RehaBuddy

Development and evaluation of a mobile technology to support a patient-centered goal-setting process in physiotherapy

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Abstract

In physiotherapy, goal-setting is an essential component of the therapy. Ideally, this process is patient-centered, which increases treatment outcomes and adherence to the home exercise plan. In practice, however, patients are far less involved in goal-setting than clinical guidelines and evidence advise.

Mobile technology might be a promising solution as it can provide a structure that employs a patient-centered approach. Thus, this thesis investigates how mobile technology can facilitate a patient-centered goal-setting process in physiotherapy. Throughout the work, a Research through Design approach is taken.

A literature review and a formative survey lay the foundation of this work. Then, the Behavior Change Wheel is used as a theoretical framework to develop an initial interaction concept that guides patients through a decision-tree-like process to identify and set SMART activity-based treatment goals. This concept was translated to a low-fidelity wireframe and then evaluated and improved in two iterations. The final wireframe was then developed towards a mid-fidelity mobile app, which got evaluated by a patient-user test, two expert interviews, and an assignment for a class of physiotherapy students.

The results show there are multiple potential roles for such technology. First, it can act as a foundation for discussion to align the expectations of the patient and therapist concerning realistic healing times. Second, it can be a motivator to consistently do the exercises for the patient throughout the therapy. The user tests showed promising first results concerning attitude towards the technology and the degree to which patients are involved during the goal-setting process. Furthermore, comparing the results from the formative study and the evaluation of the app, the goals set by patients with the technology were more timely and measurable than those set traditionally, representing two important components of a SMART goal.

Overall, the results obtained were mostly positive. However, with 5-10 people, the low number of participants per research method and the non-representative sample limit the generalizability. Moreover, this study could not assess the effects of using such technology on adherence, treatment adherence, and patient involvement during therapy. Future research could investigate these effects by conducting a longer-term study.

Contents

Chapter 1

Introduction

Patient-centeredness is a strongly encouraged theme in physiotherapy and healthcare in general [1] [2]. This means that healthcare services should be tailored to patients' needs, preferences, and values.

In physiotherapy, goal-setting is an essential therapy component [3]. In practice, however, patients are far less involved in the goal-setting process than clinical guidelines and evidence advise [4] [5], which conflicts with the encouraged theme of patient-centeredness. In contrast, when patient involvement is high, treatment adherence, motivation, and satisfaction with the therapy are also increased [6] [7]. A systematic review estimated the compliance to the home exercise plans is to be as low as 30-50% [8], which underlines that patient involvement in goal-setting is a central component of a successful therapy.

To implement a patient-centered goal-setting process, several practical frameworks have been developed [9] [10] [11]. However, several papers assessed that these frameworks do not achieve this goal to a satisfactory degree in practice [4] [5] because of a lack of therapy time [12] and training [13] or communication and resources issues [12].

One promising solution for these challenges may be to use mobile technology. Mobile technology can be used outside of the treatment time by the patient, potentially saving valuable treatment time if some tasks that would be done within the session can be outsourced. And if a technology implements a structured process through which the user is guided, less training for therapists would be needed [14]. Thus, this work investigates this opportunity through the following research question:

How can the patient-led goal-setting process in physiotherapy between patient and therapist be facilitated through mobile technology?

This thesis contributes to scientific knowledge by answering the research question in the following two ways. The first contribution is the facilitation of patient-led goal-setting in physiotherapy through mobile technology. The paper describes how mobile technology may facilitate a patient-led goal-setting process, which is a relatively new concept in the field of physiotherapy. It is investigated through a prototype that was developed in this work. Additionally, the article discusses how technology fills a gap in current practice by empowering patients to take a more active role in their treatment outside of therapy sessions, potentially improving treatment outcomes, adherence, and patient satisfaction.

The second contribution is the development and evaluation of a new behavior change technology guided by the behavior change wheel and a research-through-design approach. The work explains the development process in detail. It describes how the behavior change wheel was used to guide the development of the technology and provides details on and insight from applying the research-through-design process. Further, usability and acceptability are evaluated, which could help guide implementation efforts of similar concepts and inform future design decisions.

The next section explains how these objectives will be obtained.

1.1 Thesis outline

These contributions will be achieved by following an iterative Research through Design (RtD) approach. At the beginning of the thesis, related literature will be analyzed in Chapter 2 to form the basis of the problem space. Chapter 3 will present the methodology and research methods applied throughout this work. Afterward, chapter 4 thoroughly guides the reader through how the Behavior Change Wheel was used to develop the initial interaction concept for a prototype. Chapter 5 then explores the development and iterative improvements of the prototypes.

Chapter 6 assesses the final prototype through interviews, a patient user test, and a physiotherapy student assignment. Finally, chapter 7 discusses and reflects on the results and the applied methodology and answers the research question.

Chapter 2

Related Work

This chapter investigates the scientific state of patient-led goal-setting and why it is not as widely applied as guidelines advise. Several practical frameworks and their strengths and weaknesses are evaluated. Based on this, how technology might fill the identified gaps will be discussed. Finally, specific technologies are evaluated that intend to support a patient-centered goal-setting process.

2.1 Overview of physiotherapy and patient-led goal-setting

As mentioned in the introduction, patient-centeredness is a strongly suggested concept within physiotherapy [1] [2]. When physiotherapists follow a patient-centered approach, it supports a collaborative and trusting relationship between patient and therapist [15]. This, in turn, may positively influence treatment adherence, motivation, and satisfaction with the therapy [6] [7]. Considering that adherence to the home exercise plans is estimated to be as low as 30-50% [8], patient-centeredness is a central component of a successful therapy.

One central component where patients should be included is when setting treatment goals [3]. Goal setting in physiotherapy can be viewed as a negotiation process between patient and therapist. A review found that patients value involvement in the goal-setting process [16]. The increased ownership supported patients in knowing what exactly they needed to do [16].

In practice, however, patients are far less involved in goal-setting as clinical guidelines and evidence advise [4] [5]. For example, a survey of 202 rehabilitation practitioners in the UK found that patients are involved in the goal-setting process only in 30% of cases [17]. In cases where patients are not involved, the goals are set around functional goals, but these goals are frequently not aligned with patients' needs and preferences [18] [19]. In cases where patients are involved, goals are activity-based and relevant to the patient, e.g. returning to their sport [19]. Moreover, patients are not regularly provided with information about the goal-setting process before the treatment sessions [20]. And when goals were agreed on, only rarely were patients provided with copies of them [20].

There are multiple reasons why the rate of patient involvement is less than desired. Patients may rely on their therapist to guide their rehabilitation planning [21], or may not know what is expected of them [12]. Therapists may be overwhelmed by the complexity of collaborating during the goal-setting process [22] [12], and there is not enough time for the therapist to get to know the patient [12]. The therapist may also lack the education necessary to involve patients in the goal-setting process [13]. Or patients may just not be interested in participating [13].

Involving patients in the goal-setting process increases treatment outcomes [23] [24], self-efficacy [25], and adherence to the home exercise plan [25] compared to no goal setting. However, the lack of a control group in some studies makes it difficult to determine whether the positive effects were due to involving patients or the goal-setting process itself. The increased impact of goal setting on treatment outcomes such as disability, pain intensity, quality of life, self-efficacy, and kinesiophobia has been shown compared to advice [24]. Noteworthy is that these effects were maintained after 12 months [24].

In a study, self-efficacy was significantly increased in a patient-led goal-setting group over a therapist-led goal-setting group [25]. Brinkman et al. came to the same conclusion and investigated the reasons further [26]. They argued that self-efficacy is increased when the goal-setting process is patient-led because goals are chosen which are meaningful to the patient [26]. Moreover, a sense of autonomy in the goal-setting process further increases self-efficacy [26], relating back to the importance of the patient leading the goal-setting process. Patient-led and patient-centered describe the same concept in the context of goal-setting.

In a study, therapist-led and patient-led goal-setting conditions increased the adherence to the treatment plan compared to a control group, but without significant differences between them [25]. In a systematic review that investigated adherence to the treatment plan, low self-efficacy was a strong predictor of low compliance [8]. Thus, if patients' self-efficacy is increased further when the goal setting is patient-led, it might also have a larger effect on treatment adherence, although this relationship has not been shown yet. This is an interesting topic for future work to investigate, considering that non-compliance rates are up to 50-70% [8] [27] in physiotherapy outpatient clinics, significantly impacting patients' lives and healthcare.

On the one hand, the therapy and the goal-setting process should be patient-centered. On the other hand, it has been observed that goals set by patients are broad and long-term in nature and express their aspirations [28], which healthcare professionals consider unrealistic [29]. Therefore, clinical guidelines suggest following a structured approach within the goal-setting process [30]. A widely investigated approach to structured goal setting within physiotherapy is based on the goal setting theory, which entails that motivation largely depends on specific goals and feedback about their attainment [31]. A common acronym applying this theory is SMART goals, whose letters can stand for specific, measurable, achievable, relevant, and time-bound [32]. SMART is a widely known and effective framework for goal-setting [3]. There are other goal-setting frameworks like MEANING [33] that focus more on the rehabilitation domain. The SMART approach was nevertheless chosen as a primary goal-setting framework because it is also used by many studies that this work relies upon which increases the transferability of the results.

If the goals set are SMART, the goal-setting process was also patient-centered because of the relevant component. Selecting irrelevant goals is one of the main issues with therapist-led goal setting [18] [19].

But SMART goals alone are not the universal solution to achieve a patient-centered goal-setting process. Health practitioners applying SMART goal-setting have been criticized for being prescriptive and inflexible [34] [35], which is in conflict with the desired patient-centeredness. Moreover, goal-setting is a process that has been found not always to be straightforward [36]. Patients may not have a treatment goal already in mind or might not claim knowledge about that topic because they perceive the therapist as the expert guiding the discussion [36]. What is needed is not only the end goal in SMART shape but also some structure on how to get there, which is explored next.

2.2 Characteristics of frameworks that support a structured goal-setting process

To apply a structured goal-setting process that is also flexible and patient-centered, there have been attempts to develop practical frameworks to guide the goal-setting process in clinical practice [9] [10] [11]. One framework developed for physiotherapy practice, named PSG model [9], consists of six steps: 1) identifying problematic activities in daily life as a result of the patient's health problem; 2) prioritizing the most important activity he/she wants to work on; 3) scoring the perceived ability to perform the selected activity on an 11-point Numeric Rating Scale (0 = impossible to perform, 10 = easy to perform); 4) setting goals, i.e. translating the selected activities into treatment goals; 5) planning treatment, i.e. making a shared decision about the treatment plan; and 6) evaluating the treatment goals.

The common base for the different frameworks is that one step is always to determine what is important to the patient. This is usually done in a dedicated session with healthcare professionals and is used to create meaningful goals afterward. In these frameworks, the developed goals have the shape of a SMART goal, which indicates a significant degree of patient-centeredness because of the relevant component. In subsequent sessions, the progress toward the goals is monitored and adapted if needed.

To apply these frameworks, however, (extensive) training for the therapists was needed [9] [10]. Moreover, a multidisciplinary team was involved, which may be a barrier to adoption in clinical practice [9] [10] [11]. In physiotherapy practice, therapists evaluating one of the frameworks mentioned insufficient time to apply the method [4]. Indeed, the lack of treatment time may be one of the core differences between the goal-setting process within rehabilitation in general and physiotherapy. Comparing the PSG model [10], which was developed specifically for physiotherapy practice, and the goal-setting and action-planning framework by Scobbie et al. [9], which was developed for rehabilitation in general, the ladder required weekly goal review meetings and an integrated multidisciplinary effort, which is unfeasible in physiotherapy practice [9]. However, even in the for-physiotherapy-practice developed framework that takes the extremely limited time into account, some therapists felt they had no time to apply it during their sessions [4].

Considering the combination of the required multidisciplinary effort, the extensive training time, and the lack of treatment time in physiotherapy practice, it is understandable why patients are less involved in the goal-setting process than clinical guidelines advise [30] [4]. This leads to the question of how these barriers can be addressed to deliver the patient-centered care that is becoming increasingly important in physiotherapy [1], which is explored next.

2.3 Challenges and opportunities in facilitating patient-led goal-setting through mobile technology

One promising solution may be using mobile technology to guide patients through a structured goal-setting process. Mobile technology is a term that includes a wide variety of devices. There are wearable devices, laptops, apps, and medical treatment devices, among many others. Mobile technology in this context primarily means a device that patients own on which programmable software can be deployed and used. The most prominent format would be mobile apps, but the explanation is kept more general to not (yet) restrict the solution space to apps.

Mobile technology can be used outside of the treatment time by the patient, potentially saving valuable treatment time. And if a technology can be used independently by patients through the implementation of a structured goal-setting process, less training for therapists would be needed [14] and a structured approach to the goal-setting could always be followed [14].

On the flip side, when patients independently use technology outside treatment time, the therapist cannot give immediate suggestions and adjustments concerning which goals are attainable.

But just because the patients use the technology independently to set treatment goals does not mean that the therapist is not involved in this process at all. In a physiotherapy setting, a realistic time to use such a technology could be after the first and before the second treatment session because it may be difficult to expect from patients that they already spend significant time with technology before meeting their therapist for the first time. The therapist, therefore, already knows the patient and may be able to set some parameters that tailor the goal-setting process of the technology. Likewise, after the patient has set a goal independently, the therapist can discuss the goal in the next session and adapt it when needed. This opens up a shared decision-making time point, which has been found helpful for both patients and therapists in the goal-setting process [37].

The existence of workbooks that guide the goal-setting process [38] raises the question of why technology should be used for this. Software-based technology can store and organize data related to patients´ goals and progress effectively, which may positively impact decision-making during therapy. Workbooks are printed on paper. This means that a patient always needs to carry around these documents in order to work on them. With an app, in contrast, patients can access it anywhere. Another drawback of workbooks is the lack of personalization. With a workbook, every piece of information is always displayed, while technology can selectively show information if it is suitable for that particular user. This means that the experience for a user can be tailored to patients´ needs and preferences. How information is displayed can also be more flexible based on users' preferences. Some patients may prefer textual information. Others prefer visual images as used by Tomori et al. [37].

