NTNU
Norwegian University of
Science and Technology

Mobile User Interface for a patient-centered health care application

Linn Kristin Stokvik

Master of Science in Computer Science
Submission date: August 2017
Supervisor: Kerstin Bach, IDI
Co-supervisor: Agnar Aamodt, IDI
Paul Jarle Mork, ISM

Norwegian University of Science and Technology
Department of Computer Science

Abstract

Low back pain is a prevalent issue in the developed world as people adopt a more sedentary lifestyle. This thesis gives insight to available interactive health communication applications for self-managing non-specific low back pain, with the main focus on mobile delivered interventions. The aim of this thesis was to conceptualize and prototype a mobile user interface for the decision support system selfBACK which is providing an interactive self-management program for non-specific low back pain.

We conducted three workshops with a multidisciplinary group of people specialising in technology, medicine and user experience design. The outcome of this process was the initial sketches of the conceptual design. After this we conducted a review of existing solutions in found in literature and a review of commercial mobile apps. Finally, all the ideas from the workshops and existing solutions were brought together in a complete design proposal. In order to conduct experiments to validate the design, we implemented both a native Android and iOS prototype which is communicating with a restful backend server. The prototyped allowed us to conduct the user test with a survey of non-implemented functionality, a usability test of the implemented components and a post-test questionnaire. The participants were five eligible testers having suffered from back pain. The results and feedback from the user test were compared to previous research, and finally we present suggestions for improvements to design proposal.

Sammendrag

(This is a Norwegian translation of the abstract)

Smerter i korsryggen er et økende problem i industriland, i og med at befolkningen får en stadig mer stillesittende hverdag. Denne avhandlingen gir et innblikk i interaktive helseapplikasjoner for egenhåndtering av korsryggsmerter, med et spesielt fokus på programmer som er levert på mobile plattformer. Målet med denne oppgaven er å designe og implementere en prototype av et brukergrensesnitt for systemet selfBACK. SelfBACK leverer interaktive, personlig tilpassede planer for egenhåndtering av korsryggsmerter.

Vi organiserte tre workshoper med en tverrfaglig gruppe. Resultatet fra denne prosessen var det initielle utkastet til designet på appen. Deretter undersøkte vi eksisterende løsninger ved å gjennomføre et litteratursøk, og en gjennomgang av kommersielt tilgjengelige mobilapper. Ideene fra workshopene og eksisterende løsninger ble til slutt satt sammen til det endelig forslaget på brukergrensesnittet. Vi implementerte også en smarttelefon-app for Android og iOS for å validere det foreslåtte designet. Denne prototypen ble deretter brukt til å utføre en brukertest med deltakere som har hatt ryggsmerter. Brukertesten bestod av en spørreundersøkelse om funksjonalitet som ikke var implementert i prototypen, samt en fysisk gjennomgang av funksjonalitet i appen og et avsluttende spørreskjema rundt denne gjennomgangen. Deretter samlet vi tilbakemeldingene fra brukertesten og sammenlignet disse med eksisterende løsninger. Vi presenterer til slutt styrker og svakheter med ved foreslåtte designet, og gir forslag til forbedringer.

Preface

This report is the deliverable in a master thesis carried out at The Department of Computer Science (IDI) at the Norwegian University of Science and Technology (NTNU).

I would like to thank my supervisor Kerstin Bach for the guidance and support along the way. I would also like to thank the rest of the selfBACK team for technical assistance.

Linn Kristin Stokvik
Trondheim, August 18th, 2017

Table of Contents

Abbreviations

LBP	=	Low back pain
CBR	=	Case-based reasoning
IDSS	=	Intelligent decision support system
IHCA	=	Interactive health communication applications
CBT	=	Cognitive behavioural therapy

Chapter 1

Introduction

1.1 Motivation

Low back pain is an increasingly common widespread disorder that is considered a global financial burden (Deyo et al., 1991; Hoy et al., 2012), and it is one of the most common reasons for seeking medical care in the developed world (Hoy et al., 2010b). Hoy et al. (2012) estimates that approximately 40 percent of the global population will experience low back pain during their lifetime, while some estimates up to 84 percent in western countries (Airaksinen et al., 2006). However, the research does not receive enough attention or financial support to reflect these circumstances (Hoy et al., 2010b).

The majority of people experiencing low back pain have no underlying pathological explanation or other symptoms, and the cause of the pain is never recognized. This condition is referred to as non-specific low back pain (Balagué et al., 2012). The expected course of recovery is very promising, and many will recover on their own without intervention from medical professionals. Research shows that how the pain is perceived is a decisive factor for the recovery time, and it is common, especially in chronic cases, to show fear of movement and thus avoiding activity altogether (Grotle et al., 2004). Introducing education on the subject and reassurance of a promising recovery period can help control these beliefs for many individuals. Wong et al. (2016) created a summary of clinical practice guidelines for non-specific low back pain, and most of these recommend to stay active and return to normal activities as quickly as possible. Self-management programs and active patient participation is thus effective and significant components in back pain management (Dirmaier et al., 2013).

Online delivered self-management programs, both for web and mobile, have shown promising outcomes both in reducing pain and increasing quality of life (Chiauzzi et al., 2010; Carpenter et al., 2012). The current emergence of ehealth applications lowers the barrier to introduce such a tool in general practice. There are many products for self-management of low back pain available in commercial app stores, but none of these have been thoroughly tested in a research setting (Machado et al., 2017). On the other side, the majority of apps created in research are not commercially available.

This research is a contribution to an ongoing research project at NTNU called selfBACK [1]. SelfBACK is a decision support system that will provide personalised self-management plans by using case-based reasoning (CBR). CBR is an artificial intelligence (AI) method where one solves new problems by applying solutions from previously known cases (Aamodt and Plaza, 1994). It is very similar to how medical practitioners traditionally operate, and has been proven useful in many expert systems. However, it is uncommonly incorporated in non-expert user systems. The goal in this thesis is to conceptualize and prototype a mobile user interface for the selfBACK system, but it will be an independent contribution and could be applied to similar decision support systems. The main focus will be on the interaction with an intelligent system and how to create a personalised and motivational experience based on the advice provided by the decision support system. There is often a gap between ehealth applications and what the mobile user is accustomed with in other domains. It is important to focus on usability and motivational components in user interfaces, both for the purpose of getting more accurate results in research and to enhance the user experience.

1.2 Goals and research questions

The main contribution in this project will be to design and implement a mobile app delivering self-management of non-specific low back pain. Throughout this report the use of the terms low back pain and back pain is always referring to non-specific low back pain which is the only focus on this study. The process towards the final design is described by two goals.

G1 - Identify existing solutions delivering self-management programs for non-specific low back pain.

RQ 1 What is the current state of the art in ehealth applications with focus on non-specific low back pain?

RQ 2 What are existing online applications in today's market and research for self-management of non-specific low-back pain?

RQ 3 Which features are included in the applications found through RQ 2 for providing a tailored and personalised user-experience?

The self-management plan provided by selfBACK is focusing on three main components; 1) education on low back pain, 2) daily activity level, and 3) back specific exercises. The literature study will only include solutions focusing on any of these components. Both web and mobile applications will be reviewed. The intention is to use the results found

[1] selfBACK - A decision support system to improve self-management of non-specific low back pain `http://www.selfback.eu`

through the first research goal to achieve the secondary goal of this project:

G2 - Design a user-friendly mobile application for self-managing non-specific low back pain.

RQ 4 How should the application flow be designed to make it understandable for a broader user group?

RQ 5 How should the educational material be presented to the user?

RQ 6 How should the exercise advice and activity be presented to the user?

This research implements a cross-platform mobile application. The app communicates with the selfBACK system, which will provide the user with a personalised self-management plan. The aim is to support existing research in this field, and explore new methods for enhancing the experience of online delivered self-management programs. The focus for this goal will be on the three main components of the self-management plan, and how to motivate the user to be an active participant in the decision making process. In addition, it will focus on how the underlying artificial intelligence should be presented and interacted with from the user's perspective.

1.3 Research methods

This research is using a mixed methods approach. To be able to fulfil the first goal statement and address the research questions, the process started of with a literature review to get a complete overview of the different domains this project comprises. This also includes a review of available commercial mobile apps.

In order to identify the requirements for this prototype, we conducted several design workshops with people having expertise in graphic design, computer science and medicine. As part of this process it has also been necessary to evaluate technical requirements, which includes type of activity sensor and how to communicate the data between the components. The mobile application was finally be tested on usability, readability and design. Including whether it is considered a useful and supportive tool for the target user group. We conducted a usability test to be able to investigate this behaviour, and included a survey to support this test. This paper will present frameworks and features that can promote long-term adherence to the self-management plan, but these are included as suggestions to future work and should be tested over a longer period than the span of this project.

1.4 Thesis structure

This report is divided into seven chapters. Chapter 2 will give an introduction to non-specific low back pain and intelligent decision support systems. In addition it presents similar systems found through a literature review and a review of commercial projects. Chapter 3 presents the conceptual design that was created in this process, and Chapter 4 describes the implementation of a prototype with this design. In Chapter 5 we explain the planning and results from the experiment that was performed to test the prototype and the proposed functionality. The results from this and the findings through the literature review are compared and discussed in Chapter 6. Finally, conclusion and future work are presented in Chapter 7.

Chapter 2

Background

This chapter will explain what non-specific low back pain (LBP) is and how self-management interventions can be used in this context. Throughout this report the use of the terms low back pain and back pain is always referring to non-specific low back pain which is the only focus on this study. This chapter will also provide an introduction to intelligent decision support systems (IDSSs), and how case-based reasoning (CBR) can be used in these systems. Lastly, it presents a review of similar systems for self-management of non-specific LBP in 1) interactive health communication applications (IHCAs) found in literature, and 2) smartphone apps found through a commercial review by searching mobile app stores.

2.1 Non-specific low back pain

Back problems are one of the most common reasons for seeking medical care in Norway[1] and in the rest of the developed world (Hoy et al., 2010b). Hoy et al. (2012) estimates that approximately 40 percent of the global population will experience LBP during their lifetime, while some estimates up to 84 percent in western countries (Airaksinen et al., 2006). In most cases there cannot be identified an underlying pathological explanation associated with LBP, and this is referred to as non-specific LBP (Balagué et al., 2012) and will be the sole focus of this study.

For many, the pain can be extremely disabling, and thus making it difficult to keep a normal routine. The treatment of non-specific LBP is a debated subject crossing multiple domains, however most studies focus on and recommend conservative, noninvasive treatment of LBP (van Tulder et al., 2006). A recent review, Wong et al. (2016), found that most high-quality material recommend education, staying active, manual therapy and use of nonsteroidal anti-inflammatory drugs (NSAIDs) only in some cases as initial treatment options for LBP. The review compared (13 qualified) clinical guidelines published between

[1] GPs and emergency primary health care: `https://www.ssb.no/en/helse/statistikker/fastlegetj/aar`

2005 and 2014. A summary of these findings are presented in table 2.1. These are in agreement with previous clinical guidelines (Koes et al., 2001; Airaksinen et al., 2006), except for the recommendation of massage and acupuncture which might be due to new discoveries in more recent studies.

Acute	Chronic
Recommended by *all* guidelines:	
Advice / reassurance / education on expected course of recovery and self-care to manage the pain	Education on self-management, expected course and self-care. Interventions for short-term improvement. Stay active and early return to activity.
Return to activity, stay active, avoid longer periods of bed rest	Exercises based on patient preferences
Paracetamol or nonsteroidal anti-inflammatory drugs (NSAIDSs)	Paracetamol or nonsteroidal anti-inflammatory drugs (NSAIDSs)
Muscle relaxants	Manual therapy
Spinal manipulation (if self-care options are not helpful)	Short-term use of opioids
	Multimodal rehabilitation (including physical and psychological interventions)
Recommended by *some* guidelines:	
Short-term use of opioids (when severe pain)	Massage
	Acupuncture
	Antidepressants

Table 2.1: Summary of clinical guidelines for noninvasive management of nonspecific low back pain (Wong et al., 2016). Acute pain is defined as episodes lasting less than six weeks, and chronic is defined as episodes lasting more than six weeks.

2.1.1 Fear and pain avoidance

Many studies have identified a connection between fear and chronicity, and the domain has recently received increased attention. Gheldof et al. (2005) found that pain related fear is an important factor for LBP becoming chronic which is consistent with clinical models of chronic pain. The same results were found in (Picavet et al., 2002), with an emphasis on pain catastrophizing. Better understanding of fear-avoidance beliefs in early stages of LBP is needed in order to prevent the risk of increased pain and long-term disability. In 1983, Lethem et al. (1983) proposed a theoretical model, called the fear-avoidance model. The goal was to explain why some patients with LBP develop greater psychological symptoms than others. The model proposes two possible scenarios when acute pain occur. First, the patients who perceives the pain with low fear will most likely confront the situation and recover within a short period of time. Second, the patients that perceives the pain as catastrophic will avoid activities that might trigger pain and experience enhanced disability.

2.2 Self-management plan

Our mind is a powerful tool, and to a certain degree we have the ability to control our well being. Self-management consists of skills that can be learned and these develop with practice. The goal of self-management is to increase the patient's self-efficacy which in turn yield better clinical results (Bodenheimer et al., 2002). Self-management is evidently important for patients with chronic conditions (Warsi et al., 2004), but considering the believed strong connection between fear beliefs and chronicity, it is important to explore the concept at an earlier stage.

According to (Barak et al., 2009), Internet-supported interventions should include these key components: Program content, multimedia choices, interaction and feedback. The focus when conceptualising the app is heavily based on this. Evidence shows that programs teaching skills to handle the underlying problem, are more successful than those that just provide information (Bodenheimer et al., 2002). Another factor to success is internal motivation (Baranowski et al., 2003). People get motivated by reaching goals and gain confidence to accomplish to new challenges. Thus it is encouraged to give patients the power and tools to chose their own path and allowing them to be active, instead of just telling them what is the best way. However, the person must be willing to make the change in order for the intervention to work (Baranowski et al., 1998). An important part of the self-management process is cognitive behavioural therapy (CBT), with it's relevance dependent on patient self-efficacy and psychosocial factors (Gatchel and Rollings, 2008). The main focus in CBT is to change negative thinking and emotions related to the pain with more positive adaptive thoughts, through a practical problem-solving process with for instance motivational self-instructions, relaxation or goal setting (Gatchel and Okifuji, 2006).

The Internet has in many cases been utilised for behaviour change in chronic diseases and as an intervention platform (Lorig et al., 2002, 2006). It is an efficient and cost-effective method to monitor and follow-up patients when there's no pathological explanation for pain. It opens up for contact both between peers and professionals, and online (mediated) discussion groups have been proven to have a positive impact on health status for patients with chronic pain (Lorig et al., 2002). However, some individuals might be more acceptive and open to online treatment, in particular those who are more familiar with the Internet. A clinical trial of an online intervention website for patients with chronic back pain reported both more frequent interaction and better clinical results in participants recruited online compared to those recruited through a pain clinic (Chiauzzi et al., 2010). It is worth investigating how a diversified group perceives online health advice.

2.2.1 Components of the self-management plan

The self-management plan provided by selfBACK consists of three main components; *activity*, *exercise* and *education*. A summary of (recently updated) recommended treatments for non-specific LBP is shown in table 2.1, and these are in agreement with the self-management components which are the focus of this study.

(In)activity. Activity is an important component to the self-management plan. Both in acute and chronic occurrences of LBP, it is recommended to maintain a normal activity level for the most efficient recovery period (Malmivaara et al., 1995; Wong et al., 2016). The system will guide and motivate the user to increase daily activity and promote shorter periods of inactivity.

Exercise. Back-specific exercises are recommended for individuals with chronic LBP, there is however no evidence supporting a beneficial outcome for back-specific exercises in acute cases (Malmivaara et al., 1995; Hayden et al., 2005; Koes et al., 2006; Wong et al., 2016). The system should adapt accordingly.

Education. Strong evidence show that adherence to the activity and/or exercise component may increase if the user receives high quality information about LBP and treatment of LBP (Henrotin et al., 2006) and education on expected course of recovery (Wong et al., 2016).

2.3 Intelligent decision support systems

Systems designed to assist medical decisions are already widely implemented, and is utilised by both general practitioners and specialists (Martínez-Pérez et al., 2014). However, IDSSs are less commonly employed in non-experts user systems, like the selfBACK[2] system which is implementing predictive CBR models in order to provide personalised recommendations directly to individuals with LBP. The following section will give a brief introduction to CBR and current domains of application.

2.3.1 Case-based reasoning

Using CBR in health sciences has proven very useful, and was first suggested to support medical decision making back in 1980 (Montani, 2008). The artificial intelligence (AI) technique works very much like the traditional diagnostic and treatment process. CBR is an approach to general human reasoning, i.e. we rely upon experience and knowledge to solve a problem including good techniques for remembering (and labeling) past experiences (Riesbeck and Schank, 2013). In CBR, a common cycle consist of these four steps 1) retrieve, 2) reuse, 3) revise and 4) retain (Aamodt and Plaza, 1994). A new problem is tackled by *retrieving* relevant cases and then *reusing* successful solutions from these situations. If necessary the solution is mapped to fit the current problem. The solved problem is then tested against the domain and *revised*, before it is *retained* and stored in the case base for future retrievals. One example of such a system is CASEY (Koton, 1988), which

[2]selfBACK project: `http://selfback.eu/`

was designed to diagnose heart failure patients. CASEY was one of the first CBR systems in this domain. It diagnosed a new patient by looking at previous patients with known diagnosis and compared the cases based on a model of the human heart.

There are many arguments supporting the use of CBR applications in the health domain; e.g. medical records (case histories) are used both for training and diagnostic purposes (Gierl et al., 1998), uncertainties surrounding a disease are difficult to comprehend for formal models and the complexities in the human body are unsuited for general models (Bichindaritz and Marling, 2006). CBR have proven useful in several medical contexts, such as diabetes (Marling et al., 2009), Alzheimer's disease (Marling and Whitehouse, 2001), cancer (d'Aquin et al., 2006; Song et al., 2007; De Paz et al., 2009) and dermatology (O'Sullivan et al., 2007). Begum et al. (2011) presents a comprehensive review of recently deployed CBR systems in health sciences. Complementary reports of work prior to 2003 can be found in (Gierl et al., 1998; Nilsson and Sollenborn, 2004). The majority of systems identified from the last fifteen years are constructed for diagnostic purposes, meaning assistance in a medical expert decision. Other purposes include planning, tutoring and classification. These systems are usually so called Multi-Modal reasoning systems, i.e. they comprise other AI techniques together with CBR functionality on top to organise the modules and output.

The initial plan in this study was to conduct a review of IDSSs using CBR designed for LBP. However, the search for similar systems returned empty, and we also refer to a review conducted by the selfBACK team[3]. They found two systems that provide patient advice in the same way that the selfBACK system: 1) The docQuery system (Bach et al., 2010) which provide advice to travellers about important healthcare related issues in different locations, and 2) the 4DSS system (Marling et al., 2011) which is supporting insulin management for diabetic patients. As both of these systems are outside the scope of this thesis we concluded that the main focus area should be online IHCAs for self-managing LBP.

2.4 Similar systems

Through a literature review, no similar projects were identified, that is (mobile) self-management interventions for LBP using AI. However, this project is connected to several subjects, with the main focus on user experience and features in the application (user interface and dialog). Thus this paper will present (partially) similar research projects, in addition to projects found through an online search for commercial products, apps or prototypes. However, there was in general a lack of proper description of features and implementation in many of the studies, thus only papers where the system in use was described were included. The presentation of similar systems is divided into two parts. First it will present the findings in a literature review, which was conducted using Google Scholar and NTNU Oria, in addition to support from the selfBack team. Both IHCAs designed for web and mobile were included in this part. The second part is a review of smartphone apps found in mobile app stores and through online sources. For both parts, only projects fo-

[3]Literature Review (D1.1), June 2016: `http://selfback.eu/`

cusing on LBP are included. In addition, only projects presented in Norwegian or English were considered. An overview of included papers can be found in table 2.2 and included commercial projects in table 2.4.

2.4.1 Research projects

The search to identify research projects was conducted by using the search string "(low back pain OR lbp OR back pain) AND (self management OR patient advice) AND (online application OR mobile app OR webpage)" in Google Scholar and NTNU Oria. By reading the abstract we excluded papers that did not include LBP as main focus, and the papers that did not focus on either one of the three elements in the self-management plan: activity, education or exercise. Through a full text search we excluded papers that did not describe the system in use. A total of seven research projects were included in the final result which are presented in table 2.2.

