback for the modest patients profile on the BioCoach’s User Interface, to support these patients during their first 6-8 weeks of THA rehabilitation. The desired effect is to improve the quantity and quality of their exercises, enhance a good posture and walking pattern and manage pain and anxiety - while creating a positive atmosphere around their rehabilitation.”

PROGRAM OF REQUIREMENTS & WISHES - FOR THE MODEST PATIENT PROFILE

In the conclusion of chapter 2.4, design guidelines are presented per patient profile. These guidelines are mostly focused on the product function and interaction preferences. Here, an overview of all requirements and wishes that should be taken into account for the modest patient profile are presented. These requirements are based on the whole analysis phase and user test results, and can therefore be seen as the foundation for the conceptualization phase. Concepts can be assessed on the basis of (or a part of) these requirements and wishes.

A) Performance - Functionalities

Requirements

The product should support the patient in self-management during their THA rehabilitation (see figure 3-4):

Before surgery:

1. The product should **visualize** the rehabilitation **end goal** and the rehabilitation **process** (expectation management).

After surgery:

2. The product should **recognize** and **monitor** exercises for hip mobility and muscle strength of the operated leg.
3. The product should **remind** the patient for daily activity and remind them on their final goal.
4. The product should provide visual (video) **explanation** about the exercises.
5. The product should provide **feedback** on exercise performance and walking activity.
6. The product should provide **progression** insights: progression in the **total** process and progression on the **daily** exercise program to create awareness and find a right balance in exercise quantity.
7. The product should enhance a good **posture** and **walking** pattern.

During the complete journey:

8. The product should help the patient in **managing pain** and medication use.
9. The product should have the possibility to **share experiences** and express emotions.

Wishes

12. The **accuracy** of measured data should be as high as possible.

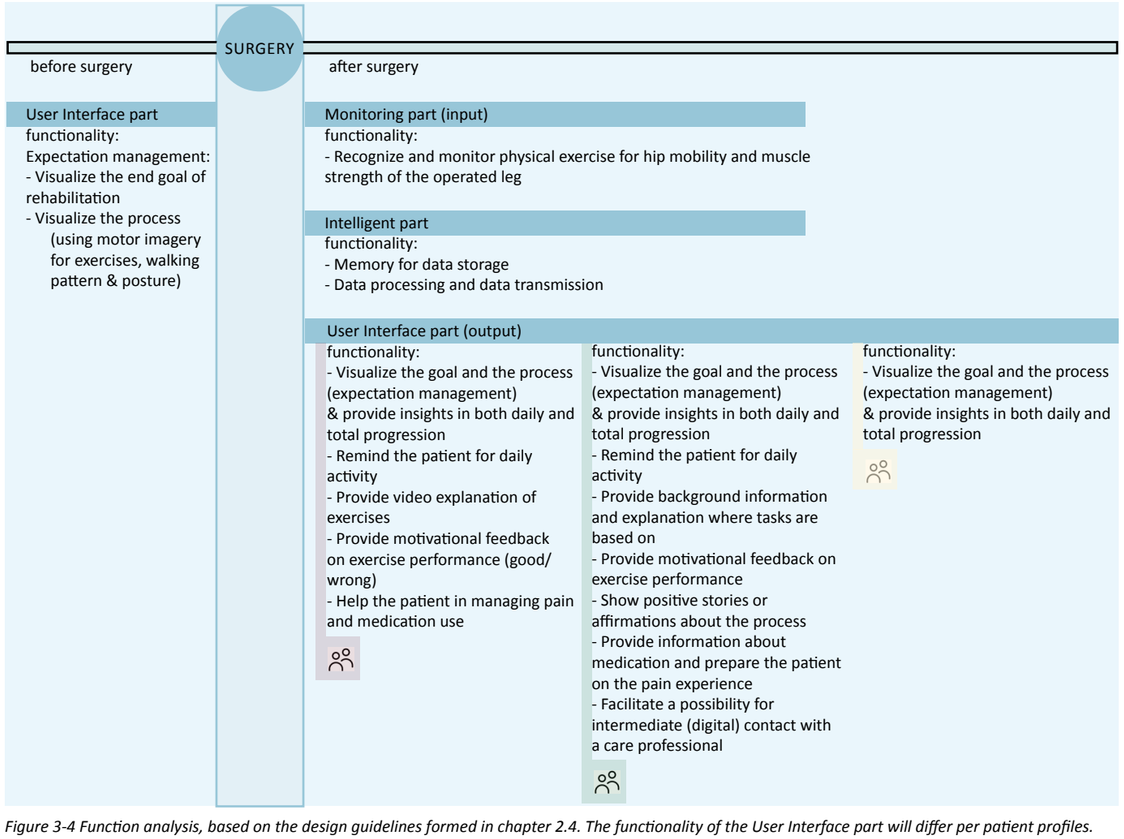


Figure 3-4 Function analysis, based on the design guidelines formed in chapter 2.4. The functionality of the User Interface part will differ per patient profiles.

B) Usability

Requirements

1. The product should be **understandable** for the elderly, and lower educated patient, without the need for previous experience with the product.
   a. The product must provide **clear, easy reachable** information and advice in **simple language**.
   b. The product's **User interface** (UI) should be elderly friendly: understandable iconography, text and images without stimulus overload.
2. The product must work for the patient **independent of Internet** usage, since 25,6% of these patients never uses Internet.
3. The product must be clearly **visible.**
4. The product must be **portable**, to carry with you to the healthcare professional consult or on a walk.
5. The user must not experience dis**comfort** while using the product.
6. The **size** and **shape** of the product must be suitable for the elderly patient's (60-90 years) body dimensions.

Wishes

7. The product should be **easy to use**: as little patient's actions as possible.
8. The product should be as **light** as possible.
9. The product must be easy to use in combination with **normal clothing**.

C) User experience

Requirements

1. The product should feel **familiar** to the modest patient profile.
2. The appearance of the product must be attractive to the user by giving a feeling of **simplicity, consistency, guidance, empathy, commitment, reassurance, joy, and respect.**
3. The product should increase **motivation**, **engagement** and **self-efficacy** for active participation during the rehabilitation process.
4. The product should **lower down anxiety** and uncertainty and provide a feeling of support.
5. The product should communicate the **style** of Zimmer Biomet's new 'Rehabilitation product portfolio'.

Wishes

6. The product should stimulate a **positive atmosphere** and mindset around their surgery and rehabilitation. Ideally, patients will experience the rehabilitation process as an experience that enriches their life.
7. The product will lower down the **pain** experience.
8. The product should be unobtrusive for the environment, **not stigmatizing**.
9. The product should feel as a '**buddy**' to the patient: a reliable friend, which could guide the patients and could take them by the hand, like a professional guide, but who feels more familiar; to share experiences with and who will support you in uncertain situations to reduce anxiety. Someone who understands you and communicates in the same way.
10. The product **empowers** the patient and gives a feeling of **independency**.
11. The patient should **feel taken seriously** by the product, but the product should feel at the same time **fun** or joyous to use.
12. The product itself should feel as something **valuable** and positive.

D) Future perspective

Wishes

1. The product should anticipate on future developments around THA surgery: sensing **chip implant** in the hip prosthesis (see figure 3.5).

Other requirements:

E) **Life in service**: The product will be used during rehabilitation, of max half a year, on a daily basis. After this period, the product will be returned to the supplier for reuse.
I) **Reliability**: The product may not give wrong advice or be demotivating

Other wishes:

J) **Production cost**: The production costs should be as low as possible without compromising the functionality.
K) **Maintenance**: All parts of the product must be able to be cleaned easily by the user themselves.

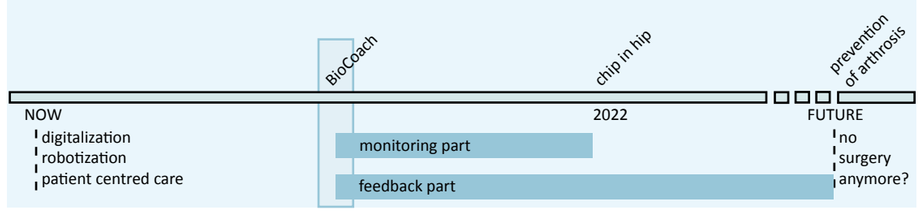


Figure 3-5 Future perspective of product life span

STARTING POINT

Previous chapters:
Design guidelines for the BioCoach
Design direction & challenge
Interactions qualities & requirements

STUCTURE CHAPTER 4

4.1 Ideation

Associative methods
How-tos brainstorming

Analytic-systematic method
Function analysis
Morphological chart

Creative confrontation method
Analogies

Clustering - ideation drawings

4.2 Conceptualization

Concept directions

Choice concept direction

Concepts feedback device

Choice feedback device concept

4.3 Concept development

Final concept: Design of a new rehabilitation journey
Overview of the Final concept
Development of Screen interface
Development of Cover
Development of Sensing Plaster

4.4 User Test

User test:
Evaluation of Final Concept

Chapter 4

Synthesis: creating a concept for the Modest patient profile

This chapter includes the ideation and conceptualization process towards the final concept, starting with idea generation to eventually form concept directions. After this, a concept choice is made and a concept development is done based on a list of criteria.

4.1 Ideation

To come up with new, suitable ideas for the BioCoach, different idea generation methods are used, starting with associative methods: brainstorming with how-to's.

Brainstorming
The used how-to's are coming forth from the design guidelines for the modest profile and possible (sub-)functions of the BioCoach and includes questions like:
• How can you monitor physical exercise?
• How can you measure an upright posture, cadence or a good walk pattern?
• How can you make progression insightful?
• How can you motivate someone? Enlarge commitment, adherence, and involvement?
• How can you enlarge self-efficacy?
• How can you lower down pain?
• How can you lower down anxiety?

Also a brainstorm is done about the desired interaction qualities: how can you present information, feedback and advice in a simple, clear, easy-reachable way? How can you determine the right amount of information for a patient? How can you guide someone, unobtrusively? How can you create a positive atmosphere?

First, brainstorm sessions were done individually, since I had as a designer lots of input from both patients and physiotherapists to have a good brain dump. Then, some brainstorming and idea evaluation sessions have been executed with design students and physiotherapists (T.Tournier, W.van Dijk, personal communication, March 22, 2018). Also, an expert is consulted about measuring the walking pattern (H.Vallery, personal communication, March 21, 2018).

Function analysis
Beside the brainstorm sessions, analytic-systematic ideation methods are used: a function analysis is done and a morphological chart is made. In this morphological chart, sub-functions are listed and possible solutions are collected (Figure 4-1 or Appendix 8). This collection of possible solutions is coming forth from a clustering of the most promising brainstorm session ideas.

Figure 4-1 morphological chart

The sub-functions in the morphological chart are focusing on the qualities of the user interface and include: providing feedback; progression insights; explanation or (background) information; lowering down pain; lowering down anxiety; indication of the pain level; a reminder; enhancing a good posture and walking pattern; goal visualization; increasing motivation and positivity, and finally, sharing experiences or expressing emotions.
A clear choice has to be made which functionalities the product must include for the modest patient profile. Since we want a simple, easy-to-use product, we don't want the patient to overload with lots of functions and possibilities. Only the essential, desired functionalities will be integrated, such as:
• monitoring the physical activity during the day;
• visualizing the goal & motor imagery for walking pattern, posture and exercises before the physical activity;
• reminder for activity;
• video explanation of exercises;
• providing motivational feedback on physical activity (good/wrong, progression).

main functions	sub-functions
- Visualize the goal and the process (expectation management) & provide insights in both daily and total progression - Remind the patient for daily activity - Provide video explanation of exercises - Provide motivational feedback on exercise performance (good/ wrong, progression) - Help the patient in managing pain and medication use	motivation, lower down pain, lower down anxiety, increase positivity, share experiences/ express emotions

Figure 4-2

In comparison with the other patient profiles, the list of functionalities for the Managing patient profile will be extended with for example providing background information to explain were every step is coming from. The list for the Optimistic profile will be much shorter and might only include the functions of goal and movement visualization and the functions of providing insights in their progression (Figure 3-4).

Another analytic-systematic method used is the WWWWWH (Who, What, Where, When, Why, How) and the 'life phases of the product-to-be'. By writing down the several life phases, new relevant questions come to mind that must be taken into account during the design process.

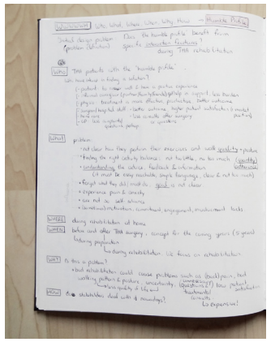


Figure 4-3 WWWWWH

Analogies
Thirdly, creative confrontation methods are executed: analogies and metaphors. You see an existing problem through the lens of another domain. The metaphors for the different patient profiles were explained in chapter 3, which will be 'an experienced travel buddy' for the Modest profile. This metaphor is helpful for communicating particular messages to users and represents the meaning that a product evokes (Delft design guide, 2013).

An analogy is used for the 'problem' of staying motivated for doing physical exercises. The analogy applied here is staying motivated during building a new habit. The new physical exercises of the patient can be seen as implementing a new habit into your life. Inspiration can be found in motivational habit apps that support the user in building new habits. An example that is used for inspiration is the motivational app 'Fabulous' (Figure 4-4).

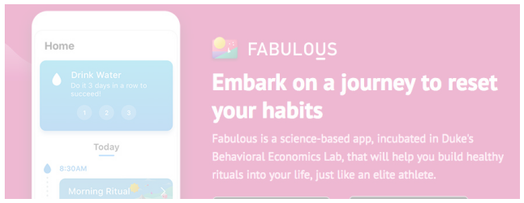
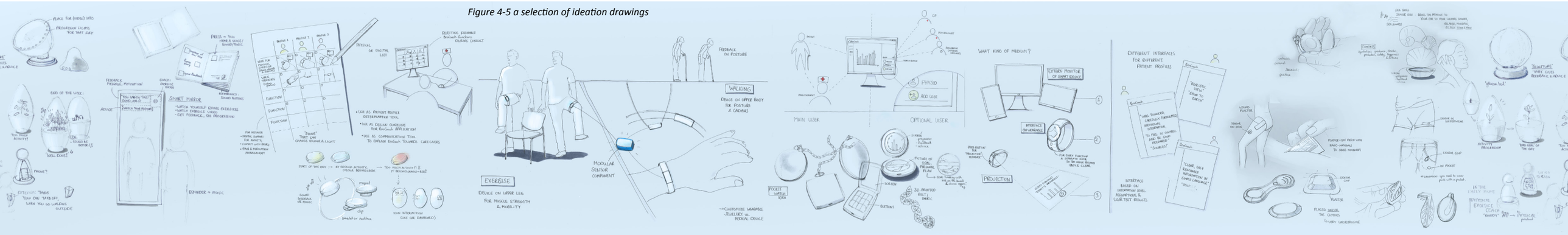


Figure 4-4

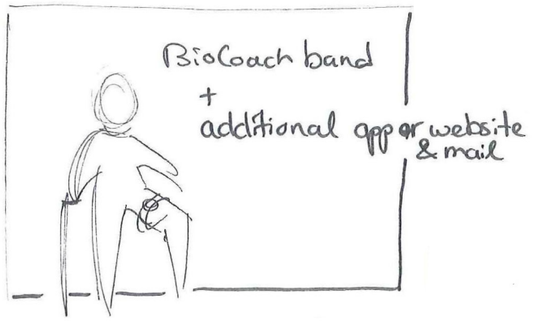
Figure 4-5 a selection of ideation drawings

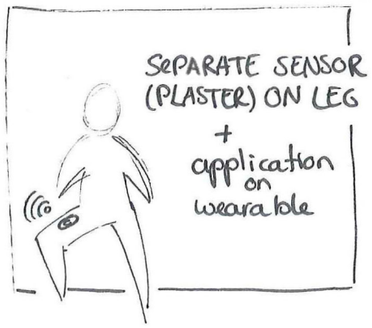


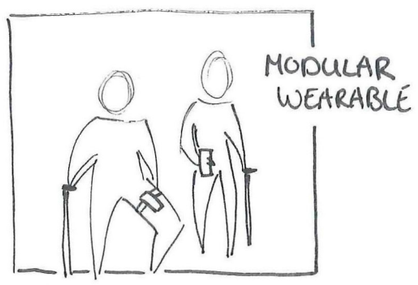
4.2 Conceptualization

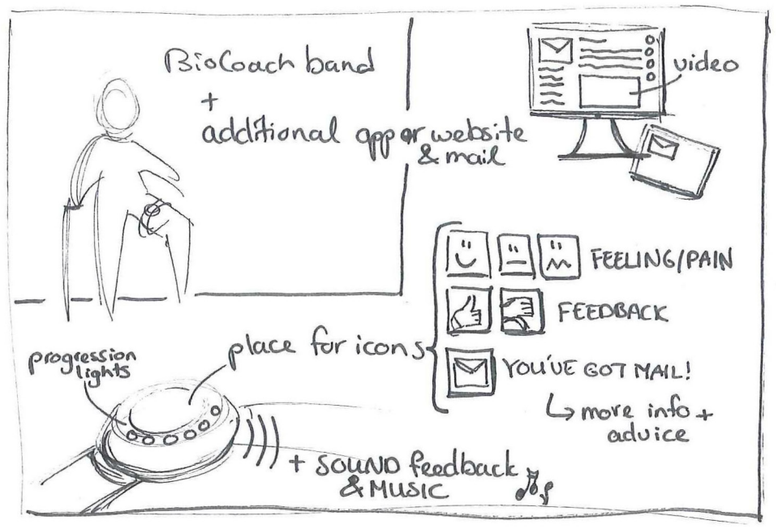
4.2.1. CONCEPT DIRECTIONS

As explained in the previous paragraph, a morphological chart is made in which ideas with similar functionalities are clustered. With the design guidelines for the modest patient profile in mind, combinations are made with the most promising ideas. This results into three different concept directions.









Concept direction 1 – upper leg device

What

This concept stays most close to the current BioCoach concept: one device that includes all required functions; it will monitor the physical activity and provide feedback to the user. In this concept, the feedback is more tailored made for the modest profile by using icons and voice messages from the physiotherapist. The icons make the feedback more intuitive and easy to understand; the voice messages create a more familiar, emphatic feeling which could enlarge the commitment of the patient to their exercise program.

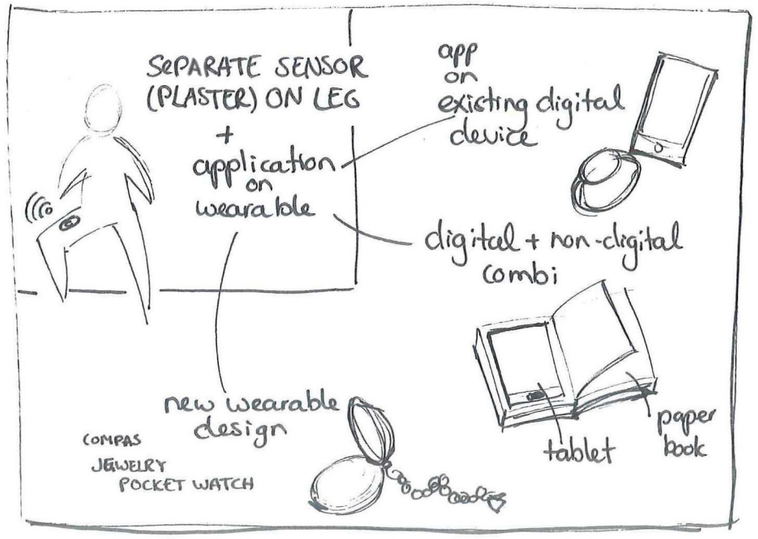
An additional application could provide video explanation about the exercises and background information.

Usage

The product will be worn around the upper leg, above the clothing. The patient will put the band on in the morning and takes it off before bed time. This way, exercising at home and the patient's walking activity could be monitored both. No additional actions are needed by the patient to make the product function.

Points of attention

- The band should be designed in a way that it can be easily placed in the right position by the patient and will not turn or move during physical activity.
- The patient should be able to wear pants under the band. A skirt is not convenient to wear, since the interface of the product will not be visible anymore.
- Obtrusiveness: when performing the physical exercise at home, it doesn't matter if the product is obtrusive or not. So, this concept is suitable for performing the physical exercises at home. But since the band it quite obtrusive, it can be considered if this is attractive for monitoring the walking exercise outside. When continuing with this concept, the design of an appealing band will be important.
- The product must be able to be used without using the additional app or having Internet.
- Since the feedback will be given on the upper leg, it can be researched if this will influence the posture of the patient during their physical exercise and walking, since they will possibly look to the product's interface.



Concept direction 2 – separate sensor unit and feedback device

What

In this concept, the measurement functionality and feedback function of the BioCoach are separated into two different products. This makes it possible to design an unobtrusive, small sensor component for the monitoring function, with which the patient doesn't need to interact with, and a feedback device that has all design freedom to come up with a best possible solution for the user group, since you are not bound to a specific place on the body or another product part.

The measurement part will be a sensing plaster that will be placed on the upper leg by the hospital physiotherapist after surgery and just stays there until the patient will see a physiotherapist again. Measurements will be done automatically, so no actions by the patient are needed. Since the patient has already a wound plaster on their hip, the sensing plaster is not something completely new for the patients and could be seen as an extension of their current plaster.

For the feedback part, the design space is big; the product could be an application on an (existing) wearable device or something static. Several concepts could be created and a suitable choice can be made by testing these concepts with criteria and testing and evaluating it with patients.