A very important advantage of technology over paper-based workbooks is increased accessibility for disabled patients. In modern apps, it is possible to increase the font size, enable a color-blind mode, and use screen readers to help to digest and navigate through the presented information, which is not possible with paper-based workbooks.

Lastly, software can also facilitate patient-to-therapist communication by enabling the patient to ask questions, which can be answered asynchronously.

These are the immediate advantages of technology over workbooks during the goal-setting process. Many potential benefits are noteworthy but not central during the goal-setting process. To name some, clinicians could track what goals their patients have set. Patients can be reminded through notifications about their goals, and technology might support not only the goal-setting process but also the process of achieving and monitoring progress toward the goal. To conclude, software-based technology can open up a new paradigm of collaboration between patient and therapist, where there are almost endless possible promising features to explore, investigate, and evaluate.

2.4 Previous studies on goal-setting through mobile technology in physiotherapy

Several studies have investigated the use of technology to facilitate goal-setting. The section highlights the most relevant works. First, the main findings of a scoping review by Strubbia et. al [39] will be presented to give an overview of the characteristics of existing technologies that facilitate goal-setting. Afterward, details of selected works will be elaborated on to understand how the specific technology facilitated the goal setting.

Strubbia et al. investigated 16 different technologies, 9 were mobile apps, 5 were websites, and 4 were a hybrid of website and app [39]. 12 of of 16 technologies were disease-specific, and all technologies were applied in a rehabilitation setting [39]. For 9 of the technologies, the patient has chosen the goal. For five technologies, a shared decision moment was possible, and for the other 4, the goals were either set automatically or could be chosen from a list [39]. Although this also represents the guidelines that goal setting should be patient-centered [1], most goals in those studies were measured with and based on the step count of a patient [39]. This leaves some ambiguity concerning the degree to which patients could choose their goals, as the primary goal of some patients may differ from increasing their physical activity. Nevertheless, increasing physical activity is essential to rehabilitating many conditions [40]. This gets important later in this work when developing a prototype.

The following sections explore a few technologies in more detail. However, because they all have been developed for a rehabilitation context for specific illnesses, the focus is on how they implemented the goal setting rather than on the treatment outcomes the technology achieved for that particular injury. The purpose is to identify promising concepts that are also applicable to physiotherapy, which in turn will act as inspiration for the interaction concept of this work.

RESTORE, a web-based resource to support self-management

Foster et al. [41] developed a self-managing web intervention to manage cancer-related fatigue (CRF). The main aim was to increase self-efficacy, making the study also relevant to physiotherapy because self-efficacy is an important predictor for treatment adherence [8] and one of the primary outcomes of patient-led goal setting [25]. Their intervention was based on Bandura´s theory of self-efficacy [42]. They applied behavioral techniques in 5 different phases to try to increase self-efficacy. The first session consisted of basic information about CRF. In the second session, participants were educated about SMART goal setting and how to apply them. During the rest of the sessions, the impact of the disease on work and home life, managing thoughts and feelings, and talking to others were explained, and how goal-setting might help this area. What stands out from this intervention is that patients had many options to learn about goal-setting and their disease. The goal-setting process was explained on the web page, additional written resources were linked, patient stories were available, and even YouTube videos were linked [41]. After each learning module, patients were prompted to set a goal. Unfortunately, more details were not reported. It would be interesting to know whether the system somehow ensured that the goals were shaped according to the SMART structure. When they logged in again and a week passed, they could report whether they achieved their goal. Subsequently, they were either presented with a congratulatory message or were suggested to take some time to reflect on the outcome they wanted to achieve and then set new goals. In an RCT that followed, with 85 participants, no statistically significant differences in any outcome could be observed [43]. Furthermore, dropout rates were also reported to be higher than usual, which the authors attribute to the chronic nature of the condition, loss of interest, and salient content inherent to web-based interventions [43]. A potential disadvantage of this intervention may be that although a lot of information concerning SMART goals is available to the patient, the patient, in the end, had to independently write the goal down without a clear set structure, which may result in the ambiguity of whether the plan represents the SMART components.

Aid for Decision-making in Occupation Choice

Another tablet-based software, Aid for Decision-making in Occupation Choice (ADOC), was developed by Tomori et al. [37]. This iPad application facilitates finding goal areas with shared decision-making between patient and therapist. It is intended to be used during a treatment session in occupational therapy. From 94 images showing a selected range of activities, the patient and therapist each select items important to them. When both have chosen their activities, they discuss and agree on the five most important ones. Afterward, each item is placed on a 2D importance-urgency matrix. And the patient rates the satisfaction of engaging with each of the selected activities. Based on these results, the therapist can document goals and plans in a text box for each activity in the app. This file is then printed out and handed to the patient. The intervention was perceived positively by patients and therapists. 90% of patients stated that they could give their opinions and preferences using the system [37] and over 90% of therapists noted that this tool would be helpful in their clinical practice [37].

The strength of this system was the interesting approach to narrowing down important goal areas by selecting images of activities, agreeing with the therapist on the most important ones, and then identifying the most relevant ones. This systematic approach also allows adding other activities not listed by the application, further supporting patient-centered care. This concept of identifying relevant activities and ranking them on an importance-urgency matrix will be used later as a basis for the prototype in this work. However, once activities important to the patient are identified, the goals still have to be formulated, and the system does not support doing that. The goal formulation has to be done without any structure, a simple text field is given to insert the goal. Furthermore, the treatment plan must be written on the iPad, which might be cumbersome for the therapist and takes time. The authors motivate the system with time-saving, taking about 30 minutes to complete. Thirty minutes of treatment time is precious in any therapy, but especially in physiotherapy, where the treatment time is extremely limited. The components of selecting relevant goal areas of this intervention will be used as inspiration later in the design phase. Nevertheless, possibilities will be explored to take up less treatment time.

Self-management app for spinal cord injury

Mortenson et al. developed a self-management app for spinal cord injury patients for guidance after being released from the hospital [44]. This app has many different tools, but the relevant component of this work is the goal-setting feature. Clinical experts being interviewed stated that self-monitoring is a necessary feature of goal identification [44]. If an app monitors some aspect of the therapy, patients should be able to set goals according to that, and the app can show the progress towards that goal because it is tracking that aspect. They gave a bower or bladder as an example in their use case. In this work, if an app delivers the home exercise plan digitally and tracks when exercises are done, patients could set goals relating to exercise adherence.

They implemented goal setting by defining the goal for a specific aspect of the therapy, emptying the bladder X times a day. The patient had no choice of changing this goal but could decide between three options on the exact number of times they aim to go to the toilet that day. The same was also done with drinking water. This is an interesting mix of prescribing goals that are useful for the therapy and giving the patient some freedom concerning the difficulty of the goal. In the physiotherapy context, this concept could be applied to exercise adherence. Although it may not be the primary motivation of patients to do their exercises (they want to get rid of their symptoms and do activities), it is an essential part of the therapy. Therefore, a goal could prescribe to try to do exercises X times during the next week, and the patient decides on the difficulty of that goal. Of course, every option available should still benefit the therapy. Setting the goal to do the exercises 0 times during the next week would be counterproductive.

An app that was developed by Hartzler et al. to facilitate self-management for chronic conditions implemented goal setting in a similar way [45]. The app had fixed goals, for example, achieving a step count a day, but let the patient decide between 3 options on the difficulty. When patients reported their progress, they could say they did achieve it, did not, or almost achieved it. Afterward, they were prompted to report how tired they were. At the end of a week, based on their performance and goal achievement, the patients were asked whether they wanted the goal to be more challenging or stay the same in case they achieved their goal.

2.5 Summary of key findings

It is clear from evidence and guidelines that patients should be involved in a goal-setting process [2] [1] that is structured [30]. This increases treatment adherence, satisfaction with the therapy [6] [7], and self-efficacy [25]. However, current approaches do not achieve this goal [4] [5] because of a lack of time [12] and training [13], or communication and resources issues [12]. To overcome these challenges, mobile technology might be a promising solution because it can potentially save treatment time and employ a structured goal-setting approach without requiring much training for the therapist. Several interventions have used mobile technology to support a structured goal-setting process in rehabilitation. Each of the interventions has promising concepts that will partly inspire this work's interaction concept.

Chapter 3

Methodology

Goal-setting in physiotherapy is complex, and there is no straightforward approach to designing a technology that supports this process. A Research through Design (RtD) approach is taken to explore the possibilities and share the insights gained during the development, which will be explained in section 3.1. To give the research more structure, the Double Diamond model [46] is applied. In each of the phases, several research methods were employed. An overview will be given in section 3.2.

3.1 Research through Design

A Research through Design (RtD) approach was applied throughout this work. Research through design is an approach to doing research coined by Christopher Frayling in 1993 [47]. Its purpose is to generate new knowledge by applying methods of design practice. This contrasts standard design practices where the goal is a product or artifact. In RtD, it is important to document the artifact produced and the processes and rationales for the decisions taken throughout the research work [48]. This enables other researchers to build upon the knowledge gained.

To give more structure to the implementation of the RtD approach, the Double Diamond design process was applied.

3.2 Double Diamond model

The Double Diamond model 3.1 is an established framework by the UK design council to guide the process of design projects [49]. It is based on the idea of divergence and convergence applied to both the problem and solution space. In the discovery phase, the context of the problem is explored. Much data is gathered at this stage, and there is no clear problem statement yet. This changes in the definition stage, where all the data is managed, organized, and filtered, such that at the end of the stage, there is a clear problem statement defined. In the development stage, the design process starts. Here, design and development methods can be employed to

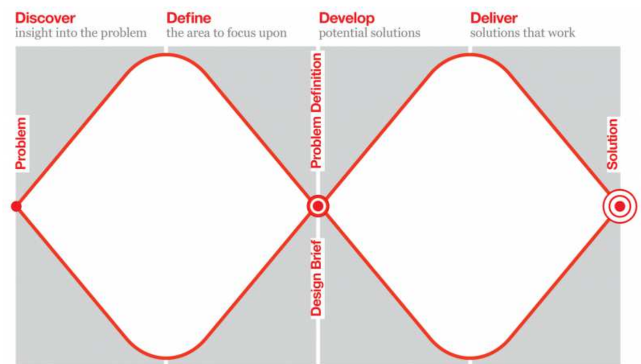

Figure 3.1: The Double Diamond model by the UK design council [46]

draft prototypes. Noteworthy is that patients can and should already be included in this stage. And finally, in the delivery stage, the prototype is tested by users and then launched or finished depending on the project. Although this explanation suggests a linear approach, each phase may be iterative, and it is also possible to go back and forth between stages if new knowledge suggests it. New knowledge in a certain stage might also lead back to the discovery stage. The following sections describe the employed research and design methods in each phase.

Discover phase

The whole research process started before this work during the research topics project. The issue at hand was that rehabilitation and exercise compliance rates in physiotherapy were low, with estimates ranging from 30-50% [8] [27] [50]. This may lead to chronification of the symptoms [27], unnecessary change of the therapy [27], frustration for the therapist [51], increase risk of re-injury [8], and a decrease in long term outcomes [8]. A literature synthesis investigated facilitators and barriers to exercise compliance during the research topics. The most prevalent predictors for low exercise compliance were low physical activity at baseline [8] [52], low self-efficacy [8] [53] [54], anxiety/helplessness/stress [8][52], a greater number of perceived barriers [8], and low social support [8][52][55].

In the next step, successful strategies and behavior change techniques (BCTs) were identified to increase exercise adherence. BCTs are small, active ingredients of behavior change interventions [56]. Strategies included helping patients to understand pain [57] [55] and providing clear verbal & written instructions [58]. Promising BCTs were (patient-led) goal setting [59][60], behavioral contracts [59], self-monitoring [59], social support [59][55], rewards [59], reminders [59], feedback [59] [55], and instruction [58][55].

The research topic's work gave insight into many different directions to potentially investigate in this thesis, which is exactly the goal of the discovery phase.

Define

The define phase aims to arrive at a final problem definition. In this work, the final problem definition is the defined research question based on the results of the research topics. The goal was to identify one promising concept, that is suitable for generating knowledge through investigating and iteratively developing a solution prototype. To generate new knowledge, it was also important to find an area with a knowledge gap in related work.

This was an iterative process where abstracts for different topics, including gamification, goal-setting, and social support, were formulated, and their pros and cons were discussed. Goal-setting was the domain chosen for which a relevant research question had to be developed. Although the initial ambition was to evaluate the effectiveness of some to-be-developed intervention, from discussions it got clear that this would entail a longer-term study, not realistic to conduct within the same work as the development of a potential solution. Thus, the focus was set on research questions that can be answered without conducting a long-term effectiveness study.

As elaborated on in the related work section, the literature points to a lack of patient involvement during goal-setting activities, which was taken as the main focus area of this work. After multiple iterations, the final research question has been formulated to investigate how mobile technology can facilitate patient-led goal-setting.

Develop

The development phase started with having an extensive account of the literature on the problem space. To integrate users as early as possible in the development process, a formative survey was conducted with patients to gain insight into which parts of the goal-setting process are especially important to focus on while prototyping and learn from solutions that they had used previously. Moreover, it was investigated to what extent the SMART components were represented to compare later when evaluating it against patients using the final prototype. The main insight from the survey, in which ten patients participated, was that most of the goals lacked the timely aspect of the SMART components. Table 3.1 gives an overview of all the applied evaluation methods during this work.

Then, a theory-driven approach was taken to develop the initial interaction concept. The Behavior Change Wheel (BCW) by Mitchie et al. [61] was used to identify promising components of the solution and how they should be implemented. The BCW and its process are detailed in section 4.2. The results of the BCW were integrated with the Goal Setting and Action Planning (G-AP) framework shown in figure 4.3, which has been developed to employ a patient-centered goal-setting practice in a healthcare setting [9]. Moreover, promising concepts from related works have also inspired components of the initial interaction concept.