One of the major limitations in the research is a high dropout rate in intervention programs (Jordan et al., 2010), including exercise adherence which is known to be affected by many different elements (Nicolson et al., 2017). Different measures can be considered to promote continued usage of ehealth applications. Weymann et al. (2015) compared a tailored, interactive website to a static website both containing (the same) information on chronic low back pain, pain management and decision support. The interactive website dictated the information flow through a dialogue, but to provide the user with some power, it was possible to select what to read next from a subset of all categories tailored specifically for current user (Dirmaier et al., 2013). The content tailoring was based on the user's placement in the avoidance-endurance model (AEM) (Hasenbring and Verbunt, 2010). The study reported almost twice as much usage of the tailored application, and this group had greater knowledge of LBP after the three months trial. Simon et al. (2012) tested a similar dialogue-based tool, called *Patient Dialogue*, also using a flexible structure to tailor the content for each user. The appearance and content was tailored using multiple variables, such as characteristics, familiarity with the Internet and knowledge of the disease. The study focused on shared decision making on the different treatment options for acute LBP and depression. The tailored *Patient Dialogue* was also tested against a static website with the same information, but reported a high dropout rate and could not find a difference in treatment adherence after four months usage.

Krein et al. (2013) conducted a 12 months study on chronic LBP patients receiving care from the U.S. Department of Veterans Affairs. The main focus of the study was a walking program, as this is an activity that most adults can perform regardless of their health status. The eligible participants were given an enhanced pedometer, access to a website with content on exercise self-efficacy and a peer to peer / professional community (forum) to help strengthen adherence (Krein et al., 2010). The pedometer data had to be manually uploaded to the website, and intervention participants received a weekly reminder by e-mail to upload the data, whilst the control group received the same reminder on a monthly basis. The system automatically created a weekly step goal for each participant, helping them advance in their intervention program. The website shows a historical overview of number of steps and goals, and the presentation is adjusted based on gender. Personal

Refence (name)	LBP	Personalisation	Self-management	Adherence	Mobile app	CBR / other AI
Irvine et al. (2015) (FitBack)	x	tailored by job type	x	x	x	
Amorim et al. (2016) (The IMPACT App)	x	tailored activity plan and goals by a health professional	x		x	
Krein et al. (2010) (N/A) RCT (Krein et al., 2013)	x	generated step goal	x	x		
Dirmaier et al. (2013) (N/A) RCT (Weymann et al., 2015)	x	tailored content based on AEM coping style	x	x		
Chiauzzi et al. (2010) (painACTION-back pain)	x	tailored based on user input	x	x		
Simon et al. (2012) (Patient Dialogue)	x	tailored based on user preferances	-	x		
Carpenter et al. (2012) (Wellness Workbook)	x	-	x	x		

Table 2.2: Research papers included in background review

motivational messages, research or relevant news articles was posted on a regular basis to encourage interaction and give a more dynamic feeling when using the website. The study reported greater improvement for the intervention group than the control group at 6 months. However this did not last over entire 12 months period, which according to the authors might be related to the decline in engagement.

A clinical trial from 2010 tested an interactive self-management website for patients with chronic back pain - *painACTION-Back Pain* (Chiauzzi et al., 2010). During two weekly sessions over four weeks in total, the study participants were presented with tailored information and feedback through the website. The system utilise a recommendation algorithm based on user input. User characteristics are mapped to existing lessons and generates personalised content for the individual user. The website [4] also offers customizable self-management material for other chronic pain conditions, such as cancer, migraine, neuropathic and arthritis pain. *PainACTION-Back Pain* is solely focusing on the patient-professional relationship, with no interaction between peers.

Carpenter et al. (2012) introduced a concept called the *Wellness Workbook (WW)*, a web-based CBT tool that provides guiding and advice on self-help to manage chronic LBP. The program material is divided into six chapter, which includes information on back pain, treatment options, exercise advice and relaxation methods (stress management and meditation). The application employ a variety of visual representation techniques for displaying the content, e.g. patient stories with audio recordings and photos. The stories and characters are fictional but based on a combination of real patient narratives. Reflective and interactive exercises are also included in the *WW* to emphasise how our thoughts and mood affect pain and quality of life. Carpenter et al. (2012) suggested that CBT as treatment for pain might be more suitable for female participants since the initial group comprised of 83 percent women, in addition to more men leaving during the trial period. The study also reports a higher dropout rate amongst participants above forty years old.

In research projects, websites are more commonly used than mobile applications to deliver self-management intervention. However, a recent report found that for the first time ever the majority of Internet usage came from mobile and tablet devices[5], which highlights the importance of responsive websites (Mohorovičić, 2013). Irvine et al. (2015) introduced the application called *FitBack*, which is a responsive web application delivering self-management for non-specific LBP. *FitBack* uses gain-framed messages to motivate the user to progress, meaning that the message is structured to focus on the potential gain from e.g. a situation, action or product. According to Latimer et al. (2007), gain-framing can have a positive impact on behaviour change in health, and is most effective when the outcome of an proposed action is certain (and accepted by the recipient). In the application, users can track their pain level, log activities and get advice on healthy activities to manage the pain. In addition, users are encouraged to keep a journal of daily life and the pain management. Another responsive web design is proposed by Amorim et al. (2016)

[4] painACTION - back pain website: `http://www.painaction.com/`

[5] `http://gs.statcounter.com/press/mobile-and-tablet-internet-usage-exceeds-desktop-for-first-time-worldwide`

intended as an intervention platform for physical activity in chronic LBP - *the IMPACT app*. They propose a platform between physiotherapists and patients, with a joint effort to construct a plan to manage LBP. Data from a pedometer (*Fitbit* watch) will be logged in the application, and it gives the user opportunity to monitor activity plan, goals and serves two-way communication with a health professional both for feedback and motivational messages.

2.4.2 Commercial projects

For the purpose of this project it is interesting to explore ideas outside the scientific literature. Mainly to gather inspiration and user stories for products available to the public. There is a variety of products to support back pain available online. Everything from simple information providers to specifically designed products for exercise and back strength monitoring. There are products for preventing back pain, such as the BackApp[6] chair, indented to strengthen the core muscles by balancing, which is suitable for individuals with a sedentary lifestyle or work situation. You can also find products for relief and management of back pain for instance in the form of training videos. However, many of the providers fail to specify sufficient evidence for their solution, which makes it even more difficult to navigate through the many options. In addition, the price point of these products can get unreasonably high. Table 2.3 shows some examples of available products and their current price. Other less expensive options include books, DVDs, sleeping aids and pain relief products such as foam rollers.

Name	**Description**	**Price**
BackApp chair	Balancing chair	6500,-
Instashiatsu	Neck and back massager pillow	2500,-
Lumo Lift	Posture sensor and pedometer (includes app)	850,-
BetterBack	Wearable belt to support posture	500,-

Table 2.3: Price list for back pain products. Prices are listed in NOK.

This part of the review is twofold. Firstly, it will cover smartphone applications intended to help prevent or manage back pain. Secondly, it will cover wearable activity tracking devices since this is an important component to the self-management plan. This part also includes the tools to view the data and follow up on (activity) progress. To limit the scope, the review only includes devices and mobile applications with established traction in the market, either derived from big online retailers or mobile application stores respectively. Regardless, the result presented here will be a selection of what is available online and the intention is to give a broad representation of the market. Table 2.5 shows an overview of all included commercial projects, and how they relate to the different components of the self-management plan.

[6]BackApp website: `http://backapp.eu/`

Smartphone applications
The first search was conducted using Google Play Store[7] for Android apps and Apple's App Store[8] for iOS apps with the phrase ”back pain” and ”back pain management”. Only apps that had been updated recently and having at least 5,000 downloads were included. Considering that number of downloads only is available in Google Play Store, it ended up including only apps for Android or both Android and iOS. The search was directed toward apps delivering exercise or mindfulness programs, although it also yielded apps for yoga and alternative therapy methods (such as acupressure), but these were considered out of the scope for this project. The final result included six apps which can be found in the overview in table 2.4 (#1 - #6), and more detailed information in Appendix A. The search yielded no app covering all three subjects; exercise, mindfulness and education. A complete overview of which categories each product covers is shown in table 2.5. All the selected apps can be downloaded for free, although some have additional content that can be purchased in the app.

High quality user experience focused apps within this domain, both in terms of information and design, are yet to be developed. The majority of applications found in both stores were mainly delivering back specific exercise advice and guidance. The most facilitated versions incorporate a timed session displaying an animation or image of the exercise to perform. 6 minutes back pain relief (Appendix A.1) provide such functionality, where each session consist of three different exercises with 90 seconds duration. The app has a total library of nine exercises from which the three are randomly selected. Lower Back Pain Relief (Appendix A.2) works in the same way, but has a fixed session of eight exercises. In addition, it includes introductory information about what back pain is to support usage of the app. None of the aforementioned apps can be adjusted in number of exercises or length of session. Another way of presenting the exercises can be seen in Back Pain Relieving Exercises (Appendix A.3). This app displays the exercises in a simple list view where each exercise is explained with an image and a short description including recommended number of repetitions. It is also the only app delivering guidance on which type of exercises to perform by giving the user the option to choose between forward and back bending exercises, depending on how the pain is relieved. It also includes simple everyday advice on for instance posture and sleep.

As previously discussed, education is important to promote adherence to the self-management plan. Therefore, this review includes how the educational material is presented to the user in order to enhance this process. The majority of educational back pain apps have a static textual representation of the material with no interactive change in the flow, like reading a book. Audio Book - Back Pain (Appendix A.4) is included to show this functionality. The app contains twelve chapters with information about back pain, but it also utilises the Text-to-Speech (TTS) functionality for Android devices so the user can listen to the text like an audio book. One of the largest libraries can be found in WebMD Pain Coach (Appendix A.5), containing hundreds of tips, videos, articles, slideshows and quizzes. The library is stored in a folder structure making it difficult to get a complete overview, but

[7] Google Play Store website: `https://play.google.com/store`
[8] Apple - App Store website: `https://itunes.apple.com`

#	Name	Category	Platform	Updated	Downloads*
1	WebMD Pain Coach (Appendix A.5)	Pain support	Android, iOS	May 2014	100,000 - 500,000
2	Audio Book - Back pain (Appendix A.4)	Information	Android	Jan 2017	50,000 - 100,000
3	6 minutes back pain relief (Appendix A.1)	Exercise	Android, iOS	July 2016	50,000 - 100,000
4	Back Pain Relieving Exercises (Appendix A.3)	Exercise	Android	Sep 2016	10,000 - 50,000
5	Pain relief hypnosis (Appendix A.6)	Hypnosis	Android, iOS	Feb 2017	10,000 - 50,000
6	Lower back pain relief (Appendix A.2)	Exercise	Android	Aug 2016	5000 - 10,000
7	Lumo Lift (Appendix B.1)	Posture	Android, iOS	Dec 2016	10,000 - 50,000
8	Upright (Appendix B.2)	Posture	Android, iOS	Apr 2017	5000 - 10,000
9	Valedo (Appendix B.3)	Exercise	Android, iOS	July 2016	1000 - 5000

Table 2.4: Overview of commercial projects. #1 - #6 are standalone apps, and #7 - #9 are apps for activity trackers.
**Based on numbers from Google Play Store*

there is a search field which is useful if you are looking for a specific topic. The app is designed to support several chronic pain conditions, such as back pain, neck pain and migraine. The main feature of the app is however the pain journal where the user can track their daily pain level, symptoms and triggers, as well as adding personal notes. The app also provide predefined goals that are specifically recommended for each pain condition. Each goal has associated tips and tricks to help the user reach a goal. It is also possible to add a custom goal.

Mindfulness is a minor part of the self-management plan, and it is closely associated with the education component of the plan. However, the public acceptance of mindfulness is confirmed by the increased popularity in the mobile application stores. Hypnosis is believed to be effective for relieving and managing back pain (Elkins et al., 2007). The Pain Relief Hypnosis (Appendix A.6) app is providing 30 minutes daily hypnosis sessions, although it does not include any pain specific information or feedback. Other relaxation techniques, such as meditation (Morone et al., 2008) is also increasingly popular, for instance Headspace[9] and Calm[10] which both have more than a million downloads. Many of

[9] https://www.headspace.com
[10] https://www.calm.com

these include gamified elements like achievements and social competitions.

Activity trackers with mobile app support
The most common activity tracking device is the activity watch. All the major producers in this domain (e.g. Fitbit, Polar, Samsung, Apple) have developed an accompanying smartphone application which is mainly used to pair the watch and smartphone to exchange data, change settings and customize the experience. These apps usually come with limited functionality and serve merely as the foundation in their activity platform. Instead it is common to have open APIs allowing other developers to employ the data and create more niche products. High quality reviews of activity watches can be found by many online contributors[11,12] and in scientific literature (Van Remoortel et al., 2012). Which is why this review focus on alternative tracking devices related to back pain suffering. More specific it will cover posture trackers/trainers and the apps that come with these devices. This was the most popular commercial product (besides activity watches) found in online stores. There are wearable devices for other purposes available, for instance monitoring body temperature, muscle motion and brain activity, but these are mainly used in medical environments.

The search for alternative activity trackers was conducted using Amazon[13] and Google Search with the initial phrase ”back pain device” and ”back pain activity tracker”. Only tracking devices with mobile app support were selected. In addition, only products with customer reviews were included. The search yielded three products which are summarised in table 2.4 (#7 - #9), and more details are described in Appendix B.

The most popular device in Google Play Store (Table 2.4 (#7 - #9)) is called Lumo Lift (Appendix B.1). It is both a posture tracker and pedometer. The small magnetic device should be attached onto clothing around the collar, but it cannot be used with loosely fitting clothes as the sensor needs to be calibrated in a fixed position aligned with the body posture[14]. However, when attached properly, both the pedometer and posture sensor works fine. The posture sensor vibrates when you slouch, but this is only when you are not moving around. It is possible to set goals for both good posture minutes per hour and daily number of steps. The app presents historic data in a list view where each entry is a daily summary of steps and good posture hours, in addition to a details page for each day with a bar chart showing what hours you were active.

Upright (Appendix B.2) is a posture trainer, and as opposed to the Lumo Lift which is intended to be worn all day, this device is for 15-60 minutes daily training sessions. The device should be attached with adhesive tape directly to spine or shoulders for posture feedback, and it will vibrate when you slouch. Upright offer custom training programs

[11]The Best Fitness Trackers of 2017: `http://www.pcmag.com/article2/0,2817,2404445,00.asp`
[12]Best fitness trackers 2017: Fitbit, Garmin, Misfit, Withings and more: `https://www.wareable.com/fitness-trackers/the-best-fitness-tracker`
[13]`https://www.amazon.co.uk/`
[14]`https://support.lumobodytech.com/hc/en-us/articles/211307326-How-to-wear-my-Lumo-Lift`

that will slightly increase session length over time, and it uses notifications to motivate progress. The device needs to be calibrated every time you attach it, but it uses smart calibration that adapts to each individual's back and movement. The app displays a simple overview of the training plan, both of previous and future sessions. Both Lumo Lift and Upright appear to have a simple app with limited functionality, but they are recently started companies and they are rapidly adding more functionality to the platform. However, this also makes it difficult to find more detailed information about the two products.

More developed features can be found in the Valedo (Appendix B.3) platform which is created by Hocoma[15], a Swiss based medical device company. Valedo consists of two motion sensors that should be attached to upper and lower back. The sensors track movement while the user is controlling a character through a game using the upper body. The app, which is compatible for desktop, tablet and smartphone, provides real-time feedback to ensure that the exercises are carried out correctly. The gameplay is set in a village with six districts; torso, core, floor, hip, twist and special. Each district has several difficulty levels but these can also be customised. The user can unlock achievements from playing in the different districts and completing various objectives. In addition, it is possible to generate a full report of for instance time spent on each back specific exercise, which could be useful for patients who wish to combine this experience with physiotherapy. Hügli et al. (2015) found in a randomised controlled study the Valedo system to be just as effective as traditional physical therapy exercises.

[15] `https://www.hocoma.com/`

Name	Exercise	Education	Mindfullness
WebMD Pain Coach	Exercise specific goals.	Library with information about back pain.	
Back Pain Relieving Exercises	List with exercises. Text and image description.	Precautions: Simple advice to avoid pain	
Lower back pain relief	Timed session with eight exercises. Text and image description.	Introductory information about back pain.	
Upright	Posture trainer	Library with information about posture and back pain.	
6 minutes back pain relief	Timed session with three exercises. Animated description.		
Lumo Lift	Posture and step tracker		
Valedo	Game with back specific exercises.		
Audio Book - Back pain		Twelve chapters with information about back pain	
Pain relief hypnosis			30 minutes hypnosis session per day. Relaxing audio recordings.

Table 2.5: Categorisation of included commercial projects

Chapter 3

Method and design

This chapter will explain the proposed design for the app and the decision process towards this goal. The literature and market review revealed several advantages and disadvantages with existing solutions. As explained in Chapter 1 the goal is to build a user friendly app closer to what the mobile user is accustomed with. This chapter will first present the steps taken in the design process. Thereafter, a top-level overview of the system and definitions used to describe this. Lastly, it presents the final design and the reasoning behind these choices.

3.1 Process

The process towards the final design involved three steps, 1) a concept called 6-up Brainstorm, 2) ideas from existing solutions for low back pain in today's market and research, and 3) additional inspiration from gamification. These are described in the following paragraphs.

6-up Brainstorm is a common brainstorming technique initially proposed by the design company Adaptive Path[1], and was also suggested by Kerstin Bach, the supervisor of this thesis. The purpose of the exercise is to achieve high level rough ideas on how to present and design a problem, whilst avoiding to delve into details. The focus should be user experience and interaction rather than specific design components. The participants each get a piece of paper folded into six parts (see figure 3.1). During intervals of 6 x 60 seconds (with 10 seconds of rest in between) they can choose to draw out a new idea or continue on a previous drawing in each cycle. All participants get three minutes in total to present their ideas, followed by a round of questions from the rest of the group. Finally, everyone vote for their favourite ideas amongst all contributions, having four votes each.

[1] `http://www.adaptivepath.com`

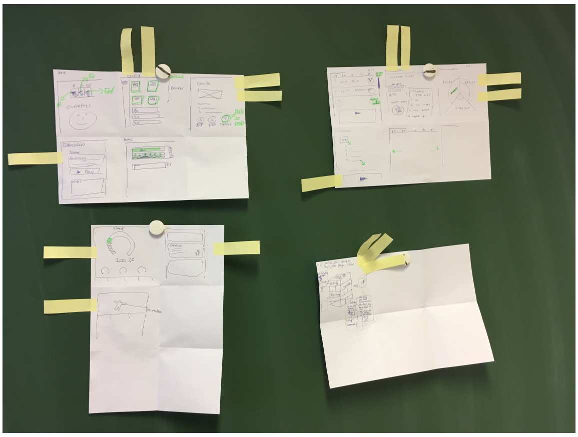


Figure 3.1: Result from the first workshop with 6-up brainstorm. The post-it notes represent votes.

To diversify the outcome we arranged three workshops with participants having technical, medical and design skills. The same background material were presented to each group before the brainstorming session. However, some of the participants are involved in the selfBACK project, giving them greater insight than others. The main goal in the workshops was to sketch ideas for the mobile user interface of the app. Exercise, (in)activity and education were introduced as key features of the system, and the participants could choose freely from any of these topics. Some ideas were introduced across groups. A presentation of sketches from each session (including participants) and the workshop guidelines, can be found in *workshop-results.pdf* which is located in the additional material folder.

The sketching rounds was the first part of this process, mainly to have a fresh start when drawing ideas. After completing the brainstorming sessions we searched for ideas from existing solutions for low back pain in today's market and research. The review was conducted in spring 2017. Finally, all the ideas from existing solutions and brainstorming sessions were brought together, and we started sketching the design and define functionality in the app. During this process we decided to make an effort to improve engagement and the overall user experience by including gamification elements. Gamification is the process of using components from games in non-game contexts for motivational purposes. For example the concept of implementing levels and experience points as seen in many commonly played games. Hamari et al. (2014) highlights the importance of what context gamification is applied to in order to achieve positive behavioural outcomes. Thus when selecting gamification elements for this app, it was important to maintain a serious experience.

3.2 System overview

The app is intended to help individuals suffering from low back pain, but the demographics of this group is very diverse. A few limitations must be defined to narrow down the scope, and these are:

- The target user is above 18 years old.
- The target user owns a smartphone, and understand basic functionality in their device.
  A recent survey[2] from the US reported smartphone owners in ages 18-29 (92%), 30-49 (88%), 50-64 (74%) and 65+ (42%). Seeing that low back pain is most common for individuals ages 40-80 years (Hoy et al., 2012), many of these individuals might not own a smartphone.
- The target user seeks for help and wants to make a change in their lifestyle.

3.2.1 SelfBACK

The app will connect to the selfBACK system, but will be designed as an independent component that can easily be implemented with other decision support systems. For the design of this app it is assumed that initial setup is handled by the decision support system. This includes initial data collection and user creation. The app flow will start at login (with the user created by the decision support system) and introduction screens as described in the upcoming section.

3.2.2 App flow

The app flow will be dynamic and adapt to the user's preferences. To simplify the design process, we have defined five different phases in the flow as shown in Figure 3.2 and described in detail below. These are designed to ensure that the user is presented with the intervention plan in an orderly manner, and is constructed based on the expected course of low back pain (Hoy et al., 2010a). Some users might stop using the app during this cycle, but the main goal is to guide them to phase 4.