Usage

The usage of the sensing plaster requires no actions by the patient; it will be placed by the physiotherapist.
The usage of the feedback device needs to be defined later, when a choice is made for this concept. Criteria for the usage will be: simple to understand and feeling related to, preferably with less action as possible for the patient, to limit the change of misusage or uncertainty.

Cost estimation (look to components)

[€] When designed for patient with affinity with smart devices, an application can be designed for their existing smart phone or tablet.
[€€€] When designed for patient without affinity and the ownership of smart devices, which is the case for the Modest patient profile, it is best to design a new, elderly friendly feedback device.

Points of attention

- The placing of the plaster on the body must be defined and must be clear for the person who put it on, which will be the (hospital) physiotherapist or nurse.
- The sensing plaster must be designed in a way that it feels comfortable on the elderly skin for more days, preferably two weeks, so that the patient doesn't need to put it on or off between consults.

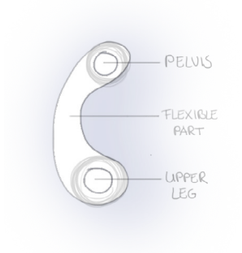
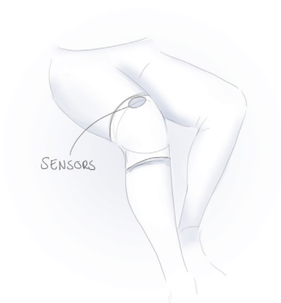
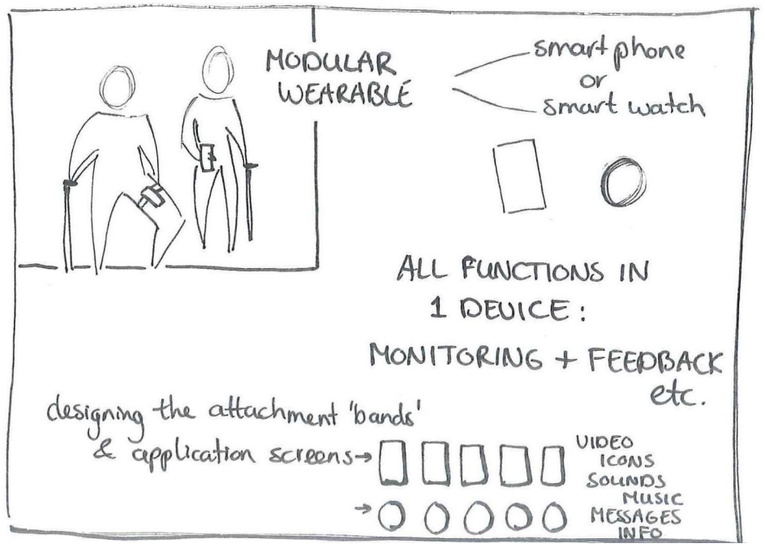


Figure 4-6 sensing plaster with a sensor place on the pelvis and on the upper leg



An alternative on the sensing plaster is a thin sensor band around the knee that could be worn under the clothing. Because of the knee shape, the patient has a reference point for the placement of the band. Also, the band will not move or turn easily around the knee, in contrast to the upper leg. The patient could put the band on in the morning and off before bedtime.

Figure 4-7 alternative on sensing plaster: sensing knee brace



Concept direction 3 – modular sensor unit on leg band and belt

What

One device monitors the patient's physical activity and provides feedback to the patient. During the physical exercise at home, this component will be worn around the upper leg with a leg band, over the clothing, just like the current BioCoach. The rest of the day, also during walking training outside, the component will be attached at a belt around the waist. This makes it possible to measure the quality of the walking pattern, for instance if the patient has a waddling gait.
This concept is an answer to the obtrusiveness of concept 1, since wearing a belt is not that obtrusive as a band around the upper leg. Side issue is that the patient needs to perform several actions to attach and detach the device to the band and belt every day.

Usage

Before usage, the device needs to be attached to the belt. The patient will put on the belt in the morning. When performing the physical exercise at home, the patient will replace the device: the device will be detached from the belt and will be attached to the leg band. Then, the patient put on the leg band around the upper leg and performs their exercises. After exercising, the device needs to be attached to the belt again.

Cost estimation

[€] When designed for patients with affinity and the ownership of smart wearable devices, only an attachment band and an application should be designed.
[€€€] When designed for patients without affinity or the ownership of smart devices, which is the case for the Modest patient profile, it is desirable to design a elderly friendly device that can be attached to the different bands.

Points of attention

- the attachment and detachment of the device to the belt and leg band must be easy and logical.
- putting on and putting off the belt and leg band must be designed in a way that it is easy to do without the chance of misplacement.

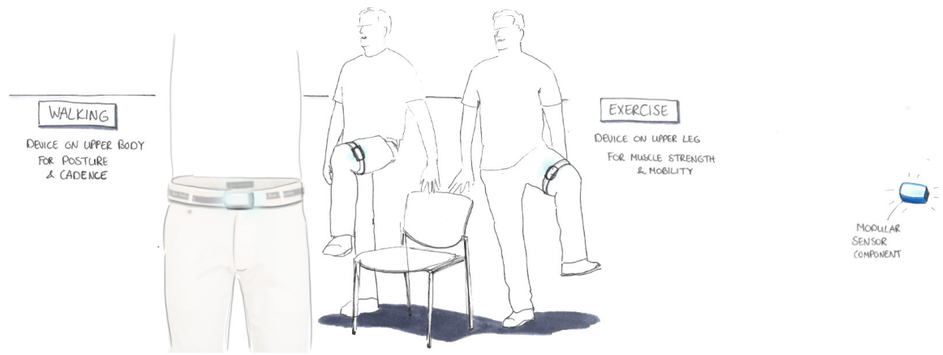


Figure 4-8 Modular monitoring component for leg band (home exersices) and belt (walking)

Evaluation and choice of concept direction

The different concept directions are evaluated with a selection of **wishes** from the list of requirements and wishes (chapter 3.3), to be able to make a right choice for a concept direction to continue with.

Selected criteria:

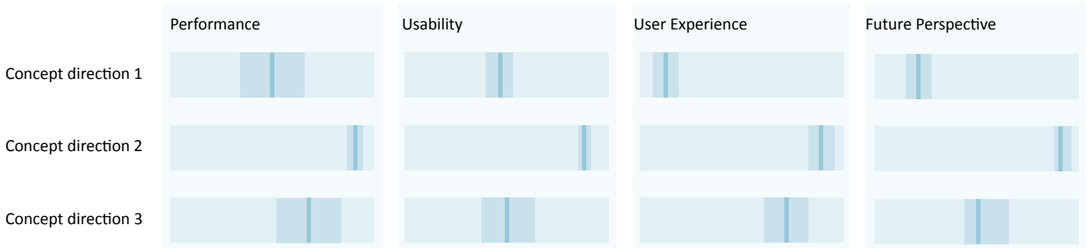
A) Performance
- The product provides high accuracy of measured data (A12).

B) Usability
- The product should be easy to use: the product requires as little patient's actions as possible (B7).
- The product must be easy to use in combination with normal clothing (B9).

C) User Experience
- The product should be unobtrusive for the environment, not stigmatizing (C8).

D) Future perspective
- The product should anticipate on future developments around THA surgery: sensing chip implant in the hip prosthesis (D1).

Since the concepts are not developed and tested yet, the concepts have a certain 'uncertainty margin' in their score on the above criteria. However, with the analysis knowledge in mind, we can predict how the concepts would score. This prediction is visualized in the map beneath and discussed at the right page.



A sensor on the skin (concept 2) has higher accuracy than a sensor above the clothing (concept 1 & 3).
Concept 3 has a higher accuracy in measuring the walking pattern than concept 1.

Since a belt could be placed wrongly, be forgotten to wear or may rotate during exercise, the accuracy of concept 1 and 3 has a higher 'uncertainty margin' that concept 2.

A plaster could be worn under the clothing and could stay there for more days. A wearable sensor belt must be putting on and taken off every day (so require patient actions) and require specific clothing (no long skirt).
Concept 2 changes from belt during walking and exercising; this creates more freedom in clothing choice during walking. The replacement requires most patient actions of all concepts.
However, how this will affect usability exactly must be tested; therefore an 'uncertainty margin' is indicated.

Concept 1 is most obtrusive: it will be worn over the clothing for all activities.
Concept 2 is only obtrusive during home exercise, during walking the sensors are placed on a belt.
The plaster is most unobtrusive.

In concept 2, the monitoring function and 'interaction functions' (such as feedback and progression insights) are divided into two products: plaster and feedback device. When the monitoring product will be replaced by a sensing chip implant, the same 'feedback device' could be used. In concept 1 and 3, monitoring and (some) interaction functions are integrated into one product. A chip implant makes this product useless and the interaction functions require a new design. In conclusion, concept 2 is the most efficient from a future perspective.

Discussion

If the function of the BioCoach was only to monitor the exercises at home, concept 1 would be suitable; an obtrusive appearance is less important and it is comfortable to wear.
But since the choice is made to measure both exercises at home and the walking activity during the whole day, concepts 2 and 3 score better on user experience and usability.

Concept 3 could be a good choice for athletes or (younger) patients who have affinity with smart devices; in that case you only have to design an attachment band, for their own smart device, and an application. Also, the placing of the sensors is accurate in this concept: the walking pattern can be measured excellent around the waist and the leg band is suitable for the mobility exercises. Beside this, the sensing belt can be continued to wear after the first 6-8 weeks of rehabilitation—to coach patients in their walking pattern and posture.
However, several attachment actions need to be performed by the patient, which might not be comfortable and easy for the modest patient profile, who are mainly elderly people who are not used to these actions. Chance for misusage exists, such as misplacement of the band or forgetting to put on the belt.

In comparison, concept 2 doesn't require any actions by the patient before usage. Also, this direction fits well with the future developments of an implemented chip in the hip prosthesis, and therefore this concept has the most future perspective (see figure 3-5). When the implantable chip technology will be introduced in the market, it will come instead of the sensing plaster and the feedback device could still be used. So, this direction is also a good test case to optimize the feedback device, before introducing the chip implant in the market.
Elderly are familiar with a plaster, however, one attention point is if the sensing plaster will be comfortable on the elderly skin. Follow-up research should investigate this.

In conclusion, concept 2 will be chosen to continue with in this project.

CHOSEN CONCEPT DIRECTION: SENSING PLASTER AND FEEDBACK DEVICE

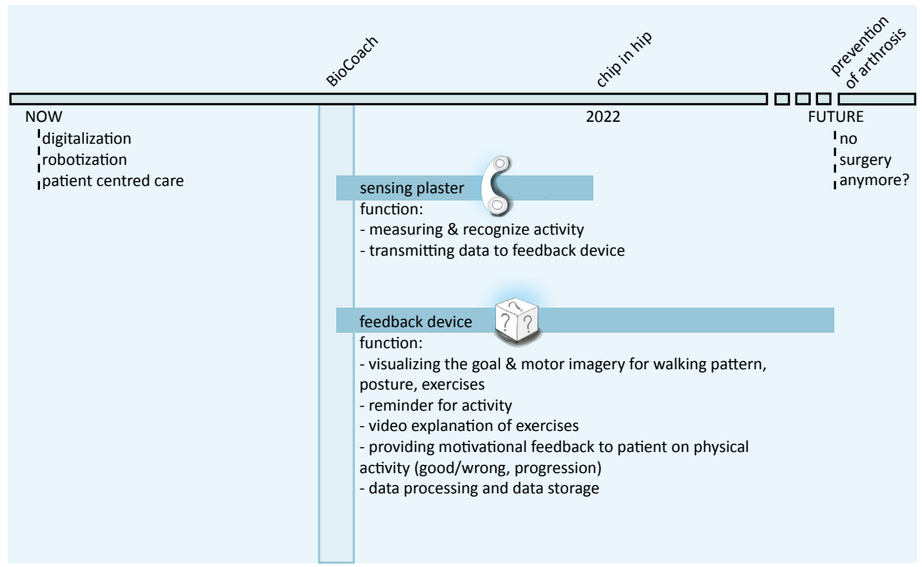


Figure 4-9

4.2.2. CONCEPTS FEEDBACK DEVICE

Within the chosen concept direction, three concepts are created for the feedback device. The data measured by the sensing plaster will automatically be sent to the feedback device, without any patient's action required.

All feedback devices fulfill the same functions (see figure 4-9). Therefore, all devices contain the same type of technical components:
- LCD screen
- Battery
- Wireless connectivity
- Microphone en speaker
- Light: RGB LED
- PCB
- Casing

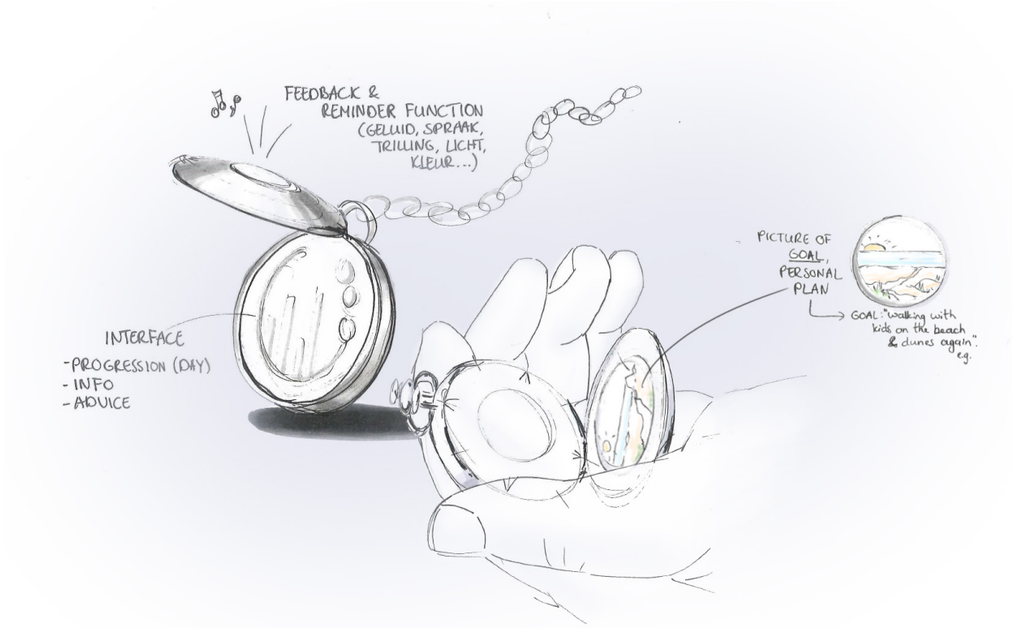
Differences between the concepts are in the shape and size, which influence its **usability** and **user experience.**

We have to keep in mind that the modest patient profile doesn't have much affinity with smart devices and often doesn't own or uses such a device, as can be seen in the table beneath.
Therefore, Zimmer Biomet should not only provide a service, but also an accessible physical product around it.
In this chapter, three concept ideas are explained. If these concepts will include an existing product (part) or require a totally new design, should be further investigated in the concept development and could be later validated in a final user test or future research.

		Mean	Profile 1 - Optimistic	Profile 2- Managing	Profile 3 - Modest
Internet usage	Daily	59.9%	**65.0%**	**65.1%**	**41.0%**
	Multiple times a week	15.9%	16.7%	14.5%	17.9%
	Once a week	4.9%	5.0%	3.6%	7.7%
	Monthly	2.2%	0.0%	1.2%	7.7%
	Never	17.0%	13.3%	15.7%	25.6%
Device usage	PC/laptop	71.1%	**75.4%**	**73.5%**	**60.5%**
	Tablet	44.9%	47.5%	45.8%	39.5%
	Mobile device	39.6%	47.5%	45.8%	16.3%

Table 1 - data about internet usage and device usage of the three different patient profiles (Dekkers, n.d.).

Concept 1 - BioCoach compass



What
The BioCoach compass is a new designed wearable device for the elderly user that just includes the desired functions and has no additional options that could create an impulse overload, which could be the case when using an existing smart device (Gaggero, 2009). The shape is like a compass jewel, which symbolizes guidance, direction, protection, safety and happiness.

The wearable has a screen to provide video explanation and visual feedback with icons. Physical buttons are placed to switch between screens. Beside this, voice messages of the physiotherapist will be played while doing the exercises. When the patient indicates to feel anxious or to feel lots of pain, the product can be placed by the ear, like a sea shell, to hear calming nature sounds and music with positive, calming affirmations to release fear, pain and make the coping process less heavy.

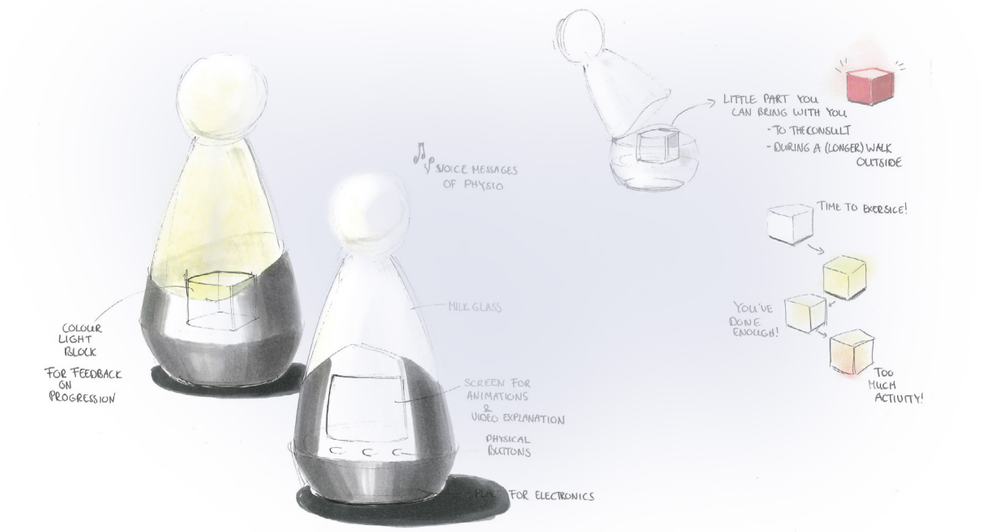
Figure 4-10 Sea shell idea: calming sound to release pain and anxiety

The BioCoach compass can easily be taken with you wherever you go, so progression can be seen continuously.

Usage
During the day the patient can carry the BioCoach compass in their pocket. A sound or buzzer signal will be given to remind the patient for their exercise program. By opening the compass, the patient can start the exercise program together with his/her buddy to make further steps on their journey. By pressing a physical button, a next screen on the interface will be shown.

Points of attention
- When the wearable is not worn, the product should be placed at a central place were the patient could easily find it.
- Video explanation should be understandable and good visible for the small screen.
- by looking continuously to the interface, the interaction with the product should not influence the body posture of the patient badly during physical activity.

Concept 2 - BioCoach buddy



What

The BioCoach buddy is a static device that could be placed on a central place at home, for instance on the kitchen table. The BioCoach is intuitive and feels as a buddy during the rehabilitation journey. The shape could refer to a buddy doll, but could also be designed more abstract. Another option is to design a shape that refers to a healing mineral stone, which gives a peaceful, fear releasing feeling.

When it is time to perform exercises, the BioCoach buddy will lighting up to give a reminder to the patient. On the device's screen, the exercise program is put ready.
By pushing a physical button, the device will coach the patient in their exercise program by showing video explanation before the exercise and provide visual feedback on the quality of the exercise with icons. Also, before and during the exercises, voice messages of the physiotherapist and music will be played, which has a fear reducing, motivating and pain relieving effect (Hole et al., 2015).

Usage

The only action the patient needs to perform is pressing the physical button to start their exercise program with the BioCoach buddy and go through the consecutive screens.

Points of attention

- the product must be playful but not childish
- the product or a part of the product should be able to carry with you to the physiotherapist consult.

Concept 3 - BioCoach guide

"let's go on a journey together"

What

Concept 3 is an interactive book that has both digital and non-digital parts. The book will be designed in a way that it is intuitive and feels as a buddy during the rehabilitation journey.
The cover provides feedback on the progression by colored light interaction. When it is time to perform exercises, the cover will light up that function as an exercise reminder to the patient. The patient can open the book to start the exercise program together with his/her buddy to make further steps on their journey.
When a patient tends to exercise too much, the color of the cover will become orange-red, to warn the patient and to suggest to take a break.

Inside the book, the patient will find a screen that will coach the patient in his/her exercise program by showing video explanations before the exercise and provide visual feedback with icons on the quality after the exercise. Also, before and during the exercises, voice messages of the physiotherapist and music will be played, which has a fear reducing, motivating and pain relieving effect (Hole et al., 2015).

At the bottom part of the journal there is also a place for personal notes. Here, the patients can write down or draw their goal, questions or experiences. Also, peers and relatives can place a personal message to the patient, like a poetry album or 'get well soon card'. So, patients could share in this way their experiences.

Usage

The actions that need to be performed by the patient are opening the book when exercising at home and pressing a physical button underneath the screen to go to a next screen. On the screen it will be indicated when it's time to press this button.

The book can easily be taken out with you, when the patient goes for a longer walk and want to keep an eye on their progression, by looking at the cover lights.

Points of attention

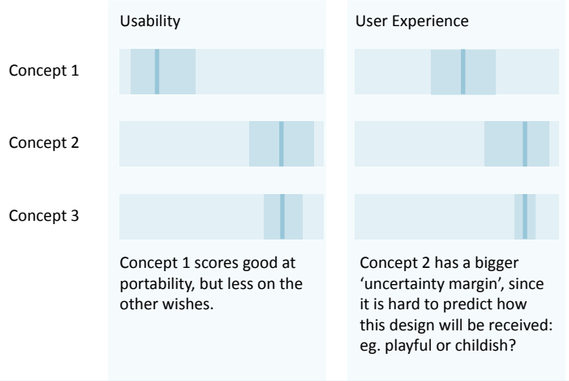
- the book should be placed so that the cover with progression lights is easily visible
- the 'serious book' appearance must not discourage the patient, but give a feeling of empowerment
- Patients should be able to carry the book with them, preferably in their pocket.