The resulting interaction concept explained in detail in section 4.4, was translated to a low-fidelity horizontal wireframe. What followed were two iterations with physiotherapy experts to improve the wireframe. First, a physiotherapy student spent significant time (3-5 hours) understanding and evaluating the wireframe, which was discussed in a two-hour feedback session.

The main improvement was to not only shape the short-term goal according to the SMART components but also the long-term goal. The complete results are discussed in section 5.1. The wireframe was improved based on the feedback and then evaluated again by an experienced physiotherapist. The most relevant improvement was that the short-term goals had to be changed to be more distinct. This resulted in the final wireframe being implemented into a mid-fidelity mobile app afterward.

Deliver

The final evaluation was initially planned only to feature the patient and therapist's perspectives. However, while contacting therapists, the opportunity arose to present the app to a course of physiotherapy students and formulate an assignment for them to work on. The final evaluation was thus three-fold: A patient user test, two physiotherapy expert interviews, and an assignment with the physiotherapy students.

The main goal of the patient user test was to assess to which degree the SMART components were present when using the prototype to set treatment goals and whether patients would like to use such a system in their therapy. For the two expert interviews, the goal was to assess whether the interaction concept as it was developed was missing crucial steps and which role in clinical practice such technology can take.

The unique opportunity of presenting the app to the student course was that the professor wanted the students to actively engage with the technology and teach them how they, as physiotherapists, can contribute to developing a technology. So, there was a big leverage in getting feedback from many people compared to doing interviews.

Thus, the collaboration was structured in two parts. In the first session, the concept and the app were presented. Then, the students received an assignment where they tested the app and suggested improvements. These improvements were collected with a short survey to assess the concept's viability further. In a second session, the improvements were discussed.

Table 3.1: Overview of evaluation methods

Evaluation Step	**Project phase**	**Goal of research method**	**Participants**
Formative survey	Research phase	Investigate to which degree patients are involved in goal setting process during their therapy and how much SMART components are represented in patients' goals	Patients (n = 10)
In-Depth concept evaluation	Development phase	Improve interaction concept	Physiotherapy student (n = 1)
Expert interview	Development phase	Improve interaction concept	Physiotherapy practice owner (n = 1)
Patient user test	Final evaluation	Investigate to which degree patients are involved in goal setting process using the prototype and how much SMART components are represented in patients' goals	Patients (n = 8); some overlap with formative study
Physiotherapy student evaluation	Final evaluation	Identify components of the concept that should be improved, identify potentially useful new components, and assess the usability of the prototype	Physiotherapy students (n = 8)
Expert interviews	Final evaluation	Evaluate whether the prototype misses essential steps or components during the goal-setting process, what role such technology may have in clinical practice, and for which kind of patient it is useful	Physiotherapy professors (n = 2)

Chapter 4

Development of the interaction concept

This chapter describes the development of the interaction concept. It first explains the choice of the Behavior Change Wheel as the theoretical basis for the concept. Afterward, each step of applying the theoretical framework to the problem definition is described. Finally, the developed interaction concept is presented.

4.1 Theoretical basis

To develop initial prototypes, it is advised to follow a theoretically grounded approach [62]. Or, in other words, to use an appropriate behavior change theory to guide the intervention design. Numerous behavior change theories explain how behavior might be changed. Davis et al. [63] identified 59 different theories in the health domain. The most prominent are the theory of planned behavior and reasoned action, the transtheoretical model, and the health belief model. Deciding on the most appropriate theory is the first challenging task since choosing an unsuitable one might lead to an ineffective intervention [63].

In a systematic search, Michie et al. [64] analyzed behavior change intervention frameworks for comprehensiveness, coherence, and a clear link to an overarching behavior model. They found that no single framework was comprehensive and that their focus differed from each other. Some focused on the social environment, some on beliefs and perception [64]. The authors emphasize that individual frameworks are important, but they need to be brought together, which they try to do by proposing their framework synthesized from 19 frameworks [64]. It is named The Behavior Change Wheel (BCW), and it is the theoretical basis for this work. Apart from the authors claiming the framework to be comprehensible, they claim it to be sufficiently broad to apply to any behavior in any setting [64]. Furthermore, they also published a book on this framework, which guides intervention design through every of their proposed steps [61]. A review found that only 10% of studies that claim to be theoretically driven report the links between the theoretical constructs and behavior change techniques [65]. By following the guide of the authors, the link between theoretical constructs and design decisions will be documented, in accordance with a Research through Design approach. Moreover, it decreases the likelihood that the framework is falsely used, which is one reason for ineffective interventions [63].

Before applying the framework to the research question, the main components of the BCW are explained.

4.2 The Behavior Change Wheel

Figure 4.1 shows the Behavior Change Wheel. The COM-B model lies in the inner circle of the BCW, and it addresses the interaction between capability, opportunity, and motivation as sources of behavior. A person must have the capability to perform a desired behavior, which could mean strength, knowledge, or skills. Then, there must be an opportunity in the environment to perform the desired behavior. This could mean that a behavior is socially acceptable, that the person has time, and that it is affordable. And finally, a person must have the motivation to do the target behavior over not doing it or doing competing behaviors. The COM-B model aims to identify target areas of the intervention that seem promising to address the respective issue.

The theoretical domains framework (TDF) [66] can be used as an intermediate layer on top of the COM-B model [67]. It proposes 14 different domains and 84 constructs to understand further the target behavior that needs to change. The intermediate layer, intervention functions, proposes options for addressing the identified target areas from the COM-B analysis. The authors propose a two-step process to choose from the different intervention options. First, evidence suggests intervention functions that fit certain outcomes of the COM-B analysis. Second, to apply the APEASE criteria Affordability, Practicability, Effectiveness & Cost-effectiveness, Acceptability, Safety, and Equity [64]. This ensures that the intervention can realistically be carried out and not stay as a concept. And finally, on the outer circle, policy categories determine how the intervention may be delivered. This layer is less relevant to this project because there is insufficient influence to determine policies.

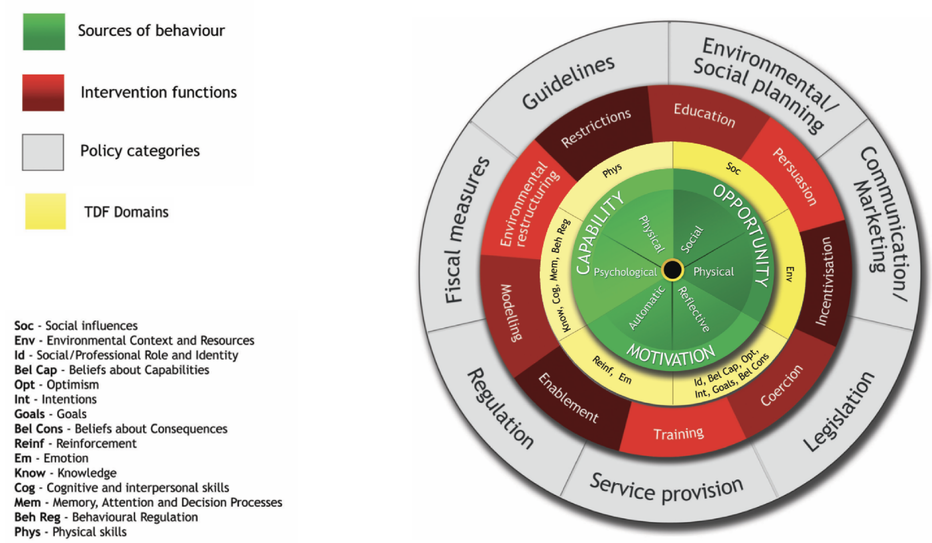

Figure 4.1: The Behavior Change Wheel [61]

4.3 Stages of the intervention design according to the BCW

1. Define the problem in behavioral terms
The first stage is concerned with understanding the target behavior. And as a first step, the problem has to be defined in behavioral terms. As mentioned earlier, goal setting is an essential part of physiotherapy [3], and patients should be included in this process [1], which happens not frequently enough [4] [5]. Thus, the challenge is to employ a goal-setting process in physiotherapy that is patient-centered.

The authors guide intervention design in three stages and eight steps, also shown in figure 4.2. This section guides the reader through each of the proposed steps. The worksheets for this section's foundation can be found in the Annex.

2. Select the target behavior
The guide proposes to generate a long list of potential target behaviors that may bring the desired output. Then, the candidates are prioritized by the impact of behavior on the outcome, the likelihood of behavior change, the likelihood to affect other positive, related behaviors, and ease of measurement. For this work, since using technology was already part of the research questions, some of the possible candidates identified were obsolete. They were nevertheless assessed to still be open-minded about other options.

Some candidates were: Giving goal-setting worksheets as homework for patients; using technology that employs a structured goal-setting process used outside treatment time; using technology that facilitates shared decision-making while agreeing on goals; educating therapists on how to include patients in goal setting, among other options. The full worksheet can be found in the Annex. The outcome of this exercise was that using technology that employs a structured goal-setting process used outside treatment time was the most promising option. The impact of behavior change was rated very promising, and the other three criteria, the likelihood of changing behavior, spillover score, and measurement score, were rated promising.

3. Specify the target behavior
Next, the target behavior is analyzed in more detail by describing who needs to do what, when, where, how often, and with whom. Since, in this context, therapist and patient are involved, these questions are answered for both. The therapist (who) needs to introduce the technology to the patient (what) at the end of the first treatment session (when), in their treatment facility (where), once for every patient (how often), and with their patient (with whom). The answers to these questions are straightforward except for when the introduction should happen. Ideally, the first treatment goals should be set at the beginning of the treatment. An option that would be interesting to explore is to have the patient use the technology before the first treatment session because the technology could already set a foundation that the therapist could work from. However, it might be difficult to reach patients before the first treatment session and convince them to use a specific technology. Therefore, the earliest point in time is after the first treatment session.

Concerning the patient (who) side, it is required to spend time outside of the treatment sessions (what)

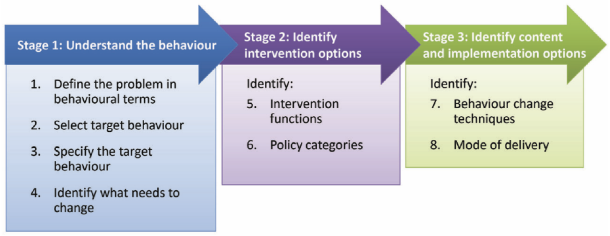

Figure 4.2: Stages of the application of the BCW [61]

after the first treatment session (when), at home or somewhere where they are undisturbed (where), alone or with a supporting person if needed (with whom). Initially, they need to spend time once and then spend time again to review and set new goals, depending on the goal intervals (how often).

4. Identify what needs to change

A COM-B analysis is performed to identify what behavior needs to change for the target behavior (using technology that employs a structured goal-setting process used outside treatment time) to occur. For each of the components physical & psychological capability, physical & social opportunity, and reflective & automatic motivation, it is considered what needs to happen for the target behavior to occur and whether there is a need for change. Furthermore, the Theoretical Domains Framework (TDF) is used to specify each COM-B model component further. The worksheets for each step can be found in the Annex. Table 4.1 gives an overview of the links between relevant COM-B components, the respective TDF domain, and the relevance of that domain. The following section will discuss the relevance of each COM-B component.

Physical capability. Patients and therapists do need the physical skills to use a mobile phone. Many physiotherapy patients are old, raising the question of whether such patients could use an app or even own a smartphone. A survey showed that 41% of 65-year-old or older people use smartphones [68]. Thus, the kind of patients the technology will apply to concerning technological competence is limited. Furthermore, these older user groups' characteristics should be considered later in the design process. For example, patients with visual impairments should have accessibility features to make using the app easier. However, from a behavior change perspective, change is unnecessary.

Psychological Capability. There are numerous requirements to apply an effective goal-setting process for the patient. Concerning the TDF domain knowledge, the patient needs to know the purpose of goal setting, which is to increase treatment outcomes [23] [24], self-efficacy [25], and adherence to the home exercise plan [25]. A study found that it is not always clear to patients what is expected of them during the goal-setting process [12]. Moreover, a barrier or facilitator of using e-health technology is the understanding of the benefits of that technology [69]. Also, some patients may rely on the health professional to direct the rehabilitation planning [39].

Furthermore, patients need to know how to apply goal setting effectively and how goals should be formulated. In their study, Baker et al. concluded that patients [and therapists] need to be educated on effective methods for patient-focused goal setting [70].

And as the last identified concern in the knowledge domain, patients need to understand what a suitable goal for them is. In an analysis of the goal-setting process within physiotherapy, patients had difficulty stating a goal because they did not know what an achievable goal is [21].

Another relevant domain is behavioral regulation. As a patient-centered goal-setting process should include iterative phases of goal negotiation, goal-setting, action planning, and review [30], patients need to get into the habit of regularly setting goals/action plans and reviewing them.

And clearly, patients need to act according to their set goals to achieve them.

In summary, there is a need for change concerning psychological capability as it cannot be assumed that patients know the benefits and purpose of setting goals and may not know how to set appropriate goals without guidance.

Physical opportunity. The relevant TDF domain within the physical opportunity component is environmental context and resources. First, the environment (e.g. time) can be a barrier to using technology. The user may not have the necessary time to use the technology or may forget to use the app despite the intent to use it. Lack of time is a limiting factor for other relevant components in physiotherapy, for example, goal setting itself [29] and doing the exercises consistently [8]. Thus, it would not be surprising that time is also a barrier to using a technology for patients.

Moreover, the environment (e.g. time) is also a barrier to executing the contents of the goal. This is because a goal might have the content of doing the exercises, which is a barrier [8]. Therefore, there is a need for behavior change.