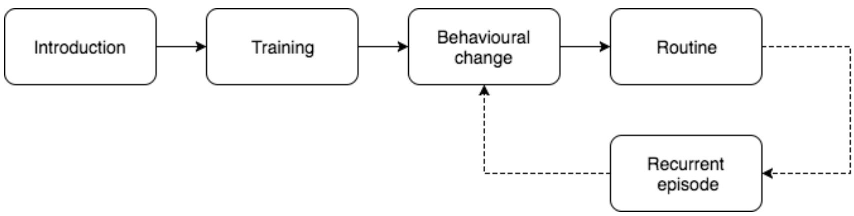


Figure 3.2: User flow: The different phases a user can be in.

Phase 1 - Introduction

This is the very first viewing of the app. In this phase the app will give a sufficient introduction to what the app will provide the user in terms of functionality as well as establish trust. This is also where the user creation is done, and collection of necessary information.

[2]Mobile Fact Sheet: `http://www.pewinternet.org/fact-sheet/mobile/`

Phase 2 - Training

The next step is to train the user to operate the app. After this phase is complete it is expected that the user knows where to find the main functionality and how to get most value from the included features.

Phase 3 - Behavioural change

This is the main phase of the user cycle, and includes encouraging the user to make positive changes to manage the pain. The goal for this phase is for the user to adopt an individual routine that they decide upon with guidance from the app. An important factor is that the user is involved in this decision so they are comfortable to follow through with the plan.

Phase 4 - Routine

When the user has incorporated a satisfactory routine, it is not expected that the user will continue using the app since many will manage on their own. Mainly because the pain should be perceived as less severe at this point. Because of this, it will not be a focus to retain users in this phase, but it should include tools for the users that want help to keep their routine.

Phase 5 - Recurrent episodes

Recurrent episodes of low back pain are very common, and people experiencing pain for longer than one day usually have another episode (Hoy et al., 2010a). As mentioned, it is expected that some might stop using the app when they are recovering and have a routine in place, but it is desirable that these users will return to the app for guidance if they experience a new episode. In this case the user will return to phase 3.

3.2.3 User requirements

The user requirements for the app are decided based on the three sources explained previously in this chapter.

- Minimal user effort
  Only require actions from the user that results in a response from the system that brings value for the user. In addition, all input data fields should be simplified and auto-filled if possible.

- Simplified data display
  Even though the app will collect huge amounts of data, this does not need to be accessible for the user. Only data that is relevant to showing the user their progress should be displayed.

- Shared decision making
  The user should be encouraged to make a change through nudges (Thaler and Sunstein, 2008), but not told what to do. The app will give the user nudges to guide

towards healthy decisions. It should also include a transparent link to the decision support system, so the user understands why they are getting the recommendations.

- Simple language
  In all communication with the user it is important to keep the language simple and understandable as well as avoiding excessive use of medical or technical terms.
- Protect user privacy
  No sensitive data should be stored in the app in order to be in compliance with regulatory guidelines for storing or transmitting health data[3].
- Offline capabilities
  The user should be able to follow progress without connectivity. The available content should be downloaded and included in the app upon installation.

3.3 App design

One of the major limitations in existing solutions and research, is the lack of features for engagement and long-term commitment. This is also documented through results from the conducted clinical trials, and is requested by several sources. With this in mind, one of the main goals was to build an overall structure in the app that could support prolonged usage. The following sections describe this functionality, and focus around the defined research questions for the design. The prototype design is included in Appendix C.

3.3.1 Flow

This section is focusing on *RQ4 - How should the application flow be designed to make it understandable for a broader user group?* The self-management program in itself is comprehensive in the sense that it comprises smaller components that are not logically connected to each other. The app flow should have an overall structure that connects these features and the ones proposed by this research. The following paragraphs describe the initial flow to get started and the top-level flow in the app.

For the overall structure we decided to look outside existing solutions within this domain, as they tend to be straightforward, targeting a specific and narrow feature. For the systems that did include more features (e.g. WebMD), it was difficult to understand how the components were connected in a bigger picture. The flow will be in line with the defined user requirements (Section 3.2.3). The top-level structure is designed around the gamification principles points, levels and quests. Although, with the broad age span among the target user group it should be a clear distinction from a common game experience, which might be unknown and intimidating to many. One way to describe the foundation in the app is as a longer educational journey, where the user has to understand why, how and what to do in order to self-manage the pain, which is a significant foundation to retain users.

[3] Norwegian regulatory guidelines for processing health data: `https://lovdata.no/dokument/NL/lov/2014-06-20-43?q=helseregisterloven`

Quest-based learning has shown promising results in an academic setting and other domains (Charles et al., 2011; Perry, 2015), and the authors emphasize the use of points and achievements as motivational and meaningful additions to the experience. When considering gamification elements it was always a priority to maintain a serious aspect and keep the focus on the actual self-management program that should be followed.

With inspiration from quest-based ideas, we introduce a feature that from now will be referred to as the package program, see Appendix C.3 for design. It can be described as a level-based program that guides the user through some of the defined phases in the flow: training, behavioural change and routine building. The package program is intended to connect all the modules in a single component to provide clarity in the flow, as well as giving the user smaller goals along the way. It is important to keep it line with the recommendations from the decision support engine. Similar to quests, the items should increase in difficulty and time consumption as the user advances in the process. This is a list with suggestions for the four first packages, but a final version of such a program should be adjusted according to usage:

#1 - Getting started
- Setup your first self-management plan
- Read introduction to Low Back Pain and this program
- Track pain
- Reach daily step goal

#2 - Get moving
- Complete a guided exercise session
- Go through five educational items (0/5)
- Reach daily step goal three times (0/3)
- Track pain five times (0/5)

- #3 - Stay active
- Complete 180 minutes of exercise (0 / 180)
- Reach 3 new destinations in your journey (0/3)
- Reach inactivity goal three times (0 / 3): *Don't be inactive for more than 20 consecutive minutes during the time window you selected*

#4 - Stick to the plan
- Create your own goal
- Challenge: 7 days streak - step goal: *Reach your daily step goal 7 days straight.*
- Challenge: 7 days streak - track pain: *Write down how you are feeling for 7 days straight.*

The first package is designed to guide the user through the initial setup and introduce basic functionality, belonging to the training phase. The second and third package should encourage behaviour change, and get the user started with the recommended self-management plan. The last package is intended for routine building. As you can see from the list, there are mainly three types of items in the program; actions, goals and challenges. Actions are designed to encourage the user to try new features in the app. Goals are intended to motivate the user along the way. A goal is either created by the user or selected from a predefined list. A challenge is a complete series of goals that must be accomplished consecutively, otherwise the counter starts at zero.

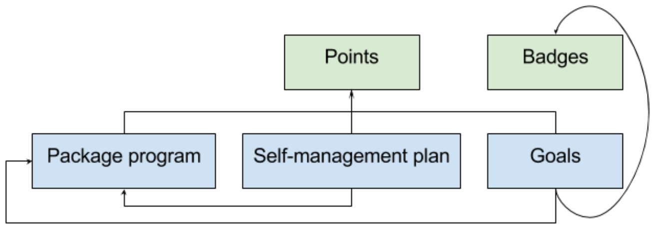


Figure 3.3: Reward system.

The overall structure includes a reward system with points and badges i.e. collecting items in the app when completing a task (see Figure 3.3). The user can gain both points and badges when completing different tasks in the app. This is connected to:

1. Package program
   Completing single items in the package program will give the user points. Including a bonus when completing all items in a package (i.e. advancing to the next level). All package items give the user a scaling amount of points, $points = base_{package} * level$, where $level$ is current package level starting at 1, and $base_{package}$ should be defined in correlation to the other tasks giving points. The bonus given after completing the entire package is defined as, $bonus\_points = points * 4$, where $points$ is the rewarded points at current package level.

2. Goals / Challenges
   Both predefined goals and goals created by the user will be rewarded by points. When completing a goal the user is rewarded with a fixed amount of points, $points = base_{goals}$. A predefined goal can also be an item in the package program, in this case the user will be rewarded from both components. For challenges the main reward is a badge, but the user will also receive the same amount of points as if completing a goal. Badges are described more in detail in the next paragraph.

3. Performance with regards to the self-management plan
   The balance between the components in the plan is important, as it is already designed to get the user started at a manageable pace. It should not be advantageous to complete more than the recommended items in either one of the categories. The formula is defined as $points = \sum weight * Min(1, completed/recommended)$ over all four categories. $Weight$ is a constant, giving all categories equal importance. The score is calculated at the end of the plan period. The maximum achievable score should be displayed to the user along with the current score. Example scenario: User A is walking more than the recommended daily steps each day, but completes none of the exercises or educational items. User B reached the daily step

goal three out of seven days, and almost completed the exercise and educational goal. In this scenario User B will receive more points than User A.

The $base_{package}$, $base_{goals}$ and $weight$ variables should be adjusted according to usage of the system, in order to achieve a satisfying and motivating points system.

Some additional features are included in the app to support the overall structure (see Appendix C.7), which are both inspired by existing solutions and ideas from the workshops:

- Journal with daily pain tracking
  Every day the user is encouraged to track their pain level. The entire log can later be displayed to show the user their own perception of the progress. It is a simplified version of the pain tracker found in the WebMD app.

- Community
  The community feature is inspired by Krein et al. (2010). However, the peer-to-professional communication is excluded because of the cost of having professionals in the forum channels. The community also include stories shared by other users. A story usually explains how the pain is affecting their daily life and how they use the app as help. As the collection of stories grows, these can be displayed based on a characteristics comparison with the user, in order to show relevant and interesting stories. Multiple characteristics are already available in the SelfBACK system making this possible.

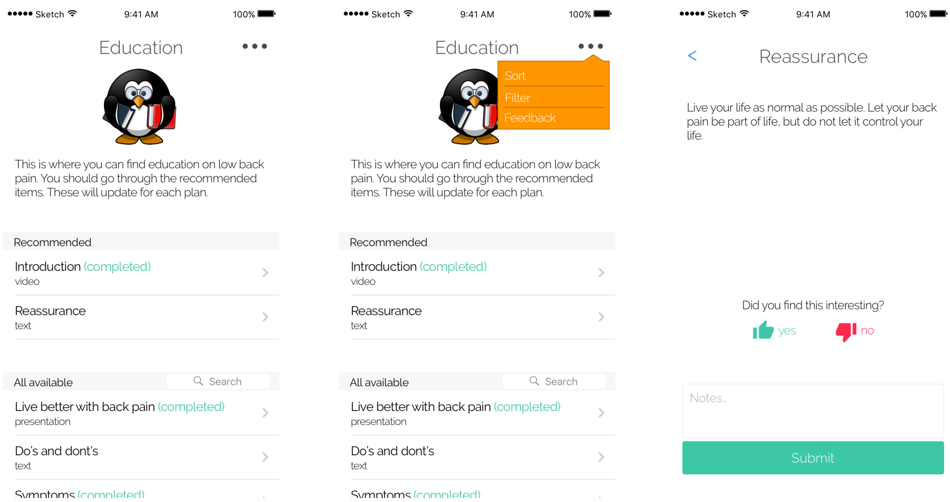
- Push notifications with gain-framed messages
  Gain-framed messages will be used for push notifications as well as in-app notifications like described in FitBack (Irvine et al., 2015). The system will send push notifications on two main subjects; motivating messages to keep the user engaged and progress updates on both the package program and the self-management plan. The user also have the option to set up up reminders to do their exercises and to reach their activity / educational goal.

- Trophy builder with badges
  A challenge also includes a ”builder platform” where the user collects parts in a bigger picture or puzzle. This is an interactive part of the app, where the user can assemble the object during the period, but this is not mandatory. The final image is rewarded as a badge. The badge is symbolising the achievement for the user. See Appendix C.7 for an example building phase.

3.3.2 Education

This section is focusing on *RQ 5 - How should the educational material be presented to the user?* Results from the workshops concluded that the educational material preferably should be presented in a relevant context. Meaning that the app should display material that is relevant to the current action a user is performing or has recently completed. The package program tries to preserve this requirement by including educational elements in the flow. However, the actual content of the educational material is given by the decision support system, so timing the presentation can only be controlled to some extent in the app.

There are two issues with regards to the presentation of educational material; what format the content has and how to structure the items for easy retrieval in the future. As one of the user requirements is offline capabilities, it is preferable that the content size is kept to a minimum. The app will thus include different types of media, but only larger files (e.g. videos) if it provides an improved experience. Folder structure, chapters and interactive dialogs were methods used to structure the material in existing solutions. A simple folder structure is viewed as sufficient for this app, which will provide the user with the ability to filter, order and search old content as the list grows (see Figure 3.4).

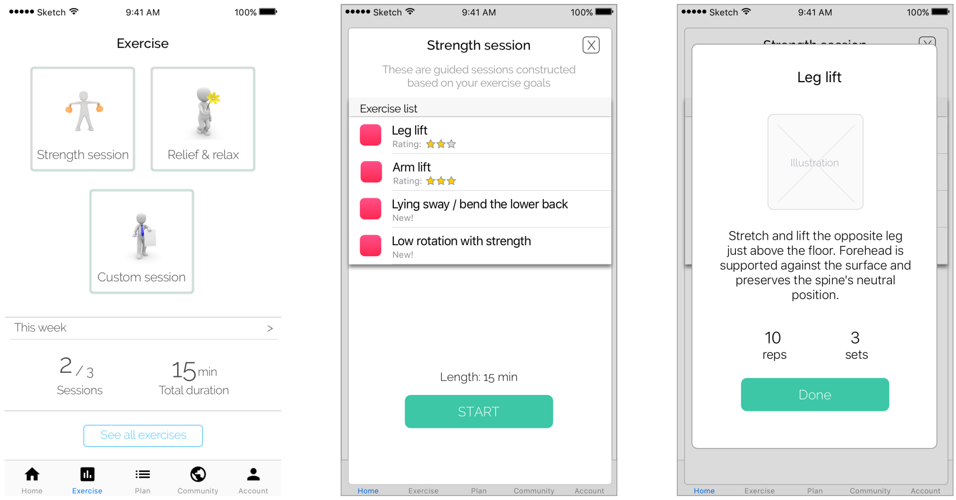


(a) Main education page **(b)** More actions **(c)** View an item

Figure 3.4: Education screen includes items with multiple media types

3.3.3 Activity and exercise

This section is focusing on *RQ 6 - How should the exercise advice and activity be presented to the user?* At least in the beginning of using the app, it is beneficial to guide the user towards their goals, and help them figure out what they are supposed to do next. Some kind of structure is needed in order to achieve this effect which is similar to the outcome of the package program. The final result is guided exercise sessions in a video format, as shown in Appendix C.6. This is similar to the apps *Lower Back Pain Relief* and *6 minutes back pain relief* where you have a timer taking the user through a predefined session, except with a dynamic content that is divided into strength, pain relief and custom sessions (see Figure 3.5). The idea is that the pain relief sessions can be used if the back pain is very painful. Strength and custom sessions will contain exercises where you work on different muscle groups, for instance abdomen and core. The guided sessions will be generated based on the exercise recommendations from the decision support system, and



(a) Main **(b)** Start session **(c)** Exercise details

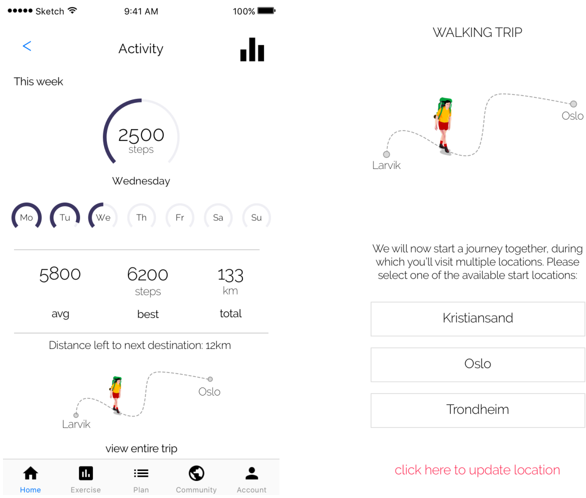
Figure 3.5: Exercise

the user will download a video with all the included exercises. After each exercise in the video, the app will ask for feedback on two parts, 1) how many repetitions and sets the user managed to take, and 2) if they liked the exercise. Information about how many exercises the user completed during a self-management plan period is important for the decision support system, and this method is believed to be a simple way for the user to provide that information.

The exercise history is divided into two layers. In the first layer, you can find current week's progress, which should be the most frequently requested information. In the second layer, you can find an overview of total exercise duration and sessions, as well as a list of the all the completed sessions. Discussions in the workshops concluded that data display using graphs should be excluded from the app if possible because many find this too complex. This requirement is preserved throughout the app.

The activity display is divided into three layers of information, for complete design see Appendix C.5. Activity is included as one the main objects of interest in the app, and the first layer is located at the home screen showing daily progress. The second layer is a weekly summary, with step count for each day and aggregations of this data. In the third layer you can find complete history of activity in a list format divided by weeks.

Activity also include a motivational component, a virtual journey (see Figure 3.6b). When starting the app for the first time the user is asked to select a city to start out in, preferably where the user is located which can be queried by system. The system will then generate a journey with several destinations to travel through, and when the user walks in real life, they will progress in their virtual journey. This is designed as a tool to visualize how far you have actually walked. The virtual journey is a new feature which is not derived from existing sources or workshops. This is why it will be one of the main usability testing objects.



(a) Main **(b)** Journey setup

Figure 3.6: Activity

Chapter 4

Implementation

As part of this work, a prototype was implemented. This is a simplified demonstration of the proposed features presented in Chapter 3. It was created for the purpose to conduct a user test, but also as a foundation for further development. This chapter gives an overview of the required technology stack and explains the implementation of the app. The implementation is presented to match the selfBACK use case. The final result and a walkthrough is available at Youtube[1] and it is included in the additional material folder (*demo-app.mp4*). This is the version that was tested with users. Figure 4.1 shows an overview of the folder structure in the project and how to locate the most important files.

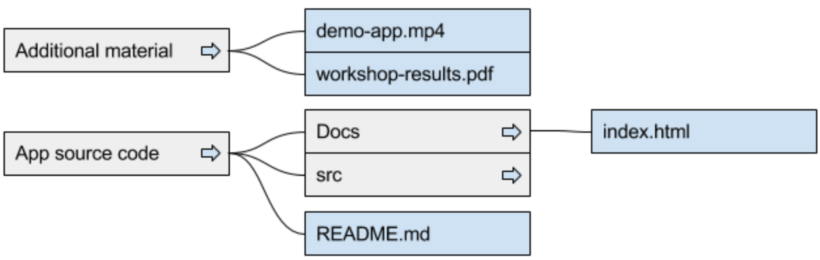


Figure 4.1: The folder structure in the deliverable. *README.md* contains the instructions of how to install and run the project. *Docs/index.html* shows the documentation of the modules created for communicating with selfBACK and the rest API. The *README.md* file content is also included in the documentation. *Additional material* includes the video walkthrough of the prototype app and a presentation with the results from the workshops. The *src* folder contains all the JavaScript code implementation.

[1] Prototype demonstration: `https://youtu.be/cXuZgUnrmAw`

4.1 System overview

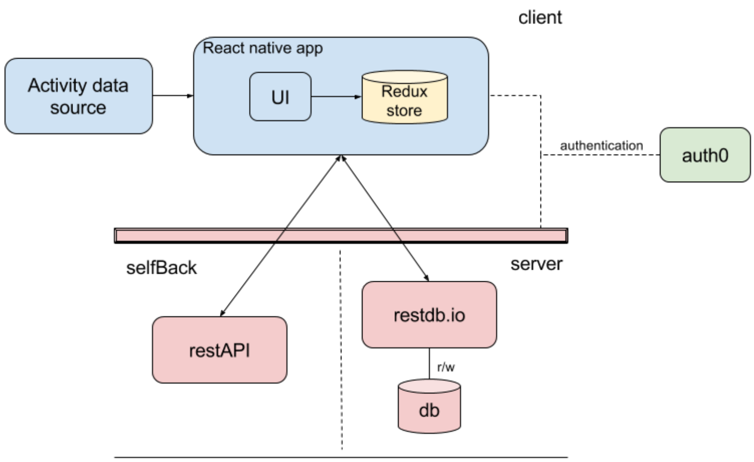


Figure 4.2: System architecture diagram.

Figure 4.2 shows an overview of the complete system architecture. The client is built using React native[2] and Redux[3] (section 4.1.1), and the server is created with RestDB[4] (section 4.1.2). The app is fetching data from an activity watch source, and this data is passed on to both the selfBACK API and the server. Password grant in Auth0[5] is used as authentication to access the mobile app and then for the mobile app to access the server. A complete security layer for the selfBACK API was not enabled at the time of developing this system. Bach et al. (2016) describes the complete architecture for the selfBACK system. To run the system locally, follow the instructions included in the *README.md* file which is located in the project's root folder. The system can be tested without a connection to a server, by using the provided mock data and only maintaining the internal app state.