Concept choice

As stated in the introdution of this paragraph, all feedback devices have the same functionality, but differ in usability and user experience.
To make a concept choice, the different concepts will be compared on criteria with a focus on usability and user experience wishes. The criteria are selected from the list of requirements and wishes (see chapter 3.3) and evaluated by using a heat map.

Selected criteria:
B) Usability
- The product's User Interface (UI) should be elderly friendly: understandable iconography, text and images without stimulus overload (B1,b).
- The product must be clearly visible. for the patient (B3)
- The product is easy to carry with you (B4)
- The product should be easy to use: as little patient's actions as possible. (B7)

C) User Experience
- The product should feel familiar to the modest patient profile (C1).
- The product should feel as a 'buddy' to the patient: a reliable friend, which could guide the patients and could take them by the hand, like a professional guide, but who feels more familiar (C9)
- The patient should feel taken seriously by the product, but the product should feel at the same time fun or joyous to use (C11).



[?!] Wearable vs. not wearable?
One important choice that needs to be made is: at what moments do we want to provide feedback to the patient? Is this only after doing the physical exercise or also during the exercises? And must the progression be continuously visible? This choice has an influence on the preference of a wearable device or just something that will be in a central place in the patient's home.

Desired moments of interaction
During the physical exercise, you don't want to be distracted by the interaction with the device, because you want to have your full attention on your own body and exercise.
By continuously looking at the feedback interface to ensure that things are going well, the patient could get due to this a wrong body posture and perform less well.

While walking outside, I also assume that only feedback afterwards on progression is the best choice. In this way, patients have to estimate for themselves what a good walking distance would be and thus learn to think independently and gradually become independent of their caregivers and tools. Continuous feedback might give an overload of information that makes the patient dependent on the device or creates uncertainty when the device falls away.
If we look at safety while walking outside, real-time feedback could result that the patient will look often at the device instead of focusing on their physical activity. This can cause a bad posture or even a misstep and unsafe situations in traffic.
Feedback afterwards could be given at home, but could also be given during a break from the walk outside, when the patient goes for a longer trip.

In conclusion: since the assumptions are made that real-time feedback is not desirable and necessary, the BioCoach device does not have to be a wearable device.

As concluded above, the advantage of having a wearable device and the ability to continuously interact is not necessary. So concept 1 (wearable) will not be chosen for the modest profile, since elderly are less familiar with such a product, the screen interface is small, and there is a greater risk that the product will be forgotten or lost because of its size and unfamiliarity. When the patient will not carry the device, the feedback is hard to notice.

Concepts 2 and 3 both have a high score. Their differences are that the 'buddy concept' is most intuitive and doesn't require the action of opening the book. This makes it easy to use for the modest patients. Advantage of the interactive book concept is the notes functionality; by writing down something yourself, patients can process and remember information better. Also, it is easy to carry with you.

Nowadays, the elderly modest patient is familiar with the interaction with a physiotherapist and with informing brochures. Looking to the product experience of the interactive book, it might be familiar and understandable to the patient.

The association of the 'buddy concept' is a personal buddy coach (or a physiotherapist). The modest profile prefers something playful, simple and not too serious, but at the same time, the modest patients want to be taken seriously. Good design here is really important, but the preference of the appearance is probably quite personal. Although, this 'BioCoach buddy' concept is potentially a great fit with the modest patient profile group, which partly consist of elderly that also like products such as the social robot of 'Tinybots', which is a robot for dementing elderly. However, probably not the whole modest profile consists of (dementing) elderly with this product preference. For some people it might feel a bit childish, far-fetched, not serious or even pejorative.

The 'BioCoach guide' concept looks more serious and still could be designed in a way that it is intuitive, simple and gives a buddy feeling, in a subtle way. Together with the advantages of the notes functionality and the fact that it is easy to carry with you, the choice is made to continue with this concept.

Figure 4-11 Chosen concept

4.3 Concept development

4.3.1. OVERVIEW OF THE FINAL CONCEPT: THE BIOBUDDY

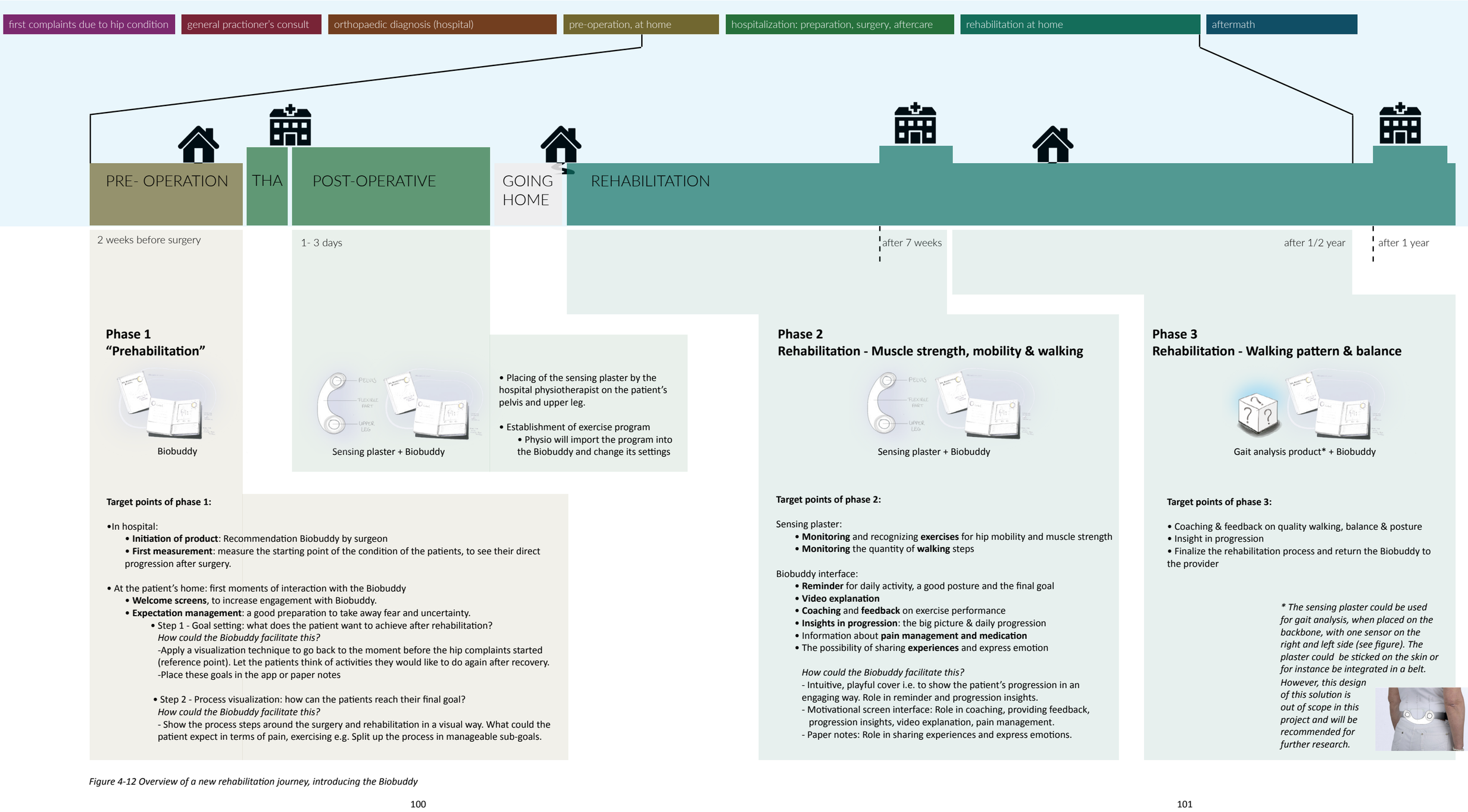


Figure 4-12 Overview of a new rehabilitation journey, introducing the Biobuddy

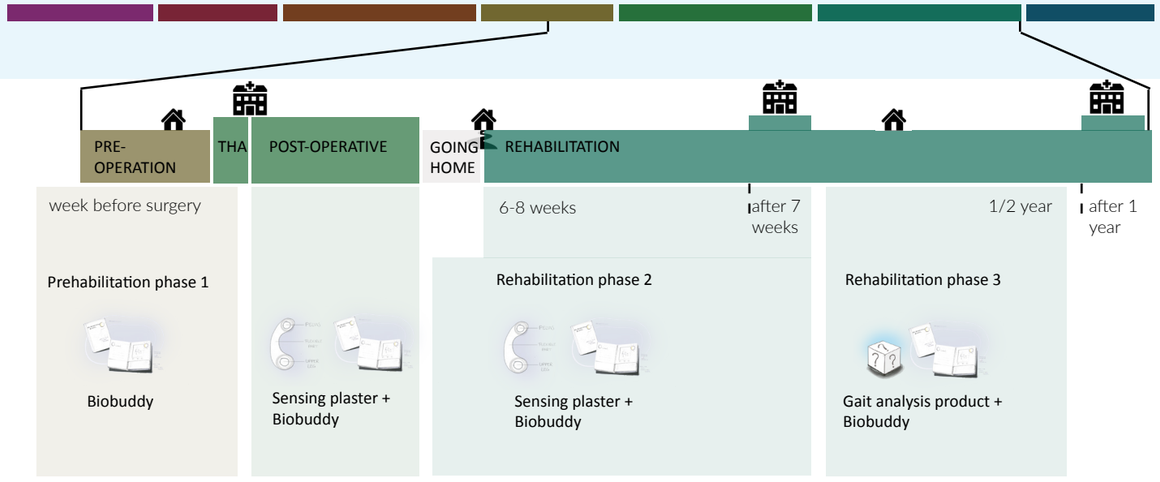
On the previous page, an overview of the final concept is shown with its corresponding functionality over time.
By implementing the Biobuddy in the patient's THA journey we can say that we have designed 'a new rehabilitation journey'. This new journey consists of three different phases:

Phase 1:
"Prehabilitation": Expectation management
Phase 2:
Rehabilitation at home: muscles and mobility
Phase 3:
Rehabilitation at home: watch your gait

In every phase, the Biobuddy has its specific role. The functions and moments of interaction of this role are defined in the list of requirements (page 82).
In this chapter, the development of the Biobuddy concept will be described, which will eventually lead to the final design, presented in Chapter 5.

Before doing this, the scope of the development and embodiment is specified (see figure beneath).

SCOPE REFINEMENT



	Phase 1 -	Phase 2 -	Phase 3 -
Whitin scope	• Screen flow & interface of Biobuddy	• Screen flow & interface of Biobuddy • Concept development of Sensing Plaster • Cost estimation of Sensing plaster	
Out of scope		• User tests & embodiment of Sensing Plaster • Embodiment of Biobuddy cover • Sustainable Eco design checklist • Business Proposal and cost estimation of application	• Design of gait analysis variant • Screen interface

4.3.2. DEVELOPMENT OF SCREEN INTERFACE

SYNTHESE

Defining content
The first step is to define the content of the user interface. The basic functionality was already defined in the list of requirements of paragraph 3.3. Since the Biobuddy has a screen with an interface, the presented content should be understandable - with a low learning curve – in a simple language. In addition, the progression of the patient should be always visible. The emphasis of the developed content for the interface is on the "Prehabilitation" at home (phase 1) and Rehabilitation at home (phase 2) (see Figure 4-12).

Moments of interaction
The Biobuddy supports specific moments in the THA rehabilitation process, as can be seen in Figure 4-12. To accompany these moments, the patient is asked at specific moments to interact with the Biobuddy application. In order to design content for these moments, a **script** has been developed to cover the patient's journey, which can be found in Appendix 9.
The content of this script is evaluated with a physiotherapist and a caregiver. A valuable comment was for example, to add voice guidance to the exercise moments, to guide the patient through the exercise. In collaboration with them, the script is adjusted and finalized, so that the content can be implemented into the application.

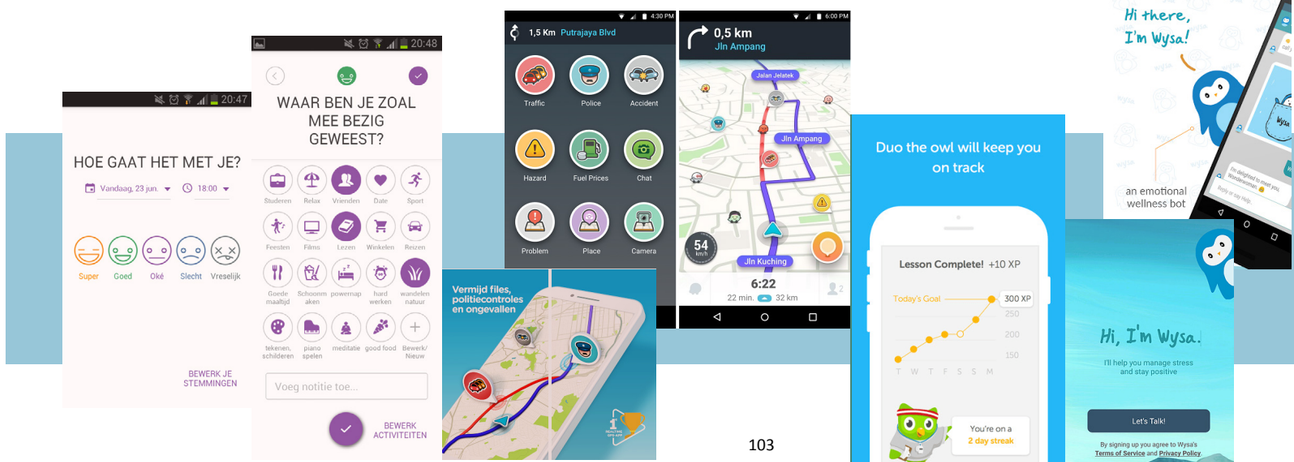


Figure 4-13 Inspiration from existing apps: Daylio, Waze, Duo Lingo, Wysa.

Screen size and shape
To determine the most suitable size of the screen, the following issues have been taken into account: orientation; notation function; size cover; touch screen versus physical buttons; and finally, using existing tablets or developing a new tablet size. As can be seen in Figure 4-14, there has been experimented with a model that includes a small screen and physical buttons. Eventually, the decision was made to continue with a tablet size in portrait orientation with touchscreen – using an existing device - to save costs and to present the required content in a handy format.
Research has shown that elderly of all abilities perform better and prefer using touchscreens compared to other input devices (Caprani, 2012). Mainly because it is intuitive, requires little thinking and is easy to learn. Also, it has easier hand-eye coordination than mice or keyboards (Caprani, 2012).

Using an existing tablet versus a new tablet design
It is considered to make a custom-made tablet for the Biobuddy. However, if we look at all the necessary components and manufacturing costs (LCD screen, battery, Bluetooth-chip, microphone and speaker, RGB LED's, motherboard, casing, buttons, wires) for a first series, it is more advantageous to use existing tablets, such as a Samsung or iPad tablet, since these manufacturers also provide a valued service to their customers.

Wireframing
Wireframes have been drawn in order to determine the hierarchy of the user interface. Through this method, the application's content and functionality are visualized in quick sketches to design the interface on a structural level; as it shows the connections between the screens and how they work together. Also, these wireframes have been evaluated with other students, to see if the connections between the different screens work and whether they are logical.

Figure 4-14 First prototypes

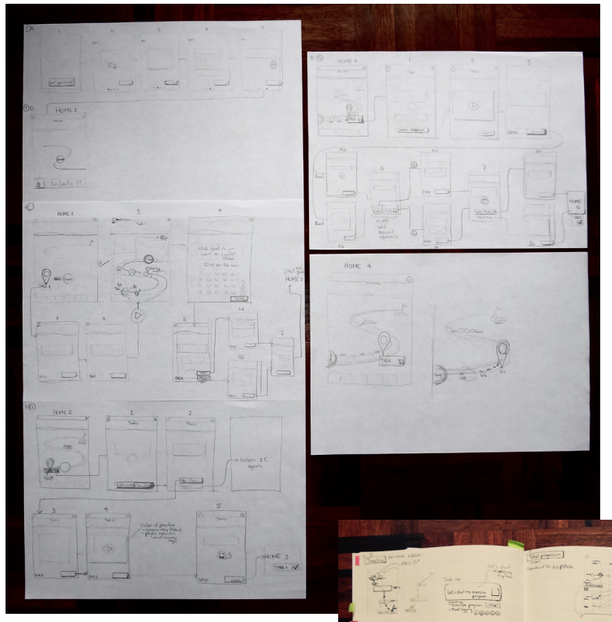


Figure 4-15 wireframe sketches

The design
Sketch time again! Sketching is the starting point of creating a design. Inspiration is found by looking to existing, good designed or high rated applications (Figure 4-13).

The UI design is created digitally using Adobe programs (Figure 4-16).

Finally, an interactive prototype is made, using the 'InVision application'. With this program, touch points can be added to the digital screen files, to create a digital 'click-through' prototype (Figure 4-17).

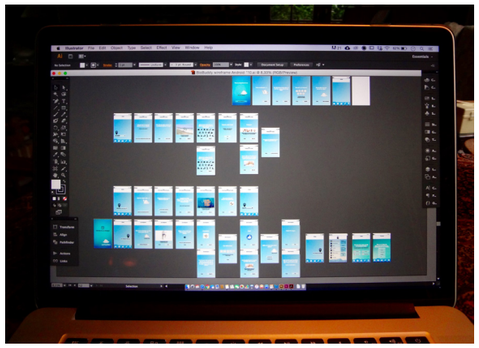


Figure 4-16 artboards in Illustrator

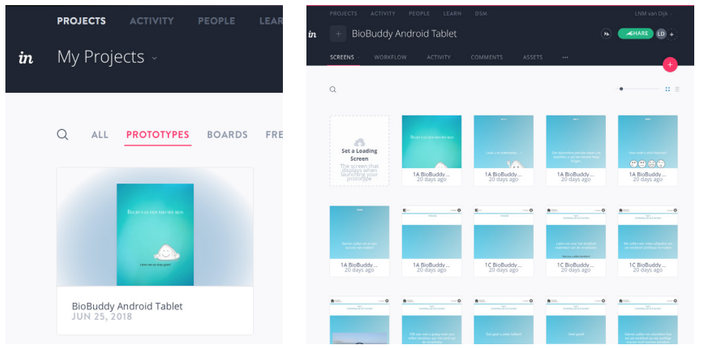


Figure 4-17 InVision app to create an interactive prototype

4.3.3. DEVELOPMENT OF COVER

SYNTHESE

As explained in the concept choice discussion, the choice for the product shape is a book, because of the familiarity of the elderly patients with this product and because of the desired product experience: it could be designed in such a way that it is playful, intuitive, simple and creates a 'buddy feeling'.

The cover could play an important role in the playful and intuitive appearance. An interactive or (partly) translucent cover will invite the patient to open the book. Other envisioned functions of the Biobuddy cover are:

- Holding and protecting the screen
- Providing a place for paper notes and a pencil.
- Providing a visual reminder signal, a progression signal

These functions will be further explored and elaborated.

Holding the screen - size and shape

As described in the previous paragraph, the size of the cover is dependent on the screen size and notation function. Sketches are made of the placement and layout of these parts (Figure 4-18).

Place for paper notes

The idea of including a paper notebook to the product is not an outcome of the analysis phase, but based on the assumption that it would be pleasant for the patient to have the possibility to make physical notes during rehabilitation and keep everything in one place. For example, it could help the patient to take notes during a consultation or write down questions for the physician.

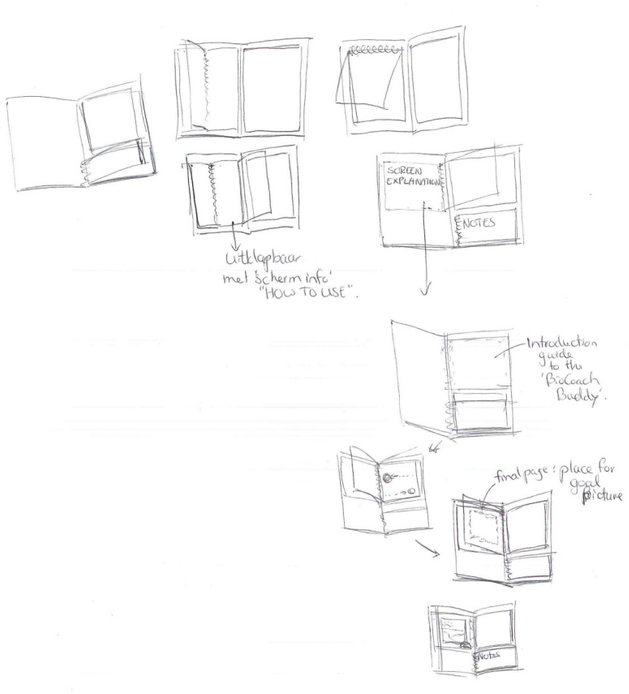


Figure 4-18 sketches of cover content.
Different ideas for the notebook purpose:
-Place to write down or draw the end goal of rehabilitation.
-Place for questions and preparation for the consult.
-Place to write down experiences, that you can share with others.
-Place for messages from others: friends, family, peers.