Social opportunity. Social opportunity relates to the perceived and expected appropriateness of performing the target behavior. First, it must be accepted in the patient's environment to use their smartphone, which is universally given except on very specific occasions. Then, to create more social support, it is useful that patients talk with (ideally supportive) friends and their families about their experience using the

Table 4.1: Links between COM-B, TDF, and intervention function of the BCW

COM-B Component	TDF	Relevance of domain	Evidence to support the need for change	Intervention Functions
Psychological Capability	Knowledge	Patients need to know the purpose of goal setting	"[...] patients may not be fully aware of what is expected of them." [12]; "[...] patients being hesitant to promote their own ideas as they rely on the health professional to direct rehabilitation planning" [39]; "[one factor of using e-health technology is] patient understanding of the benefits of the app." [69]	Education
		Patients need to know how to apply goal setting effectively / how a goal should be formulated	"Patient and therapist education is needed regarding methods for patient participation during initial goal-setting activities." [70]	Education
		Patient needs to understand what a suitable goal is.	"Patients' difficulties with stating a goal are related to patients' knowledge to propose a goal" [21]; patients may not know what an achievable goal is [21].	Education
	Behavioral regulation	Patients need to get into the habit of regularly setting goals	"Person-centered goal-setting should [...] include components of goal negotiation, goal-setting, action planning, and review." [30]	Education, Enablement
		Patient needs to act accordingly to achieve the goals set	"Patient's desire to pursue goals and modify as needed [facilitates goal achievement]." [71]	Education, Enablement
Physical opportunity	Environmental context and resources	Environment (e.g. time) may be a barrier to using technology; patients need to accept and commit to using it.	Time is a factor that can act as a barrier to goal setting [29].	Environmental restructuring, Enablement
		Environment may be a barrier to the contents of the goal (i.e. doing exercises) — the patient needs to create an appropriate environment.	"Barriers to doing exercises consistently include transportation problems, child care needs, work schedules, lack of time." [8];	Environmental restructuring, Enablement
Reflective motivation	Beliefs about capabilities	Patient needs to trust that they can set appropriate goals with the technology	"[...] its design and interface need to be user-friendly and in line with physiotherapists' and patients' expectations and everyday practice." [69]	Education, Persuasion, Enablement
		Self-efficacy that they can achieve the goals set.	A review found that theory-based motivational interventions [...] increase adherence through an increase in self-efficacy [72]. Low self-efficacy is a barrier to treatment compliance [8].	Education, Persuasion, Enablement
	Beliefs about consequences	Patient needs to acknowledge that they need to be actively involved within the therapy	"[Lack of patient involvement in goal setting may be due to a] lack of patient interest in participating." [39]	Education Persuasion
		Patients need to believe that their actions have a positive impact on the treatment	Exercise compliance is low [8] leading to decreased clinical outcomes [8], higher risk of re-injury [8], and chronification of symptoms [27]. [among other consequences]	Education Persuasion
Automatic motivation	Reinforcement	Patients need to develop a habit of setting a goal, working towards them, and evaluating it	"Person-centered goal-setting should [...] include components of goal negotiation, goal-setting, action planning, and review." [30]	Environmental restructuring
		Patients need to develop a habit of working towards the goal		Environmental restructuring

technology. However, this may happen automatically if patients like the technology, and changing the social environment in this aspect is unrealistic in this project's scope.

Reflective motivation. The first TDF domain concerning reflective motivation is beliefs about capabilities. Patients need to trust that they can set appropriate goals with the technology. Perceived usefulness by patients influences the uptake of e-health technology [69]. And the technology needs to be in line according to patients' expectations, which is to set useful goals with a technology claiming to support goal-setting [73].

Furthermore, patients need self-efficacy to achieve their goals. Self-efficacy is one of the most important barriers and facilitators of treatment compliance [8], and was identified as the reason for effectiveness in theory-based motivational interventions [72].

The second relevant TDF domain is beliefs about consequences. First, patients need to acknowledge that being actively involved in the therapy is important. A study found that a lack of patient involvement may be due to a lack of patient interest in participating [14]. Understanding the importance might also increase patient interest and, thus, participation. Change is needed in this regard, as some patients think that they do not need to be actively involved and that it is the therapist's responsibility to heal them [74] [75].

Second, patients need to believe that their actions have a positive impact on the outcomes of the treatment. Evidence is pretty clear in the detrimental effects of non-compliance. Non-adherence to the exercise plans leads to decreased clinical outcomes [8], higher risk of reinjury [8], and chronification of symptoms [27] (among other consequences). Although some patients may already understand that their actions positively impact the treatment, highlighting this aspect might still be useful as it may further increase motivation. For patients who do not currently understand this, change is highly needed as the participation of patients is the foundation of the technology.

Automatic motivation. Concerning automatic motivation, the TDF domain reinforcement is relevant. Patients need to develop a habit of setting goals, working towards them, and evaluating them, as these phases should be included in patient-led goal-setting [30]. Change is needed since the technology is supposed to be used at the start of a therapy, where this goal-setting habit has not been established.

Concluding the analysis, the COM-B components of automatic motivation, reflective motivation, physical opportunity, and psychological capability need to change for patients to use technology that guides goal-setting.

5. Identify intervention functions

In 2007, NICE (National Institute for Health and Care Excellence) proposed evidence-based principles for behavior change, such as 'Develop specific plans to change' among many others [76]. The authors of the BCW abstract from these concrete guidelines to identify nine intervention functions, each describing a broad category of actions by which an intervention can change behavior. The functions are education, persuasion, incentivization, coercion, training, restriction, environmental restructuring, modeling, and enablement. Intervention designers use behavior change theories to help decide which function to use. In their systematic review [61], Susan et al. evaluated individual theories as having varying levels of comprehensiveness, coherence, and theoretical base. Thus, from their analysis, they synthesized the BCW from 19 behavior change theories, which links the intervention functions and policy categories to the COM-B components. The intervention functions are defined in the table 4.2, reproduced with permission from the authors [61], which also gives an overview of the rating for each function.

The following section evaluates each intervention function based on the APEASE criteria affordability, practicability, effectiveness and cost-effectiveness, acceptability, side-effects/safety, and equity, as suggested by the authors. To shorten the discussion, the other criteria will not be discussed in detail if one criterion determines the unusable function.

Education. Education fits all criteria well. Of course, it initially takes a lot of resources to determine what to educate about and implement. But once it is implemented, it does not take any resources anymore. Thus, it is cost-effective. Also, there is no limit on how much education can be delivered. Moreover, education components can be implemented step by step, making it affordable. Concerning acceptability, this cannot be evaluated with certainty, but since it is an established practice to receive paper handouts in physiotherapy, receiving information through the smartphone should not be a dealbreaker for patients, although this should be investigated. In general, providing information is safe. But the advice given must not be harmful. Therefore, information should be assessed on possible misinterpretations. Overall, education is an intervention function that fits most criteria well.

Persuasion. Technology can be an effective way of implementing persuasion in healthcare. Apps can provide patients personalized feedback, reminders, and encouragement, which may increase their motivation and adherence to their physiotherapy program. Furthermore, apps can provide real-time patient progress feedback and encourage them to continue working toward their goals.

However, it is important to use persuasion in moderation to maintain credibility and prevent patients from becoming skeptical. Overusing persuasive elements may lead to patients ignoring them altogether or even feeling manipulated, which would be highly undesirable because it might negatively impact the therapist's reputation. Therefore, it is important to balance providing persuasive messages and respecting patients' autonomy and individual needs.

Incentivization. Although incentivization was found to be effective in some health applications [77], it may be challenging to provide meaningful incentives in the context of physiotherapy. Physiotherapy is often a long-term process, and providing immediate rewards that effectively maintain motivation over time may be difficult. Additionally, incentivization can be costly and resource-intensive. Providing meaningful incentives tailored to individual patients' needs and preferences can be challenging and unrealistic to implement in this context.

Coercion. Creating an expectation of punishment or cost is unacceptable from an ethical perspective. Thus, the other criteria do not need to be considered.

Training. Although explicitly training patients to learn how to use the technology effectively might be effective, it is not practicable. Time is already scarce in physiotherapy, so the technology should not require explicit training. Of course, the app should be self-explanatory and guide users through each step, but that is different from the training mentioned here.

Restriction. From the ethical perspective, it is questionable whether hard-defined rules should be placed upon physiotherapy patients, especially from the technology that is separate from the therapist. If the patient and therapist agree on "rules" that act as behavior guidelines, that is acceptable and may be useful in some cases. Furthermore, technology is in no position to impose such rules. Moreover, it is also unable to ensure the rules are followed.

Environmental restructuring. Environmental restructuring has several promising benefits. First, it can be a practical and affordable way to support behavior change. For example, putting post-its on the kitchen table to remind them to do the exercises can be a way to further influence behavior beyond the smartphone. Additionally, environmental changes can be long-lasting, providing ongoing support for patients even after their treatment has ended and when the technology is not used anymore.

It is important to note that the technology cannot do the restructuring efforts alone. But it can stimulate restructuring through prompts, which would also be cost-efficient and affordable. Another important part is that the restructuring efforts are individualized to the patient's needs. Overall, environmental restructuring is a promising intervention for supporting behavior change in physiotherapy patients.

Modelling. Modeling can be an effective way to increase patient motivation and self-efficacy [72]. By providing examples of how the technology helped patients stay active and compliant, therapists can help patients feel more confident in their ability to achieve their own goals. Modeling may also be an effective way to promote equity and accessibility. By providing patients with successful outcomes from individuals with similar backgrounds or circumstances, therapists can help demonstrate that physiotherapy is also a feasible and achievable option for them. However, modeling is not practicable in this context because there are no past success stories to show yet.

Enablement. By providing patients with the knowledge and skills they need to manage their condition and perform their exercises, therapists can help patients to feel more in control of their health and more confident in their ability to make positive changes. Additionally, enablement can help to promote long-term behavior change by empowering patients to take an active role in managing their condition. By providing patients with the tools and support they need to manage their condition independently, healthcare providers can help to foster a sense of ownership and responsibility for their health. This is also practicable and affordable as the technology intends to take this role.

6. Identify policy categories

Besides intervention functions, there are also policy categories that have been identified to support the intervention. However, the policies communication, guidelines, fiscal measures, regulation, legislation, environmental/social planning, and service provision must be applied by authorities. Therefore, this step will be skipped in this work because the measures can not be implemented.

7. Identify behavior change techniques

One of the final steps of the BCW is to select the suitable BCT that will be implemented. The process is the following. For each intervention function, there is a list of identified useful BCTs and a list of the most commonly used ones. The authors of the BCW wheel created these lists through an expert consensus exercise [61].

To identify the BCTs to be applied in this work, each BCT of the selected intervention functions from the most-commonly-used list was assessed based on the APEASE criteria and then decided whether to include it. Then, individual BCTs were picked for the rest of the potentially useful BCTs if they seemed very promising in physiotherapy goal-setting. The full worksheet can be found in the Annex. This step also includes how the respective BCT will be applied. The following section presents the chosen BCTs and how they will potentially be implemented.

Table 4.2: Intervention functions and their APEASE rating, definitions taken from [61]

Intervention function	Definition	Example of intervention function	Affordability	Practicability	(Cost-) effectiveness	Acceptability	Side-effects / safety	Equity	Total	Selected
Education	Increasing knowledge or understanding	*Providing information to promote healthy eating*	4/5	5/5	4/5	4/5 (?)	4/5	4/5	25/30	yes
Persuasion	Using communication to induce positive or negative feelings or stimulate action	*Using imagery to motivate increases in physical activity*	5/5	5/5	4/5	3/5 (?)	3/5	3/5	23/30	yes
Incentivisation	Creating an expectation of reward	*Using prize draws to induce attempts to stop smoking*	0/5	1/5	2/5	3/5 (?)	3/5	3/5	12/30	no
Coercion	Creating an expectation of punishment or cost	*Raising the financial cost to reduce excessive alcohol consumption*	2/5	0/5	2/5	0/5	1/5	2/5	7/30	no
Training	Imparting skills	*Advanced driver training to increase safe driving*	1/5	1/5	3/5	4/5	4/5	4/5	17/30	no
Restriction	Using rules to reduce the opportunity to engage in the target behavior	*Prohibiting sales of solvents to people under 18 to reduce used for intoxication*	1/5	1/5	2/5	2/5	2/5	3/5	11/30	no
Environmental restructuring	Changing the physical or social context	*Providing on-screen prompts for GPs to ask about smoking behaviour*	4/5	4/5	4/5	4/5 (?)	4/5	4/5	24/30	yes
Modelling	Providing an example for people to aspire to or imitate	*Using TV drama scenes involving safe-sex practices to increase condom use*	2/5	1/5	3/5	3/5 (?)	3/5	4/5	16/30	no
Enablement	Increasing means/reducing barriers to increase capability(beyond education and training) or opportunity(beyond environmental restructuring)	*Behavioural supportfor smoking cessation, medication for cognitive deficits, surgery to reduce obesity, prostheses to promote physical activity*	3/5	4/5	3/5	3/5 (?)	4/5	4/5	21/30	yes

Education

Information about health consequences: The technology provides information about the importance of involvement in therapy outside of the sessions, the importance of actively participating, and how goal setting supports this process.

Feedback on behaviour: The therapist should check during the treatment sessions how the goal setting works for the patient and give feedback. Since the technology is used mainly by the patient, a notification could prompt them to discuss their experience using the technology with their therapist.

Prompts/cues: The technology sends a notification to the user when an action is needed or when it supports the content of a goal.

Self-monitoring of behavior and outcomes: The technology might prompt users to write the most important things down they learned. Or it visually shows the engagement with the technology when opening the software. Considering the outcomes, there should be visual status on how far the user has progressed towards their goal.

Persuasion

Credible source: After the first treatment session, the therapist recommends using the technology with the encouraged task to set a goal till the next treatment session.

Information about health consequences: See education.

Feedback on behaviour: The technology gives feedback on the progress toward the goal and general usage.

Focus on past success: The technologies might prompt the user the reflect on past successes relating to the content of the chosen goal.

Environmental restructuring

Prompts/cues + Restructuring the physical environment: During goal-setting, the technology suggests creating post-its/other types of prompts and putting them visibly in the patient's environment.