[2] https://facebook.github.io/react-native/
[3] http://redux.js.org/
[4] https://restdb.io/
[5] https://auth0.com/

Offline capabilities	The user should be able to follow progress without connectivity. Videos and exercise sessions should be stored in memory.
Protect privacy	No sensitive data should be stored in the app. All communication should be transmitted using the SSL protocol (HTTPS).
Read activity data	The app should be able to fetch data from an activity watch.
Modularity	The system should be modular to make it easy to reuse modules.
Composition	Composition of components is an important principle in React and the system should adhere to this.

Table 4.1: System requirements

The most important requirements for the system are summarised in table 4.1. React Native provides two options for offline capabilities; AsyncStorage and local storage in the browser. AsyncStorage is a key-value store that is mainly using a serialized dictionary on iOS and either SQLite or RocksDB on Android. It is recommended to use AsyncStorage over local storage[6]. In a production ready system, all communication will be over HTTPS, this is described in section 4.2. Activity data is fetched from the Apple Health on iOS and Google Fit on Android, a prerequisite is that the activity watch is syncing data to the respective service on the operating system in use. The system should be modular mainly to make it easier for other projects to include parts of the presented system. In addition to the principle about composition of components in React, the system will be designed to match best practices for React and Redux.

4.1.1 Mobile app

The goal was to create an app for both Android and iOS. One option is to implement two separate native apps. Building native apps requires skills in two separate development environments, which is a very time consuming process. Another option is to use frameworks like Ionic[7] to create a *hybrid app*, which is a web application wrapped in a browser view (or web view) in a native app. The components in the hybrid app can be built using HTML, JavaScript and CSS like in a standard web application. One advantage with this option is that you can use the same code base for multiple platforms. The drawback is that you do not get the same feeling as with native apps, and you have limited options to utilize native features in the phone. An alternative to standard hybrid apps can be built using a framework called React Native. React Native creates native apps using JavaScript and embedded XML (JSX). It offers native UI components from both Android and iOS, and compiles into a true native app. React Native is the chosen framework for the implementation in this assignment because of 1) it requires only one code base to maintain for both platforms, 2) it provides a native app feeling, and 3) it offers rapid and easy development. Recompiling a mobile app is usually very time consuming, especially as the

[6] `https://facebook.github.io/react-native/docs/asyncstorage.html`
[7] `https://ionicframework.com/`

project grows, but React Native is relying on the JavaScriptCore[8] engine which provides a significantly faster run cycle. Hot Reload is another advantage, which let's you watch any changes in the code while maintaining the same application state i.e. not reloading the app. The main drawback is that the framework is in early stages of development, so they are still releasing some major changes in each update. This can also lead to inconsistencies between Android and iOS components as the "bridge" between JavaScript and native code might be incomplete for some components.

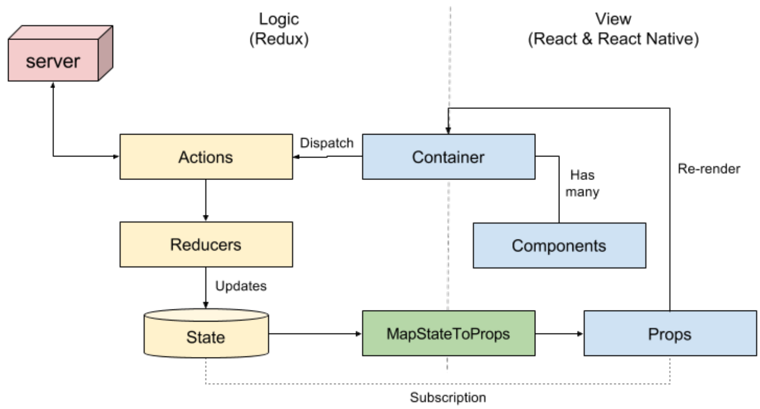


Figure 4.3: Mobile app (React Native + Redux) architecture diagram.

Figure 4.3 shows the mobile app architecture. React Native is handling the views and construction of visual objects, whilst Redux is maintaining a global state and holds the logic for communicating with servers. In this type of system the data flows in one direction. The view components can subscribe to changes from the global state, but not directly manipulate it. Instead, the container component which is basically just a wrapper around many UI elements on a screen, can trigger an action through a global event dispatcher requesting the new changes to the state. This action contains an action type and the payload. The reducers are listening to the different action types, and updates the state accordingly. The state is immutable, so in order to change the state, the reducer must return a copy of the current state including the new changes, which makes reducers pure functions. The container is notified about the updated state and all child components are re-rendered if necessary.

The state used in the app is divided into parts that are logically connected, an overview is shown in Figure 4.4. All the child nodes of the state object is the top level reducer controlling that domain, and this is reflected in the folder structure of the app. For instance, all logic belonging to exercises is stored in the exercise object in the state, which is updated solely by the exercise reducer. A reducer can only update the state of it's children in the tree structure. The folder structure in the app is reflected by Figure 4.3 and is divided into containers, components, reducers and actions, which in turn are divided into their

[8] `http://trac.webkit.org/wiki/JavaScriptCore`

respective domains.

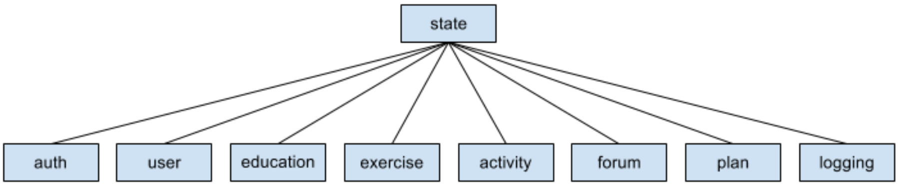


Figure 4.4: Global state.

Dependencies

A complete overview of all dependencies can be seen in *package.json*. The app is using React Native Router Flux[9] to handle navigation, which is based on the official React Native navigation implementation. The navigation state is defined in *src/root.js*. In this file you can easily retrieve the component that is controlling a specific screen. In addition to the official components included in React Native, there is already a big community supporting development of the framework by creating bridges to native libraries. However, at the time of developing this app, it did not exist a good bridge to Apple HealthKit and Google Fit. This functionality is thus implemented using Native Modules[10,11], and is based on an existing Github project[12] which is implementing a simple step counter. The Native Modules are accessed from the *src/services* folder, and are using the native implementations of `RNGoogleFit` and `RNHealthKit`.

Testing

Jest[13] is used to test the JavaScript implementations. All test files are located inside the __tests__ folder. Instructions to run the tests can be found in *README.md*. Actions and reducers are included in the test suites and all networking is mocked. It is also possible to test if the presentational components render correctly by using `react-native-renderer` which is already included in the project, but this is not included in the prototype.

4.1.2 Server

As shown in figure 4.2, the mobile app is communicating with both selfBACK and a server that is handling app specific data. The server is created on the cloud service platform restdb.io[14], which is used to store and retrieve data. Restdb.io offers a backend as a service (BAAS), and it uses the flexible noSQL database MongoDB. In this use case, most of the server side logic should be performed by the decision support system, and it is

[9] https://github.com/aksonov/react-native-router-flux
[10] https://facebook.github.io/react-native/docs/native-modules-ios.html
[11] https://facebook.github.io/react-native/docs/native-modules-android.html
[12] https://github.com/asmalik107/AwesimSteps
[13] https://facebook.github.io/jest/
[14] https://restdb.io/

thus suggested a serverless structure for the prototype. It is also possible to include real-time messaging and server-side code hooks in restdb.io if needed. The prototype project includes two JavaScript wrappers for accessing both the selfBACK api and the restdb.io api. The source code for these are located in the *local_modules* folder, and documentation can found in *docs/index.html*.

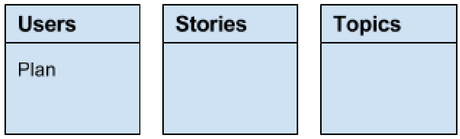


Figure 4.5: MongoDB document structure.

When testing with users, the app should refresh its state upon launch. This is why only parts of the prototype is connected to the server, and the internal state is sufficient to preserve the data for this purpose. The prototype is using a test user and a API development key to access the server. The database configuration is similar to the global app state, but is designed to match query requirements in the prototype. The structure is shown in Figure 4.5, and a complete overview of each document with its properties is presented in the included documentation. The selfBACK wrapper is using API version V.01, but this should be updated in line with the development of the selfBACK system. All the communication that is needed with the server is included in the project, but has to be connected to the internal state in the app, see section 4.2 on how to change this behaviour and how to setup login. The community (including forum and user stories) is the only feature that is fully connected to the server in the prototype implementation, while the rest of the functionality is only using the Redux state with mock data.

4.2 Further development

This section will describe how to implement the parts that are not included in the prototype. This includes networking, login, retrieving inactivity from activity data source, and proper error handling. The initial networking flow is shown in Figure 4.6 and should be implemented in the system. The user should be able to login to the app using the credentials from the selfBACK system, and the restdb.io server should thus be pre-populated with user data. Functionality to login the user is already included, but not connected to the navigation flow. The presentational component is included in *src/containers/login.js* which is connected to *src/actions/auth.js*. After logging in, the client will request a self-management plan from selfBACK, and the user will adjust the recommendations in the plan to their liking. Remaining networking requirements are already included in the app project, so after setting up a server like explained in the *README.md* file, it will work by removing this line from *local_modules/kevinoRest/restApi.js*: `this.mockServerResponse = true`.

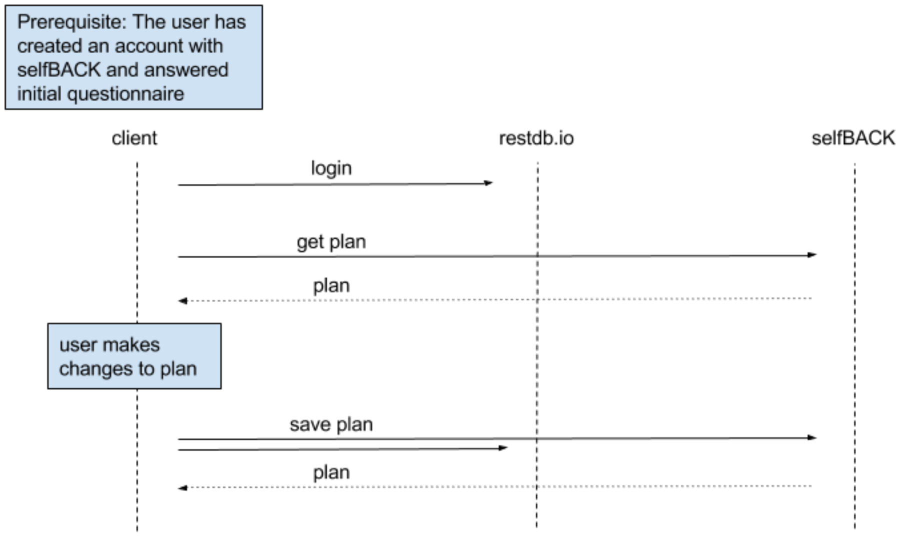


Figure 4.6: Initial networking flow.

Retrieving *inactivity data* is not implemented in the prototype due to uncertainty in the structure around this functionality, limited testing possibilities and the time frame for the project as querying both Apple Health and Google Fit is a complex process. For iOS, this could be retrieved by using `HKCategoryValueAppleStandHour`[15], which returns if the user stood up and moved around for at least one minute in the time frame specified in the query. For Google Fit the best solution found is to use `AGGREGATE_ACTIVITY_SUMMARY` over `FitnessActivities.STILL`[16] to find duration of stationary periods. Proper error handling should also be included in a final version of the app, and we suggest to use React Native Message Bar[17] which is already included in the project spec. The command `MessageBarManager.showAlert` can be called from anywhere in the project to display an error message.

In addition to implementing the missing features described in this section, the app requires some minor adjustments to make it ready for production. React Native has created a simple guide[18] on how to prepare the app for production.

[15] https://developer.apple.com/documentation/healthkit/hkcategoryvalueapplestandhour
[16] https://developers.google.com/android/reference/com/google/android/gms/fitness/FitnessActivities.html#STILL
[17] https://www.npmjs.com/package/react-native-message-bar
[18] https://facebook.github.io/react-native/docs/running-on-device.html

4.3 Tools

This is a summary of the tools used in this process. The wireframes was created using Sketch[19], and Invision[20] was used to distribute the prototype design. Sketch and Invision integrate nicely with each other, which made the prototyping faster. The text editor Sublime Text[21] was used to edit the code, which can be enhanced by the large number of available plug-ins. React Native Debugger[22] was used to debug visual changes in the app and keep track of actions and state in the Redux store. JSDoc 3[23] was used to generate JavaScript documentation. The images used in the design are free stock photos from Pexels[24] and Pixabay[25], except for the drawings made by author of this report.

[19] `https://www.sketchapp.com/`
[20] `https://www.invisionapp.com/`
[21] `https://www.sublimetext.com/`
[22] `https://github.com/jhen0409/react-native-debugger`
[23] `https://github.com/jsdoc3/jsdoc`
[24] `https://www.pexels.com/` - Images under Creative Commons Zero license
[25] `https://pixabay.com/`

Chapter 5

Experiments and results

This chapter will present experiments conducted in this research and the respective results. Summer 2017 we conducted a user test with five individuals that have suffered from back pain. The test included a survey of non-implemented functionality, a usability test of implemented components and a post-test questionnaire.

5.1 Planning

The user test is designed to support the three research questions defined for G2 - Design a user-friendly mobile application for self-managing low back pain. The app flow, exercise and activity presentation, and educational material are included as main testing objects. We recruited among employees at The Department of Computer Science (IDI) at NTNU, and defined the following requirements for the desired participants: An eligible participant must 1) have back pain, or had it recently, 2) own a smartphone and know how to use it, and 3) understand English. Five eligible participants volunteered to join, and table 5.1 shows an overview while preserving their privacy. The testing group was diverse both in age and gender. Each round of testing took about 30 minutes in total.

Gender	Age	Occupation
Female	29 - 58	Administration, Student
Male	37 - 67	Administration, professor

Table 5.1: Overview of participants.

The first item on the agenda was to answer a questionnaire on functionality that was not included in the prototype. This includes inactivity, exercise session format and feedback alternatives. The questionnaire is shown in Table 5.2. After completing this, the participant had to go through a usability test, with the following instructions:

Usability test - Part 1
Open the app.

1. Complete the three first items in the 'Getting started' program
2. Go to 'Exercise' and create a custom session.
3. Go to 'Community' and read a user story.

Usability test - Part 2

1. Find your current self-management plan.
2. Find an overview of your activities this week.
3. Imagine that you have a recurrence of back pain, how would you find help in the app?

The desired outcome of part 1 is to show if the participant can find the main components of the app upon first time usage. Part 2 contains some of the components visited in part 1, and the assumption is that the participant can recall what the functionality is and where to find it. After going through the usability test we hypothesize that:

- The user is able to locate and use the package program.
- The user is able to setup a self-management plan.
- The user is able to locate and view an educational item.
- The user is able to locate the exercise module and create a custom session.
- The user is able to locate activity progress.
- The user does at all times understand what the next step in the process is.

After these two rounds of testing on a physical device the participant will answer a post-test questionnaire using Likert scales (Allen and Seaman, 2007), shown in Table 5.3. This test includes user stories, general usage and the complexity of the app.

Question 1.
Have you used mobile apps for managing your back pain before?

a) ☐ yes b) ☐ no

Question 2.
Which of the following rating systems do you prefer to describe how an exercise is to perform for you? *Arrange these on a scale from 1 (best) to 3 (least).*

a) ☐  b) ☐ 

c) ☐ 

Question 3.
Which of these presentations of an exercise do you prefer? *Arrange these on a scale from 1 (best) to 3 (least).*

a) ☐ Video b) ☐ Pictures and text c) ☐ Animations

Question 4.
During the day, it is recommended that you do not sit longer than ∼30 minutes without a break. Which solution do you prefer to describe this? *Pick one.*

a) ☐ 

b) ☐ 

Table 5.2: Questionnaire of non-implemented functionality.

Statement	1 (Strongly disagree)	2	3	4	5 (Strongly agree)
1. I think I would like to use the app frequently.					
2. I found the app unnecessarily complex.					
3. I thought the app was easy to use.					
4. I would imagine that most people would learn to use the app very quickly.					
5. I believe that such an app could improve my knowledge about low back pain.					
6. I would recommend such an app to my friends and family.					
7. I would read the user stories.					
8. I would share my own story.					

Table 5.3: Post-test questionnaire.

5.2 Results

The results from the initial questionnaire is presented in Table 5.4. The results for questions 2 and 3 are average rating from 1 (best) to 3 (least). In general, the participants wanted more options when rating an exercise, the five points scale with stars (1.6) and the three points scale with facial expressions (1.8) are believed to be the best solutions. The presentation of an exercise is preferred in video format (1.6). Four out of five had never used a mobile app for back pain before, which is not surprising as the existing options are limited.

Question 1	a) (20%)	b) (80%)	
Question 2	a) 1.6	b) 1.8	c) 2.6
Question 3	a) 1.6	b) 2.4	c) 2
Question 4	a) (100%)	b) (0%)	

Table 5.4: Results from questionnaire of non-implemented functionality. Questions 2 and 3 are average rating from 1 (best) to 3 (least). Question 1: Have you used mobile apps for managing your back pain before? Question 2: Which of the following rating systems do you prefer to describe how an exercise is to perform for you? Question 3: Which of these presentations of an exercise do you prefer? Question 4: During the day, it is recommended that you do not sit longer than ~30 minutes without a break. Which solution do you prefer to describe this?

The results from the usability test were very diverse. This list presents a summary of the feedback in the usability test based on the hypotheses described in the previous section:

- *The user is able to locate and use the package program.*
  Only one of the participants had problems locating the package program, but others stated that they were uncertain if they should click on the card. The underlying reason was that the cards on the 'home' screen in general did not appear clickable. After opening the package program, three out of five participants read the entire description of how to perform the task, the rest only noticed the header and got lost in the process. Besides the difficulties with the design, the feedback on the package program was positive. Two of the participants stated that they enjoyed getting points when completing an item.

- *The user is able to setup a self-management plan.*
  Setting up the self-management plan is the longest closed process in the app flow, and during this the participants got impatient. However no one had any issues with selecting the desired goals. They were also able to understand the concept of the plan and retrieve the plan when asked for it.

- *The user is able to locate and view an educational item.*
  Three out of five could not find educational items on the first attempt. This is related to the issue with the cards on the 'home' screen, but this was also a problem after the participants had learned that the cards were clickable, meaning that the design of the component is unclear. There was no problems with the navigation in the list

of educational items. Two participants stated that they liked videos as part of the educational material. Only one submitted feedback in the app after viewing an item, but this was not part of the instructions.

- *The user is able to locate the exercise module and create a custom session.*
  All the participants were able to locate the exercise module on their first attempt, and had no problem creating a custom session. The level of details on a specific exercise, illustration and text, appeared to be satisfying. Two of the participants pressed the start button after confirming a set of exercises, which is showing the screen with a generated video session. It is unclear whether the rest were aware of how the exercise sessions are conducted.

- *The user is able to locate activity progress.*
  Two out of five participants had trouble locating activity progress. It appeared to be an issue with the chosen wording in the instructions for this task, because after providing them with an explanation they found it immediately. All participants understood the presentation of activity. Three out of five noticed the virtual journey, and two stated that they liked it.

- *The user does at all times understand what the next step in the process is.*
  After the initial introduction of the package program, the participants used it as a guide on what to do next. If they got stuck in the process they used the package program as help, which was the desired outcome for that feature. In some parts of the app, there were too comprehensive textual descriptions that the participants ignored. Some of these messages included introductions on how to perform the current task, which led to confusion. In general, the participants ignored longer texts when discovering a screen for the first time, but showed greater interest when visiting the screen for the second time. In terms of usability, there was a clear distinction between the two younger participants (age 29 and 37) and the three older participants (age 49, 58 and 67). The youngest group found it easier to navigate the app, and they moved around faster.

The post-test questionnaire is a follow up on the usability test, and the results are presented in Figure 5.1. The participants were positive to using the app frequently, and the majority found the content interesting. However, the app was perceived as too complex. There is a lot of information that is included in the app, some of which has to be included in order for the system to work, but the participants did not find it too difficult to get started. The majority believe that the app would improve their knowledge about back pain. The participants were also positive to referring the app to others. The older participants liked the user stories, while the younger group was not interested in using the community, but the user story feature was mistaken for user reviews of the app in some cases, which makes the results inconsistent.