Visual reminder and daily activity progression insights

The cover could play an important role in having a playful and intuitive appearance. An interactive or (partly) translucent cover will invite the patient to open the book. In addition, the cover could also play a major role in reminder signals or warnings, to stimulate for example a correct posture or warn patients when they tend to exercise too much.

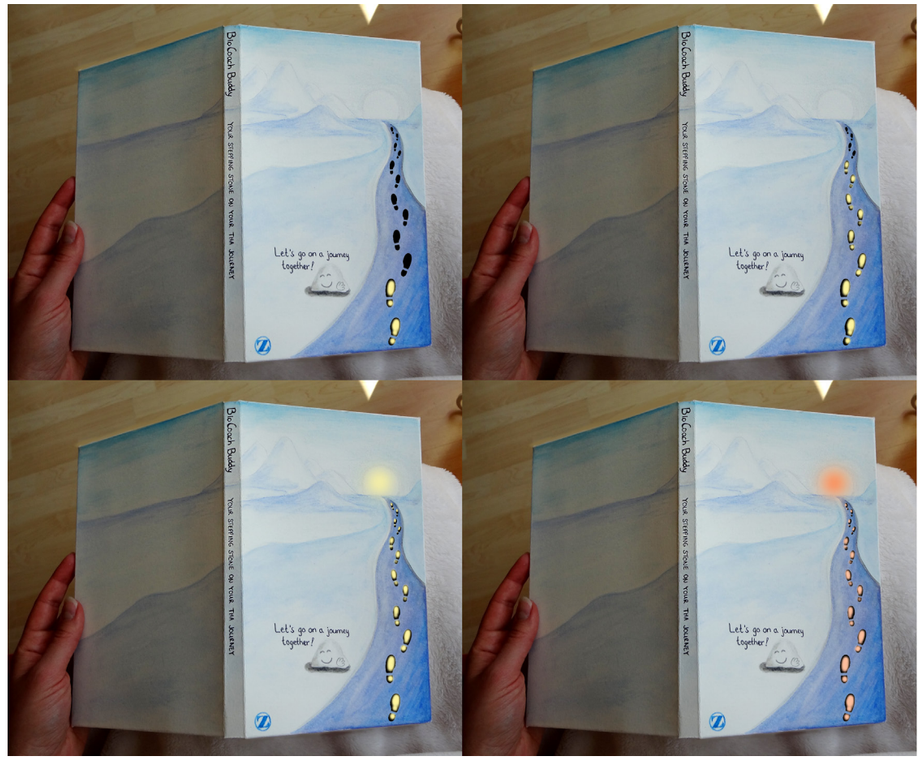
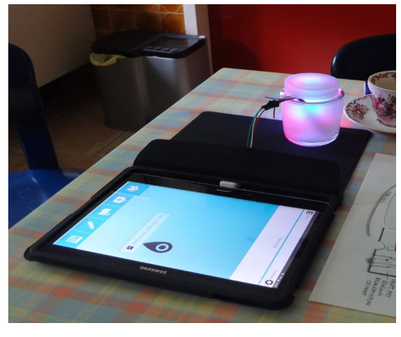


Figure 4-19 Light interaction to show the completion of the daily exercise program. Intention is to help the patient in finding the right balance of activity: not too little and not too much.



4.3.4. DEVELOPMENT OF SENSING PLASTER

SYNTHESE

Introduction
The monitor device that is able to measure the activity of the patient will be a sensing plaster. The main advantages of using a plaster are that it could be made unobtrusively, it has a higher accuracy of exercise measurements by using double sensor points and, preferably, the patient doesn't need to perform any actions to make the patch work.

In case a brace or belt with sensors would be used, the measurements are less accurate than in a patch directly on the skin.
Moreover, the patients need to put a brace on and off every day, which cost more effort. When a patient forgets to do this, activity insights are less reliable.

Besides all advantages, a big attention point is how the plaster should be designed to feel comfortable for the user when they wear the plaster for a minimum of 14 day, in between the consult of the physiotherapist. The time of 14 days would be optimal; the patient doesn't have to change the plaster in between consults by themselves.

Goal of the concept development is to figure out if the sensing plaster idea is feasible, so that a recommendation could be done for further development.

1) Functions & requirements
The sensing plaster design needs to meet the following requirements:

Functionality
1. Measure exercises for hip mobility and muscle strength improvement
   - o Active measurements for minimum 30 minutes a day.
   - o The sampling rate of sensors should be at least 50 Hz.
2. Measure the patient's walking activity by counting steps and cadence.
   - o Active measurements continuous
   - o The sampling rate of sensors should be at least 20 Hz.

Technical functions
3. Data transmission: the plaster sends the monitored data to the Biobuddy. The Biobuddy could save the data and sends it later to the online portal of the physiotherapist.
   - o Data transmission should be minimized, to save power consumption.
4. A power source must work for a minimum of two weeks without loading, so that loading could be done by the physician
5. The plaster should connect with the Biobuddy in a range of minimal 3 meter.
6. The plaster should not produce heat.
7. The plaster should not produce unhealthy radiation.
Ergonomics
8. Anthropometric data: the plaster should fit for patients (50-90 years) with a different length between the hip bone and upper leg

Comfort
9. The plaster should feel comfortable on the elderly skin:
   - o Suitable for thin, sensitive skin
   - o Smooth surface that is not interrupting with clothing and belts
10. The plaster should not be uncomfortable during sleeping or sitting

Material
11. Materials that are connected to the skin must be medical certificated.

Usability
12. The plaster should work and be able to stay on the elderly skin for a minimum of two weeks, so that the plaster could be placed and renewed by a healthcare professional; In this way no patient's actions are needed.

Aesthetic
13. Unobtrusive design: the plaster should be unobtrusively worn under the clothing.

Wishes:
- Low costs
- The plaster feels like a second skin (compact, light, flexible)
- Low power consumption
- The plaster components could be reused
- Preferably, the plaster could work for three weeks (21 days) without charging, to have a margin when the time between consults is longer then two weeks.

2) Placing of the plaster
The placing of the plaster is dependent on the comfort of usage and the monitor functionality: it must be able to measure the mobility of the hip and recognize hip or upper leg movement.

Monitoring function
The sensing plaster could be placed on both the upper and lower leg to recognize upper leg movement. However, by placing just a sensor on the leg, the stand of the upper body could not be measured.

By placing a sensor on both the leg and upper body, the plaster could distinguish between an upright position and a lying down position. This makes the mobility measurements much more reliable.

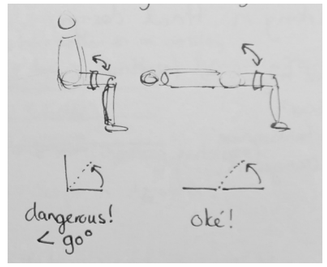


Figure 4-20 Sensor on both leg and upper body to recognize body posture.

In addition, placing two sensor parts makes the measurement more accurate. As concluded by the AED team, activity recognition is possible with only one accelerometer, with a mean accuracy of 62% (depending on the type of activity and movements involved). A second sensor adds about 20% on accuracy (D. Olguın and A. Pentland).

Comfort of place
As stated in the requirements, the sensing plaster should not feel uncomfortable during sleeping or sitting. When thick or hard components are used, a place on the body should be chosen so that the sensory part is not in contact with furniture; otherwise the patient would feel an unpleasant pressure on the body. So placing on the anterior part of the leg has a preference above the posterior part.

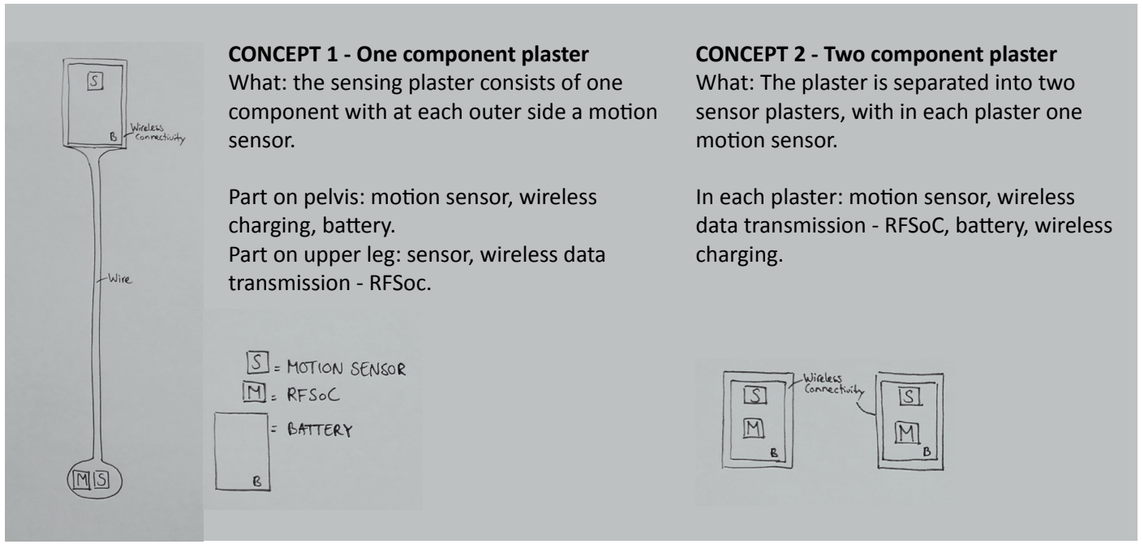
After surgery, the patient will not lie on the wound, so sleeping on your side is not preferred. Therefore, the placing of the plaster on the side of the leg, near the wound, is also an option.
Also, the plaster should not interfere with clothing, for instance thick or hard components should not be placed under a belt.

No research is done about the sensitivity of the skin on different places of the upper leg and pelvis. The assumption is made that this will not influence the comfort of placement.

Conclusion
The sensor components of the plaster will be placed on the pelvis (or above pelvis) and anterior upper leg, to get the most accurate measurements.

3) Two concepts of sensing plaster

Two concept ideas are created for the sensing plaster design.



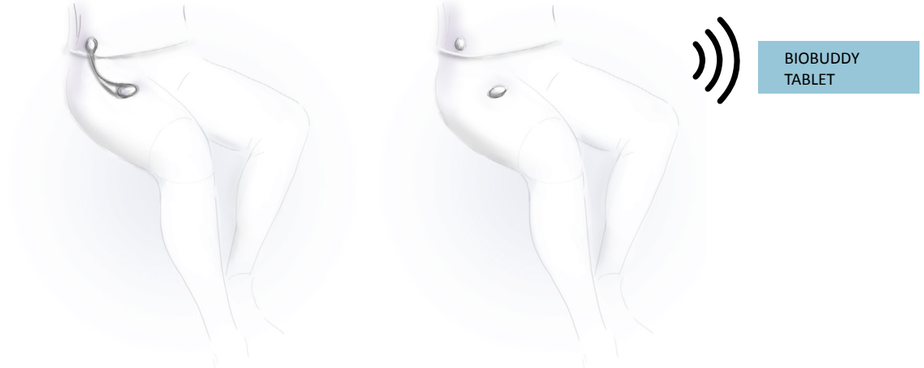


Figure 4-21 Sensors are placed on the pelvis (or above pelvis) and anterior side of the upper leg, to get the most accurate measurements.
Two concept ideas are created.

Concept discussion

The two concepts are evaluated on the following criteria: Comfort; Measurement accuracy; Anthropometric size; Lifetime and Price.

Comfort study

Factors that influence comfort:
- Area of adhesive sticker
- Shape and placement of sticker
- Material of sticker

All small test is done to figure out how the shape and placing of the plaster will influence stretching of the plaster. Because of stretching, the plaster could feel less comfortable and could create irritation, which could cause interference with movement. Also, the plaster could early release from the skin and causes bumps. Elastic plaster material could be used to catch this (partly), but limiting the stretching would be optimal.

Assumptions to limit stretching:
- a 'banana-shape' creates little bulges than a straight plaster.
- a flexible part between the sensory components will reduce the area of the adhesive sticker, so reduces stretching and bulges of the plaster. However, a loose, flexible part should not get dirty and the user has to be careful with the plaster.

Figure 4-22 Bending of plaster causes bulges. Test is done with cotton tape (left) and gaffa tape (right).

By doing more user tests, an optimal shape and size could be found that meets the comfort requirements best.
Two separate plasters (concept 2) eliminate this problem.

Measurement accuracy

In concept 1, the orientation of the sensors in relation to each other is fixed. With two separate plasters, this orientation could easily deviate. However, if this will influence the accuracy of measurements should be researched.
Another attention point is the interference of wireless parts. In concept 1, the two wireless parts (wireless data transmission part and wireless charging) are separated to prevent that they will interfere with each other.
This is not possible in concept 2. However, it is not sure if this interference will take place. So this should be further researched or tested.

Anthropometric data - Distance between sensor parts

The size of the plaster, and thus the distance between sensor parts is dependent on:
- The anthropometric distance between pelvis and upper leg, which will differ between patients.
- Clothing of patient: placing thick or hard components under a belt would not feel comfortable for the user. The preference in the height of a belt could differ per patient: waist belts or hip belts.

Therefore, the size of the plaster must be customizable or different plaster sizes must be developed.

Lifetime

In Concept 1, the wire between the two sensor parts will bend often, since it is placed on the hip joint. This bending will probably decrease the lifetime of the wire.
However, when this decrease in lifetime will not shorten the desired lifetime of the sensing plaster, this is not a problem. To figure this out, we need to calculate the decrease in lifetime and define the desired lifetime.

Costs

Probably the cost price of concept 1 will be lower, because fewer components are used (for example one battery and one microcontroller). However, when the product lifetime is shorter due to bending wires, concept 2 is more sustainable and will save money in the longer term. In addition, concept 2 is wireless and probably needs less tape. Also, when both plasters of concept 2 are equally the same, the batch size will be bigger which saves costs.
All these assumptions should be further researched to make an accurate price comparison.

Conclusion

Because of the limited time span and a focus on the Biobuddy interface within this graduation project, the above factors could not be further researched within this project.
However, to explore if the sensing plaster idea is feasible and realistic and to get an idea on cost price, one concept will be elaborated.

It seems concept 2 has the most advantages and less possible limitations. Therefore, this concept will be further elaborated on component level in the final design.

4.4 User test - Evaluation of final concept

MOTIVATION AND ENGAGEMENT DURING REHABILITATION

The insights from the earlier described quantitative and qualitative research are translated into a product proposal for the modest patient profile: the Biobuddy. The user interface (UI) of this product focuses on the feedback on the progression and performance of the patient.
In this research, the user interface of the Biobuddy will be evaluated with modest patients. Two 'parts' of the Biobuddy interface will be tested. First, the user interface on the screen inside the book will be evaluated. This interface provides coaching and feedback on the correctness of performance of the patient.
Then, the interface on the cover of the book will be evaluated, which provides a 'reminder' signal to encourage doing enough exercises, and a 'warning' signal to protect the patient from overload. All this together ensures that the feedback responds to the daily activity progression of the patient.

Introduction
During this test, insights will be gained in the experience and preferences of the modest patients on the UI by doing observations, an interview and using a questionnaire.
The goal of this test is to find out if the provided feedback and information is motivating to the patient and whether it improves their involvement in the rehabilitation process.

Research question
1) How does the patient experience the interaction with the interface on the screen?
   a. Before surgery
   b. After surgery, during home rehabilitation
2) How does the patient experience the interaction with the cover?
   a. Reminder signal & Progression insights
   b. Paper note functionality
3) What does patients think about the idea of using a sensing plaster?

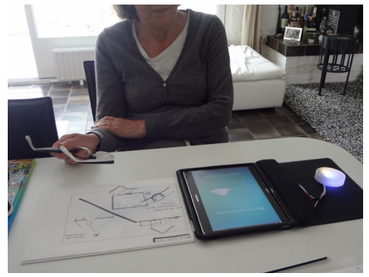
Sub-questions
a) Does the patient experience the intended interaction qualities? (Simple, consistent, convincing, emphatic, reassuring, guiding, committed, joyous, respectful)
b) Is the information clear, simple, understandable?
c) Does the product motivate the patient?
d) Does the patient feel engaged with the product?
e) Does the product enhance the engagement of the patient with the process and their adherence with the rehabilitation exercise program?
f) Does the product stimulate a positive atmosphere and mindset?

Method
Participants
A total of 5 elderly participants (male/female, 70+) participated in the test; three participants with the modest patient profile, and one of both the managers and optimistic profile.
For this study, it is not necessary to recruit new hip patients, who are currently rehabilitating. However, it is important that the patient profile is known and therefore that the participant has some experience with care process, to figure out how they cope with pain (pain catastrophizing?) and stress (active coping?).
Three of the participants are former THA or TKA patients; the others have hip or knee complaints and have experience with other types of surgery.

Procedure
During the test, three scenarios will be played and evaluated. These scenarios are explained beneath.
First, the researcher will introduce the scenario by showing the corresponding phase of the 'rehabilitation journey storyboard' (Figure 2-18) and giving a brief explanation about the context of the scenario. Then, the scenario will be played; the participant will interact with the Biobuddy UI during a specific moment of the THA journey.

During the scenarios, the researcher will observe the participant and take notes, without interrupting the participant. After each scenario, questions will be asked when something notable happened.
After playing scenario 1 and 2, the participant will fill in a questionnaire regarding their user experience of the screens (Appendix 10.1). In the questionnaire, the product experience will be evaluated with scales. The criteria in the scales are coming forth from the desired product interaction and qualities, explained in the Vision Chapter.
Finally, after finishing all scenarios, an interview will be done (Appendix 10.2).
The duration of the whole session will be around 45 minutes. There will be no behavior-changing factors.

Figure 4-23 Introducing the Biobuddy and its context.
^ *Above on the table: scenario drawing 'before surgery' to explain the context of the scenario;*
v *Beneath on the table: scenario context drawing 'after surgery'.*



Scenarios

Scenario 1: Screen interface - Before the surgery
The participant will interact with the screens, intended before surgery: the 'Welcome and goal setting' screens and the 'Process visualization' screens.

Scenario 2: Screen interface - After the surgery
The participant will interact with the screens, intended during rehabilitation at home. This included the screens before exercise (reminder and explanation screens), during exercise (voice guidance) and after exercise (feedback, reflection and appointment screens).
Scenario 2a: feeling well + good performance
Scenario 2b: not feeling well
Scenario 2c: bad performance

Scenario 3: Cover interface – Reminder signal & progression insights
The participant will experience four possible reminder signals, intended before exercising to remind the patient for doing enough exercise:

- Reminder light integrated in the cover
- Reminder light sculpture (close to concept 2, page 96)
- A reminder pop-up screen
- Alarm sound or music

To prevent that a patient will over-train, the same type of signals could be used to warn the patient. The same four options will be evaluated again.

Material
Before each scenario, a slide of the 'BioCoach storyboard' is shown to explain the context of the scenario (see Figure 2-18, slide 1-3, resp. before surgery, during surgery, after surgery). These storyboard drawings are used before, during the user test of chapter 2.4.

During the test, a digital, interactive prototype of the screen interface will be used for the screen evaluation scenarios. An existing tablet is used to display the screens (Samsung Galaxy Tab 4 (10.1))
For the cover evaluation, a physical prototype will be used that shows an example of light interaction on the cover of the Biobuddy (Figure 4-24).

After approval of the patient, photos will be made or video recording will be done during the test.

Analysis
The results from the questionnaire will be presented in graphs and analyzed afterwards. The notes taken during the observation and interview will be structured in sub-categories and analyzed afterwards.

^
Figure 4-24 Showing possibilities for the reminder signal and progression indication with colored light interaction.

^
Figure 4-25 Patients in action during a scenario

^
Figure 4-26 Questionnaire evaluation

Results
In Appendix 10.3, all results are collected in a table. Here, the relevant results are explained and clustered in themes:
1) Screen interface:
    Product experience; Usability; Functionality screen menu
2) Cover interface:
    Reminder and progression signal preferences; Paper note functionality
3) Sensing plaster

SCREEN INTERFACE

Product experience
According to the questionnaire results, the participants experienced the Biobuddy interface as: simple to understand, emphatic and respectful, playful and pleasant, convincing, motivational, reassuring and reliable.
By using this product, the participant felt engagement with product, guided, a positive atmosphere, empowered, not stigmatized or ashamed, motivated to perform their exercises well and independent.

Feedback content of Biobuddy
All participants confirmed that they like to get feedback directly after their exercise performance. A modest participant explained: "If you don't get any feedback at all, you become insecure about your state, if you are doing it well."
The manager clarified: "I want to know what I do well, but especially what I'm not doing right."
Also, all participants indicated that the type and tone of the current feedback on the screens during scenarios 2a, 2b and 2c was fine.

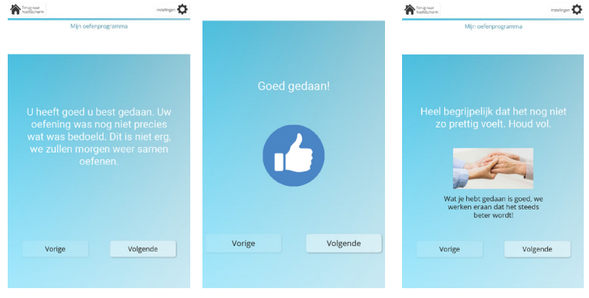


Figure 4-27 example of feedback screens

Preferred moment and place of interaction: at home
The modest users indicated they want to use the product at home, at a fixed time, not when they are outside.

Usability - Remarks during observation
Welcome screens
Clicking on the buttons was immediately clear without any explanation for the optimist, manager, and one modest participant (P5) who called herself 'digibeet' (surprising!). Two modest participants (P2, P3) asked "Do I have to press here now?". A little instruction on the screen could have taken away this uncertainty.