Enablement

Goal setting (behavior): The technology guides the patient through the process of setting goals.

Adding objects to the environment: See environmental restructuring.

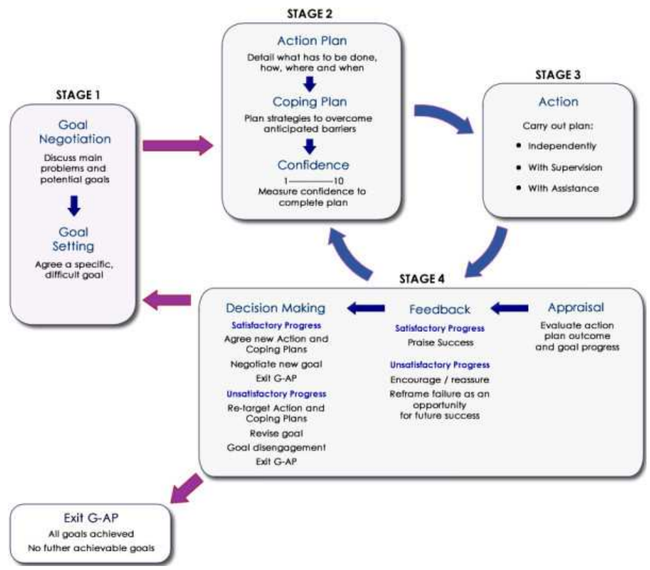

Figure 4.3: Goal setting and action planning framework in a rehabilitation setting [9]

Problem solving + action planning: As part of the goal-setting process, after a goal has been formulated, the patient is prompted to think about critical scenarios and plan what to do in these scenarios.

Self-monitoring of behaviour: The technology shows progress towards the goals.

Restructuring the physical environment: See environmental restructuring.

Review behaviour goal + outcome goal: The technology shows summaries of the achievements toward the progress of the goals.

8. Identify the mode of delivery

This step proposes to discuss through which medium the intervention will be delivered. However, this step is not applicable in this context because it is already decided that it will be delivered through a mobile app.

4.4 The interaction concept for implementation

Following the application of the BCW, a list of BCTs seems promising to increase the likelihood that a technology guiding the goals-setting process will be successfully used in practice. This list prescribes specific features to be included in the implementation. However, it is not sufficient in itself to develop the content of

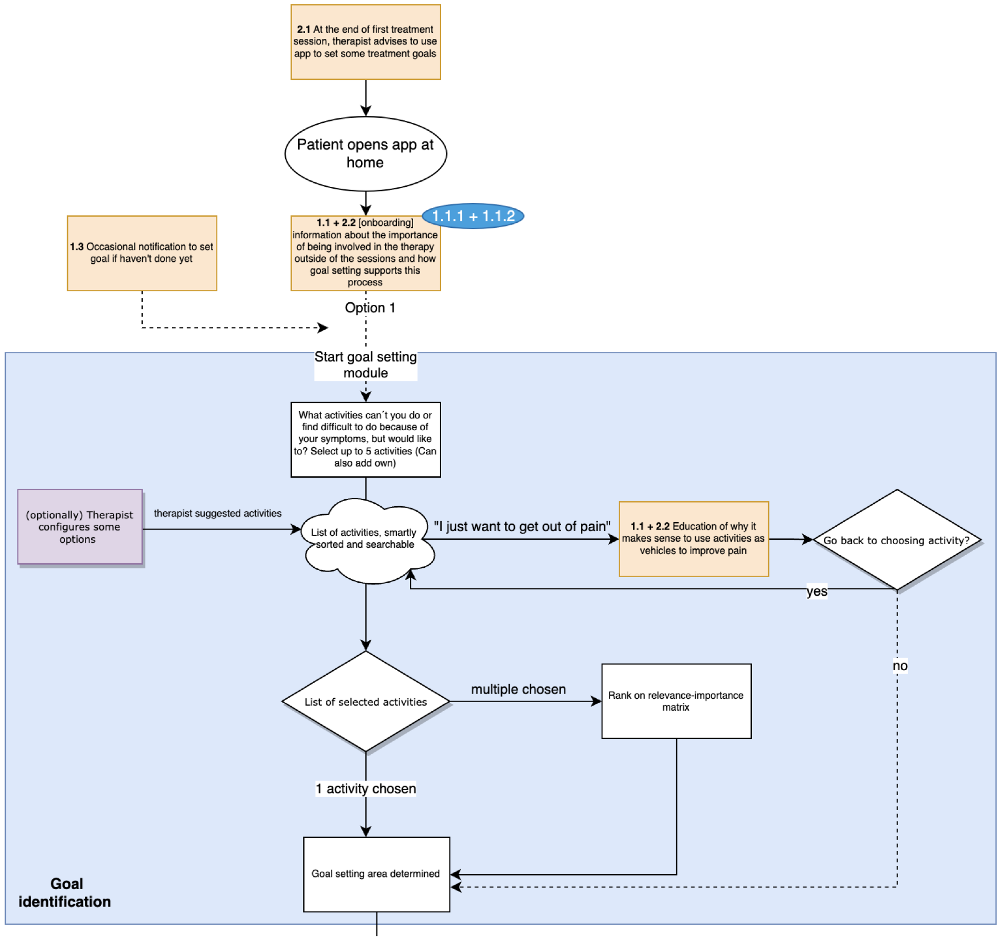

Figure 4.4: Interaction Concept - Step 1: Goal identification

the interaction concept. Thus, the basic structure is based upon the Goal-Setting and Action Planning (G-AP) framework shown in figure 4.3, which has been developed to employ a patient-centered goal-setting practice in a healthcare setting [9].

It is characterized by first negotiating and agreeing on a (long-term) goal. Then an iterative cycle of action & coping planning, an action phase, and a review phase start until all goals are reached. If the long-term goals change, new goals are negotiated.

Although the following concept covers all aspects, the prototype focuses on the first stages of goal negotiating, goal setting, action planning, and coping planning. This is crucial to determining whether such technology might be feasible in practice. The reader will be guided through the concept according to the stages *Goal identification*, *SMART goal formulation*, *Supporting measures*, *Goal review & adaptation*, *Goal identification*, *Home Screen features*.

Before starting, a few clarifications have to be made about the visuals:

- An orange card represents an item that implements a BCT. The number corresponds to the respective BCT in figure 4.6.
- The blue labels reference a prototype screen (shown later), for which multiple options for a specific part or BCT have been implemented.
- The diamond-shaped cards represent points in time where the user has to decide between multiple options.

Step 1: Goal identification

Figure 4.4 visualizes this step of the process. At the end of the first treatment session, the therapist advises using the app to set some treatment goals (BCT: Credible Source). When the patient opens the app at home, they start an onboarding process explaining the importance of involvement in the therapy outside of the sessions and how goal setting supports this process (BCT: Information about health consequences). If the app is installed, but the goal-setting process has not started for a while, the user receives a notification to start the process (BCT: Prompts/Cues).

The first part aims to identify a goal area that acts as the long-term goal area for a patient. A process inspired by the technology presented in the related work

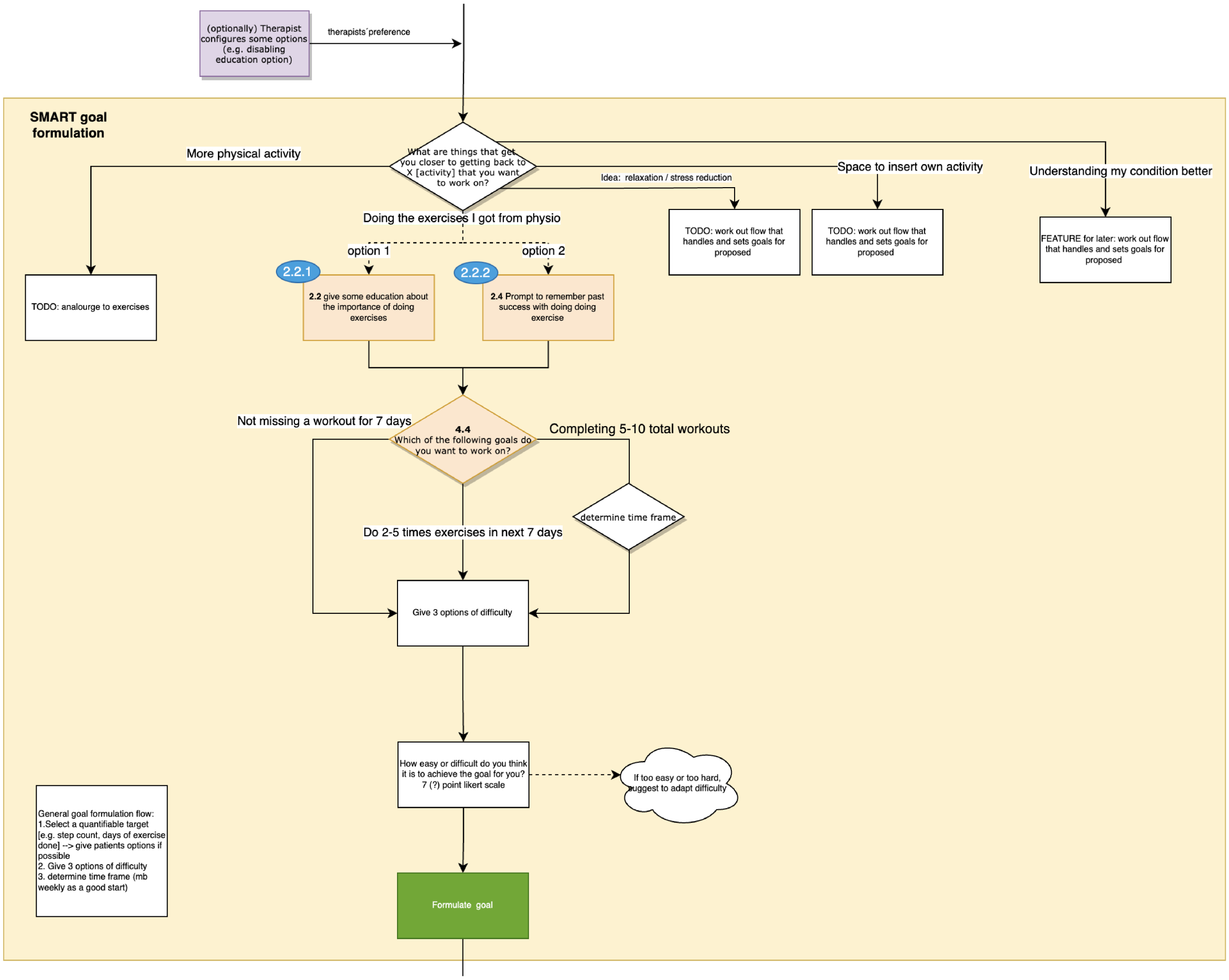

Figure 4.5: Interaction Concept - Step 2: SMART goal formulation

from Tomori et al. [37] was taken to find a relevant area relevant to the patient. First, the patient is asked to select up to 5 activities they cannot do or have difficulty doing because of the symptoms. Optionally, the therapist may suggest some options.

Many patients seek physiotherapy because of pain [78], but a sole focus on pain as a goal is not recommended [3]. In this step, patients can select that they just want to get out of pain. If they choose it over an activity, there will be an explanation of why it makes sense to use activities as vehicles to improve pain (BCT: Information about health consequences). The user can then return to pick one or more activities or continue using pain as their goal-setting area.

If multiple activities are chosen, they are ranked on an importance-urgency matrix, as inspired by Tomori et al. [37]. Then, the user can select the activity that seems most relevant.

Step 2: SMART goal formulation

From the first step, a general goal-setting area has been determined. In step 2, concrete, short-term goals will be determined. The challenge in this step is giving the patient enough space to adapt the goals to their preference. At the same time, consider that there are specific tasks the patient should fulfill, like doing the exercises consistently. Moreover, the goals should be specific to the patient, but the process should apply to a broad range of patients. Furthermore, the structure should lead to a result where the SMART components are represented.

The high-level idea is to provide different action areas that are useful for patients and let them decide which areas they want to work on. The areas are: *Doing the exercises, more physical activity, stress reduction, understanding the condition better and own activity.* While the former three options are generally good for most patients to work on as they are either directly part of the therapy or part of a healthy life, the ladder two options need to be discussed with experts on whether they make sense here. It makes sense to understand the condition better. Still, the wide range of

List of BCTs to implement from BCW

1. Education
    1. Information about health consequences
    2. Feedback on behaviour
    3. Prompts/cues
    4. Self-monitoring of behaviour
2. Persuasion
    1. Credible source
    2. Information about health consequences (--> 1.1)
    3. Feedback on behaviour
    4. Focus on past success
3. Environmental restructuring
    1. Prompts/cues
    2. Restructuring the physical environment
4. Enablement
    1. Goal setting (behaviour)
    2. Adding objects to the environment (--> 3.2)
    3. Problem solving
    4. Action planning
    5. Self-monitoring of behaviour
    6. Restructuring the physical environment (--> 3.2)
    7. Review behaviour goal(s)
    8. Review outcome goal(s)

Figure 4.6: Interaction Concept: BCTs assignments

information on the internet may lead to more confusion and be counterproductive if patients look for information themselves [79]. And with suggesting an own activity, the technology cannot assess whether the proposed activity is useful or not to focus on. In the worst case, the technology would support an activity that harms the patient. However, different patients may receive very specific tasks for them to do from their therapist, so this option would enable setting concrete goals for these kinds of tasks. Thus, it is very important to hint that this type of goal should only be used for tasks instructed by their therapist.

For the initial concept, only the exercise path is specified. However, the overall structure should be the same for each path. First, a prompt shows either an educational fact for why this area is important (BCT: Information about health consequences) or a prompt to remember past successes (BCT: Focus on past success). Second, the user selects a quantifiable target (e.g. step count, days of exercise done) from different options. Then, inspired by the work of Mortenson et al., a choice is made between three options of difficulty [44]. And finally, a time frame is determined if applicable.