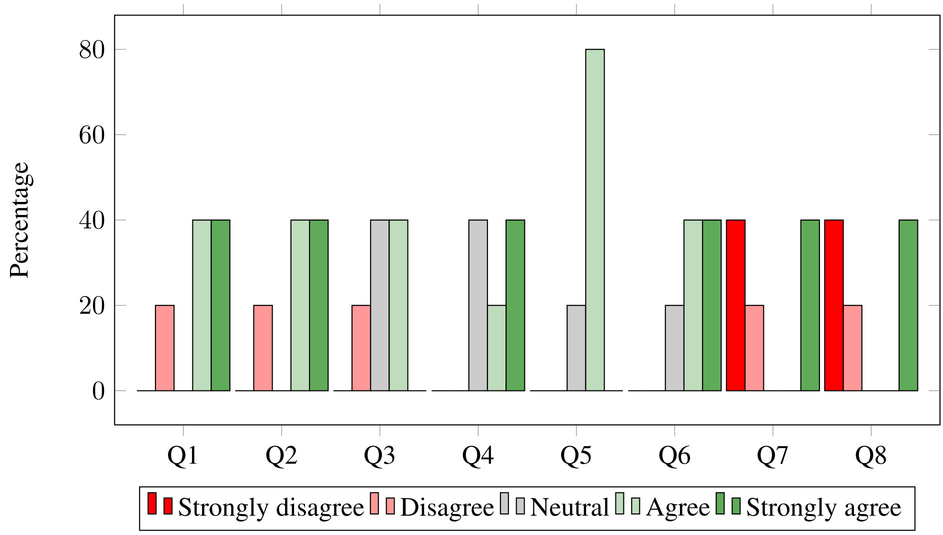


Figure 5.1: Results from post-test questionnaire. Q1: I think I would like to use the app frequently. Q2: I found the app unnecessarily complex. Q3: I thought the app was easy to use. Q4: I would imagine that most people would learn to use the app very quickly. Q5: I believe that such an app could improve my knowledge about low back pain. Q6: I would recommend such an app to my friends and family. Q7: I would read the user stories. Q8: I would share my own story.

Chapter 6

Discussion

This chapter presents a discussion around the two research goals for this project introduced in Chapter 1:

> **G1** Identify existing solutions delivering self-management programs for low back pain.
>
> **G2** Design a user-friendly mobile application for self-managing low back pain.

This chapter will first present a discussion around existing solutions and the different types that were identified. Later, it will evaluate the prototype design and implementation, and discuss the results from the user test.

6.1 Existing solutions

There are many health apps available both for Android and iPhone, even mental health issues, such as depression and anxiety, have received deserved attention in recent times. The most popular within the health category are fitness apps, usually designed for more advanced running and other workouts. Endomondo[1] and Strava[2] are two of the most popular running toolkits with over ten million downloads each, and several others can be mentioned with the same traction. These are great sources of inspiration. Both incorporate motivational components to keep users engaged such as personalised plans, goal setting and feedback. Other popular categories within health apps include both tracking and training for meditation, relaxation, sleep and nutrition. Many of these apps utilise the health data collection available from Google Fit (Android) and Apple Health (iPhone). These are established products, and many users already have useful data stored within these systems. However, this research could not identify such functionality in the apps intended for

[1] `https://www.endomondo.com/`
[2] `https://www.strava.com/`

management of low back pain. Many focus on delivering back specific exercises, but not activity tracking. Here is an overview of the type of apps found in app stores and research:

Commercial apps:

- Back specific exercises (strength, relax and relief)
- Mindfulness (meditation)
- Educational material

Research:

- Everyday activity tracking (tracking steps and setting goals)
- Back specific exercises (strength, relax and relief)
- Educational material
- Decision support (treatment and lifestyle choices)

The majority is focusing on back specific exercises, but there is also a lot of educational material available, even though many of these providers cannot be verified as a source and the products have not been thoroughly evaluated in field studies. A problem found in research projects is the high dropout rate amongst test users. Usability and design deserve more attention in this space, both for the purpose of getting reliable results in studies and creating a more valuable product for the end-user. The same appear to be a problem for commercially available apps, seeing that many of these have not been maintained over time. There are some measures that have been implemented for this problem. First of all, a mobile-friendly environment. Responsive websites and native applications have several advantages, and is considered a requirement at least for the younger population. In addition, most Internet activity, as of 2014, happens on handheld devices such as mobile and tablet, rather than a desktop computer[3]. With native applications you also have the opportunity to utilise the device's built-in features, which in many cases result in a more convenient experience for the user. The other functionality that has been implemented to support prolonged usage is goal setting, which is commonly used as a motivational factor. This was included in both market and research projects.

6.1.1 Comparison between market and research

As mentioned, there was no commercial app for low back pain focusing on light physical activity, but two of the included research projects track everyday activity using activity watch data. One exception is the Lumo Lift sensor that is also a pedometer. Even though the main focus of the app is posture tracking, the app offers a historic overview of daily steps. However, this is simply a data display, and does not necessarily help or motivate to increase activity level. There is a big difference in terms of functionality between what was found through research compared to what is available in commercial app stores. The

[3]`http://gs.statcounter.com/press/mobile-and-tablet-internet-usage-exceeds-desktop-for-first-time-worldwide`

commercial apps are in general very simplistic and have a narrow scope. They usually focus on one specific target, and the delivery feels unrefined and incomplete. This especially applies to feedback on completed tasks and other motivational components to keep the user engaged, which is a surprising discovery, as one would expect it to be the other way around. Another significant difference is that most of the commercial apps have no evidence supporting their solution, or a comprehensive explanation of the recommended method they are providing. The only exceptions are Valedo, created by the medical device company Hocoma, and WebMD which presents educational material from a collaboration of medical professionals.

6.2 Prototype design and implementation

This section will discuss around the research questions defined for the second goal in this project, which comprises the overall structure with the app flow, educational material, exercise advice and activity presentation. It will compare features found in existing solutions to the proposed design, and verify these with the results from the user test described in Chapter 5.

6.2.1 Features

Most of the solutions found in research are not visibly presented, making it challenging to compare these completely based on design features. However, they are textually described to some extent, at least in terms of top-level functionality. Gong and Tarasewich (2004) translated the *"Eight golden rules of interface design"*, initially proposed by Shneiderman, to apply for mobile devices. These rules will be used as the basis for the following discussion around features. User effort and motivation will be main focus area.

App structure

None of the existing solutions showed as many components in the system as the one we are developing, and thus did not solve the issue of connecting many non-related sub-modules. The overall structure defined for this system is comprised by the package program and a reward system. The package program was fully included in the prototype because this is one of the main components in the app, and it had to be included in the user test process. The feedback on using the program and completing items were positive, except for minor bugs in the app. The suggested fix to improve the experience with the package program is to make it possible to be sent directly to the relevant screen when clicking on an item. The package program was however confusing to some of participants in the user test, and not everyone realised that this program would continue after the initial setup process. Due to this it might be beneficial to test this functionality further with more packages.

Only the younger participants commented on the points given when completing an item, but they were positive to this functionality. There are some obstacles when designing a system for such a wide age span. For instance, the younger audience appreciate and recognise gamification elements like points and badges, while this might be a distraction to older users. It might be a good idea to create two separate apps for this purpose, one being the proposed design in this report and one simplified version, but we suggest to instead hide some of the functionality from the user unless they wish to utilise it.

The user test participants stated that the app felt too complex at first glance, and too much information were given in a short time frame. To solve this, we suggest to hide some of the functionality in the beginning of using the app. For instance, in the prototype, the virtual journey is showing up as soon as you enter the activity screen, but this overwhelmed some of the participants. It is suggested to include it in the flow at a later stage when the user is comfortable with using the app and the plan.

Another important discovery from the user testing was that the wording is significant to how the user proceeds in the flow. If the textual description is too long or misleading, the user simply ignored it and clicked around in the app in search for an answer or simply to avoid the current task at hand. One part that this especially affects is when starting to configure the self-management plan. The introduction of the plan is currently a single screen with text, but only one of the test participants read the text before starting, and thus after completing the setup the majority did not understand how the plan worked or how it was connected to the rest. The overall experience can be improved by rewriting the textual descriptions or replacing them with more dynamic content.

Additional functionality supporting the overall structure include pain tracking, community, push notifications and goal setting. We recommend to remove the pain tracking feature from the app because it displeased some of the testers. Even though it might be possible to improve the experience with this, it did not seem to be a desired component for the majority. The community feature had a positive impact on the experience. This was also included in existing solutions with both peer-to-peer and peer-to-professional communication. This app does not include professionals in the forum channels, but we believe that this is not necessary, seeing that some of the users stated that they would use the community of peers to find help if the pain was overwhelming. The user stories should also be included in the final version based on the feedback from the test group. The push notifications and goal setting were not included in the user test because it requires a longer testing phase than we had planned. However, both were requested by some of the participants, and should be thoroughly tested in a final version.

The process of onboarding users is not included in this research but will play an important role in a final version. Onboarding can be a challenging problem, especially for handheld devices as the bounce rate, i.e. how often the user navigates away from a screen, is much higher than on desktop. Mobile users also tend to be less patient, which was also the case when we conducted the user testing. Often the onboarding is the part of the process that requires the greatest coherent interaction and effort from the user. Although the onboarding process is not mentioned in all of the research papers, a few methods can be compared. These can be divided into those that require human interaction, and those that do not. Onboarding conducted together with an expert will make it easy to personalise the experience and to verify that the user is able to operate the app. Normally this incorporates a shared decision making process, where the user is guided through the options. This method can be incorporated in a randomised controlled trial (RCT), which will serve as a good foundation when scaling the system. Even though human interaction would bring a lot of benefits, it is difficult to adopt at a larger scale. The app should incorporate an onboarding process that is self-explanatory and does not rely on human interaction, in order to reach a wider audience and reduce costs, but the feedback and experience from the process of onboarding with human interaction can be used to create the final onboarding flow.

Education

A goal for presenting the educational material is to keep it brief and concise, and make it possible to track how much is read. The following methods for the structure of the educational component was used in existing solutions:

- *Folder structure* – The educational material is accessible in a folder structure. This can be divided on media type or topic.
- *Chapters* – The material is read like a book.
- *Interactive dialog* – The material is presented through an interactive dialog with the user.

The folder structure is convenient when the amount of content grows, but it might be difficult for the user to keep track of what is read, or even where to begin when starting out. The chapter structure will thus be better for new users as it introduces an order. The same applies to the interactive dialog, but this is also an easy way to tailor the content based on user preferences. The interactive component will also provide the user with more control. This is a good solution based on the workshop discussions around presenting educational material in an appropriate setting, but as mentioned previously the educational content is supplied by the decision support engine so this requires a specific structure on the material. The one project testing such a dialog (Weymann et al., 2015), could however not identify an advantage in the outcomes for knowledge and patient empowerment, but it might enhance the user experience and thus keep the motivation steady. We recommended that the app should implement this functionality since many of the test participants requested this. More specifically they wanted to get reassuring messages and advice. The push notification system in the prototype design can also be used to start the dialog. The messages should be based on user preferences combined with the recommendations. The folder structure in the prototype design worked good with the test participants, and serves as a base for the educational material.

Which media types to use for the educational sessions are also important to keep the user interested. The following media types were found in existing solutions: video, slideshow, article, image and questionnaire. The most desired format amongst the test group was videos. The testing group did not like the longer texts, but this experience can be improved by introducing a structure to the texts, for instance dividing the content into sections and having explanatory headers to captivate the user's interest.

Exercise

One problem with the exercise delivery is how to log and keep track of completed sessions. In this environment, tracking exercises will always include some user effort, but this should be expected. Exercises have been facilitated in three different ways in existing solutions:

- *Fixed timed session* – The user is presented with a set of exercises that should be performed during a time interval.
- *Guided session* – The user is guided through the session either with a healthcare professional or by an audio recording.
- *Manual session* – The user is presented with recommended exercises. In addition, some of the solutions recommend number of repetitions for each exercise.

Fixed and guided sessions will make it easier to track progress, as the system can automatically log the exercise entry after completing a session. With the manual sessions, the user obviously have to log their sessions manually. None of the solutions found offer proper logging and tracking of exercises. The most developed functionality can be found in Valedo, which logs all sessions completed with the sensors, but this is not applicable to our app. The guided sessions, as presented in the prototype design, eliminates the process of manual logging. After the user has completed a session with guidance from the app, it will automatically store the included exercises along with input from the user. However, the usability test revealed that some users want the ability to choose exercises freely, for instance they might not like a particular exercise that is included in the recommendations for the current self-management plan. The custom sessions will help support this requirement. The list presented in a custom session should include all the available exercises.

The presentation of the exercise is important for the user to understand how to perform it correctly. Just by using image and text to describe an exercise, it might be difficult in some cases to comprehend how this should be conducted. By using animations, it is possible to demonstrate involved muscle groups at each time step in the exercise. This is also possible with a video demonstration. Video format was the top choice among the test group, and this supports the suggested design for exercise sessions.

Activity

Lumo Lift was the only source including activity data. The activity history overview in the prototype is similar to this representation, with a list view of previous activity sorted by day. There are two options for importing activity data; the user can manually upload their pedometer data, or the system can retrieve it automatically. The latter is implemented in the prototype with data from Google Fit and Apple Health, and this is the most desired solution as this requires no effort from the user. The participants from the user test stated that they would use the app to track activity progress if they were to use the app to manage their pain, instead of using the app from the activity watch manufacturer. This makes it easier for the end user as they can keep everything in one place.

The journey feature that shows a virtual journey based on actual walking distance was well received by the test group. Two out of the three that noticed it stated that they would be motivated by using the functionality. It is an optional feature, that is possible to ignore if the user does not want to participate, so we suggest including this functionality in the final version of such an app as a motivational component.

Summary

Overall the user tests showed positive results. The participants stated that they would like to use the app when it was finished. The pain tracking feature should be excluded. Wording and images should be improved, and buttons should be enlarged for easier navigation. In addition, the flow should be improved by hiding some of the functionality from the start to make it less overwhelming.

Chapter 7

Conclusion and future work

This report presents an overview of the available interactive health communication applications for self-managing low back pain, with main focus on mobile delivered intervention programs. The outcome of this study is the conceptual design and implementation of an app prototype developed for self-managing low back pain. This is a contribution to the ongoing selfBACK project at NTNU. This chapter will give a summary of the process and contributions in this project.

7.1 Conclusion

The process towards the final design started with a research phase. During this phase we organised three workshops with participants having a background in technology, medicine and design. The outcome of this activity was rough ideas on how to design the final app, and we defined user requirements. After this we conducted a review of existing solutions in today's market and research and the findings are described in Chapter 2. We also reviewed and tested alternative activity sensors to get a sense of how the app and the device are connected.

This report presents a mobile app design for a system that will support self-management of low back pain. The app is receiving personalised recommendations from a decision support system. The design and included features are described in detail in Chapter 3. We planned a user test to validate the proposed design. In order to conduct this experiment we implemented a prototype of the proposed design, this includes a native iOS and Android app, and a restful backend structure. The complete system architecture is described in Chapter 4. This also includes technical specifications on how to make the system production ready. The user test was conducted with five participants having low back pain. The results from the test is presented in Chapter 5, and are believed to be reliable results.

In Chapter 6 we discuss around the proposed design and compare it to the feedback from the test group. Based on this, we conclude that with the proposed adjustments many would benefit from such a system and use it frequently.

7.2 Future work

We suggest to update the prototype according to the feedback from the user test, and allow the participants to use it in their daily routine for at least the duration of one plan cycle (two weeks), especially to test on personalisation with their own account and real data from the decision support engine. In addition, the community should be expanded with real user stories, preferably from a diverse group to connect with as many users as possible. We also suggest to include sleep as part of the self-management program, by fetching the data from the activity watch and providing recommendations on healthier sleep habits.

The main limitation with research in this space is the focus on long-term commitment, which is especially important in the case of self-managing low back pain. We suggest to test motivational components over a longer period of time, both the material presented in this report and the components found in existing solutions.

Bibliography

Aamodt, A., Plaza, E., 1994. Case-based reasoning: Foundational issues, methodological variations, and system approaches. AI communications 7 (1), 39–59.

Airaksinen, O., Brox, J., Cedraschi, C., Hildebrandt, J., Klaber-Moffett, J., Kovacs, F., Mannion, A., Reis, S., Staal, J., Ursin, H., et al., 2006. European guidelines for the management of chronic nonspecific low back pain. European Spine Journal 15 (Suppl 2), s192.

Allen, I. E., Seaman, C. A., 2007. Likert scales and data analyses. Quality progress 40 (7), 64.

Amorim, A. B., Pappas, E., Simic, M., Ferreira, M. L., Tiedemann, A., Jennings, M., Ferreira, P. H., 2016. Integrating mobile health and physical activity to reduce the burden of chronic low back pain trial (impact): a pilot trial protocol. BMC musculoskeletal disorders 17 (1), 1.

Bach, K., Reichle, M., Althoff, K.-D., 2010. Case-based reasoning in a travel medicine application. Computational Intelligence in Healthcare 4: Advanced Methodologies 309, 191.

Bach, K., Szczepanski, T., Aamodt, A., Gundersen, O. E., Mork, P. J., 2016. Case Representation and Similarity Assessment in the selfBACK Decision Support System. Springer International Publishing, Cham, pp. 32–46.
URL `https://doi.org/10.1007/978-3-319-47096-2_3`

Balagué, F., Mannion, A. F., Pellisé, F., Cedraschi, C., 2012. Non-specific low back pain. The Lancet 379 (9814), 482–491.

Barak, A., Klein, B., Proudfoot, J. G., 2009. Defining internet-supported therapeutic interventions. Annals of Behavioral Medicine 38 (1), 4–17.

Baranowski, T., Anderson, C., Carmack, C., 1998. Mediating variable framework in physical activity interventions: How are we doing? how might we do better? American journal of preventive medicine 15 (4), 266–297.

Baranowski, T., Cullen, K. W., Nicklas, T., Thompson, D., Baranowski, J., 2003. Are current health behavioral change models helpful in guiding prevention of weight gain efforts? Obesity research 11 (S10), 23S–43S.

Begum, S., Ahmed, M. U., Funk, P., Xiong, N., Folke, M., 2011. Case-based reasoning systems in the health sciences: a survey of recent trends and developments. IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews) 41 (4), 421–434.

Bichindaritz, I., Marling, C., 2006. Case-based reasoning in the health sciences: What's next? Artificial intelligence in medicine 36 (2), 127–135.

Bodenheimer, T., Lorig, K., Holman, H., Grumbach, K., 2002. Patient self-management of chronic disease in primary care. Jama 288 (19), 2469–2475.

Carpenter, K. M., Stoner, S. A., Mundt, J. M., Stoelb, B., 2012. An online self-help cbt intervention for chronic lower back pain. The Clinical journal of pain 28 (1), 14.

Charles, D., Charles, T., McNeill, M., Bustard, D., Black, M., 2011. Game-based feedback for educational multi-user virtual environments. British Journal of Educational Technology 42 (4), 638–654.

Chiauzzi, E., Pujol, L. A., Wood, M., Bond, K., Black, R., Yiu, E., Zacharoff, K., 2010. painaction-back pain: A self-management website for people with chronic back pain. Pain Medicine 11 (7), 1044–1058.

d'Aquin, M., Lieber, J., Napoli, A., 2006. Adaption knowledge acquisition: A case study for case-based decision support in oncology. Computational Intelligence 22 (3-4), 161–176.

De Paz, J. F., Rodríguez, S., Bajo, J., Corchado, J. M., 2009. Case-based reasoning as a decision support system for cancer diagnosis: A case study. International Journal of Hybrid Intelligent Systems 6 (2), 97–110.

Deyo, R. A., Cherkin, D., Conrad, D., Volinn, E., 1991. Cost, controversy, crisis: low back pain and the health of the public. Annual review of public health 12 (1), 141–156.

Dirmaier, J., Härter, M., Weymann, N., 2013. A tailored, dialogue-based health communication application for patients with chronic low back pain: study protocol of a randomised controlled trial. BMC medical informatics and decision making 13 (1), 1.

Elkins, G., Jensen, M. P., Patterson, D. R., 2007. Hypnotherapy for the management of chronic pain. Intl. Journal of Clinical and Experimental Hypnosis 55 (3), 275–287.

Gatchel, R. J., Okifuji, A., 2006. Evidence-based scientific data documenting the treatment and cost-effectiveness of comprehensive pain programs for chronic nonmalignant pain. The Journal of Pain 7 (11), 779–793.

Gatchel, R. J., Rollings, K. H., 2008. Evidence-informed management of chronic low back pain with cognitive behavioral therapy. The Spine Journal 8 (1), 40–44.

Gheldof, E. L., Vinck, J., Vlaeyen, J. W., Hidding, A., Crombez, G., 2005. The differential role of pain, work characteristics and pain-related fear in explaining back pain and sick leave in occupational settings. Pain 113 (1–2), 71 – 81.
URL http://www.sciencedirect.com/science/article/pii/S0304395904004786

Gierl, L., Bull, M., Schmidt, R., 1998. Cbr in medicine. In: Case-Based Reasoning Technology. Springer, pp. 273–297.

Gong, J., Tarasewich, P., 2004. Guidelines for handheld mobile device interface design. In: Proceedings of DSI 2004 Annual Meeting. pp. 3751–3756.