By showing the 'Welcome screen' with smileys icons, it was not clear for the participants if they had to select one of the smileys.

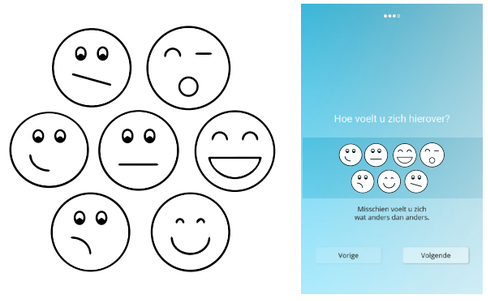


Figure 4-28 smiley icons not clear without text label

For one modest participant (P5), the meaning of the smiley icons was not obvious. For example, she asked:
"Does the '  ' face mean: 'to sit with your mouth full of teeth' (meaning to be speechless)? Or something positive?" She discussed all the icons.

Figure 4-29

Figure - task button screen

Figure - goal-setting screen

Figure - menu button

Figure - journey steps in sub-menu

Task button
Clicking on the 'task button' on the home screen to start the first task was not clear for two modest participants (P2, P3) and the manager, without telling them they could press on the task button. For one modest participant (P2) I needed to point out the button.

Task 1: goal setting
On the goal-setting screen with activity icons, it was not clear for the optimist if you could select more goals or just one. Two participants missed the option of 'normal walking', without a dog or walking stick. The meaning of all activity icons was clear for all of them. The participants did not miss any other activity icons.

Menu navigation
Opening the menu: Without any instruction, two modest participants (P2, P5) couldn't directly find the menu button on the main screen. After pointing out the menu button at the top left for them, it was clear how to open the menu.
Navigation task: The options and buttons within the menu were clear for all. A task was given to find 'tips for pain'. They could find the right buttons to navigate to this information; even the modest person who called herself 'digibeet' (P5).
Journey steps in menu: the 'checkmark icon' that shows that a task is done or phase is finished was not clear enough. The 'lock icon', intended to show which tasks aren't available yet, were also not clear. After explaining their meaning, they understood the meaning of these icons. It became not clear if the modest participants preferred to have this 'journey steps' buttons in the menu. It seemed they found it hard to imagine if they would like this. [add picture of old journey step screen]

Instruction preference
It seemed the product would already be understandable with just little explanation. All participants, except the optimist, preferred a person who would introduce and explain the product to them.

Functionality screen menu
Menu options
The **modest** participants indicated they liked to use all functions, except of the digital notation function. They believe they will not use it, because they don't feel a need to write things down or because of privacy issues. P5 stated: "It is not pleasant that people know things about you". The fact that the product monitors and thus knows your amount of activity was not a problem for her.

Figure 4-30 tab bar options: the digital notation function is not needed for the modest participant.

The **managing** participant told she would use all options, also the digital notation function. About the video, she indicated she would like to see 'daily action instructions', beside the exercise animations.

The **optimist** was clear about the options: "Seeing my progression and the videos is enough for me. It's nice to get feedback on performance, to hear that things are going well." This outcome is totally in line with the established design guidelines and the function analysis (figure 3-4).

Sound accessibility
All modest participants and the manager liked voice guidance during exercising.
Just one modest user preferred the reading function.

Personalization option
All modest participants indicated that they didn't care about a personalization option; an 'extra' option to choose your own 'buddy figure' or background theme seemed to make the product unnecessary more complicated rather than pleasant, because the user is given too many choices to choose a buddy figure or background theme or color (Figure 4-31). The modest participants emphasized that the application must work well (so it should be functional) and the appearance of figures was less important to them; the current 'buddy figure' and lay out was good and pleasant enough.

Also, for the optimistic participant, personalization was not needed. However, the managing participant liked to have the option to choose a buddy and background theme to make the application's appearance more personal this way.

Figure 4-31 Buddy figure: the modest participants didn't prefer to choose their own buddy figure.

COVER INTERFACE

Reminder and progression signal preferences
All participants prefer a pleasant, recognizable sound or music as reminder signal, above a visual light and color signal; they were neutral about the LED interactions on the cover. A reason was that you would always hear the sound and the product would probably not be in your sight all the time. The reminder signal should not sound pedantic. One modest user (P3) liked to have both a colored light and sound signal.

The manager also liked to get a reminder message on her smart phone, especially when she is doing something wrong, so she could correct herself immediately.
The same type of signal is preferred to get a 'warning' signal when a patient tends to do too much exercise.

Paper note functionality
The participants of the user test did not think they would make use of a paper note functionality. One modest participant (P5) explained that she has already a notebook and a diary to help remember her experiences. Another modest participant (P3) would have preferred a functionality to directly add digital notes in the Biobuddy app. A third modest patient (P2) thought she would not write anything down, because she never did this before, also not during her previous THA rehabilitation process.
In summary, this test shows that the participants did not experience any added value of the paper note functionality.

SENSING PLASTER

All participants think it is a practical, easy and clever idea. Nobody had something against the sensing plaster idea.
They would like to make use of the Biobuddy and sensing plaster when receiving a new hip and have the Biobuddy on loan.

Discussion

Reliability of research method

Observation, interview and questionnaire

The combination of observing the participants and asking spontaneous open questions was found to be the best method to obtain valuable insights about their experience, more than with the set up questionnaire. For example, during the observation of the first participant, through scenario 1 and 2, it was clear that the usage was immediately easy and clear, without any additional instruction from the researcher. For participant 2, the usage of buttons was less obvious.

Some additional accompanying instructions would be helpful for her.

In the questionnaire afterwards, both participants gave the same score on usability experience, regardless of their different performances. It is seen as positive that both participants experience the product as simple and understandable. However, to be able to make a redesign, the insights gathered through the observations resulted in richer and more accurate insights than just analyzing the questionnaire afterwards without any contextual knowledge. This can be seen as more raw data to analyze for the researcher, but this ultimately yields more valuable insights.

A second example is the questionnaire outcome of participant 3. She seemed quite positive about the design, but gave medium scores in the questionnaire. After asking about her ratings, she explained: "You want to be sure it is good. It has yet to come, that is so exciting and scary. I do not know how it will be." "Eerst zien dan geloven." Therefore some of her ratings were doubtful.

The questionnaire seemed more a starting point for discussion rather than an accurate indication of the user's experience.

Amount of participants

The amount of five participants is little. However, according to Francik (2015), testing with five users generally unveils 85% of the core usability problems, so this amount of participants will be most time efficient in this stage of the design process. The test gives a good indication in the usability and experience of modest users to make recommendations for further research and development.

The variation in patient profiles among the participants provides interesting insights in their different product preferences, which fits the profile assumptions that are made earlier (chapter 2.4, page 71), although the small participant number. However, to validate preference differences between patient profiles and to validate the Biobuddy design on patient satisfaction and rehabilitation outcome on the longer term, more participants have to be recruited which could be done in follow-up research.

Modest profile: harder to do research with

In my experience, participants from the managing and optimistic profile were easier to recruit for a user test. Modest patients are more reluctant, and often doubted whether they would be suitable participants, thus the chance arose that they would withdraw earlier.

During the user test, I experienced that the modest patients had less imagination; they found it harder to imagine how a final design would look like and if they would like it.

Their imagination is influenced by the material you show and the moment of testing: by showing an unfinished product, it is more difficult for some people to imagine how it really would look like or work. For instance, optimistic users could be involved earlier in the test, when 'unfinished' drawings of the design are available. For the modest user, it was important to show a prototype that was near the final design and to accompany this with a good introduction about its contextual use, to eventually test the usability and experience of the design.

DESIGN INPUT

Conclusion

After interpreting the results, conclusions have been drawn on the additions and adjustments to the Biobuddy's interface.

SCREEN INTERFACE	**Adjustments and suggestions to improve usability of screen interface** *Navigation:* • Opening a task: since this step was not clear without instructions and actually didn't had any function, this 'in between step' of seeing the main screen before opening the task could be skipped. This makes the app more content-centered and saves time, distraction and unnecessary actions for the modest user. *Instructions on the screens:* • Add a text label to (new) buttons: explain the intention of the button and point out what the user could do (i.e. "Click here to go to the next page") • Explain when more options could be selected, eg. in the goal-setting screens. • Add a text label to the smiley icon buttons to explain their meaning. • Journey steps in menu: explain the check mark and lock icon or change the design. Follow-up research should investigate whether this 'journey step menu' is useful or not. *Instruction before usage:* • A physiotherapist or other caregiver should introduce the product to the user and give basic explanation about the intention and usage of the product, by showing the core options. *Voice guidance and reading function:* • Voice guidance during exercise was desired by all participants. I suggest to put this function on as a standard. Users who doesn't want this voice could change this by pressing the sound button on the 'exercise screen'. • Reading function is desired by some. I suggest to add this option in the settings.	**Adjustments to the menu options** *Tab-bar on home screen* The modest participants indicated that they would not use the digital notation funtion. Therefore, the choice can be made to totally remove this option from the app, or give the notation function a less prominent place. This option could be removed from the home screen and be moved to the side-menu screen. I suggest the last option for the next redesign and to do research on how this option will be used after the product's introduction. If it turns out the notation function will still not be used, it could be removed. For the manager, all current options will be included. I suggest to add extra background information for this profile. Accompanied with For the optimists, only the progression insight option and video explanation will be included, including the introduction videos with process and goal visualization. *Personalization* The modest participants indicated they didn't care about this option, so personalization will not get any attention, but could be placed in the settings for users that would like to customize the appearance of the app. For the managers, I advice to add a personalization option to the 'welcome and introduction' screens, so they could directly choose a preferred 'buddy figure' and lay-out theme.
COVER INTERFACE	**Signals** Implement a pleasant, recognizable (music) sound as reminder or other attention signal. **Paper note functionality** Looking at the results, it seems not useful	to add a paper notebook to the Biobuddy cover with 'pre-set pages' with tasks or functionalities. It could even work confusing or distracting in combination with the screen interface. So, for the final design the choice has been made to discard this idea.

STARTING POINT

Final Concept &
User evaluation input

STUCTURE CHAPTER 5

5.1 Biobuddy application - user interface

5.1.1. Functionality
5.1.2. Flow chart
5.1.3. Usability
5.1.4. User experience
5.1.5. Motivation, engagement and adherence

5.2 Sensing Plaster

5.2.1. Technology - electronic components
5.2.2. Cost price estimation

Chapter 5

Final design - the Biobuddy

The Biobuddy is a product-service system that supports modest patients in self-management during their total hip rehabilitation. Intended to enhance the patient's engagement, motivation and adherence to have a positive care experience and successful rehabilitation outcome.

The product consists of two parts. The monitoring part, which is a sensing plaster, will be worn on the pelvis and upper leg of the patient. The plaster can recognize and measure exercises for muscle strength and mobility.
The monitoring data will be transmitted to the Biobuddy: a booklet including a touchscreen with an application, which is tailor-made for the modest patient profile.
A successful rehabilitation starts with a good preparation. The Biobuddy helps with goal-setting and process visualization.
After surgery, the app will coach the patient by providing video explanation, giving feedback on exercise performance and providing insights into the progression. Besides this, information about pain and medication is available.

The design of the Biobuddy application is easy to use and intuitive. Modest patients experience the product as simple to understand, empathic and respectful, playful and pleasant, convincing, motivational, reassuring and reliable.

5.1 Biobuddy application - User Interface

Introduction
In this chapter, the final design of the Biobuddy application is presented in more detail. First, the necessary functionalities and flow chart of the user interface are covered. Then, the usability of the design choices in the user interface will be discussed. Next, the interaction qualities that evoke the desired user experience are explained. As such, a well-thought-out usability and user experience increases motivation and commitment. Therefore, this chapter concludes with motivational theories embedded in the final design to support this desired effect.

USER INTERFACE
To guide the patients in their THA rehabilitation journey, a well-thought-out User Interface is needed that meets the requirements and wishes with regard to the patient profile. The design of the interface is based on the design guidelines for the modest patient profile, established in chapter 2.4. As framed in the Program of Requirement, these design guidelines for the Biobuddy's User Interface could be split up in functionality, usability and user experience. Ultimately these guidelines are necessary to achieve the intended effect: to increase motivation and engagement for the modest patient; and to achieve their personal goals and rehabilitate successfully. As such, these three factors also influence each other: a good usability improves the user experience and a good usability and user experience improves motivation and engagement.
N.B. The screen interface is in Dutch, for the English script see Appendix 9.

5.1.1. FUNCTIONALITY

In order to comply with the established requirements for the Biobuddy, the application meets the necessary functionalities to support patients in their rehabilitation process. The included functionalities are listed below and they are illustrated with corresponding examples from the user interface.

Before surgery:
• *Expectation management: Visualization of the rehabilitation process and end-goal*

Before surgery, two tasks are designed to prepare the patient on their rehabilitation.

The first task is to create a good image of the final goal of rehabilitation. In this task, a video is shown that includes an outcome-visualization technique, in which the patient will be guided to remember a pleasant physical activity moment before their hip complaints, for instance walking without pain. Walking without pain will be possible again after rehabilitation, so could be a motivating rehabilitation goal. The patients will envision themselves achieving their goal.
After the video, the patient will select activity icons of their desired goals, which will be saved in the application.

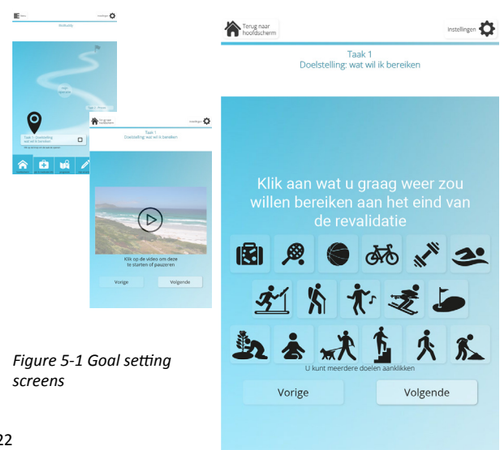


Figure 5-1 Goal setting screens

The second task involves envisioning each of the actions necessary to achieve the desired rehabilitation outcome. In a video, the process steps will be explained to prepare the patients on what they could expect, e.g. regarding pain experience and physical exercises.

Figure 5-2 Process visualization screens

After surgery, the app reminds the patient on their goal by displaying the goal-setting icons on the main screen, which were selected during task 1. Activity icons are placed on the user path in order of difficulty. For instance, for one patient walking without crutches is possible after 6 weeks, cycling after 3 months and doing yoga after 6 months. In this way, patient can work towards motivating sub-goals or 'milestones', which are visualized on their journey path.
Of course, the time path differs per patient and will be estimated by the physiotherapist.

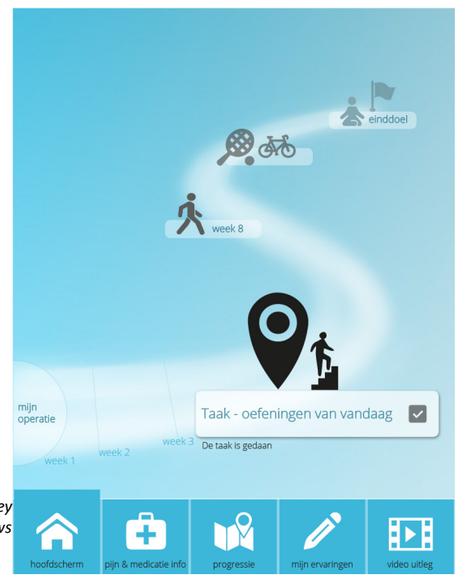


Figure 5-3 The intuitive journey path on the main screen shows the patient goals over time

After surgery:

• *Reminder signal*
The app reminds the patient for daily activity by displaying a notifying pop-up window and the ringing of a pleasant tone.

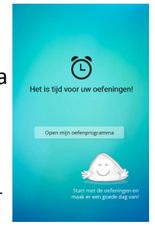


Figure 5-4 Reminder pop-up screen

• *Video explanation:*
The product provides visual (video) explanation about the exercises, by opening an exercise task. In addition, a video menu is added on the main screen to watch exercise videos and practical daily movements videos, such as going in and out of bed, getting into a car, and putting on socks and shoes.

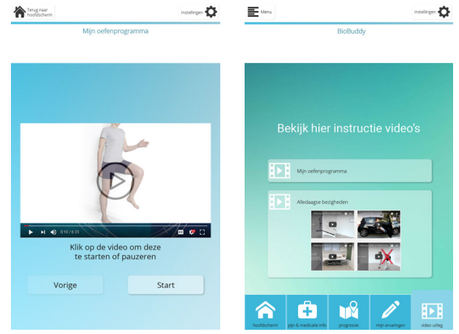


Figure 5-5 Video explanation in exercise programm and video menu

• *Feedback after exercise:*
The product provides feedback on exercise performance directly after the exercise program.

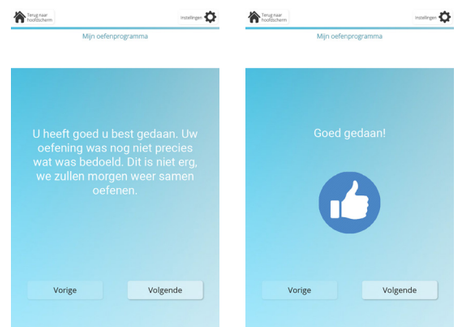


Figure 5-6 Feedback screens

• *Progression insights*
The product provides progression insights in the total process, and progression on the daily exercise program to create awareness and find a right balance in exercise quantity.
The progression menu shows insights in:
- o Range of hip motion (mobility exercise)
- o Muscle strength exercise
- o Walked steps
- o Mood

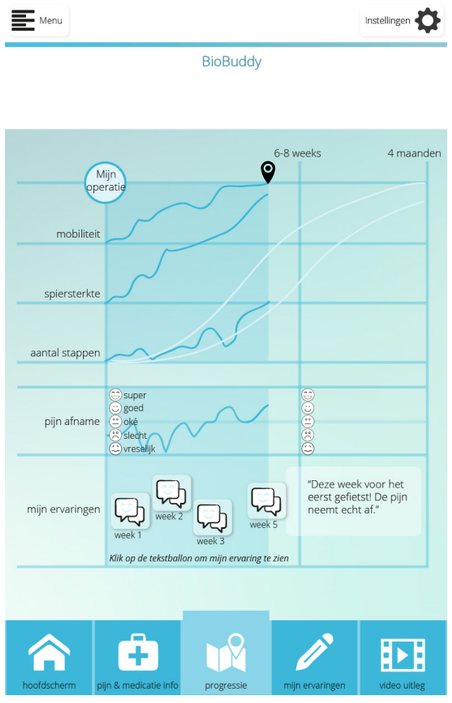


Figure 5-7 Overview of total progression

Progression in the quality of the walking pattern and posture could be added in rehabilitation phase 3.

• *Enhances a good posture and walking pattern*
During rehabilitation phase 2, the Biobuddy enhances a good posture and walking pattern, by showing reminder messages on having an upright posture.
In rehabilitation phase 3, more attention will be paid to the quality of the walking pattern.

During the complete journey:
• *Pain and medication information:*
The Biobuddy helps the patient in managing pain and medication use, by preparing the patient on the pain experience in the 'process' video during task 2 before surgery.
Beside this, in the 'Pain and medication information'-menu , information can be found about medication, tips for pain and frequently asked questions (FAQ).

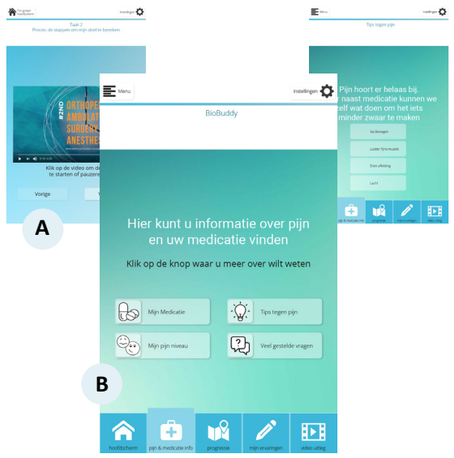


Figure 5-8 (A) Preparation on pain experience during the process visualization tasks before surgery; (B) Pain & medication- menu

• *My experiences: digital notation function*
The notation function creates the possibility to share experiences and express emotions.

• *Setting preferences*
Settings could be changes on accessibility (e.g. reading function, volume) and preferences in for instance reminder sounds and music.

• *Side-menu*
The side-menu can be seen as a content list of the Biobuddy. To open this menu, a button is placed on the top left corner of the main screen. With one click, a 'full-screen navigation' menu will be available, that provides an overview of all navigation destinations of the Biobuddy.

Options with a lower priority, envisioned as being important for users only in certain circumstances, are placed in the side-menu. This is done to avoid overwhelming modest patients with too many options on the main screen.
Beside the core options, new options that could be found in the menu are 'Appointments' (calendar function); 'Profile settings' and 'About the Biobuddy'. At the right side of the menu, an overview of the patient's path is shown with its corresponding tasks. Tasks could be reopened.