Before finishing the goal-setting process, confidence in reaching the goal is prompted. The patient is prompted to adapt the difficulty if the confidence is very low or very high. Otherwise, the goal is set.

Step 3: Supporting measures

To support patients in achieving their goals, several supporting measures are introduced. First, problem-solving will be implemented. There are two different options specified. One option prompts the patient to think about what barriers could come in the way of achieving the goal and then ask to make a plan to prevent the barrier from stopping them from achieving their goal. The second option lets the patient choose from common problem areas that may hinder the goal achievement. The app then gives general recommendations for the respective problem area (BCT: Problem-solving).

Then, the patient is asked whether they want to be reminded via notifications to stay on track with their goal (BCT: Prompts/Cues).

Finally, a specific recommendation suggests the user put post-its as reminders somewhere in the patients´ homes where they frequently walk by (BCTs: Prompts / Cues, environmental restructuring, adding objects to the environment). Now the patient has done the initial work, and it is time for them to act according to their goal.

Step 4: Goal review & adaptation

When the time for the goal is up, patients review their goals. The work of Foster et al. inspired the process of this step [41]. First, it is asked whether they achieved the goal (BCTs: Self-monitoring of behavior, review behavioral goals). If they have achieved it, they receive an appreciation message. Afterward, they are asked whether to increase the difficulty or stay at the same level. If they do not achieve their goal, they receive a soothing message and are prompted to remember past successes (BCT: Focus on past successes). Afterward, they are asked whether to decrease the difficulty or stay at the same level.

Then, it is asked whether the general goal area stayed the same. If it stays the same, the user is led to step 2 to set a new short-term goal. If it changes, they are led to step 1 to adapt it.

Step 5: Home Screen features

When the patient opens the app while a goal is currently active, they can see the status of their current goal (BCT: Self-monitoring of behavior), an accumulated view of their past goal achievements (BCT: Self-monitoring of behavior), and an education center where they can read up on the importance of goal setting.

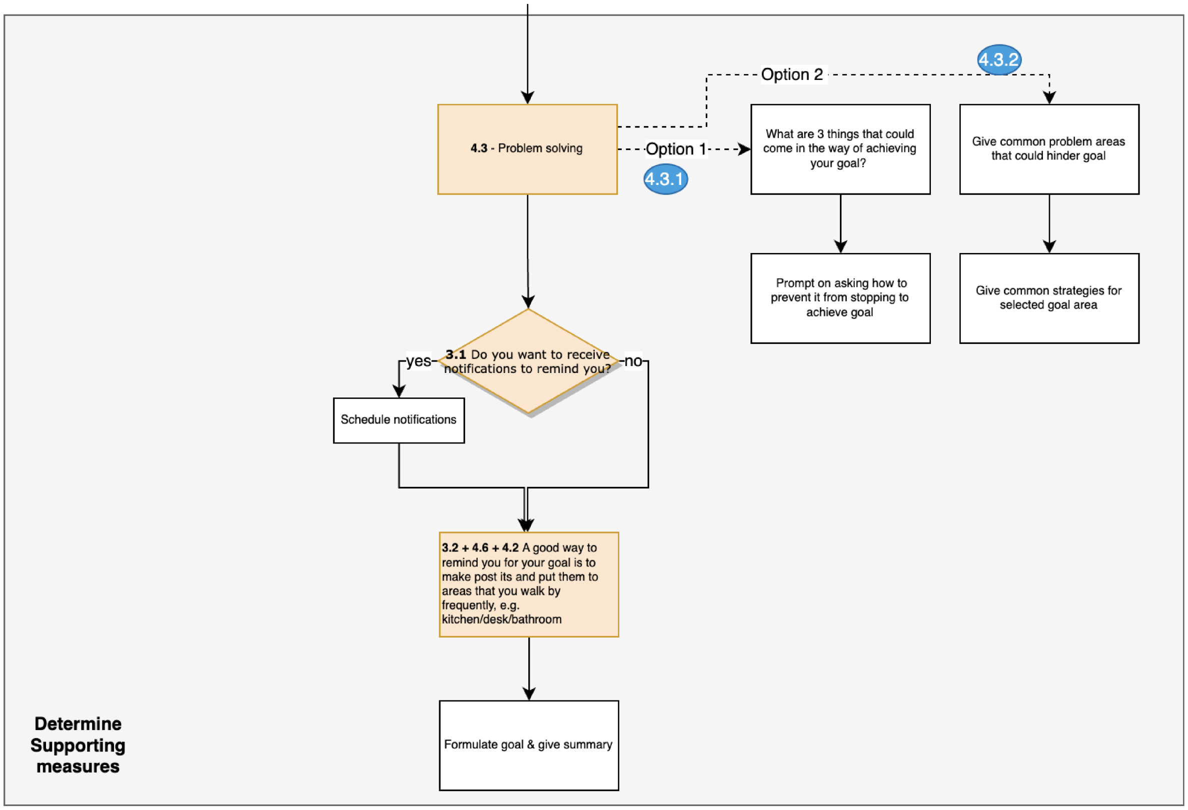

Figure 4.7: Interaction Concept - Step 3: Supporting measures

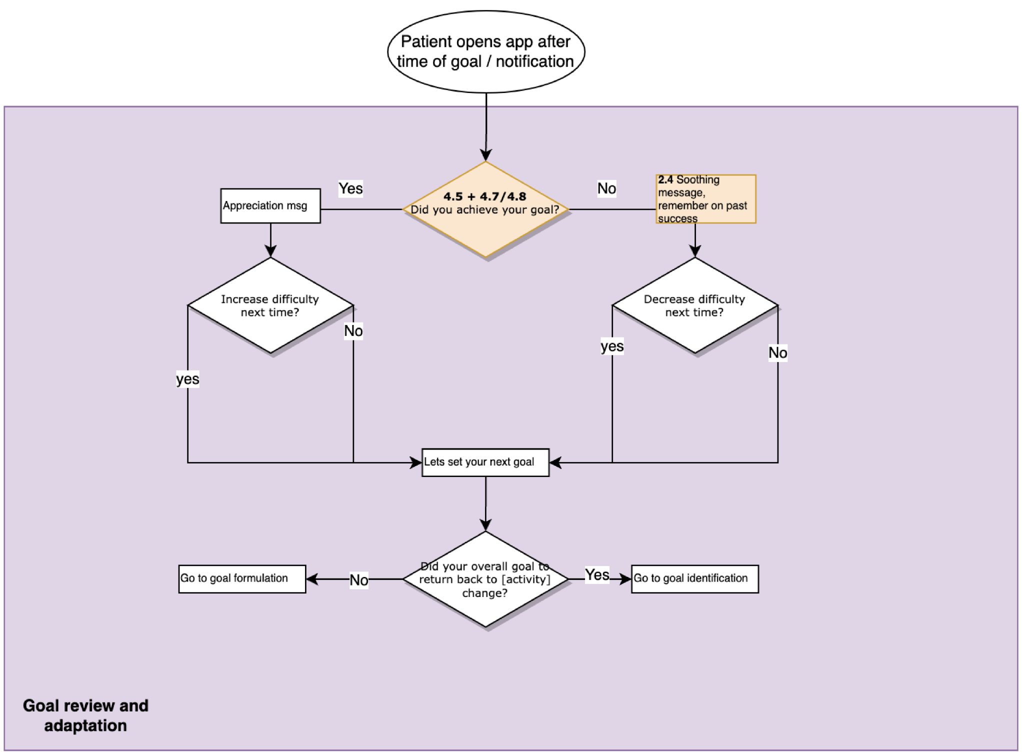

Figure 4.8: Interaction Concept - Step 4: Goal review

Chapter 5

Prototype Development

This chapter shows the iterative improvements to the interaction concept, ultimately leading to the final prototype.

The interaction concept is still relatively abstract, leaving much room for interpretation. Thus a low-fidelity, horizontal wireframe prototype has been designed. It was created to build a concrete understanding of what is presented to a patient, enabling discussions with users. The screens of the first version can be seen in Appendix A.

5.1 Feedback on & improvements of interaction concept

With this prototype, the first evaluation was conducted. It entailed a detailed feedback session with a sixth-semester physiotherapy student who also has 2-year work experience as a therapist. The unique opportunity with this person was that she was willing to spend significant time understanding the concept in detail and how it was developed before the feedback session. This allowed for an insightful discussion about the interaction concept. A briefing document was provided that explained the overall goal of the concept, which steps were followed to develop it, and links were provided to explanations of the behavior-change-wheel, the interaction concept, and wireframes, as well as questions she could focus on. The briefing document can be found in the Annex. After two weeks, the unstructured feedback session was held, which lasted two hours.

The following section elaborates on the main insights and the respective improvements.

- *Pain education:*
  When users choose to get out of pain, instead of selecting activities, they are led to a screen explaining why focusing on activities instead of solely on pain makes sense. It was mentioned that education should differ in complexity, depending on the length of the symptoms. For more chronic cases, education also gets more important and should be provided in more depth. **Improvement:** A screen is added that asks the user how long the symptoms have been present. Based on this decision, brief or more elaborate pain education is given.

- *Including a motivational question:*
  When a user determines the goal area on which to focus on, a suggestion was to include a question on why the goal area is important to the patient. This stimulates the patient to reflect and motivates them to take action to get back to their desired activity. **Improvement:** The suggestion was added to the concept.

- *Long- versus short-term goals:*
  In physiotherapy, long- and short-term goals can be differentiated. Short-term goals reflect exactly the *SMART goal formulation* part of the concept. And long-term goals are set based on activities, similar to the *goal identification* part. According to the therapist, there is an opportunity to adapt the *goal identification* part towards setting a long-term goal in that the SMART components are also represented. Moreover, this part has similarities to the patient-specific functional scale (PSFS). The PSFS is a valid, reliable, responsive, and efficient outcome measure developed in 1995 by Stratford et al. [80]. It quantifies the degree of inability of activities that cannot be done because of patients´ symptoms through a simple 11-point scale. **Improvement:** The idea is to assess the chosen activity's ability score, then set a long-term goal to increase this score by several points and a determined time frame. The part *goal identification* becomes *long-term goal*, and the part *SMART goal formulation* becomes *short-term goal*.

- *Design options:*
  Figure A.5 shows different design variations for specific parts of the concept. In the interaction concept, these parts are labeled by blue fields referencing the screens. First, for the onboarding

(1.1.1 + 1.1.2), there was a strong preference for the quiz over simply providing the information because it is more engaging and increases the learning effect.

Second (2.2.1 + 2.2.2), since setting short-term goals is repeated regularly, displaying a small fact/statistic was thought to be more valuable than prompting patients every week to think of past success.

Third (4.3.2 + 4.3.2), the second option was preferred for problem-solving since expecting patients to come up with solutions for potential problem areas by themselves is unrealistic.

- *Miscellaneous:*
  It was noted that the last question of the *short-term goal* was redundant, where the user was asked to rate how difficult they perceived the goal they had just set. Thus, it was removed. Then, a disclaimer should be made at the end to let the therapist review the goals to validate that the goal is aligned with the individual patients' needs. Finally, minor design decisions were discussed and improved.

Second iteration & results of therapist interview

The previously described points for improvements were implemented in the wireframe, as seen in Appendix B. To only include two wireframe versions, Appendix B also already includes improvements from the feedback of this iteration.

The goal was to get another round of expert feedback before coding the final prototype. Many physiotherapy practices were contacted, but only one therapist agreed to an interview at this stage. The interview was conducted online and lasted 45 minutes. Before the start of the session, the information document and consent form were sent and signed by the therapist. He has been a practice owner for 20 years and focuses on child neurology rehabilitation. But his practice also treats other types of injuries.

The interview started with getting to know the therapist and his current practice relating to goal setting. Then, the wireframe was presented and discussed via screen sharing while explaining it.

Results & Discussion. The therapist discussed that the high-level approach to goal setting is valid regarding selecting one activity and setting a goal based on the ability score. Also, he liked the way it was handled when the patient selected the focus on pain instead of selecting activities. It is useful to educate patients at this point, differentiating between short-term and long-term pain and advising them to select an activity instead while still making it possible to continue setting a goal relating to pain if the patient persists on it.

However, he was hesitant when the screen was shown when it was time to set the long-term goal based on the ability score of the selected activity. He could not specifically pinpoint what was bothering him, but it related to how realistic the goal was. Indeed, supporting a patient to set a realistic goal without the input of a therapist is difficult because it is the therapist's role to determine what is realistic. Furthermore, it was discussed that this type of goal setting might not fully represent how he applies goal setting in practice. For example, a fictional patient wants to run a marathon again but cannot walk at all. Then, he would set the intermediate goal first to walk 1km, then run 5km again. The technology would not support this type of goal setting. This finding underlines that technology does not fully replace the goal-setting done by a therapist in practice. When seeing it as a useful addition instead of a replacement, the therapist perceived the long-term goal-setting component more positively. Indeed, this finding opened up the conversation that the role of such technology could be more one of assessing patient expectations in the form of a specific goal instead of immediately creating realistic goals. It can be a tool to align the expectations between patient and therapist if they differ significantly. The long-term goal-setting component could consequently be used iteratively. The first step is assessing the expectation of the patient. The next step would be to discuss the goal with the therapist in a subsequent session, and then to adapt the goal in the app again. This finding lifted the pressure of of guiding patients to set realistic goals without the input of a therapist.

The idea of defining short-term goals was seen as very useful. However, the specific choices of goals relating to doing the exercises were seen as confusing because the difference between the options was not understood. Indeed, the goals were formulated similarly, as seen in the first wireframe version. The redundant options were removed to improve on this issue, and an option was added to specifically plan the exact times when the patient wants to do the exercises for the next week.

Finally, the therapist stated that the technology only applies to a subset of patients. It is not viable for very short-term injuries because the process with the app would be way too extensive to expect patients to set goals in such detail. Furthermore, he works with many very young children, who he said would not understand the point of using such an app.