Grotle, M., Vøllestad, N. K., Veierød, M. B., Brox, J. I., 2004. Fear-avoidance beliefs and distress in relation to disability in acute and chronic low back pain. Pain 112 (3), 343–352.

Hamari, J., Koivisto, J., Sarsa, H., 2014. Does gamification work?–a literature review of empirical studies on gamification. In: System Sciences (HICSS), 2014 47th Hawaii International Conference on. IEEE, pp. 3025–3034.

Hasenbring, M. I., Verbunt, J. A., 2010. Fear-avoidance and endurance-related responses to pain: new models of behavior and their consequences for clinical practice. The Clinical journal of pain 26 (9), 747–753.

Hayden, J., Van Tulder, M. W., Malmivaara, A., Koes, B. W., 2005. Exercise therapy for treatment of non-specific low back pain. The Cochrane Library.

Henrotin, Y. E., Cedraschi, C., Duplan, B., Bazin, T., Duquesnoy, B., 2006. Information and low back pain management: a systematic review. Spine 31 (11), E326–E334.

Hoy, D., Bain, C., Williams, G., March, L., Brooks, P., Blyth, F., Woolf, A., Vos, T., Buchbinder, R., 2012. A systematic review of the global prevalence of low back pain. Arthritis & Rheumatism 64 (6), 2028–2037.

Hoy, D., Brooks, P., Blyth, F., Buchbinder, R., 2010a. The epidemiology of low back pain. Best practice & research Clinical rheumatology 24 (6), 769–781.

Hoy, D., March, L., Brooks, P., Woolf, A., Blyth, F., Vos, T., Buchbinder, R., 2010b. Measuring the global burden of low back pain. Best Practice & Research Clinical Rheumatology 24 (2), 155–165.

Hügli, A. S., Ernst, M. J., Kool, J., Rast, F. M., Rausch-Osthoff, A.-K., Mannig, A., Oetiker, S., Bauer, C. M., 2015. Adherence to home exercises in non-specific low back pain. a randomised controlled pilot trial. Journal of bodywork and movement therapies 19 (1), 177–185.

Irvine, A. B., Russell, H., Manocchia, M., Mino, D. E., Glassen, T. C., Morgan, R., Gau, J. M., Birney, A. J., Ary, D. V., 2015. Mobile-web app to self-manage low back pain: randomized controlled trial. Journal of medical Internet research 17 (1), e1.

Jordan, J. L., Holden, M. A., Mason, E. E., Foster, N. E., 2010. Interventions to improve adherence to exercise for chronic musculoskeletal pain in adults. The Cochrane Library.

Koes, B., Van Tulder, M., Thomas, S., et al., 2006. Diagnosis and treatment of low back pain. British Medical Journal 7555, 1430.

Koes, B. W., van Tulder, M. W., Ostelo, R., Burton, A. K., Waddell, G., 2001. Clinical guidelines for the management of low back pain in primary care: an international comparison. Spine 26 (22), 2504–2513.

Koton, P. A., 1988. Using experience in learning and problem solving. Ph.D. thesis, Massachusetts Institute of Technology.

Krein, S. L., Kadri, R., Hughes, M., Kerr, E. A., Piette, J. D., Holleman, R., Kim, H. M., Richardson, C. R., 2013. Pedometer-based internet-mediated intervention for adults with chronic low back pain: Randomized controlled trial. Journal of medical Internet research 15 (8), e181.

Krein, S. L., Metreger, T., Kadri, R., Hughes, M., Kerr, E. A., Piette, J. D., Kim, H. M., Richardson, C. R., 2010. Veterans walk to beat back pain: study rationale, design and protocol of a randomized trial of a pedometer-based internet mediated intervention for patients with chronic low back pain. BMC musculoskeletal disorders 11 (1), 1.

Latimer, A. E., Salovey, P., Rothman, A. J., 2007. The effectiveness of gain-framed messages for encouraging disease prevention behavior: is all hope lost? Journal of health communication 12 (7), 645–649.

Lethem, J., Slade, P., Troup, J., Bentley, G., 1983. Outline of a fear-avoidance model of exaggerated pain perception—i. Behaviour research and therapy 21 (4), 401–408.

Lorig, K. R., Laurent, D. D., Deyo, R. A., Marnell, M. E., Minor, M. A., Ritter, P. L., 2002. Can a back pain e-mail discussion group improve health status and lower health care costs?: A randomized study. Archives of internal medicine 162 (7), 792–796.

Lorig, K. R., Ritter, P. L., Laurent, D. D., Plant, K., 2006. Internet-based chronic disease self-management: a randomized trial. Medical care 44 (11), 964–971.

Machado, G. C., Pinheiro, M. B., Lee, H., Ahmed, O. H., Hendrick, P., Williams, C., Kamper, S. J., 2017. Smartphone apps for the self-management of low back pain: A systematic review. Best Practice & Research Clinical Rheumatology.

Malmivaara, A., Häkkinen, U., Aro, T., Heinrichs, M.-L., Koskenniemi, L., Kuosma, E., Lappi, S., Paloheimo, R., Servo, C., Vaaranen, V., et al., 1995. The treatment of acute low back pain—bed rest, exercises, or ordinary activity? New England Journal of Medicine 332 (6), 351–355.

Marling, C., Shubrook, J., Schwartz, F., 2009. Toward case-based reasoning for diabetes management: A preliminary clinical study and decision support system prototype. Computational intelligence 25 (3), 165–179.

Marling, C., Whitehouse, P., 2001. Case-based reasoning in the care of alzheimer's disease patients. In: International Conference on Case-Based Reasoning. Springer, pp. 702–715.

Marling, C., Wiley, M., Cooper, T., Bunescu, R., Shubrook, J., Schwartz, F., 2011. The 4 diabetes support system: A case study in cbr research and development. In: International Conference on Case-Based Reasoning. Springer, pp. 137–150.

Martínez-Pérez, B., de la Torre-Díez, I., López-Coronado, M., Sainz-De-Abajo, B., Robles, M., García-Gómez, J. M., 2014. Mobile clinical decision support systems and applications: a literature and commercial review. Journal of medical systems 38 (1), 1–10.

Mohorovičić, S., 2013. Implementing responsive web design for enhanced web presence. In: Information & Communication Technology Electronics & Microelectronics (MIPRO), 2013 36th International Convention on. IEEE, pp. 1206–1210.

Montani, S., 2008. Exploring new roles for case-based reasoning in heterogeneous ai systems for medical decision support. Applied Intelligence 28 (3), 275–285.

Morone, N. E., Greco, C. M., Weiner, D. K., 2008. Mindfulness meditation for the treatment of chronic low back pain in older adults: a randomized controlled pilot study. Pain 134 (3), 310–319.

Nicolson, P. J. A., Bennell, K. L., Dobson, F. L., Van Ginckel, A., Holden, M. A., Hinman, R. S., 2017. Interventions to increase adherence to therapeutic exercise in older adults with low back pain and/or hip/knee osteoarthritis: a systematic review and meta-analysis. British Journal of Sports Medicine.

Nilsson, M., Sollenborn, M., 2004. Advancements and trends in medical case-based reasoning: An overview of systems and system development. In: FLAIRS Conference. pp. 178–183.

O'Sullivan, D., McLoughlin, E., Bertolotto, M., Wilson, D. C., 2007. Mobile case-based decision support for intelligent patient knowledge management. Health informatics journal 13 (3), 179–193.

Perry, B., 2015. Gamifying french language learning: a case study examining a quest-based, augmented reality mobile learning-tool. Procedia-Social and Behavioral Sciences 174, 2308–2315.

Picavet, H. S. J., Vlaeyen, J. W., Schouten, J. S., 2002. Pain catastrophizing and kinesiophobia: predictors of chronic low back pain. American journal of epidemiology 156 (11), 1028–1034.

Riesbeck, C. K., Schank, R. C., 2013. Inside case-based reasoning. Psychology Press.

Shneiderman, B., 1998. Designing the user interface : strategies for effective human-computer interaction.

Simon, D., Kriston, L., von Wolff, A., Buchholz, A., Vietor, C., Hecke, T., Loh, A., Zenker, M., Weiss, M., Härter, M., 2012. Effectiveness of a web-based, individually tailored decision aid for depression or acute low back pain: a randomized controlled trial. Patient education and counseling 87 (3), 360–368.

Song, X., Petrovic, S., Sundar, S., 2007. A case-based reasoning approach to dose planning in radiotherapy. In: Workshop proceedings, the 7th international conference on case-based reasoning ICCBR. Vol. 7. pp. 13–16.

Thaler, R. H., Sunstein, C. R., 2008. Nudge : improving decisions about health, wealth, and happiness. Yale University Press, New Haven, Conn.

Van Remoortel, H., Giavedoni, S., Raste, Y., Burtin, C., Louvaris, Z., Gimeno-Santos, E., Langer, D., Glendenning, A., Hopkinson, N. S., Vogiatzis, I., et al., 2012. Validity of activity monitors in health and chronic disease: a systematic review. International Journal of Behavioral Nutrition and Physical Activity 9 (1), 84.

van Tulder, M. W., Koes, B., Malmivaara, A., 2006. Outcome of non-invasive treatment modalities on back pain: an evidence-based review. European Spine Journal 15 (1), S64–S81.

Warsi, A., Wang, P. S., LaValley, M. P., Avorn, J., Solomon, D. H., 2004. Self-management education programs in chronic disease: a systematic review and methodological critique of the literature. Archives of Internal Medicine 164 (15), 1641–1649.

Weymann, N., Dirmaier, J., von Wolff, A., Kriston, L., Härter, M., 2015. Effectiveness of a web-based tailored interactive health communication application for patients with type 2 diabetes or chronic low back pain: randomized controlled trial. Journal of medical Internet research 17 (3), e53.

Wong, J., Côté, P., Sutton, D., Randhawa, K., Yu, H., Varatharajan, S., Goldgrub, R., Nordin, M., Gross, D., Shearer, H., et al., 2016. Clinical practice guidelines for the noninvasive management of low back pain: A systematic review by the ontario protocol for traffic injury management (optima) collaboration. European Journal of Pain.

Appendices

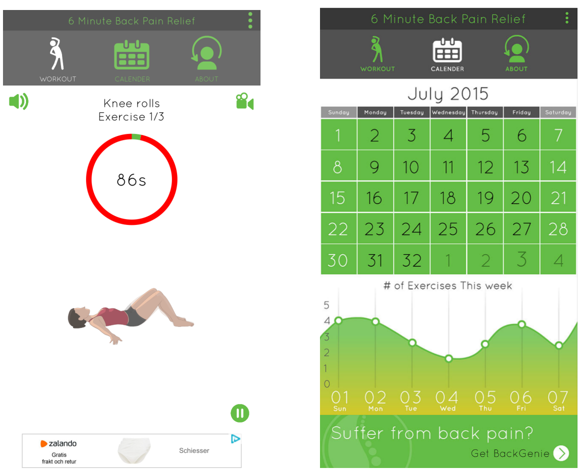
Appendix A

Smartphone applications

A.1 6 minutes back pain relief

Android: `https://play.google.com/store/apps/details?id=com.tcmardoc.minutebackpainrelief`
iPhone: `https://itunes.apple.com/no/app/6-minute-back-pain-relief/id1069869410`

This exercise application offers guided and timed workout sessions with an animated explanation of each exercise. There are three exercises in each session picked at random from a total library of nine exercises.



(a) Exercise display **(b)** Historic data

Figure A.1: In the app

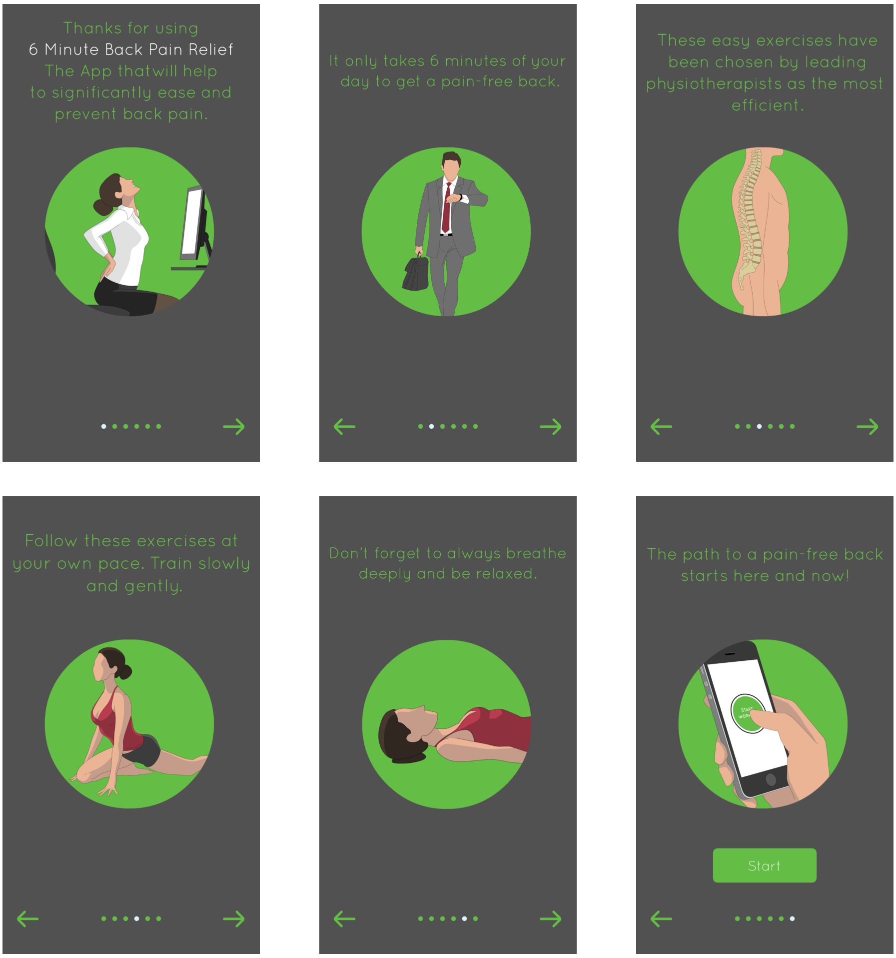
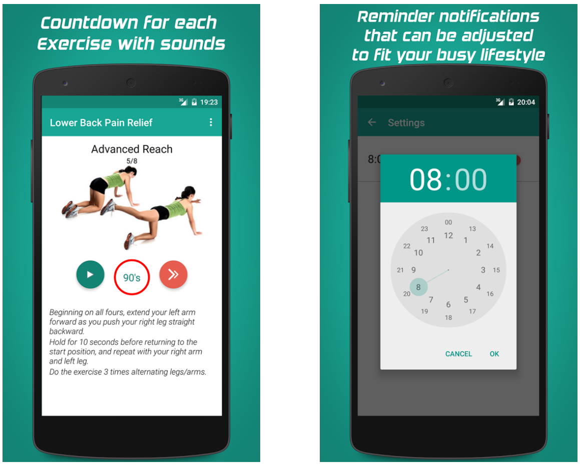


Figure A.2: Introduction

A.2 Lower back pain relief

Android: `https://play.google.com/store/apps/details?id=com.gongadev.lowerbackpainrelief`

This is an exercise app with timed sessions of a fixed amount of eight exercises. It is possible to set workout reminders. All content is downloaded for offline support.



(a) Exercise display **(b)** Configure reminder

Figure A.3: In the app

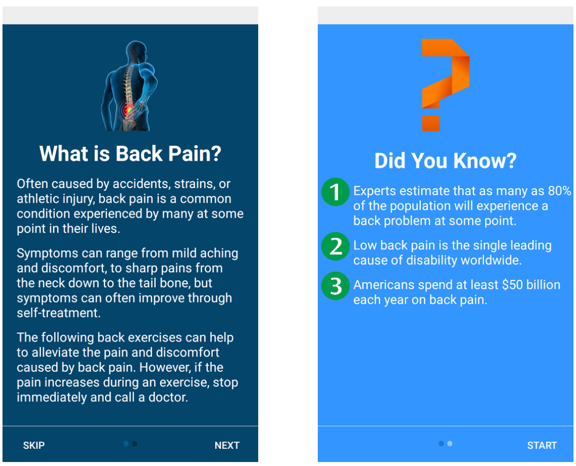
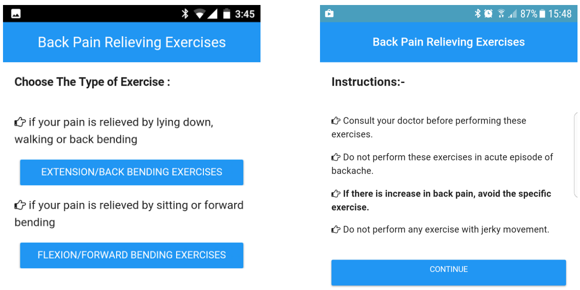


Figure A.4: Introduction

A.3 Back Pain Relieving Exercises

Android: `https://play.google.com/store/apps/details?id=com.backpainrelievi` `backpain&hl=no`

This exercise application provides the user with two types of exercises; extension and flexion, as shown in Figure A.5a. The exercise display is a simple list view using text and images to explain each exercise. It also has advice on things to do and what to avoid to prevent pain from occurring.