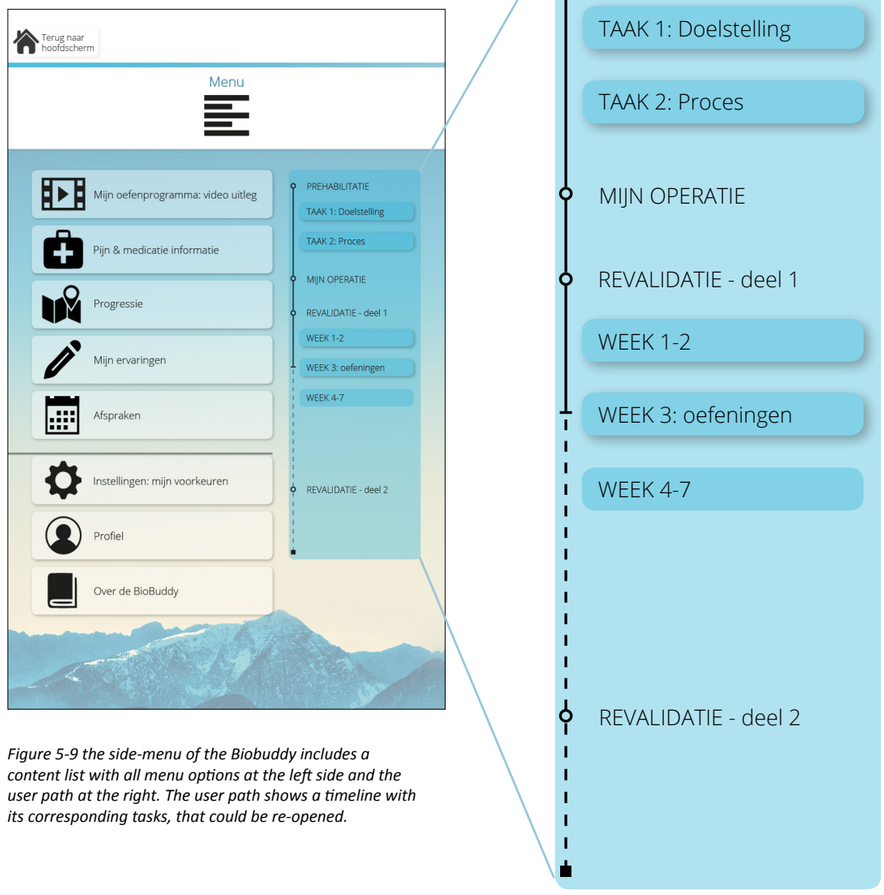


Figure 5-9 the side-menu of the Biobuddy includes a content list with all menu options at the left side and the user path at the right. The user path shows a timeline with its corresponding tasks, that could be re-opened.

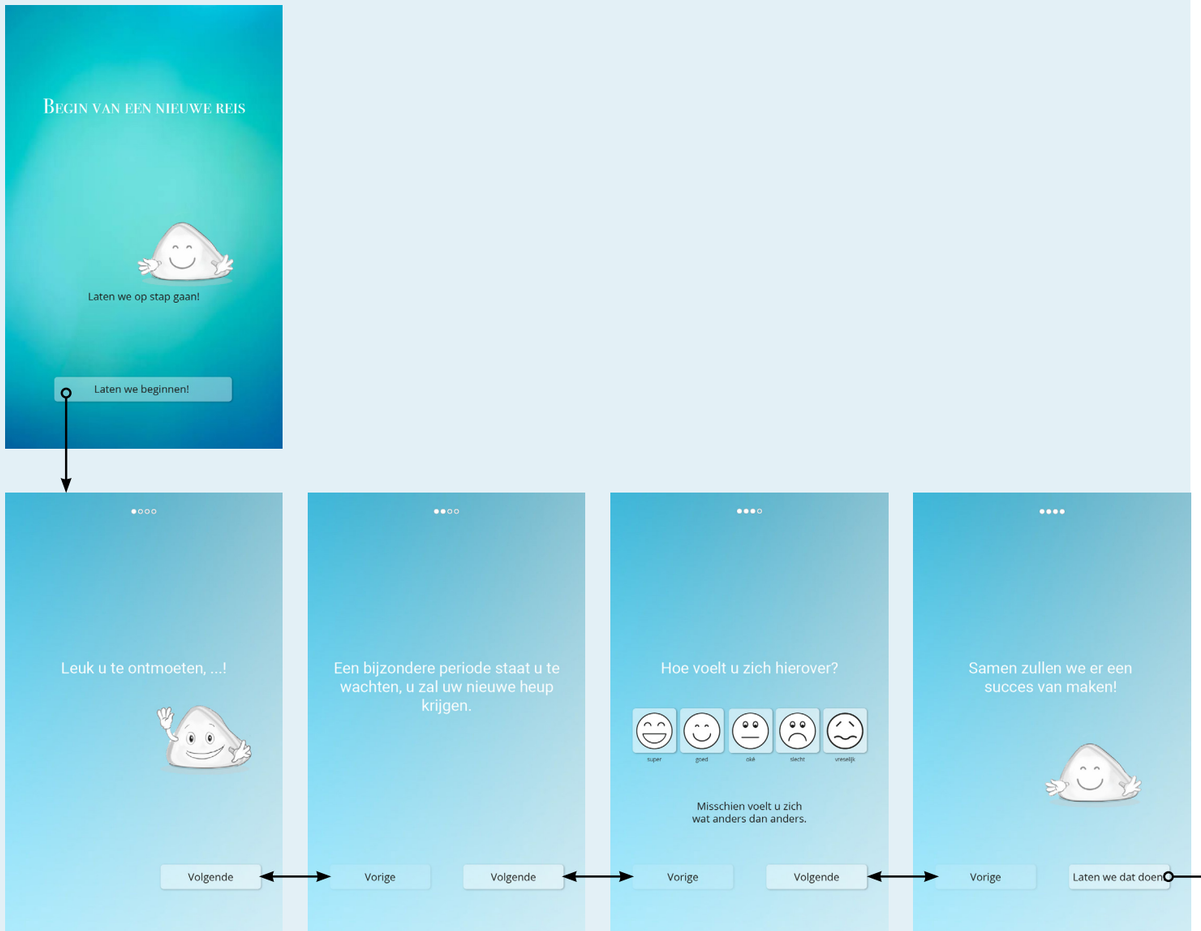
5.1.2. FLOW CHART

In the flow chart, the different screens and their functionalities are structured in a logical way. It gives a good insight how users make their way through the application to reach their goal. In addition, it can also be seen that each phase of the journey has its own flow. Also, it shows the connections between the different screens and how they work together.

Navigation between screens is possible by pressing tab buttons.

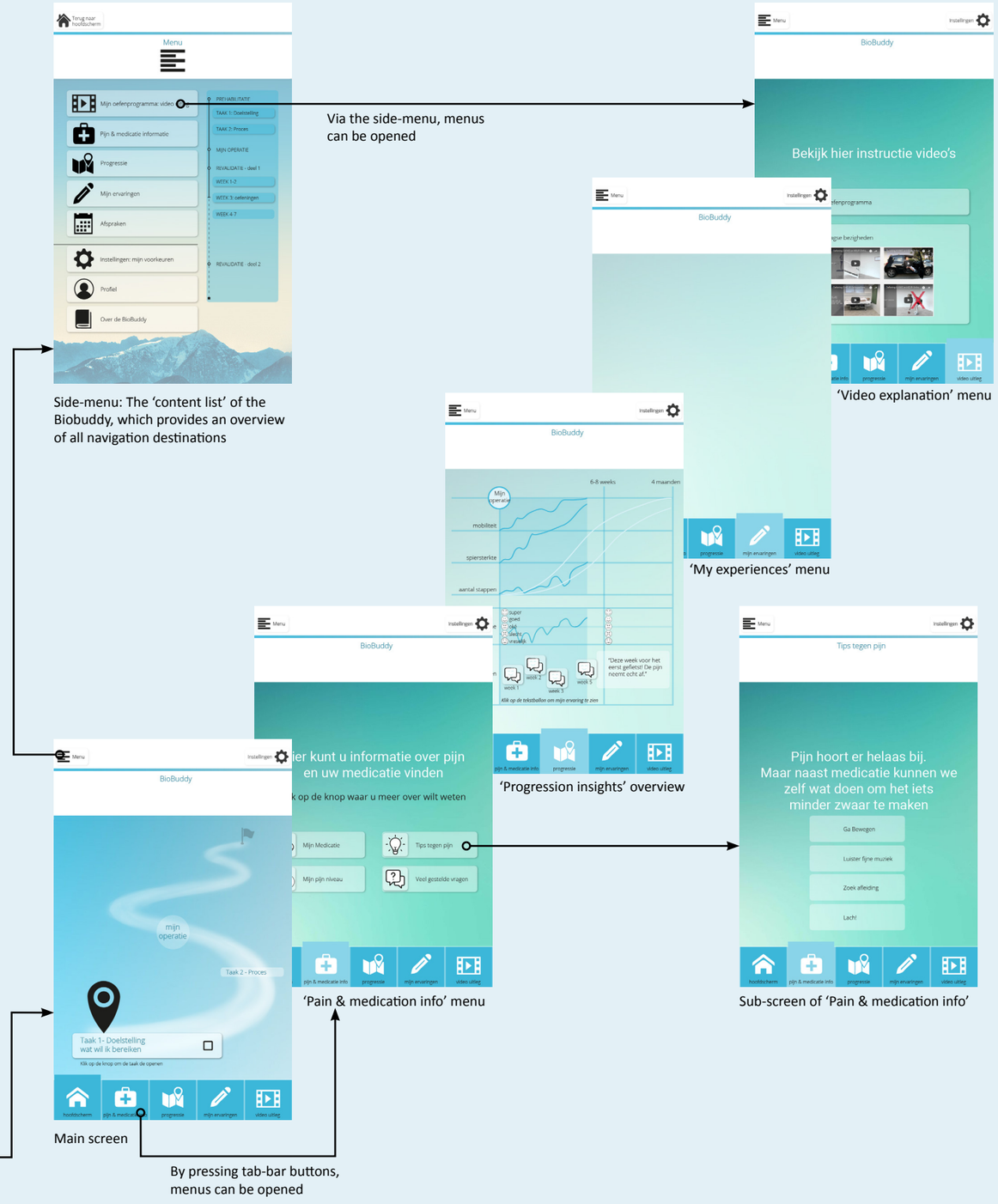
Screens before surgery

WELCOME SCREENS



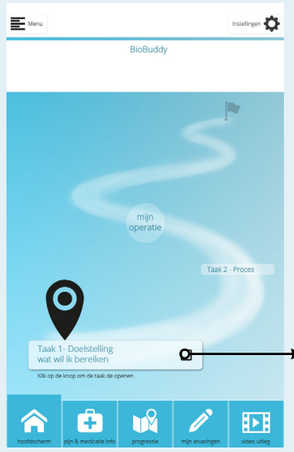
Menu screens - available during the complete journey

MAIN SCREEN - TAB-BAR MENUS - SIDE-MENU

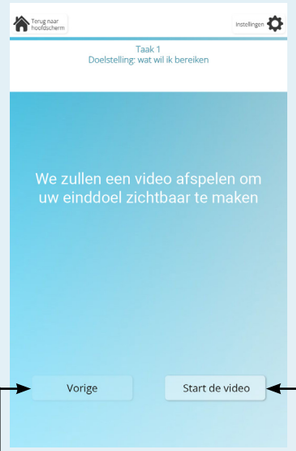


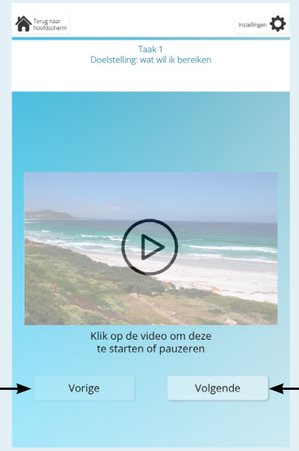
Screens before surgery - expectation management

TASK 1 - GOAL SETTING



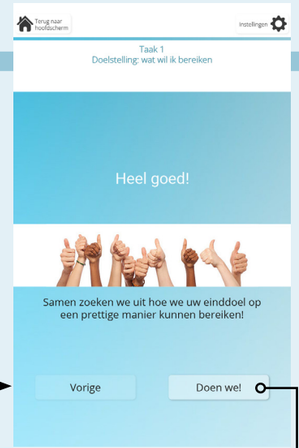
Task 1 - goal setting - will be placed on the main screen, two weeks before surgery

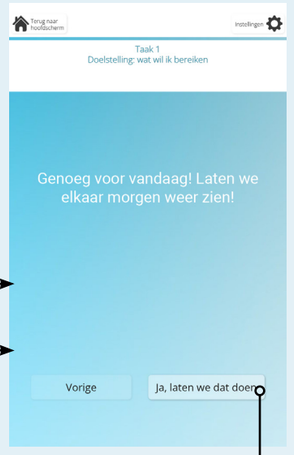




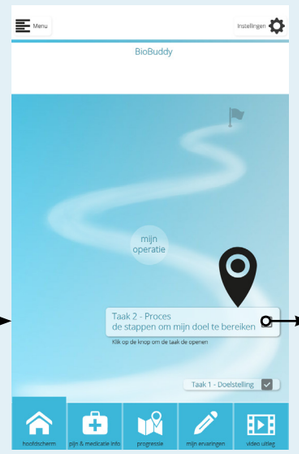
Video, including outcome visualization technique

The patient could select their desired goals of rehabilitation by clicking on an activity icon button

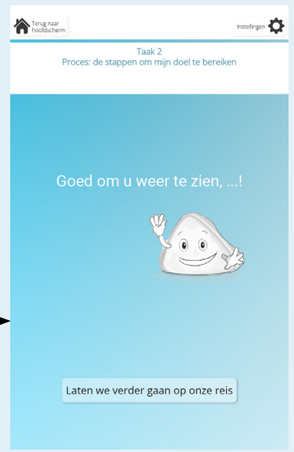




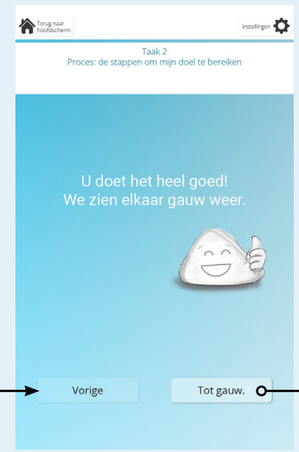
TASK 2: PROCESS VISUALIZATION

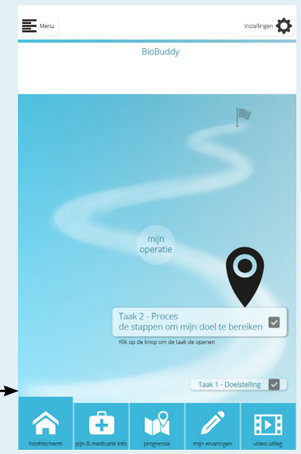


After completing Task 1,
Task 2 - process visualization - will be placed on the main screen.



In a video, the process steps will be explained to prepare the patients on what they could expect.

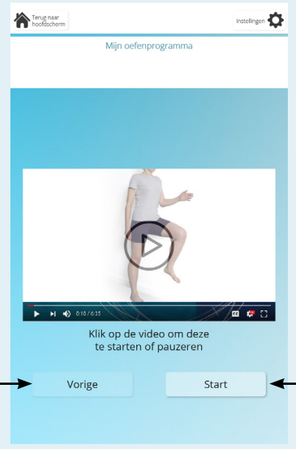




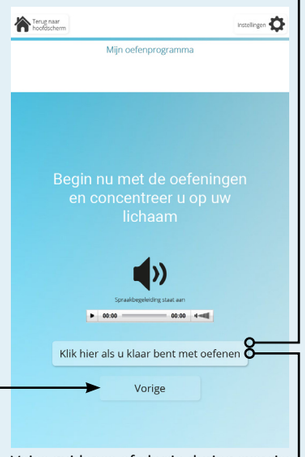
Screens after surgery- physical coach

TASK - DAILY EXERCISE PROGRAM

Reminder pop-up screen, accompanied with pleasant sound signal.



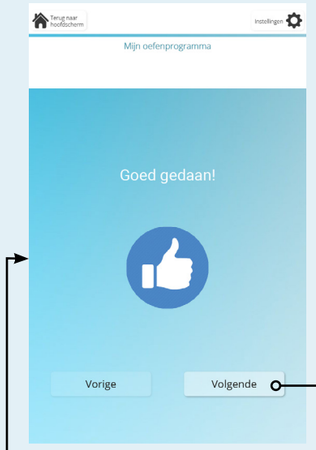
Exercise explanation video



Voice guidance of physio during exercise

feedback after good performance

Feedback screens



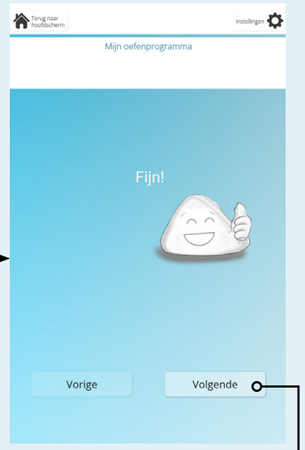
Celebration feedback after good performance

feedback after bad performance

Reassuring and supportive feedback when performing unsufficiently

Reflection screens

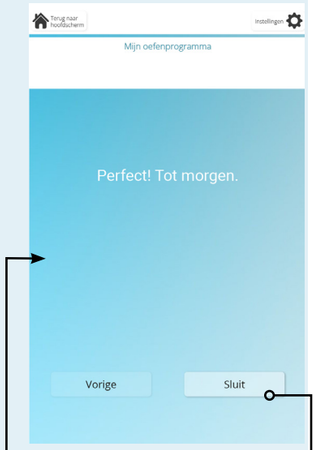
Icon input of patient about their state (pain level)



Celebration when the patient feels well

Reassuring message when feeling bad

Appointment screens



Confirmation to exercise again

Motivation to exercise again

Home screen after exersice

5.1.3. USABILITY

The usability of the application is about how patients understand and interpret the user interface. As previously written, the product should be understandable and user friendly for the modest patients. When they start using the Biobuddy for the first time, we want to make sure that they understand the product, to increase their motivation. The design goal is to make the Biobuddy understandable enough so that the modest patient can use it without the help of others. To achieve this, the following optimizations have been implemented:

Eliminate patient's actions

• The app is content-centered, which means that every main function of the app needs to be easily accessible for the user. The navigation between screens must be clear and when possible, with as little steps as possible. When opening the Biobuddy app, you go directly to the 'task screen', or the function that is relevant at that moment. It saves time, distraction and unnecessary actions and choices for the modest user

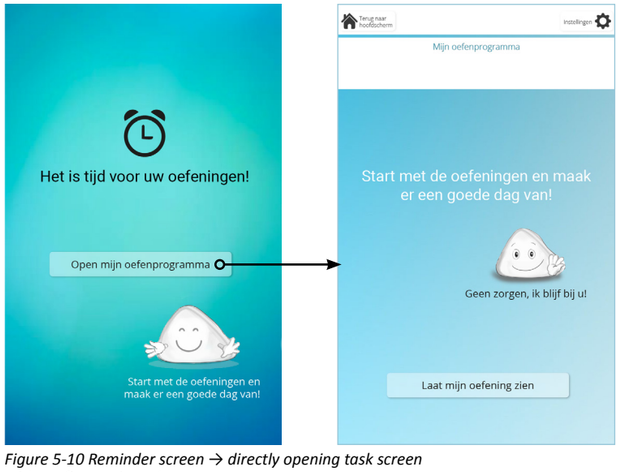


Figure 5-10 Reminder screen → directly opening task screen without first seeing a home screen

• The Biobuddy provides preset options and settings, to limit unnecessary choices for the patient while working with the app. Examples of preset options are:

- Appearance: standard background theme, buddy figure and lay out;
- Standard Music for the alarm;
- Voice guiding during exercise on, reading function off.

These options can be adjusted by the patients themselves, but they can also do this together with a physiotherapist during the introduction of the application.

Visible and consistent navigation

The modest patients should be able to navigate and flow through the app with ease. The challenge for the navigation was to make all core options easily visible for the patient, without creating a cluttered interface. Therefore, the Biobuddy uses navigation that is not hidden and thus easy to find, by making use of 'tab bars' and 'tap on buttons'. This is also reflected in the literature: Wroblewski (2015) stated that exposing menu options in a more visible way increases engagement and user satisfaction. As a comparison, gesture-driven navigation (such as swiping) is not obvious and intuitive for elderly users. They could get confused about how to interact with the app, since gesture-based navigation is invisible and not easy to learn or remember. It requires user effort and increases the application's learning curve (Norman, 2010).
Although, gestures are designed to be easy to use and intuitive if you master them. It could make the design attractive and more 'clean', since it could take away clutter on the screen. However, the 'WOW effect' of gestures is less important for this application, because the emphasis in the program of requirements is on the user-friendliness of the product - without a steep learning curve.

Tab-bar of the Biobuddy

A tab-bar on the main screen includes the core options of the Biobuddy. As defined in the design guidelines, these functions are envisioned as being used the most frequently by the patient. Therefore, they are positioned in such a way that they get high priority and that they are easy accessible with just one tap on this bar. In addition, the big clear icons, in combination with the explanatory texts, makes these core features – home screen, pain and medication info, progression, my experiences, and video explanation - easy to recognize at a glance.

Figure 5-11 Tab-bar with the core functions of the Biobuddy

Visible location

To prevent users from becoming disoriented and lost in the application, the Biobuddy ensures that the 'current location' is always clearly visible on the screen. The tab-bar on the main screen communicates the current selected option by highlighting and magnifying the selected button at the bottom of the interface. The tab-bar is permanently present during navigation between core option menus: the navigation remains in sight, regardless of which page the user is viewing.

However, when a task on a sub-screen is opened, the tab-bar disappears and the current location inside the flow-chart is indicated at the top of the screen. This choice was made based on the following argumentation: When the patient opens a task, you want the patient to complete the task without being distracted by options from the tab-bar. This also prevents the patient from accidentally pressing a tab-button, causing the current task accidently be interrupted or shut down.
On task screens, the 'home button' is always visible in order to be able to navigate back to the main screen. On this main screen, the core options are visible again.