5.2 The implemented prototype

The previously described improvements were incorporated into the wireframe, as seen in Appendix B. Afterward, it was implemented into a medium-fidelity app. The technology chosen was Flutter [81], which is a mobile cross-platform development framework that allows for relatively fast prototypical development. Using a cross-platform framework is useful because the unfinished app can be sent to iOS and Android users to test it, which is useful later in the final evaluation. Figure 5.1 shows the main implemented screens. The reader is referred to section 4.4 for a description of the interaction flow. A few screens, especially from the supporting measures part, are not shown in the figure. An explanation of how the reader can download and test the prototype is in the Annex.

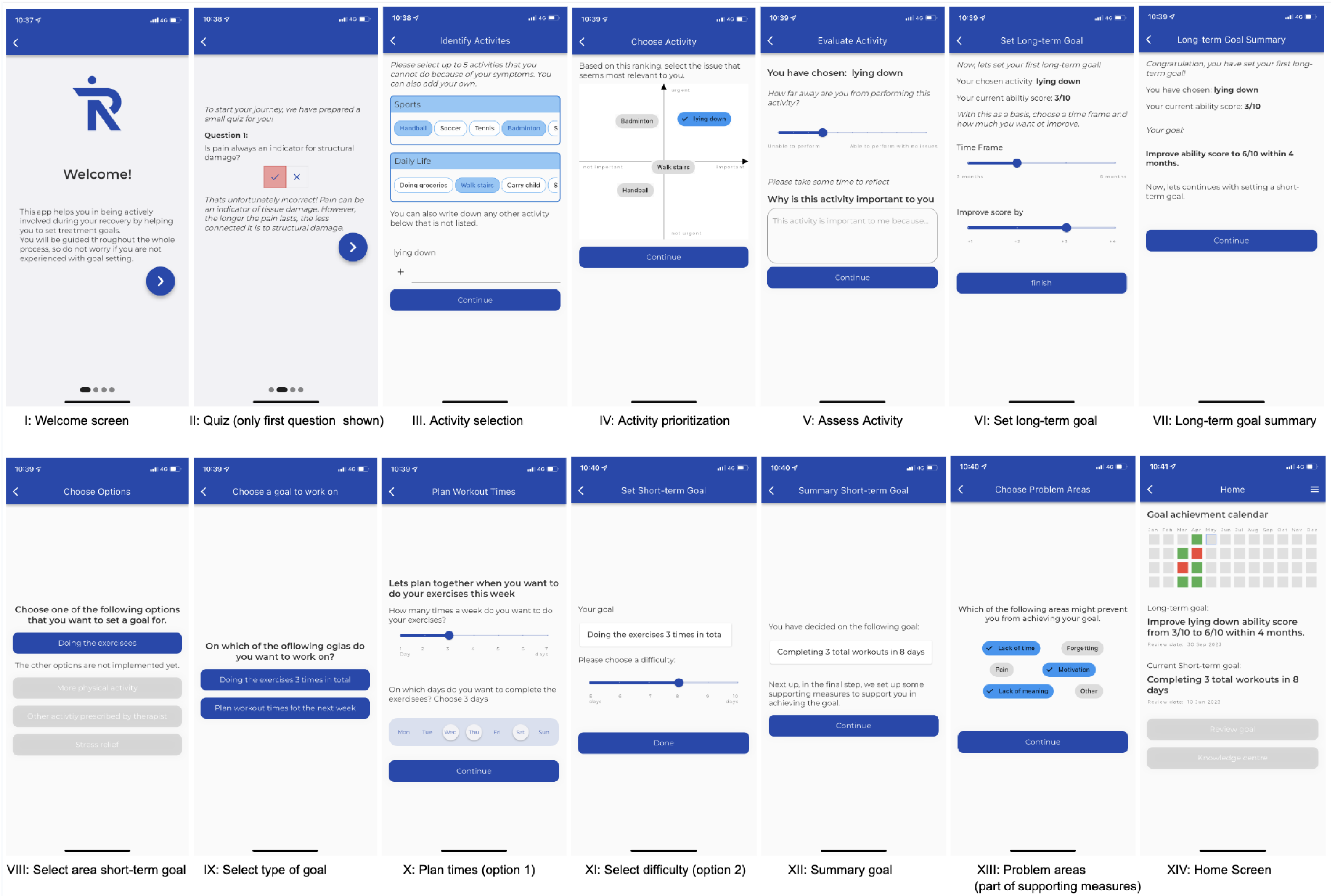

Figure 5.1: Screens of the final prototype (some screens are not shown)

Chapter 6

Final evaluation

This chapter entails the final evaluation of the mid-fidelity app prototype. The evaluation was three-fold. First, the patient user test is described and discussed, followed by two physiotherapy expert interviews, and finally, an assignment with physiotherapy students.

6.1 Patient evaluation

The purpose of the patient evaluation was to determine to what degree the SMART components are represented in goals set by patients with the app, how much included they felt, and if patients would like to use such a technology in their therapy.

Procedure and participants

The patient evaluation entailed patients testing the app to set treatment goals and filling out a survey afterward. Initially, a short interview was planned after the survey. However, the opportunity with the physiotherapy students arose, which required much preparation. Dismissing the interview made it possible for participants to test the app asynchronously.

8 Patients that were acquired through the personal network were sent an information document explaining the steps to complete the study. It consisted of the information document of the study, the informed consent form, how the app was downloaded, and the link to the evaluation survey. The questions of the survey, and the other documents, can be found in the Annex.

Participants were acquired through the personal network of the researcher. The inclusion criteria were that participants must have received physiotherapy within the last 18 months.

Results and discussion

The survey consisted of two main parts. The first part was questions developed using the Technology Acceptance Model (TAM) [82]. The results are displayed in table 6.1. There is no standardized way of calculating a total score to set the results in context, therefore, the questions were answered on a 7-point Likert scale.

Table 6.1: Technology acceptance results, n=8, full questions in Annex. Higher score = better

Question	**Rating**
Involved during process	5/7
Help to set and achieve goals	4.9/7
Improve the effectiveness of therapy	5.1/7
Ease of use and understanding of app	5.5/7
Accessibility for disabled people	4.5/7
Likelihood of using such a technology	5.1/7
Likelihood of recommending to friends	5/7
Attitude towards setting goals with app	5.3/7
Perceived usefulness of app	4.9/7
Perception of how much therapist likes use of app	5.4/7
Perception of social pressure to use app (lower = better)	3.6/7
Is app compatible with infrastructure of therapy clinic	5/7
Average rating	5.1/7

The average rating for all questions was 5.1, which is 0.6 points higher than a neutral answer indicating a positive tendency. The highest-rated question was concerning the ease of use, with 5.5. This is an important aspect since the technology is supposed to be used by many people. Nevertheless, accessibility was rated as average, which is to be expected from an early prototype. Features like supporting the use of screen readers and other accessibility features are usually implemented later in the development process. Another good sign is that the attitude of using an app to support the goal-setting process was rated well, with 5.3.

However, it is important that these results should not be overanalyzed since the number of participants is low. Moreover, the user group is also not representative because most other students participated. The same argument holds for the second part, in which the patients self-evaluated how well each of the SMART components was represented in their goals. For the app test, short- and long-term goal was asked individually. As shown in table 6.2, these results were compared with the forma-

Table 6.2: SMART components of goals set with the app versus formative survey

Aspect	Rating app (n=8) [Long-term, short-term, avg.]	Rating formative study (n=10)
Specific	4.6, 6, 5.3 /7	5/7
Measurable	5.9, 6, 5.9 /7	5/7
Achievable	5.9, 6, 5.9 /7	5.3/7
Relevant	6.4, 6.1, 6.3 /7	6/7
Timely	5, 5.3, 5.1 /7	2.5/7
Average	5.6, 5.8, 5.7 /7	4.8/7

tive survey conducted before the development process started. Patients rated the SMART components of the goals that they have set during their therapy.

Overall, with a total average rating of 5.7/7, it can be said that the SMART components are indeed well represented when using the prototype to guide goal setting.

Comparing the results with the formative survey, the app performed better overall, mostly due to the goals being more timely and measurable. This shows that guiding patients through a structured goal-setting process might indeed be useful to enforce at least the timely and measurable component. Surprisingly, the goals set with the app were perceived as more achievable since this was a challenging aspect throughout the development phase. It may be due to patients who tested the app already successfully finished their therapy and can now better develop a realistic goal.

Despite the limitations of the quantitative data obtained, the overall results were positive and suggest that further developing such a concept is promising.

6.2 Therapist evaluation

The therapist evaluation aimed to answer whether the prototype misses essential steps or components during the goal-setting process, what role such technology may have in clinical practice, and for which kind of patient it is useful.

Procedure and participants

One hour online interviews were done with two physiotherapists. The first part was used to get to know the therapist's background and current practice of goal setting. In the second part, a short presentation explained the app concept on a high level. Afterward, the app was demonstrated through screen-sharing by using it from a patient's perspective. Finally, the concept was discussed in a semi-structured format.

Over 100 physiotherapy clinics and 10 Universities were contacted via e-mail, from which only two professors were willing and could do an interview. The fact that none of the therapists from physiotherapy practices could be recruited underlines the recurrent theme of this field that time is extremely scarce in physiotherapy.

Both interviewed professors had some years of working experience as a therapist. However, in recent years, they focused on the theoretical and research part of physiotherapy.

Results and discussion

Both participants mentioned that this technology does not apply to every physiotherapy patient. It may be most suitable for structured patients since other patients might not be able to make sense of the predefined process. Furthermore, for many physiotherapy patients, exercises may not even be part of the treatment program, for whom it does not make sense to set short-term goals relating to doing the exercises. Another concern from previous evaluation rounds was that older people might struggle with using the technology. However, one therapist said that older people might enjoy the extensive process because they have a lot of time and are happy to gather and insert their information somewhere.

Conversely, the overall process through which patients are guided is lengthy. Some patients may feel discouraged and abort the process when they lose focus. It was discussed that splitting the process into two parts, one for the long-term goal and one for the short-term goal, would be a viable solution.

It was also discussed whether it is problematic when patients can fully decide how much they want to improve when setting their long-term goals because the goals set may be unrealistic. Both therapists did not think that this was a problem. It is good to stimulate the autonomy of the patient. If patients are unsure, this step could be done in consultation with their therapist. Moreover, one therapist mentioned that this would be an ideal foundation for a discussion to align the patient and therapist's expectations. In this discussion, the patient's expectations can be managed if their goals are unrealistic.

Moreover, it forces the therapists to keep the focus of the therapy on the patient's goals, which, the therapist said, is frequently not the case. The app, however, does not replace the functional goals that therapists set. But this is not an issue since the app's purpose is to motivate patients and not to replace the diagnostic treatment of the therapist.

When discussing whether the range of how much patients want to improve their ability score should be restricted (to make goals more realistic), a suggestion was made to use colors to show what, in general, is a good start for a goal. This could, for example, be the range between 2-4 improvement points on the ability score and give some initial expectation management that improving the score from 1 point to 10 points may be unrealistic.

Another point of discussion was that the activities chosen may not be specific enough for some patients. Walking could mean a lot of different activities for different patients. And this may frustrate some users if they cannot specify what they are prevented from doing.

Overall, the process through which patients are guided was considered useful. It was compared to the Patient Specific Functional Scale [83], a widely used valid, reliable, responsive, and efficient outcome measure, but in better and more intuitive. Both therapists think that no important step is missing in the interaction concept. Since the time is so restricted, patients should also be supported outside of the treatment time. And according to one therapist, the prototype is a good solution. There is a high financial interest in improving therapy outcomes since injured people are very expensive for healthcare insurance. However, it cannot be determined at this point how effective the solution would be in practice. A pilot study would be needed for this.

6.3 Physiotherapy student evaluation

While contacting universities, one professor teaching the course health technology to graduate physiotherapy students was interested in using the prototype as an assignment for the students. His goal was that his students learn how they, as physiotherapists, can contribute to developing health technology. The opportunity from the research perspective is that there is a big leverage to get a lot of input from soon-to-be physiotherapy experts.

The goal from the research perspective was thus to identify components of the concept that should be improved, identify potentially useful new components, and assess the usability of the current prototype.

Procedure and participants

The class consisted of 20 sixth-semester physiotherapy students who had already treated patients during internships. The collaboration was done within a one-month time frame. The concept, the app, and the assignment were presented in the first online session. The voluntary assignment, in which 10 students participated, was structured as follows.

An information document was given to the students that explained what they needed to do. First, they needed to read the information document and then sign the consent form. Second, they downloaded the prototype to their smartphone and tested the app from a patient's perspective. Afterward, they were instructed to identify three areas in the concept and suggest improvements. They could pick from a predefined list of parts of the concept that already have been identified as challenging or problematic, or they could freely choose. One of the suggestions had to be visualized by a paper sketch. Finally, their suggestions were handed in through a survey, where structured feedback concerning the app was collected. Because the students spent significant time exploring the prototype, the usability was assessed using the system usability scale. All the documents can be found in the Annex.

Table 6.3: SUS results of physiotherapy student survey (n=10)

SUS question	**Average score**	**Direction**
Would like use such a system as a patient	3.8/5	Higher = better
Unnecessarily complex	2.0/5	Lower = better
Easy to use	4.0/5	Higher = better
Need of a technical person to use	1.3/5	Lower = better
Functions well integrated	3.9/5	Higher = better
Too many inconsistencies	2.3/5	Lower = better
Most people fast learn to use	4.0/5	Higher = better
Cumbersome to use	1.7/5	Lower = better
Confidence using system	4.5/5	Higher = better
Learn a lot before using system	1.6/5	Lower = better
Average SUS score	80.75/100	Higher = better

In a second online session, some of the suggestions were presented and commented on from a technical perspective in terms of how well these suggestions could be implemented.