(a) Types of exercises **(b)** Instructions

Figure A.5: Introduction

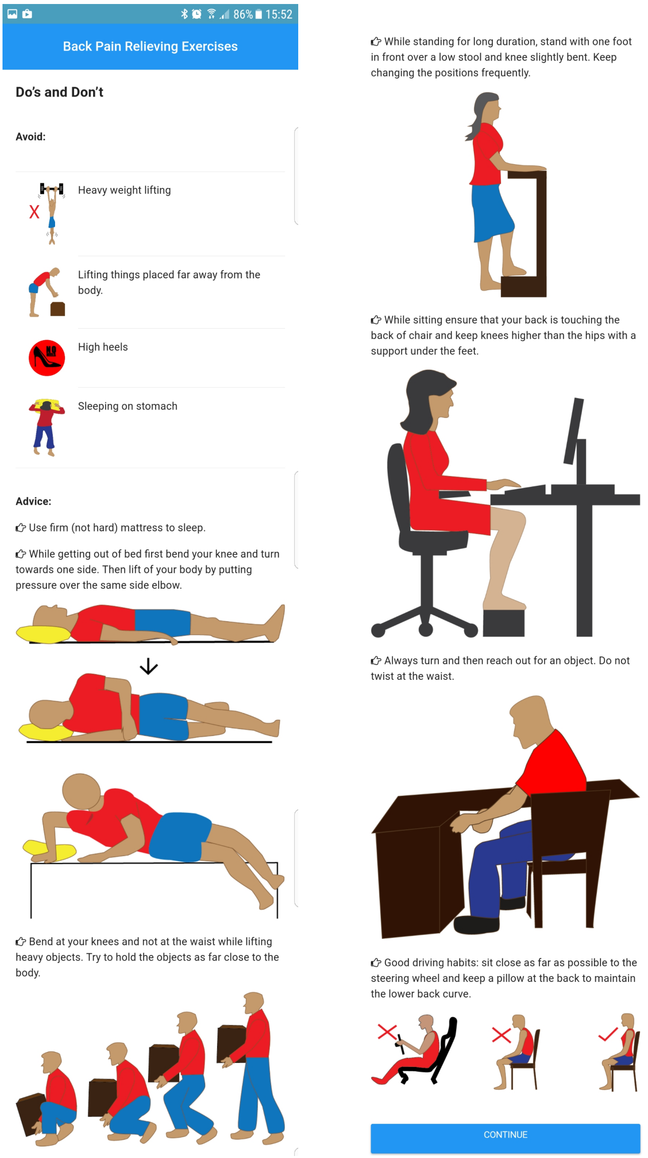


Figure A.6: Do's and don't

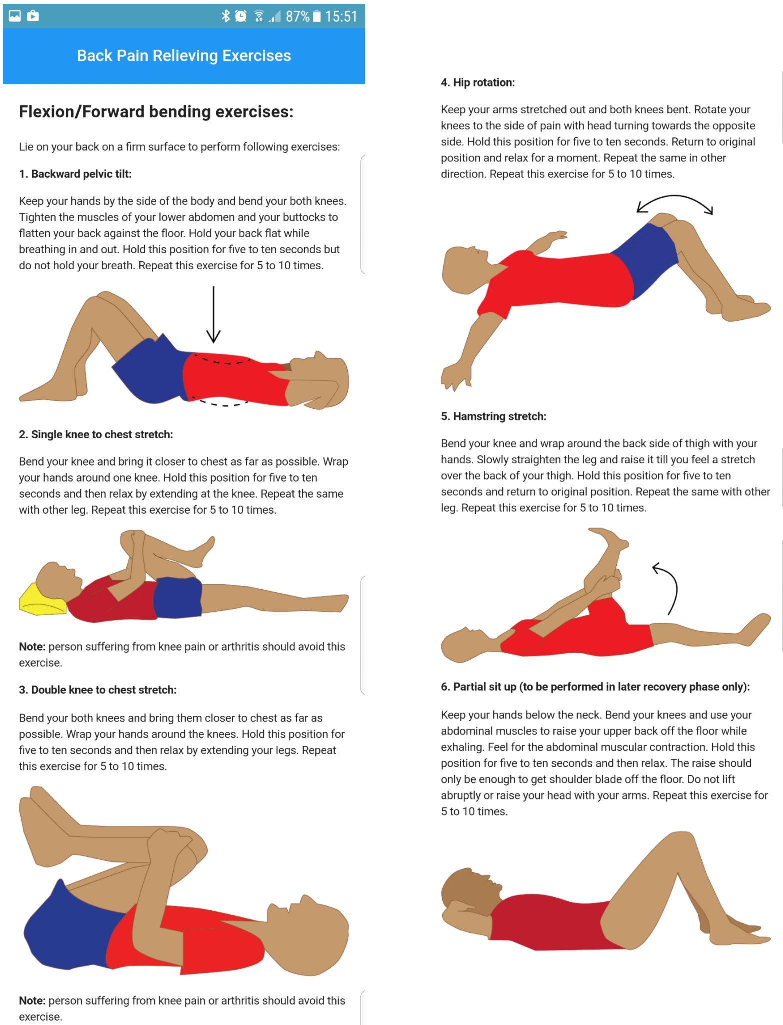


Figure A.7: Forward bending exercises

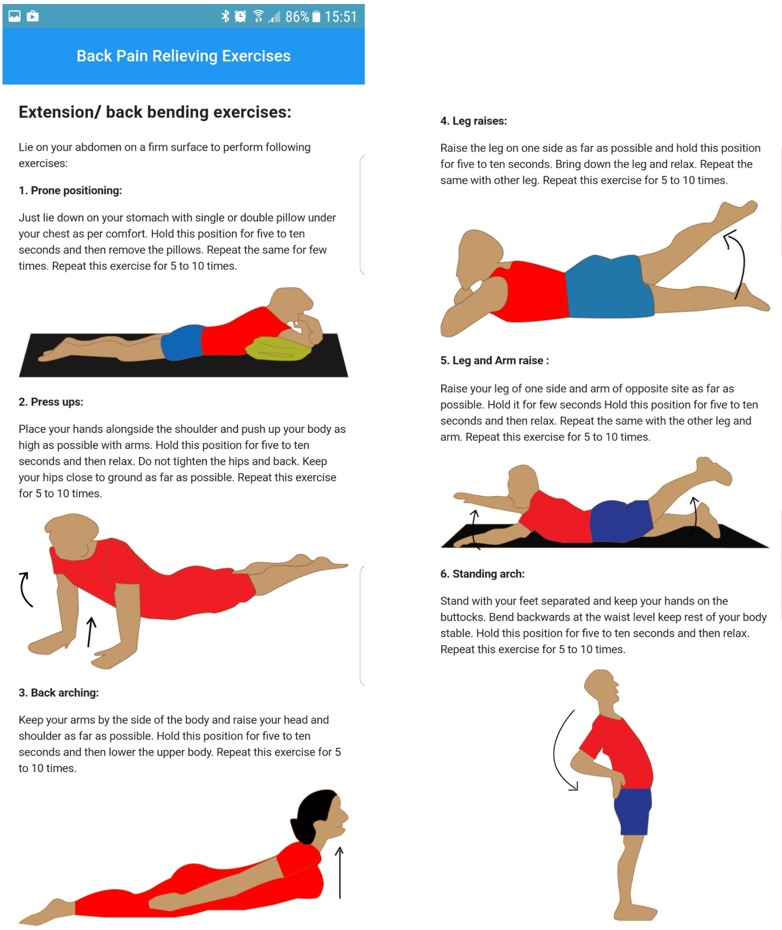
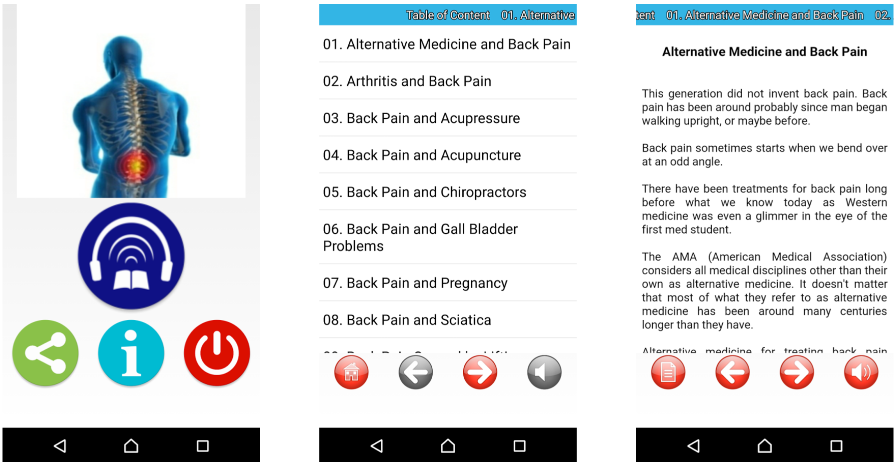


Figure A.8: Back bending exercises

A.4 Audio Book - Back pain

Android: `https://play.google.com/store/apps/details?id=anace.com.audiobooks.backpain`

Library with information about back pain, which is divided into chapters. It uses Android's Text-To-Speech technology to make it possible to listen to the content.



(a) Audio book display **(b)** Table of content **(c)** Reading a chapter

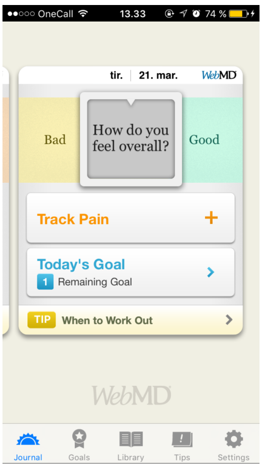
Figure A.9: In the app

A.5 WebMD Pain Coach

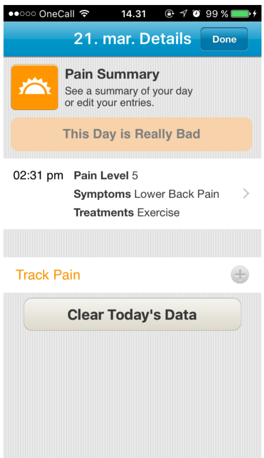
Android: `https://play.google.com/store/apps/details?id=com.webmd.paincoach`
iPhone: `https://itunes.apple.com/no/app/webmd-pain-coach/id536303342`

Pain tracker

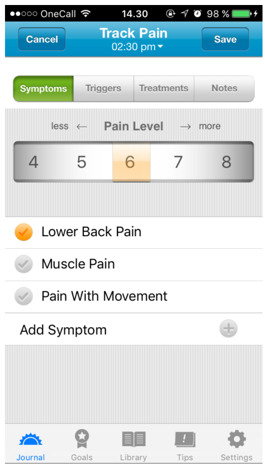
The pain tracker is the main feature of the app. It allows the user to track daily pain level, and follow how the pain develops over time. In addition, it is possible to add triggers, treatments and notes for each pain entry.



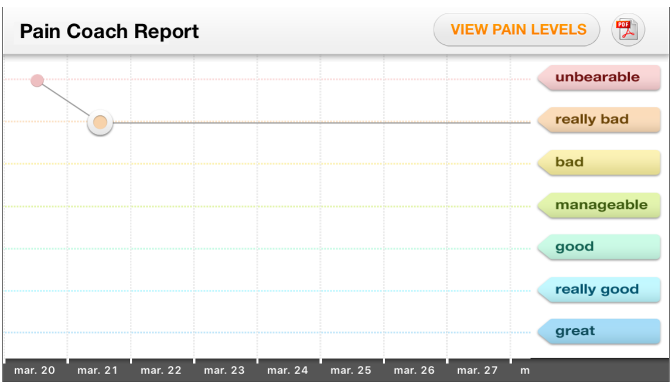
(a) Main screen



(b) Summary screen



(c) Details screen

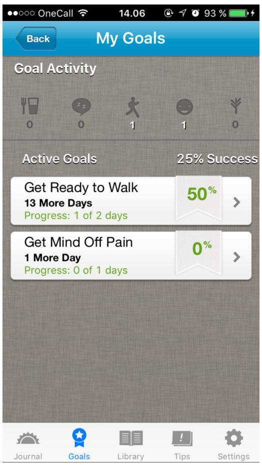


(d) Historic overview

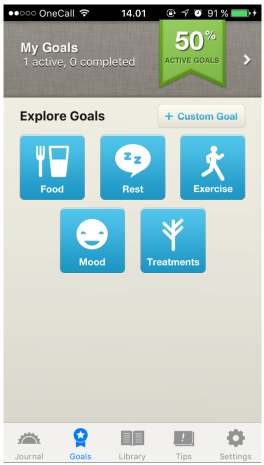
Figure A.10: Pain tracker

Goals

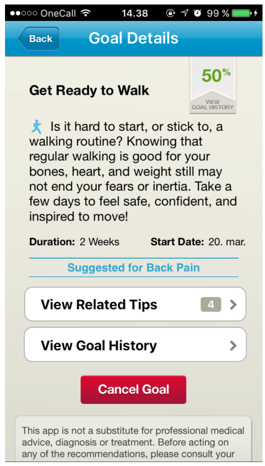
The goal screen allows the user to track both long -and short-term goals. This comes with a list of predefined goals from five categories; food, rest, exercise, mood and treatment. The goals are recommended based on the user's condition. Each goal has a list of different tips on for instance how to get started and follow through to complete the goal. It is also possible to add a custom goal.



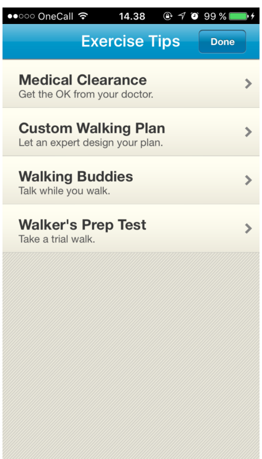
(a) Overview of goals



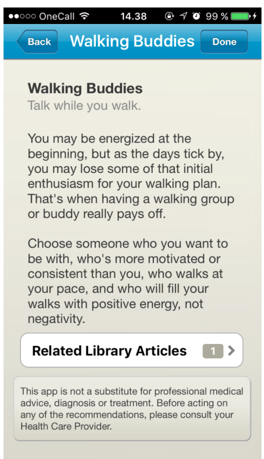
(b) Predefined goals



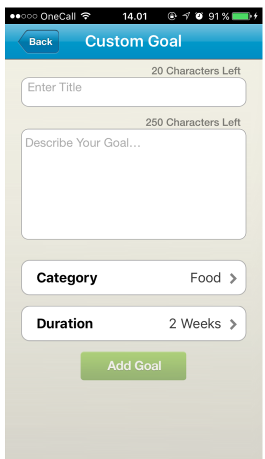
(c) Goal details



(d) Goal related tips



(e) Tip details



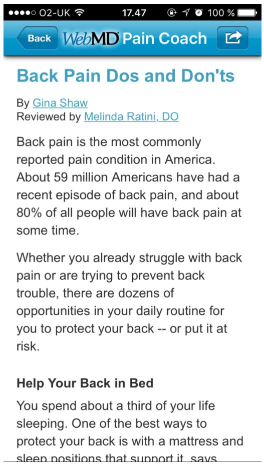
(f) Add custom goal

Figure A.11: Goal feature

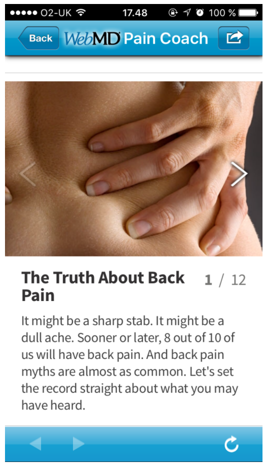
Library

The app also has a huge library with information about the different pain conditions. It includes articles, videos, slideshows, tips and quizzes to test your knowledge on the subject. All the content is reviewed and verified by doctors, and this information is clearly displayed for each contribution. The media content is presented in a folder structure as seen in Figure A.13b.

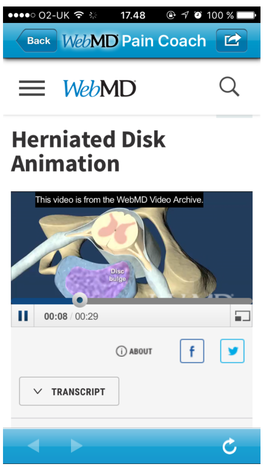
(a) Folder structure - start



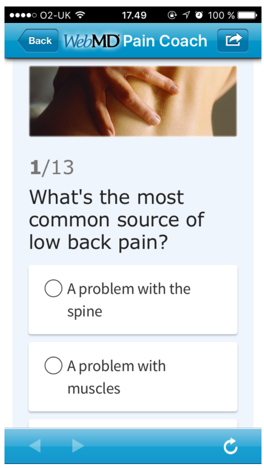
(b) Article example



(c) Slideshow example



(d) Video example



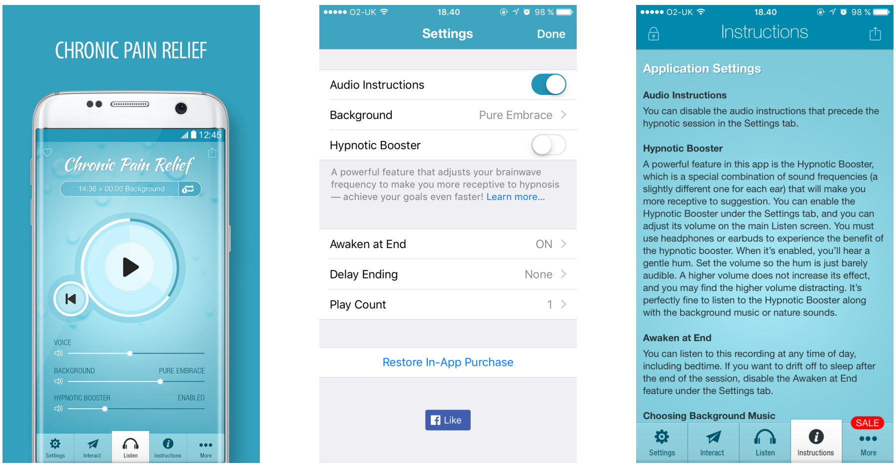
(e) Quiz example

Figure A.12: Library with information about back pain

A.6 Pain relief hypnosis

Android: `https://play.google.com/store/apps/details?id=com.surfcityapps.painrelief`
iPhone: `https://itunes.apple.com/no/app/pain-relief-hypnosis-my-chronic-pain-killer/id917133072`

Hypnosis recordings with adjustable voice, background and hypnotic booster. It is also possible to adjust the awaken at end functionality, which is useful if used before bedtime.



(a) Hypnosis recording **(b)** Settings **(c)** Intructions

Figure A.13: Hypnosis app

Appendix B

Wearable devices

B.1 Lumo Lift

Android: `https://play.google.com/store/apps/details?id=com.lumobodytech.lumolift`
iPhone: `https://itunes.apple.com/no/app/lumo-lift/id884303137`
Website: `http://www.lumobodytech.com`

Lumo Lift is a device for tracking posture and step count. The magnetic device should be attached onto clothing around the collar.

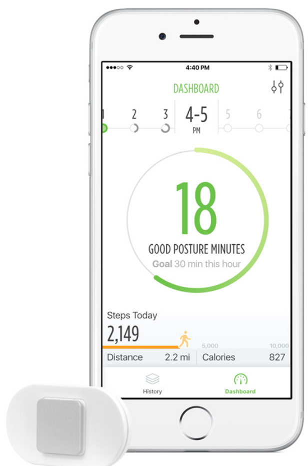


Figure B.1: Device and app

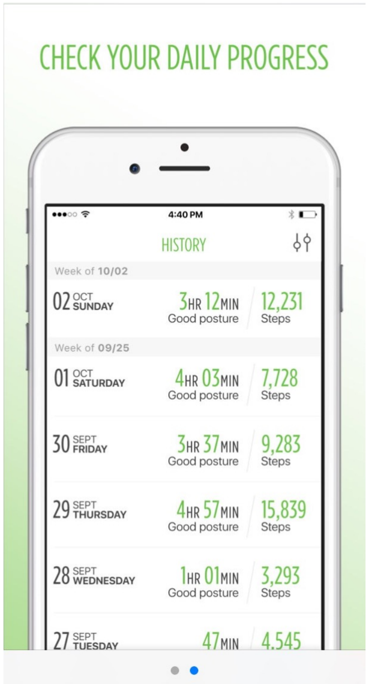


Figure B.2: Historic overview

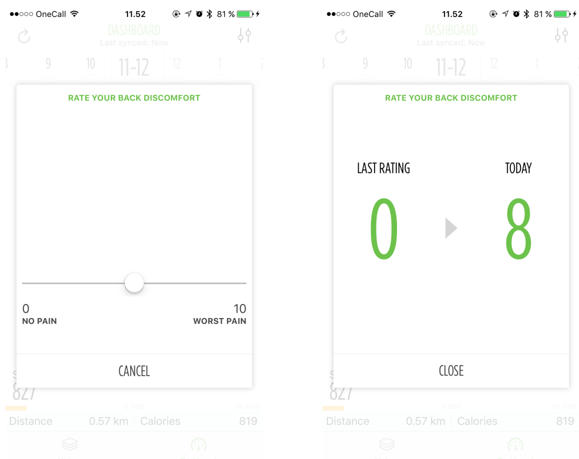


Figure B.3: Rate back pain

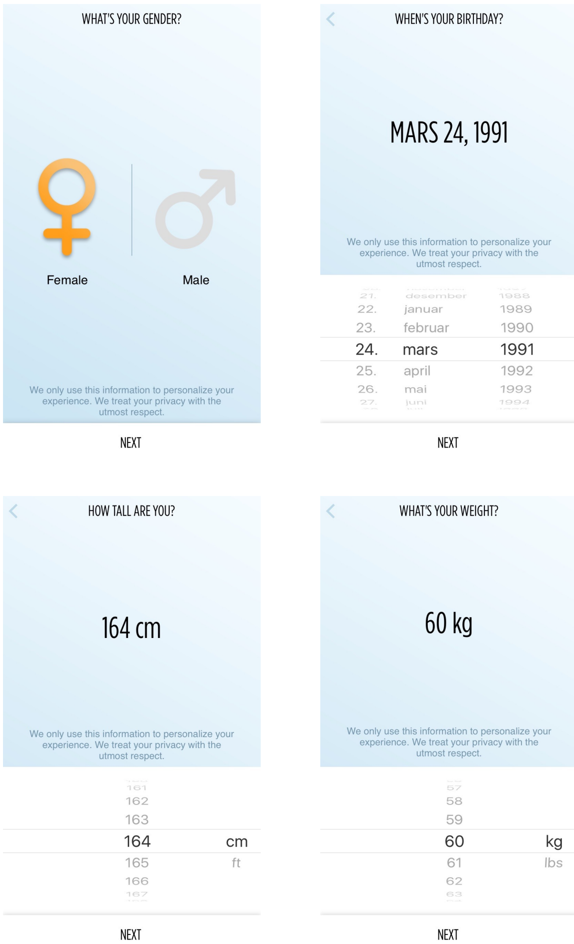
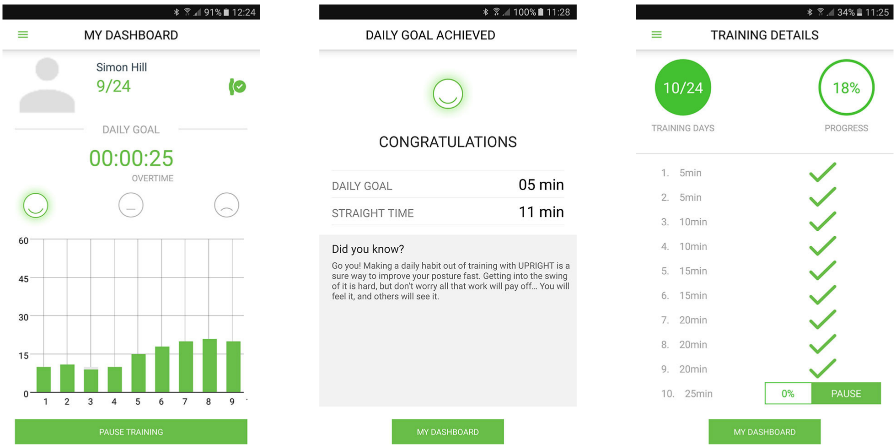


Figure B.4: Setup process

B.2 Upright

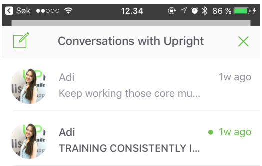
Android: https://play.google.com/store/apps/details?id=com.uprightpose.upright
iPhone: https://itunes.apple.com/no/app/upright-trainer/id1057748334
Website: https://www.uprightpose.com

Upright is a posture trainer intended to be used for 15-60 minutes long daily sessions for about a month. The device is attached directly to spine and provides accurate posture feedback. The app has a small library of videos and articles on what back is. It generates a workout program for each individual user, and slightly increases difficulty over time.