Tab-buttons

Tab-buttons on the Biobuddy's touchscreen are used to select options and to navigate through the application. The buttons are similar in their size and shape, and they also have a consistent positioning on the user interface to increase user friendliness. This continuity is also created by using the same type of buttons, with the effect that it also lowers the learning curve for modest patients. In addition, the user test also shows that this design choice eliminates confusion during usage.

Eventually, the application of a touchscreen has been chosen instead of physical buttons next to a screen. Current research shows that elderly of all abilities perform better and prefer using touchscreens compared to other input devices, such as physical buttons (Caprani, 2012). This is mainly because it is intuitively in use, requires little thinking and is easy to learn. Also, it has easier hand-eye coordination, than for example mice or keyboards (Caprani, 2012).

Accessibility

• The user test has shown that, by making use of visual content, such as icons, images and videos, the application is more intuitive in use, because the patient is guided through the rehabilitation journey by these content elements. In addition, these visual content elements also ensure that the application is more accessible for the modest patients, because this prevents the reading of long pieces of text.
When the patient is asked to give input, they can choose from pre-set, visual answers, such as selectable smiley icons.

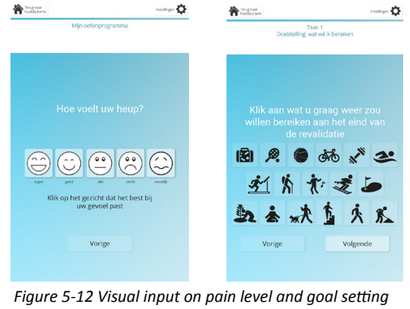


Figure 5-12 Visual input on pain level and goal setting screen

This way, typing inside the application is not necessary. This finding was also reflected in the user test: the modest patients had a strong preference for predetermined choice options or checkboxes and visual content (user test, chapter 2.4).
Text labels are added to icons to explain their meaning and reduce ambiguity, except for the goals-setting icons: these icons seemed clear in the user test (chapter 4.4) and are left open for own interpretation.

•A reading out loud option is a pleasant alternative for patients with poor vision or low literacy.

Dosing information
The challenge of dosing information is to provide enough information to make it understandable and supportive, while at the same time protecting the patient from an overdose of text and actions—to prevent too much complexity of information for the user at once. This phenomenon is addressed in the final design by displaying the messages on one screen as short and simple sentences.
When tasks contain many steps and actions, these steps and actions are divided into sub-screens, as can be seen in de flow chart of the task screens.

5.1.4. USER EXPERIENCE

In order to achieve the desired effect - to motivate and engage modest patients to achieve their personal goals - the User Experience should comply with previously established interaction qualities. As discussed in the the vision chapter, the Biobuddy should feel familiar, as a 'buddy', by empathising with modest patients to give them a feeling of being understood—in a respectful way. Among others, these desired qualities, embedded in the final design, will be explained in more detail below.

Familiar
•The Biobuddy feels familiar because a personal buddy guides the patient during their rehabilitation journey. This buddy, an abstract, affective figure, speaks to the patient during the different tasks to motivate them to achieve their personal goals.

The buddy figure evokes specific feelings by expressing an emotion, for instance hope or excitement, in a modest way to avoid a feeling of power distance.
Feelings that will be evoked are especially a feeling of empathy, commitment, reassurance, guidance, joy, and respect.

The visualization of the buddy is experienced as pleasant by modest users. The user tests have shown that patients can see different things in this character, such as a vegetable, cloud or stepping stone. Modest patient had no desire to choose another type of figure.

However, with the appearance of the Buddy could be further experimented, so that it fits the style of the interface best.

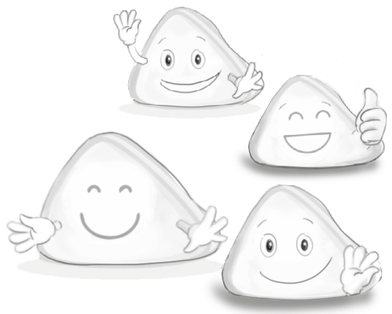


Figure 5-13 Affective buddy figures to trigger different emotions during the journey

• A second strategy to enhance a familiar feeling is voice guidance of the physiotherapist during exercise performance. This helps the patient to get the feeling a physiotherapist is with them and could personally assist them - just like during a consult - which works stimulating.

Empathizing
To give the user a more familiar feeling, it has also been shown that patients desire for a sense of understanding. Beside the affective buddy figure, this feeling is achieved in the final design by asking about the patient's mood, for example by choosing a smiley. In addition, the Biobuddy also asks for confirmation whether the patient has understood their tasks and exercises.

Attractive
The blue tone of the user interface is experienced as a soothing and pleasant in appearance. The user test shows that this color scheme does not distract patients from their tasks and personal goals. The different gradients are applied consistently in task screens.

Also, the typography and design of buttons is consistent throughout the application: visible blocks with rounded edges.
This makes the buttons attractive to click on and are also easy to find. The simple text makes the steps easy to follow. The simplicity, consistency and guidance are experienced as pleasant and enhance the user's ability and motivation.

Playful
The patients experienced the layout and content of the Biobuddy as playful, because of the use of icons and figures. The visual time path on the main screen (Figure 5-14) shows progression in an intuitive way.

Release of anxiety and pain experience
Feelings of anxiety can be reduced by having a good preparation and getting feedback on tasks. Moreover, the buddy gives the patients the feeling that they are not alone and are taken seriously. These experiences are confirmed by modest users (chapter 4.4).
An example to reduce anxiety and increase the confidence of the patient can be seen in the feedback of the Biobuddy after goal-setting: the Biobuddy has faith in the patient that they have the ability to reach their goals.

Finally, music has a positive effect on the reduction of pain and anxiety (Hole, 2015). By opening the Biobuddy app, music could start playing. The Biobuddy could be connected to an existing music app or have a pre-set playlist.

Overall, the user test has shown that these are the most important experiences to motivate and engage patients for active participation during their rehabilitating process.

Figure 5-14 The visual time path on the main screen creates a playful and intuitive experience

5.1.5. MOTIVATION, ENGAGEMENT, AND ADHERENCE

As stated before, the intended purpose of the final design is to motivate and engage patients to make the rehabilitation process run smoothly and successfully by adhering to their personal goals. Therefore, this chapter concludes with motivational theories embedded in the final design to support this desired effect.

Motivational theories
Several tricks are applied in the user interface to enhance the motivation of the patient. In Appendix 9, the methods can be found beside the English script of the task screens.

Goal setting and visualization techniques
In preparation for the rehabilitation, the Biobuddy uses two types of visualization techniques to prepare the patient: outcome visualization (goal setting) & process visualization. Goal setting has a positive influence on self-motivation and performance (Lunenburg, 2011). The visualization techniques increase the patient's self-efficacy to achieve their goal.

Visible goals
The main screen of the Biobuddy shows the user path, which provides insight into progression and goals after surgery. Being reminded of your goals and seeing progression works motivating.

5.2 Sensing plaster

Introduction
The monitoring device that could measure the physical activity of the patient is a sensing plaster. During the concept development of the sensing plaster, described in chapter 4.3.4, the functionalities and requirements are defined. In this chapter, the sensing plaster proposal will be elaborated on the technical component level (Hardware).

5.2.1. TECHNOLOGY – ELECTRONIC COMPONENTS

In the figure below, a schematic overview is given of the required components per concept.

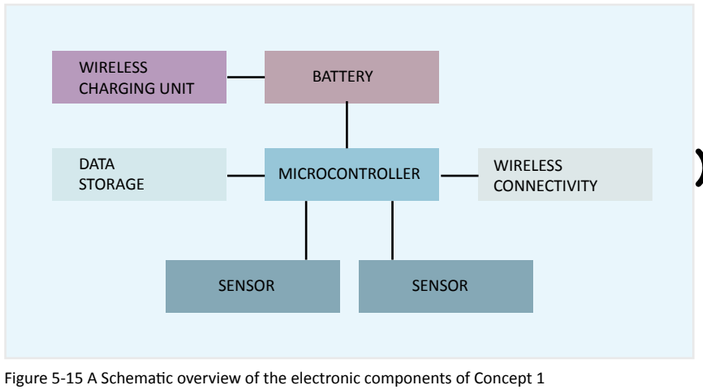


Figure 5-15 A Schematic overview of the electronic components of Concept 1

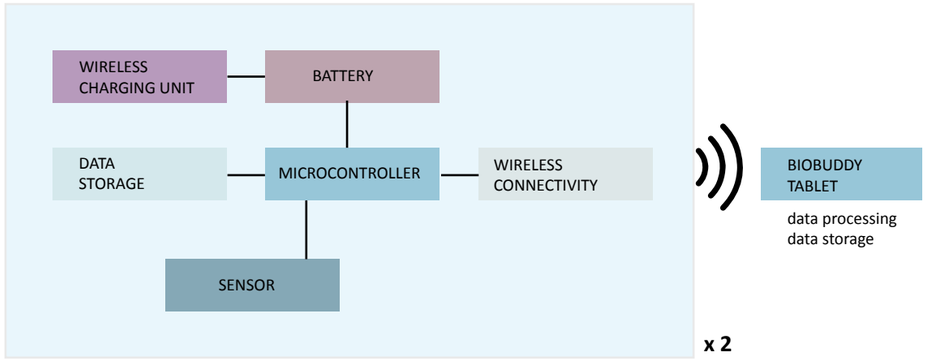


Figure 5-15 B Schematic overview of the electronic components of Concept 2

SENSOR

Figure 5-16 Motion sensor: combination of accelerometer, gyroscope and DMP microcontroller.
Price: €0,80 per piece
Dimensions: 4 x 4 x 0,9 mm
Fabricant: InvenSense

Sensors
Two sensor combinations of a 3-axis accelerometer and gyroscope are implemented in the sensing plaster. As concluded by the BioCoach AED team (Kraak, 2013), the combination of an accelerometer with a gyroscope provides more accurate data than a single accelerometer and could detect more different exercises.

The chosen component is designed for low power, low cost, and high-performance requirements. The component also includes a Digital Motion Processor (DMP), which processes complex 6-axis MotionFusion algorithms that converts motion to an angle. This allows the algorithm on the tablet to be faster and simpler, which could save system development time and costs.

Microcontroller, data storage and wireless connectivity

Wireless connectivity and data transmission
Wireless connection is desirable, above, for example, an USB cable, so that no gates are needed in the patch. To select a suitable technology for the plaster, four options are considered, as can be seen in the right table.

Bluetooth low energy	NFC	RFID	Wi-Fi
Range			
approx. 3 m	<10 cm	10 m	30-100 m
Power source and power consumption			
battery/accu, medium power consumption	powered by NFC reader	active: battery passive: reader	battery/accu, high power consumption
Direction communication			
two way	two way	one way	two way
Price			
moderate	low	active: high passive: low	low
Speed data transmission			
approx. 6 sec	0,1 ms	0,1 ms	

Figure 5-17 Wireless connectivity options

Two-way directional communication is needed, so RFID is not suitable. The desired range must be at least 3 meters. By using NFC, the NFC reader must be close to the hip. You could integrate an NFC reader into a band around the hip, but this takes away the advantages of the simple sensing plaster.
Wifi has a high power consumption and is therefore less suitable.
Bluetooth low energy seems to be the best option. Also, Bluetooth connectivity is available in many existing tablets. When a technology such as NFC is selected, a tablet should be designed that supports this connectivity.

Concluding, Bluetooth low energy is chosen for wireless connectivity, because of its range, low power consumption and two-way communication.

Connection between tablet and plaster
For the security of monitored data, encryption can be applied. The encryption key could be delivered in the form of a QR code in the package of the plaster. The Biobuddy tablet could scan this code. By scanning this code, the tablet can connect to the plaster and decrypt the data.

Chosen Component
A 'RadioFrequency System on a Chip' (RFSoC) is selected that includes the combination of a microcontroller, data storage, and Bluetooth low energy.

An advantage of this component is that it is commonly used; many people can program software for it. Also, it has many low energy functions.

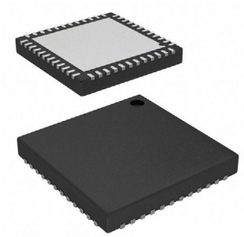
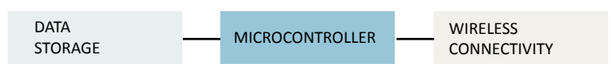


Figure 5-18 Combination of microcontroller, Bluetooth low energy and data storage.
Price: €1,24 per piece
Dimensions: 0,35 x 3,83 x 3,83 mm
Fabricant: Nordic Semicondutor
order number: nRF51822-QFAC-R



Glossary:
**Flash memory= memory storage device for computers and electronics. Flash memory is one kind of Non-volatile random-access memory and can keep its data intact with no power at all. It is slower than RAM.*

***Firmware= embedded software*

****RAM= Random Access Memory (RAM) is the memory or information storage in a computer that is used to store running programs and data for the programs. When power is turned off, RAM loses all its data.*

Data storage
The RFSoC has a 256kB embedded flash program memory*. The firmware** is stored on the flash memory of the RFSoC and needs to be at least 64kb, according to findings of the AED team (Kraak, 2013). So 256 kB is enough. See appendix 12 for the data sheet.

The RFSoC component has 32kB RAM***. To find out if this is enough to store the measured data, we should calculate the size of the measured data.

The size of the measured data of the plaster is dependent on the number of measurements (the frequency of sensors) and the accuracy of numbers that will be captured: the lower the frequency, the lower the data storage and besides this, the lower the power consumption. However, the frequency of the sensors has to be high enough to have an accurate measurement.

The monitoring function is divided into two types of measurements: monitoring the exercises on specific moments during the day and counting steps during the whole day.
Therefore we need to know the desired frequency of both measuring the exercise movement and measuring walking steps.

Sampling rate for exercises
The frequency or sampling rate of the sensors to monitor exercise movements are based on the results found by the AED team: the frequency of the sensors should be at least 50 Hz.
Measurement time (recommended by physiotherapists): 3 x 10 minutes a day.
Including a margin we take 60 min a day.

Data storage for exercises:
All sampling data is preferred to gather to be able to analyze the movements afterwards.
50*60= 3000 samples/min
Concept 2:
Per sensor 3 axis, so for 1 gyroscope and 1 accelerometer 6 measurements.
6*2= 12 bytes.
3000*12bytes= 36000 bytes = 36kB

(Concept 1:
Per sensor 3 axis, so for 2 gyroscopes and 2 accelerometers 12 measurements.
12*2= 24 bytes.
3000*24bytes= 72000 bytes = 72kB)

When the plaster will transmit its data every minute to the tablet during the exercise program, data storage of at least 36 kB is needed. The sensor data will be captured in the RAM and is periodically saved to the flash memory. Therefore, it is not necessary to have more than 32 kB of RAM.

Sampling rate for walking
In an experiment of Ryu (2013), an adaptive step detection algorithm could catch the average step count accuracy up to 98.9% at 10 Hz sampling rate and 99.6% at 20 Hz sampling rate, by using one 3-axis accelerometer.
Therefore, a sampling rate of 20 Hz seems suitable for the Biobuddy.
Measurement time: whole day (24 hours)

Data storage for walking:
2 bytes (an amount of 2^16 steps could be count)

On the flash memory, 256 - 64= 192 kB is available for sensor data. So there will be enough space for the 36 kB (or 72kB) of sensor data.

Concluding, no extra memory component is needed.

Power source
To select a suitable battery, the minimum battery capacity needs to be known.
The battery capacity is dependent on the power consumption of the components - 1x sensor and 1x RFSoC per plaster - and the desired battery lifetime. (For concept 1: 2x sensor and 1x RFSoC).

Battery lifetime
Most desired battery lifetime is a minimum of 14 days, so that charging is not needed in between physiotherapist consults.
Another – but less desired – option that requires limited patient's actions is to implement wireless charging in an unobtrusive way. For instance by placing a wireless charging transmitter component in the bed of the patient (on the mattress or pillow) or in a favorite chair, so charging will be done during sleeping or sitting.

Power consumption of components
The power consumption of the components is influenced by the frequency of measurements: the lower the frequency, the lower the power consumption. The frequency for the exercise measurement is 50Hz and for walking 20Hz (see previous section about data storage).

To minimize power consumption, we define when it's possible to put the component in sleep mode, by defining the moments of having the frequency in action to have an accurate measurement.
Also, limiting the moments of data transmission saves much power.
A calculation on power consumption is made to optimize battery lifetime (Appendix 11 & 12).

During exercising: the two sensors are fully needed, so both the accelerometer and gyroscope are activated (normal mode). Data transmission is done for 10 seconds per minute (RF active). The other 50 seconds, the RFSoC only uses data storage (normal mode), which saves power.

During walking: only one accelerometer is needed (low power mode) and the RFSoC could be in normal mode. So, Bluetooth is only activated when the Biobuddy tablet is used during the exercise program.

By applying this system, the charge needed for one day is: **6,98 mAh** per plaster for concept 2. (10,88 mAh for concept 1)

For the battery capacity, a margin is added to this charge since it is not advantageous to drain a battery. Concept 2:
For **two weeks battery capacity: 9*14 = 126 mAh** per plaster.
For **three weeks: 9*21= 189 mAh** per plaster
(Concept 1, for 14 days capacity: 14*14 = 196 mAh for the whole plaster)

Battery choice
Since the power consumption per day is relative low, a battery lifetime of 21 days is possible with a Lithium-Polymer battery of 200mAh.
This battery type is suitable because of its capacity, small size, wireless charging option and low price.

N.B. The selected component (figure 5-19), could be cheaper and smaller when doing a good search.

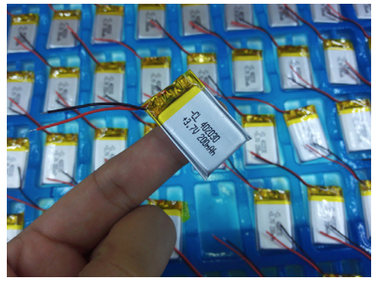


Figure 5-19 LiPo battery of 200 mAh, to have power for 21 days.
Price: €3,56. Dimensions: 4 x 20 x 30 mm.

WIRELESS CHARGING UNIT

Wireless charging component
Induction charging may be most suitable to apply, because then the components could be totally embedded whitin the casing. A point of attention is that is is important to perfectly outline the coils of the charging transmitter and receiver, to prevent power loss (see figure beneath). Therefore it is recommended to design a charging station.

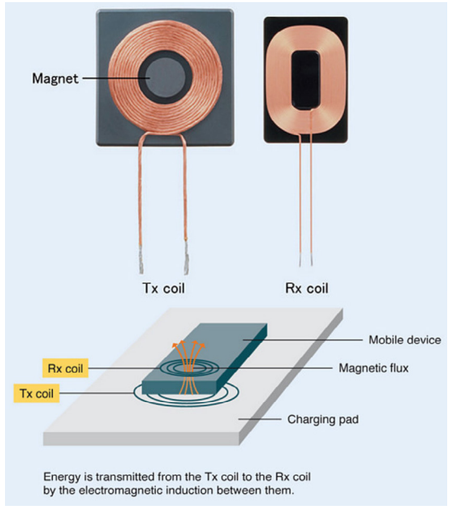


Figure 5-20
Induction charging

PCB
The electronic components are placed on a PCB (Printed Circuit Board). This could be on film (flexible) or glass fiber. When all components will be placed on the battery, flexibility has no advantage, since the battery is not flexible. But a thin layer is preferred above a thick (glass fiber) layer.

Product architecture
Suggestions on the product architecture are done in the figure beneath.

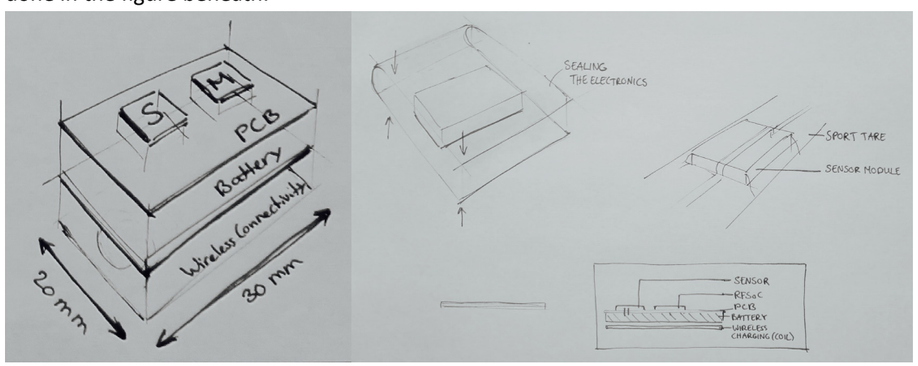


Figure 5-21
Product architecture
suggestion sketches

Production and materials
Material is needed for the casing around the electronic components.

One suitable option is to seal the electronics, which could be done with ultra-sone welding, plastic welding or hot bar welding.
The production method and material selection should be further investigated.

Adhesive part
For the sticker, an existing plaster or sport tape could be used that will be placed over the sealed package with the electronics.

Commonly used sport tape by physiotherapists is Blue 42 Classic sport tape (€4,50 for 10m x 3,8 cm). This tape is recommended by physiotherapists and has a high-quality adhesive layer and rarely causes skin irritation. Also, water resistant plasters exist that could be used for two or three weeks, without causing irritation on the skin. A company such as 3M does research about the comfort of these long-lasting plasters (Allen, 2017).

By analyzing this literature and possibly doing some additional tests, an optimal adhesive part could be defined and designed.

Further research should be done on e.g.:
- the way of applying the tape
- double fixation or only adhesive on the sides
- water resistance
- comfort of the skin, by placing a soft, slightly breathable material between the sealed electronics and the skin.

5.2.2. COST PRICE ESTIMATION

To make an estimation on cost price, we need to know the batch size of the sensing plaster.

In the Netherlands, more than 24.000 people receive a total hip replacement each year. This number is expected to rise to 32.000 in 2030 (LROI, 2016). We make an assumption that when introducing the sensing plaster, 26.000 people receive a total hip replacement. The electronic components could be reused, which saves costs in the long term.

The cost price of the sensing plaster is estimated for three scenarios:

- Optimistic batch size: 20% of THA patients in the Netherlands will use the Biobuddy with the sensing plaster: 5200 patients per year, 10400 plasters
- Normal batch size: 10% of THA patients in the Netherlands will use the Biobuddy with the sensing plaster: 2600 patients per year, 5200 plasters
- Small batch size: 5% of THA patients in the Netherlands will use the Biobuddy with the sensing plaster: 1300 patients per year, 2600 plasters

Price per component:
RFSoC: €1,24
Motion sensor: €0,80
Battery: €3,56
Wireless charging receiver: €1,00
PCB: €0,75 (this price is an estimation, based on the price indication of an electronics expert)
Sealing: dependent on material choice and production
Plaster tape: €0,20 (this price is an estimation)

Estimated cost price of concept 2

Optimistic batch size: €9,77 per plaster, €19,54 for a duo set.
Retail price for two plasters: €40,77

Normal batch size: €9,84 per plaster. €19,68 for a duo set.
Retail price for two plasters: €41,77

Small batch size: €9,97 per plaster. €19,94 for a duo set.
Retail price for two plasters: €41,69

As comparison, the estimated cost price of concept 1
Normal batch size:
Cost price: €11,17
Retail price: €23,30

See appendix 13 for the cost price estimation sheets.

Point of attention: When the sensing plaster concept will be further developed, the cost price estimation could be done more accurately.
When the plaster component will be reused for more patients, the batch size will decrease and the costs per patient will be lower.

STUCTURE CHAPTER 6

6.1 Evaluation of final design
- Evaluation of patients
- Evaluation of orthopedic surgeon
- Evaluation of former designer of the BioCoach

6.2. General conclusion
- Design guidelines final version

6.3. Recommendations
- Recommendation for further development of the Biobuddy
- Recommendations for further research of the Biobuddy
- Recommendations for the Sensing plaster
- Recommendation on the development of the system
- Recommendations from a business point of view

6.4. Final reflection
- Comparison design variant between profiles
- My vision on the role of the physiotherapist in the future
- Relation of this project to the master IPD
- Refection on the design process

Chapter 6
Evaluation

6.1 Evaluation of final design

EVALUATION OF PATIENTS

Impact of the product on physiotherapist according to patients
The five participants of the user test in Chapter 4.4 are asked about their view on the impact of the Biobuddy on physiotherapy consults.

Less physiotherapy consults needed
All five participants thought they would need less physiotherapy consults when using the Biobuddy. However, the modest and managing patients still prefer to see a physiotherapist once in a while. One modest user (P3) emphasizes that she really likes the effect of the Biobuddy on the possible decrease in consultations, because fewer consults are reimbursed; otherwise her treatment will become expensive.
The interviewed optimist preferred to use only the Biobuddy application instead of seeing a physiotherapist. It seems that optimistic patients like to rehabilitate independently, in their own way.

All asked participants believe that by getting insight in monitoring activity data, the physiotherapist can provide more informed feedback to the patient during the consult.
The advice and instructions of the physiotherapist could be more specific and treatment could be more efficient, by having insight into. They like the idea that the treatment program is based on accurate measurements.

Opinion about the Biobuddy product service system
Patients indicated that the Biobuddy could take away uncertainty and gives hope for a good outcome. Modest patient (P5): "Met dit product heb ik het idee: hier kom ik verder mee. Anders dobber je maar wat."
The product facilitates collaboration between the patient and a 'physical' and 'digital caregiver'. Other quotes of patients can be found in Appendix 10.3.

EVALUATION OF ORTHOPEDIC SURGEON

The Biobuddy interactive prototype has been evaluated with an orthopedic surgeon, specialized in hip surgery. His reaction:

"I would like to use this. I think this can certainly support patients in their rehabilitation journey. The timeline on the main screen is nice!"

With the ultimate goal in mind that the care experience should be improved for the patient:

"I do not want that that the Biobuddy would cause competition between physiotherapy practices. Preferably, the hospital or surgery clinic could enter into a partnership with physiotherapy practices so that the product is available for all practices."

EVALUATION OF FORMER DESIGNER OF THE BIOCOACH - Msc. S. ANDARY

The Biobuddy's interactive prototype and sensing plaster concept has been evaluated with a designer of the AED team, who worked on the previous version of the BioCoach.
Overall meaning: *"Great to see so many improvements Lisanne has made on the original solution of the BioCoach.*

Sensing plaster: *"I see a lot of advantages compared to the original BioCoach. The most outstanding feature is the ability to measure the exercises much more accurately."*

Screen interface: *"Great to have the patient focus on their exercises and only use the screen for preparation and evaluation purposes. Progression screen: I would totally have use it for my own rehabilitation!"*

6.2 General conclusions

Biobuddy
We can conclude that the Biobuddy succeed in its design for the modest patient profile by meeting all requirements.

The Biobuddy includes all required functionalities to support the patient in self-management during their THA rehabilitation. Before surgery, the Biobuddy visualizes the rehabilitation end goal and the rehabilitation process.
After surgery, the sensing plaster monitors exercises for hip mobility and muscle strength of the operated leg. The Biobuddy application provides feedback on the exercise performance and walking activity. Furthermore, the product remind the patient for daily activity, provide visual (video) explanation about the exercises, provide progression insights. The product enhance a good posture and walking pattern.
During the complete journey, the Biobuddy helps the patient in managing pain and medication use.

The product experience and usability of the Biobuddy interface is evaluated in the user test of Chapter 4.4. The five participants experienced the Biobuddy as intended: easy to use, simple to understand, emphatic and respectful, playful and pleasant, convincing, motivational, reassuring and reliable.

Sensing plaster
The goal of the concept elaboration was to find out if the sensing plaster idea is feasible.
With a retail price well below 50 euros and a design that contains relatively small and light components which is able to monitor movement for a minimum of three weeks, I think I can state that this product proposal is feasible and has much potential to become a successful addition to the product portfolio of Zimmer Biomet.
Advantages of the sensing plaster compared to the current version of the BioCoach:

- The sensing plaster could distinguish between sitting and lying down, since it has a sensor on both the upper body and upper leg. This makes measurements more **reliable**. Beside this, it is possible to give a **warning signal** during dangerous movement (angle < 90 degrees or a fall).
- It has a **higher accuracy** of exercise measurements because of double sensor points, and the sensors are precisely kept in place.
- It is possible to measure steps during the day and **walking** cadence. Later on, the plaster could be used for gait analysis (phase 3).
- The design is **unobtrusive**. It will be worn under the normal clothes of the patient.
- No patient actions are required to put the product on or off which is **easy** for the modest user. It saves effort and makes the activity insights reliable, since the product could not be forgotten to put on.
  It eliminating the need for bands or other uncomfortable components to properly affix the technology.
- It has a **low price.**

The Biobuddy product-service system is received positively by both patients, orthopedic surgeon and former designer of the BioCoach.

Adjustment of design guidelines (version 3)
After establishing the design guidelines in chapter 2.4, no deviating results among patient profile needs and preferences are found during the continuation of the project.
Moreover, the correctness of guidelines was confirmed during new user tests (chapter 4.4). Therefore, the content of these guidelines can stay the same.
However, the categorization of the guidelines could be improved by using labels that are common for designers:

Usability	*Information level*
Functionality	*Physical, mental, communication, pain level*
User experience	*Interaction qualities & moments of interaction*

6.3 Recommendations

Recommendation for further development of the Biobuddy:

• *Develop and produce the videos intended for the phase before surgery: goal setting and process visualization*

Two visualization techniques are applied in the video content idea of the 'expectation management'-task screens. Despite that the videos are not developed yet, the content was positively received by patients from all profiles during the evaluation test (chapter 4.4).

I recommend to further develop the video content en test the effect of the visualization techniques on the patient. Another visualization technique that could be integrated and researched is 'motor imagery': mental rehearsal of voluntary movement without body movement (Jeannerod et al., 1995). According to research, motor imagery has positive effect on performance; reduces anxiety levels; increases intrinsic motivation; increases self-efficacy and improving accuracy and technical quality of movement (Martin, 1995).

• *Design a gait analysis variant of the sensing plaster for phase 3 in the rehabilitation*

This product could monitor the quality of walking and the posture of the patient. The sensing plaster could be used for gait analysis, when placed on the backbone, with one sensor on the right and left side. The plaster could be sticked on the skin or for instance be integrated in a belt. Another option is to make use of existing gait analysis tools.

• *Design a Biobuddy or Biocoach variant for the optimistic and managing profile.*

Recommendations for further research of the Biobuddy:

• *Introduction and instructions*

Further research could determine if certain instructions can help the patient on their way. Is it desired to educate the patient during an 'onboarding experience' to learn using the app? Or provide a manual with visual guidance? And what should the content be? We do not want to overload the patient with information, nor with an extensive instruction, if it turns out that this is not necessary.

To illustrate the importance of dosing the (instruction) information, an example is given:.

Example of the importance of dosing information

Modest patient about her new washing machine: "I got 15 min explanation from the mechanic, he showed everything about the washing machine. When he was gone, I did not know how to wash because he gave so much information. But I thought, I will read in the manual. But the manual was too complex, too much info, I didn't know where to look." 2,5 weeks later she could do her first wash, with help of her cleaning lady. (Participant 5, Evaluation test chapter 4.4)

An option for instruction could be:

- A brief, visual paper instruction beside the screen with its main functions, navigation options and usage explanation.
- Add a little 'instruction tour' after the welcome screens (see Figure 6-1) >

• *Personalization*

This project is about tailoring healthcare products, by using patient profiling. Therefore, the content and design of the Biobuddy is already tailored for the modest patient profile. Still, patients within the profile could have different preferences. Therefore, another tailoring strategy could be implemented in the BioCoach: personalization (Hawkins et al., 2008). For instance, the Biobuddy could call the patients be their name. Or the patients could choose their own background theme or buddy figure. A more personal experience could higher patient satisfaction and engagements (Hawkins et al., 2008).

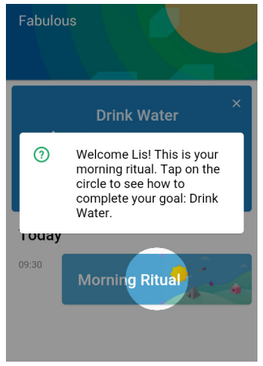


Figure 6-1 Example of an instruction on the screen.

This personalization option is evaluated in the user test (4.4). The participants were not interested in this option. However, because of the small amount of 5 participants, further research could enrich the insights about personalization.

• *Music*

Implementing music in the Biobuddy could improve the user experience. Research the effect of music during the rehabilitation process: does music lower down the pain and anxiety experience and does this influence the activity level and the healing process in a positive way? What are desired moments to use music?

Recommendations for the Sensing plaster

Failure mode and effect analysis

It is recommended to do a failure mode and effect analysis, to indicate possible risks of the sensing plaster. The outcome needs to be taken into account in further development of the plaster.

Two concepts are created for the sensing plaster. To exclude which concept will be most suitable, the following point should be researched:

• For concept 1, more research needs to be done on comfort of the plaster shape and size.
• In concept 1, the orientation of the sensors is fixed in relation to each other. With two separate plasters, this orientation could easily deviate. The influence on the accuracy of measurements should be further researched.
• Test if interference of wireless parts (charging and data transmission) will take place and define what the minimal distance between these parts should be.
• Test and iterate on the comfort of usage
• Optimize the aesthetics
• The production method and suitable materials should be further researched.
• It is recommended to design a charging station for the Wireless charging component to perfectly outline the coils of the charging transmitter and receiver, to prevent power loss.

• Develop a business proposal and do a competitor analysis for the sensing plaster. (Possible competitors: Delsys, Active Pal, Trac patch, Claris reflex).

Recommendation on the development of the system

Develop the algorithm to measure physical exercises. The AED report (Kraak, 2013, page 81-82) provides suggestions for suitable exercises to implement. When existing, validated algorithms could be used, it will save development time and costs.

Recommendations from a business point of view

• Validate the Biobuddy system for the hip. Apply the product for other joints, such as the knee, to enlarge the batch size.

• Introduction of a new 'Rehabilitation product' portfollio for Zimmer Biomet, by implementing the Biobuddy and sensing plaster product service-system. Since Zimmer Biomet owns the 'Patient Journey App' (see chapter 2.1.2), this existing app may be a good base of knowlegde for the development of the Biobuddy app.

Business case in pain medication

Lower down the standard medication provision for patients that doesn't experience much pain.

Other

Role of the physiotherapist vs. technology

Could the establishment of the exercise program for the hip patient be automated by doing measurements with the sensing plaster? Is this desired by patients and ethical accepted in society?

6.4 Final reflection

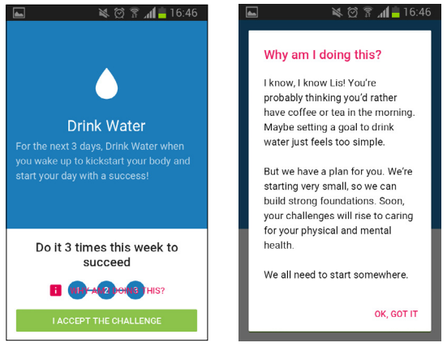
Comparison design variants between profiles
The Biobuddy design is intended to be as simple as possible. This was an important requirement for the modest patient profile. Only the core information is added, to prevent an information overload.

For the other profiles, a simple, intuitive product in simple language was not a requirement. However, I think a simple and easy-to-use product is desirable for everyone. Therefore I see the Biobuddy as a good base for a 'BioCoach variant' for the other profiles, especially the managing profile.
I assume that when the Biobuddy application has an understandable interface for the modest patients, it will also be easy usable for the other profiles.

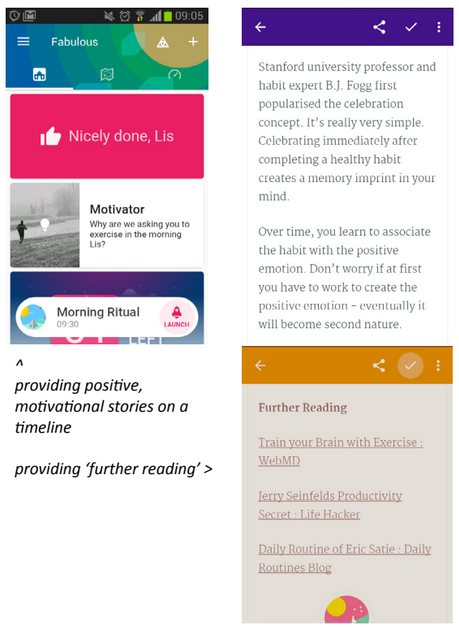
Based on all insight gathered during the user test with patients (Chapter 2.4 and 4.4), I predict the following product variant to be desired for the managing and optimistic profiles.

Managing profile
Envisioned product design: a Biobuddy variant with additional explanation, background information, and personalization option.
Since lots of information is desired, a tablet could be suitable. Also a paper-booklet (sensitizing booklet) could be considered, when reading is not an obstacle and video content is not a must.

According to the user test, is seems that the managers prefer to get feedback immediately after something gets wrong, so to have continuous access to the product.
Quote of the managing patient during user test (4.4): "The more information you get, the better, otherwise you become uncertain. If I do something wrong, I would like to be notified immediately."
Therefore, an additional wearable or smart phone app may be desired, to receive pop-up messages and (warning) signals throughout the day when a patient tends to exercise too much, makes dangerous movements (i.e. ROM > 90 degrees) or to motivates the patient. However, further research should investigate this.



^
Providing background information and extra explanation. Name scientific sources.



^
providing positive, motivational stories on a timeline

providing 'further reading' >

Figure 6-2 Envisioned product examples for managing patient profile

Optimistic profile
Functionality: video preparation before surgery and progression insights after surgery.
Product design: simple, small product to get insight in progression. This could be a wearable (smart watch or bracelet such as FitBit) or a smart phone app. No big screen is needed for additional information. Video content could be watched on their own computer or tablet.

Figure 6-3 Envisioned product examples for optimistic patient profile

My vision on the role of the physiotherapist in the future
I think it is technically possible to automate the exercise program in the future and rehabilitate without any physiotherapist consult. However, people need to get used to this idea and want to be sure this will not be disadvantageous for their recovery. Therefore, my advice is to slowly reduce the consults over the years to convince patients and care professionals that the use of a monitoring product in combination with a digital advice (e-health) works well.

Role of the physiotherapist during this new rehabilitation journey
Before this automation is possible, the physiotherapist will determine the exercise program after surgery and adjust this program during the first phase of rehabilitation. The program will be imported in the Biobuddy app via the 'BioCoach physiotherapist' app, so that the patient will see the right explanation videos and get feedback on their exercise quality. Also, voice guidance could be imported. When desired this physiotherapist app could be integrated into the Biobuddy app on the tablet.
Besides this, someone is needed to put on the sensing plaster and perhaps adjust patient preferences into the app.

Role of other caregivers
The role of the other stakeholders will not change by implementing the Biobuddy to the THA rehabilitation journey. However, some little actions are recommended:
• Orthopedic surgeon: give a recommendation to the patient during the consult to use the Biobuddy.
• Informal caregiver: when desired by the patient, help with the usage of the application, for instance to change settings. However, the usability of the app is designed to be understandable for the elderly patient without affinity with apps, so the help of others will not be necessary for most patients.

Relation of this project to the master IPD
This project focused on the development of the user-centered product the Biobuddy, in which design and technology are integrated to meet all needs and wishes for one patient profile to accomplish the THA rehabilitation process.
The IPD master covers the entire design process, starting from a design brief and ending with user-centered innovative products and product service combinations, based on a balance between the interests of users, business, and societal challenges. After the analysis phase, wherein both the context of the market and the stakeholders have been researched, I went into conceptualization, including prototyping and testing, followed by the embodiment design to end with a final product. This is done by applying systematic theories and methodologies and by integrating user, technology, and business aspects.
However, this project has also a big focus on design for interaction.

Interface of the project with business
The Biobuddy aims to create higher patient satisfaction and better patient outcomes. As stated in the introduction, a tailored patient experience may increase efficiency in healthcare. So from a business perspective, this could save time and costs in healthcare. As a result of this, the market position of the hospital improves.

The Biobuddy product service-system (or ecosytem) could be the first eye catcher of Zimmer Biomet's new 'Rehabilitation product portfolio'.
When it is validated that the use of the Biobuddy will work positively for specific patient profiles, healthcare professionals and companies can be convinced to implement this product into their healthcare system, which is profitable for the company Zimmer Biomet.

The guidelines for different patient profiles and insights gathered in this project, could be used as a base for a final set of guidelines for patient profiling, which can be sold to and used by (medical) design agencies and consultants.

Interface of the project with human interaction
Three patient profile groups and care professionals have been thoroughly analyzed. The user has been involved during the whole process, starting with analyzing their needs and (interaction) preferences, and followed by user tests during the conceptualization and embodiment phase, to be able to design a user-centered product. All stakeholders were involved during the analysis phase.

Interface of the project with technology
The implementation of technology into the rehabilitation process, in the form of a product-service system, had the focus throughout the whole process. First, the used technology of the BioCoach was analyzed. Later on, potential roles of the BioCoach product were 'embodied' on paper in a storyboard. Then, concepts were created in which existing technology was integrated. By placing just the essential technology on the right place of the body and eliminating redundant components, the plaster idea had arisen.
During the embodiment phase, an elaboration on technical components is done to investigate if the sensing plaster proposal was feasible and to make a cost price estimation.

Refection on the design process
Personal goals
Before starting this project, I thought about points I wanted to learn or work on during this last master project of my study. One goal was to work visually, to improve my drawing skills and become more confident while drawing, which I definitely did. Also, I wanted to gain more experience with user testing and learned something about sensors and electronics, which I both did.

Besides this, I learned a lot of new things I didn't expect. For instance, I never made an application before, which was surprisingly nice to do and probably something I want to do again in future work. I gained more experience with Adobe programs as well. Gaining experience with rapid prototyping techniques will stay on my 'wish list' and will be a goal of a next project!

Last but not least, probably the most important goal was that I wanted to enjoy this last master project and make sure I had a good time management. I'm happy with the work I could do in the limited time span of graduation and surely enjoyed working on it.
I learned to work more efficient over time. However, as a perfectionist, it is still a challenge to make choices and not wanting to do EVERYTHING.

Research
Looking back to the whole process, from the beginning till the end I did different types of research and studies: literature research, qualitative and qualitative data analysis and user research with different stakeholders: physiotherapists and different types of patient. I found out that I really like to do research and analyze situations. Especially in user research, you get into depth in a short time with someone you actually don't know. It is interesting and often quite fun to dive into the minds of others and get new insights.

Final design
I'm happy with the final result. I truly believe in the Biobuddy and sensing plaster concept and think it will improve the rehabilitation experience of patients.

Concluding, I'm satisfied with this last masterpiece of my study!

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Appendices