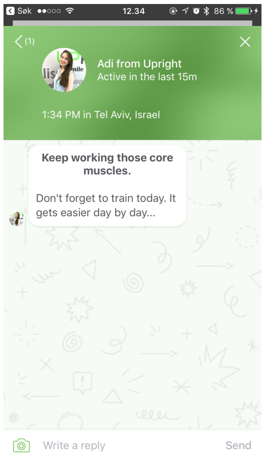


(a) Dashboard **(b)** Daily goal **(c)** Daily goal

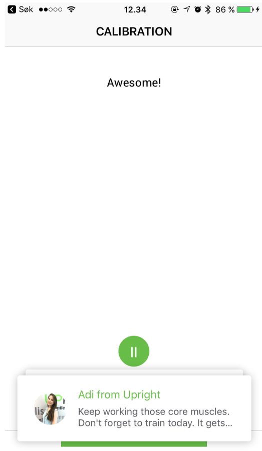
Figure B.5: Posture training



(a) All notifications

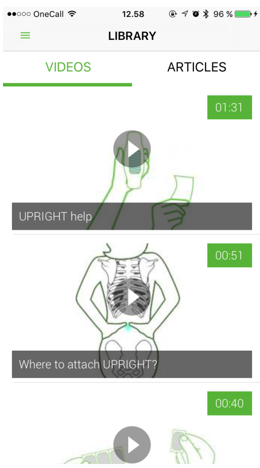


(b) Detailed notification

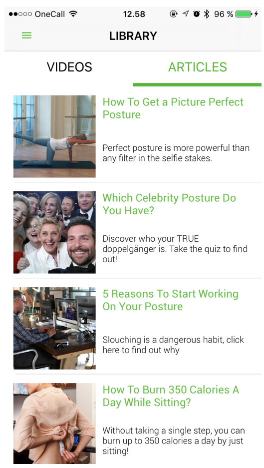


(c) Overlay display in app

Figure B.6: Notifications



(a) Videos



(b) Articles

Figure B.7: Library

B.3 Valedo

Android: `https://play.google.com/store/apps/details?id=com.hocoma.valedoapp`
iPhone: `https://itunes.apple.com/no/app/valedo/id863104705`
Website: `https://www.valedotherapy.com`

Valedo is a game with back specific exercises. It comes with two sensors that should be attached to upper and lower back to track movement. The user is controlling a character in the game by moving the upper body. The game is set in a village with six districts; torso, twist, hip, special, floor and core. It is possible to generate a full report of the exercises performed and specific movements.

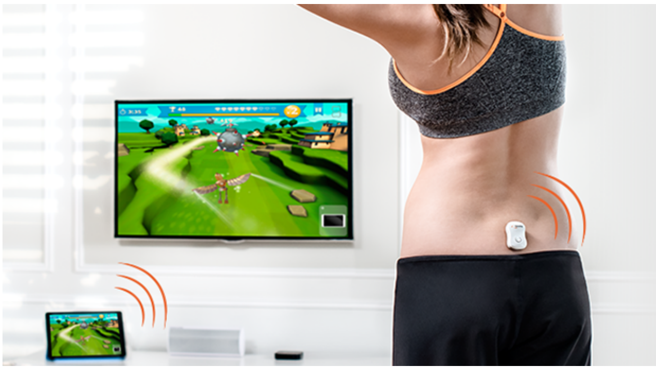


Figure B.8: Game play

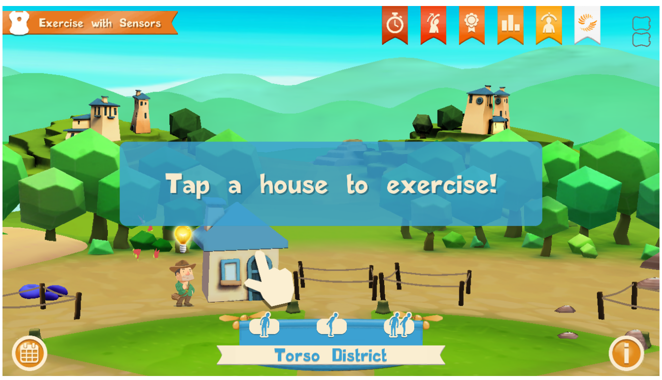


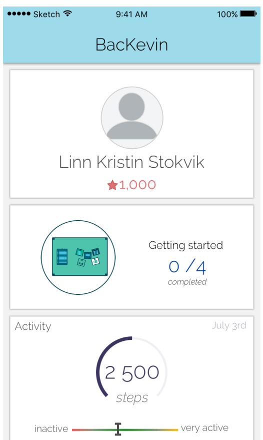
Figure B.9: Game play

Appendix C

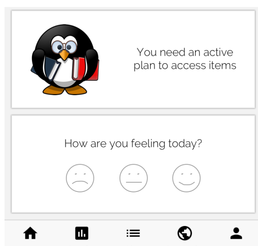
Prototype design - Kevino

C.1 Main screens

The home screen gives the user access to account, package program, activity, education and pain/activity limitation tracker. The package program and activity progress is easily accessible, as this is rated as the most frequent requested features. The account view is intended to personalise the experience.



(a) Account, package program and activity

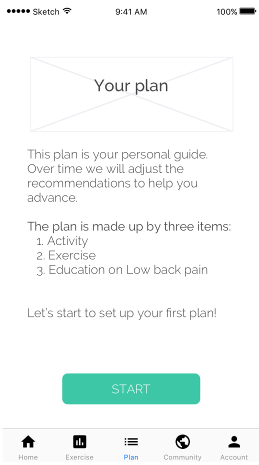


(b) Education and pain / activity limitation tracker

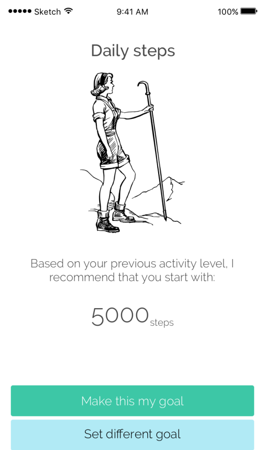
Figure C.1: Interactive home screen

C.2 Self-Management plan

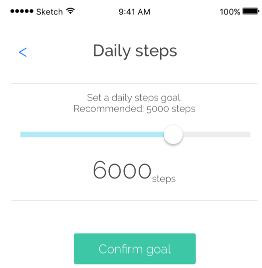
This is the flow in the self-management plan setup. The idea is to make it as easy as possible to stay with the recommendations from the decision support system. Thus if you want to edit this, you will be sent to a new screen. Ideally this process is complete in four steps.



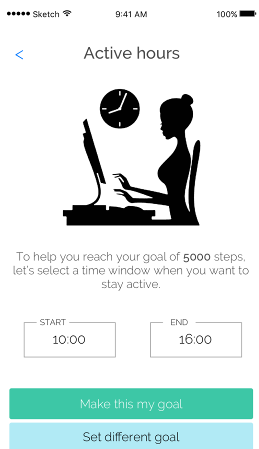
(a) Introduction



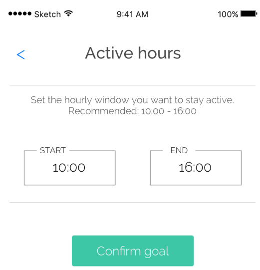
(b) Steps



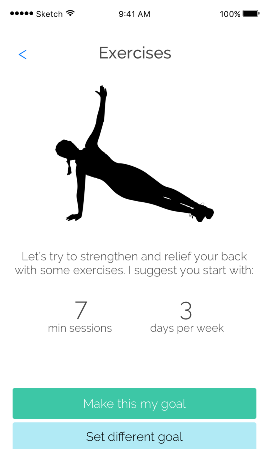
(c) Edit



(d) Active hours

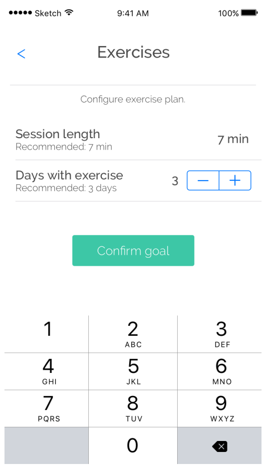


(e) Edit active hours

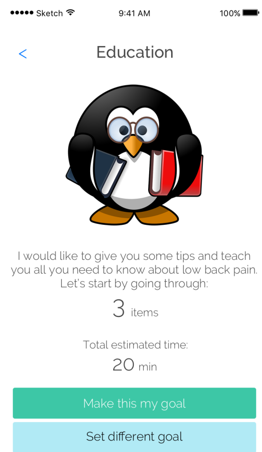


(f) Exercise

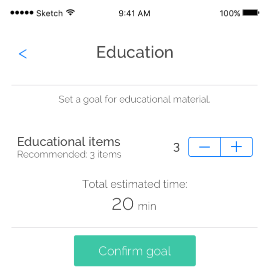
Figure C.2: Plan setup



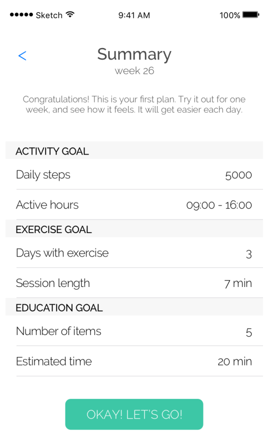
(g) Edit exercise



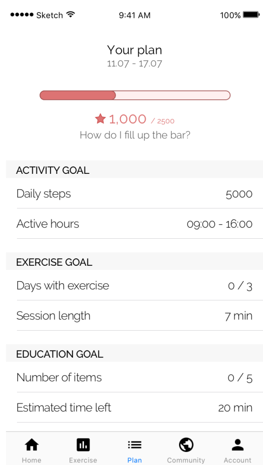
(h) Education



(i) Edit education



(j) Plan summary



(k) Plan progress

Figure C.2: Plan setup (continue)

C.3 Package program

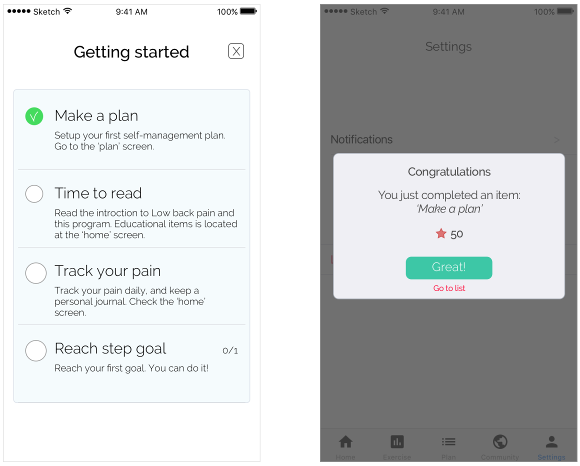
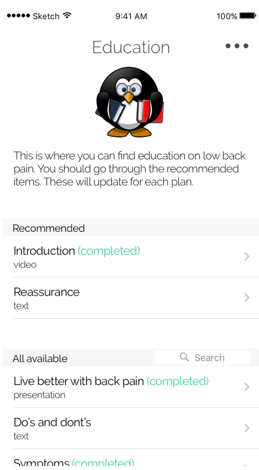
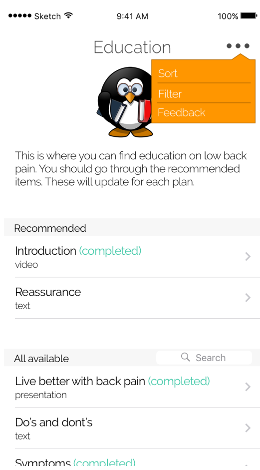


Figure C.3: Package program

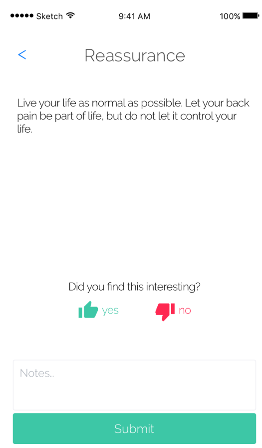
C.4 Education



(a) Main education page



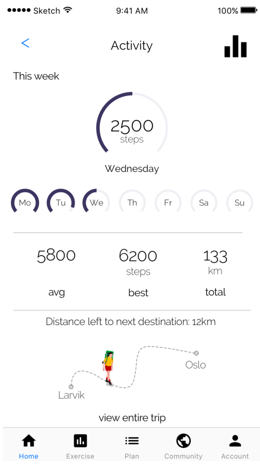
(b) More actions



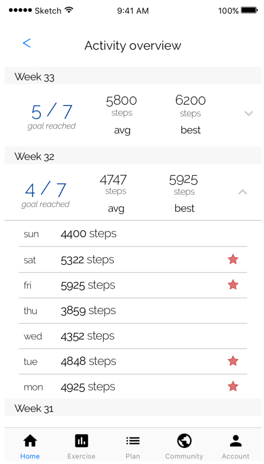
(c) View an item

Figure C.4: Education screen includes items with multiple media types

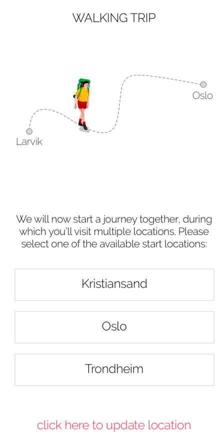
C.5 Activity



(a) Main



(b) Activity history

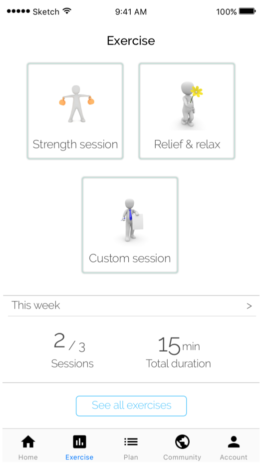


(c) Journey setup

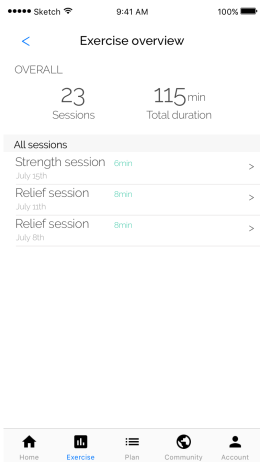
(d) Journey setup

Figure C.5: Activity

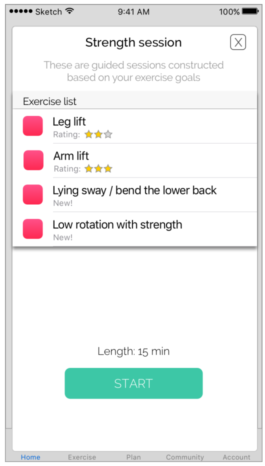
C.6 Exercise



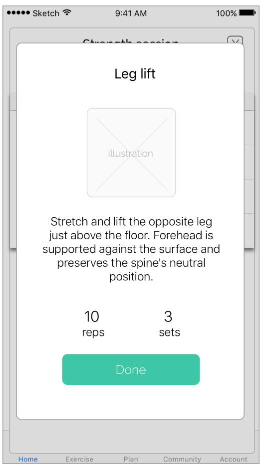
(a) Main



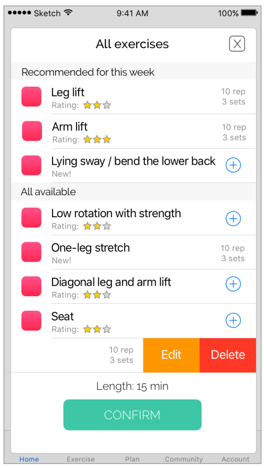
(b) Exercise overview



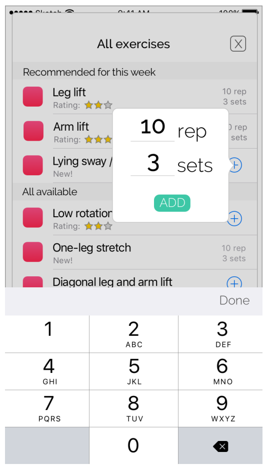
(c) Start session



(d) Exercise details



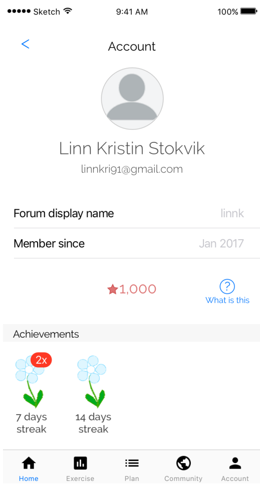
(e) Edit exercises



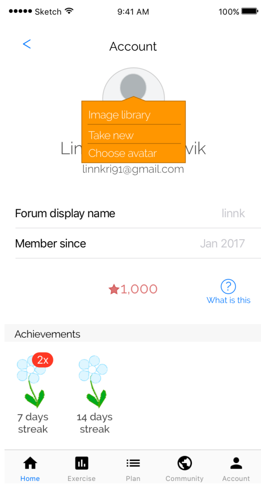
(f) Edit exercises

Figure C.6: Exercise

C.7 Additional features

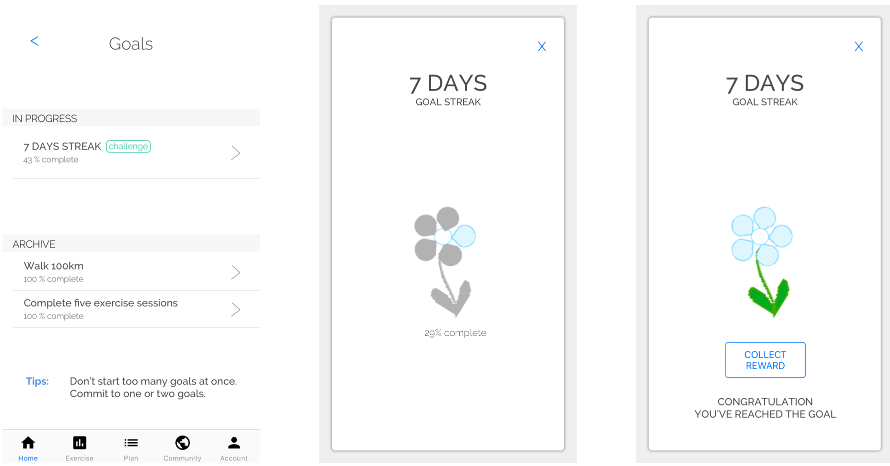


(a) Account includes points and achievements



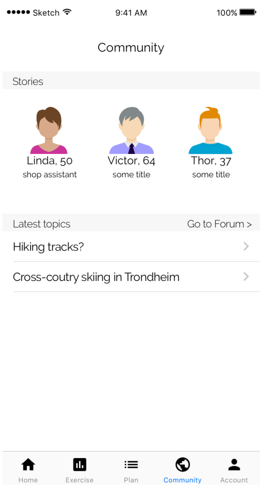
(b) Personalise by selecting a profile picture

Figure C.7: Account

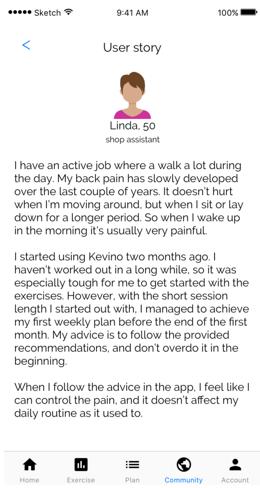


(a) Main **(b)** Trophy builder **(c)** Trophy builder full

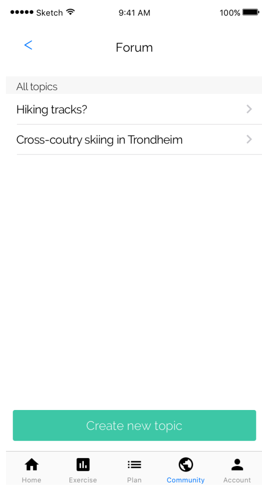
Figure C.8: Goals



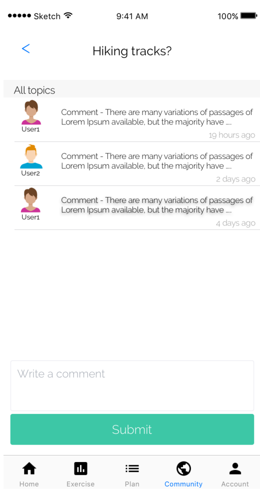
(a) Stories and forum



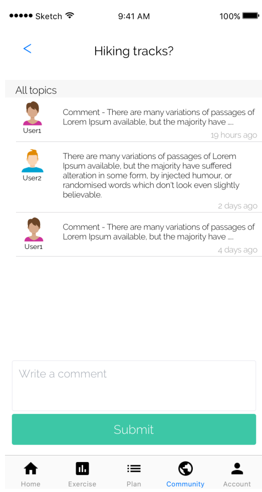
(b) Story



(c) Forum



(d) Topic



(e) Dynamic cells

Figure C.9: Community