Results and discussion

The result of the individual questions of the SUS can be seen in table 6.3. Overall, with a total average SUS score of 80.75/100, the prototype's usability is quite high. In the biggest SUS database, a score of 80.75 belongs to the 20% percentile [84]. Noteworthy is that the students considered the system to be quite self-explanatory. However, this result needs to be treated with caution, as physiotherapy students who are not patients were testing the app. And it had only 10 participants, which limits the interpretability of quantitative data in general. Nevertheless, it paints a first picture that the components of the interaction concept were well translated into the design.

Many suggestions for improvement of the prototype were handed in. In the next section, some interesting submissions are presented.

Patients must place the activities on an urgency-

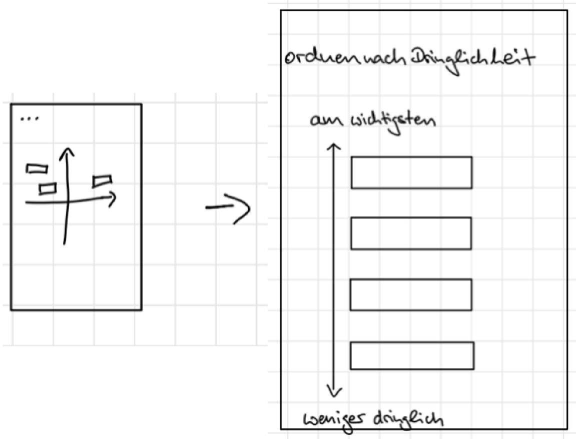

Figure 6.1: Improvement suggestion: Ranking instead of importance-urgency matrix

importance matrix to determine which of the selected activities is chosen as the long-term goal target. One concern was that older patients may not understand what is expected of them. Thus, a suggestion shown in figure 6.1 was made to replace the matrix with an importance list representing a ranking that can be ordered. In this way, the complexity would be reduced. This suggestion was later also discussed in one of the interviews, where the therapist had no concerns that a matrix would overwhelm older patients. The added benefits of a second dimension would need to be assessed to decide whether the one or two-dimension version should be implemented.

Next, it was mentioned that patients frequently do not notice their progress. A success diary could help show patients what they have improved, as shown in figure 6.2. When opening the app, a prompt could ask in which areas the symptoms improved. The home screen could then show a collection of past improvements. Patients can use this to reclaim motivation by looking through their success history.

Another suggestion for an additional type of short-term goal (next to doing the exercises) was managing daily life. This category could specify activities like emptying the dishwasher, meeting a friend, or cooking. Returning to daily life activities can be a long-term goal for some patients. They might struggle with a specific activity, for example doing groceries. In terms of short-term goals, they could then select activities they already can do. Even if the chosen activity might not directly positively influence the rehabilitation progression, the process of consciously setting and achieving a goal might already increase motivation and self-efficacy.

For the short-term goal category of physical activity, a suggestion was made to let the patient decide between strength, agility, and endurance and then propose activities for each sub-category.

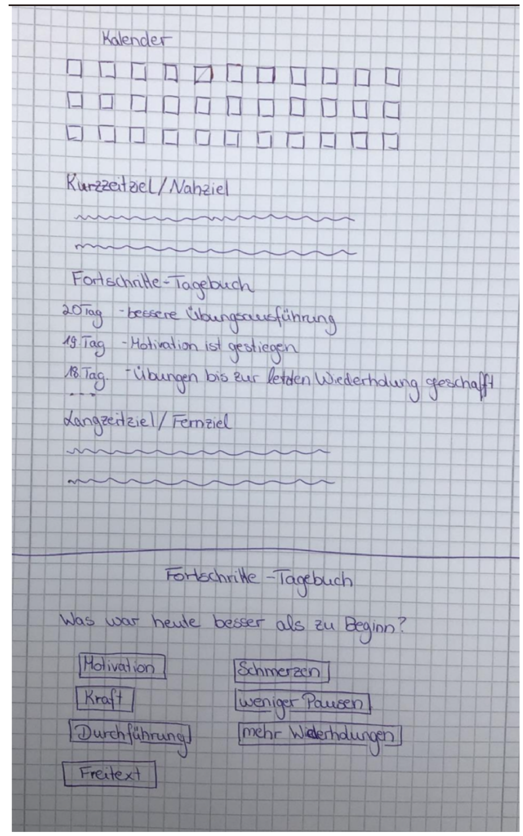

Figure 6.2: Improvement suggestion: Success diary

One of the challenging aspects of the concept was how to guide patients so that their goals are realistic. Two suggestions were handed in. Firstly, a matrix with a time frame and maximal realistic improvement of the ability score could give feedback, shown in figure 6.3, when users want to set a too-ambitious goal. It is questionable, however, whether such a matrix can be created. Secondly, the user could be prompted when half of the time towards the long-term goal has passed, whether they want to stay with or adopt the goal.

Other suggestions included inserting the specific home exercises into the app, adding playful elements and sounds to trigger emotions, social features to chat with other patients, adding a therapist account to monitor exercise adherence, and other minor design improvements.

Overall, many new ideas arose from the students' suggestions. Considering that not every feature that might be interesting can or should be implemented, the following improvements would be made if there were another iteration of development. Additionally to the importance-urgency matrix, just ranking each activity would be added. Both versions could then be tested with patients to see what they prefer. The suggestions for the short-term goal areas of daily life and physical activity would also be implemented. And finally, the success diary would be implemented to test afterward

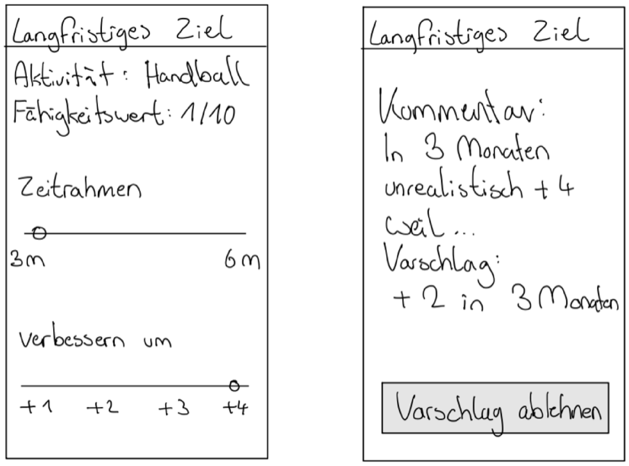

Figure 6.3: Improvement suggestion: Success diary

whether patients like it.

Chapter 7

Discussion

This final chapter of the thesis evaluates the study's outcome and answers the research question. The research question of this work was: **How can the patient-led goal-setting process in physiotherapy between patient and therapist be facilitated through mobile technology?**

The following sections first present the research outcome. The different positions where such technology might be used in practice are presented. It also will be discussed for which kind of patient the concept is promising. Furthermore, the iterative process, the RtD approach, and the Behavior-Change-Wheel framework will be critically evaluated.

Finally, the strengths and weaknesses of the study are discussed.

7.1 Research outcome

This section discusses the research outcome starting with the role of technology during a patient-centered goal-setting process. It continues with discussing which type of patient might benefit from such technology and finishes with reflecting on the Behavior Change Wheel and the Research through Design approach.

The role of technology to support a patient-centered goal-setting process

Throughout the research, different roles in clinical practice arose for the technology. Initially, the rationale was that clinical practice frequently has no structured patient-focused goal-setting process. Thus, the concept was intended to replace the goal-setting process and be a solution that patients can independently use to set their goals. However, the early expert evaluations revealed that guiding patients toward a realistic goal is challenging. Patients frequently have a wrong perception of what goal is realistic for them. Determining a realistic goal is a complex process with many variables, which has been deemed unrealistic to assess with technology without the input of a therapist. Some suggestions attempted to give some general guidance, for example, based on how much improvement is generally possible in a certain time frame. But without the input of a therapist, it could not be confidently stated that the goals that patients set are realistic.

Therefore, a suggestion to overcome this challenge involved that when the patient reaches the point of setting the long-term goal, a prompt appears to set it together with their therapist during the next treatment session. The role thus changed towards a more collaborative function between patient and therapist.

Embracing this role, another physiotherapist thought it was not an issue if the patient first set an unrealistic goal. Quite the opposite, it could be an ideal starting point for an informed discussion that the patient could prepare before the first treatment session. Based on the specific goal the patient independently sets, the expectations can be managed, and the goal can be adapted to be more realistic. Moreover, according to a therapist, this technology function forces therapists to keep the goal patient-centered, which is frequently not the case in practice and the main focus of this work.

For whom is it useful?

With every interview, it became more evident that such a technology is not applicable to every physiotherapy patient. From the treatment perspective, some therapies do not include exercises or focus more on a patient's mental well-being than on improving physical symptoms.

Although it might not be exclusively useful for this group, patients with musculoskeletal complaints may be a good first target population since their therapy usually includes home exercises. However, the process that patients are guided through is quite lengthy. Patients with minor complaints, which might resolve independently without requiring sustained effort by doing the exercises consistently, might not be patient enough to go through an elaborate goal-setting process. Therefore, patients with a longer rehabilitation time might be more suitable to use such an app. This depends, though, on the role of the technology. Suppose only the long-term goal-setting part of the technology is used to build an initial common understanding of the patient's expectations. In that case, it is also viable for patients with a shorter rehabilitation time.

Furthermore, it was mentioned that personality type also influences how well a patient benefits from such a technology. Some people are very structured and probably like such a concept, but others might not like rigid structures and rely more on intuition. It might feel like a constraining burden for these people to force them through a strictly structured process. Also, the app is unsuitable for very young children because they would have trouble understanding the purpose of the app.

A first-user test showed that, in general, patients that participated understood the app's purpose and could set treatment goals with the app, and the SMART components were well represented. The technology acceptance was above neutral, although the results could not be set into context. These results suggest that patients are at least willing to try such a technology. However, future research has to test this hypothesis with a more diverse user group.

But even if looking at the patients that would benefit from the prototype, their requirements for successful therapy are still different. When considering patient education, for example, a patient with chronic pain may benefit from information about the nature and processes of pain more than a patient with a sprained ankle. This issue was addressed in one iteration of the prototype by giving patients with longer-term persisting pain more elaborate information about pain. This concept of asking questions and branching to give specific pieces of information and resources could be applied and investigated on a bigger scale. An example could look like the following. Information resources for the most common injuries and complaints could be gathered and labeled in the app. Labels could include the specific injury, but also general knowledge about anatomy about body parts, pain, or habit formation. Depending on the extensiveness of this knowledge library, the user can be prompted with questions about what they like to learn about, for example, learn about their condition, pain management, or other topics. The resources would then be filtered based on their labels, and the patient can access the resources specifically relevant to them.

Another question concerning the highly individualized nature of physiotherapy is whether the effectiveness of the app developed in this work is inversely correlated with the case's complexity. For common issues, there are standardized approaches for treatment, and thus it is relatively easy to provide patients with specific information relating to their injury. In a complex case, it might be more difficult to provide the patient with the right information and tools to manage their issue which brings up the mentioned question. It has already been mentioned multiple times that such an app is not applicable to every type of patient. The therapy needs to include exercises, which in most cases it does. It does not really matter which exercises need to be done, but the app currently abstracts from specific exercises to the concept of just doing the exercises. These could include the same 3 exercises, or each week new exercises, the goal setting of, for example, setting a short-term goal to do them 3 times within the next 7 days would be formulated exactly the same. In the future, a useful feature might include adding specific exercises, but even then they could be changed. Furthermore, the long-term goal-setting component is purely activity-based. It does not matter how complex the treatment of an injury is, the component works exactly the same. First, the most important activity that is inhibited by the injury is identified, which then is quantified, and a goal is set, based on this quantification. In more complex cases, patients may have had some previous failed treatments already. It may be speculated, that those complex cases might benefit even more from such an app because they understand the importance of consistently doing their exercises and being proactive during the therapy.

Another question is how much time is spent by a therapist to individualize the treatment plan for patients. The interviewed therapists said that usually the whole first session is spent on this. They also stressed that it is rarely the case that a therapist has the whole treatment plan in their head exactly at the end of the first session. This was discussed during the question of whether using the app after the first treatment session may be too late to have a positive impact. The answer was that any way to align the expectations between patient and therapist is useful at any time during the therapy. Even though the long-term goal set by the patient may not be realistic initially, discussing this mismatch in a consequent session results in a more realistic goal than not having used the app at all to quantify the expectation of the patient.

Lastly, in a paper that investigated how goal setting can be applied to facilitate symptom tracking for migraine patients, Schroeder et al. found that it is important to support the evolution of goals. As symptoms progress, the type of goal might change [85]. For this context, it means that it might be useful to enable patients adapting their long-term goal. For example, when the symptoms are initially very bad, being able to walk the stairs might be the most relevant activity to perform. But as the symptoms improve, this might change to being able to do sport again. This paper also concluded that technologies used independently by patients are a great tool to facilitate collaboration between patient and healthcare provider. This point is further strengthened by the finding of this work that the long-term goal-setting can be used as an assessment of the expectation of the patient

Development and evaluation of a new behavior change technology guided by the behavior change wheel and a research-through-design approach

The Behavior Change Wheel was used as a theoretical basis to develop the initial concept. It differentiated itself from other behavior change theories by providing a supplemental book describing a thorough framework application process. Moreover, it was designed to create behavior change interventions compared to explaining behavior change. This left much less room for interpretation on how to apply it, which increased the probability that it was applied correctly. It is an advantage over other frameworks since the wrong application of theoretical frameworks is one cause of why interventions might be ineffective [63].

Even though the process of applying the BCW was extensive, many assumptions still had to be made. Especially in the stages of identifying what needs to change in current behavior, further user research would have brought more insight leading to a better-grounded decision-making process along each step.

Overall, using the BCW and explaining each step of the application was still highly useful because the links between theoretical constructs and design decisions are described, which a review found is only the case in less than 10% of papers that claim to be theoretically grounded [65]. Moreover, it fits well with this thesis's Research through Design approach. The thesis's contribution is not the initial concept or the final prototype but the knowledge gained throughout the development process.

This knowledge was produced in multiple iterations. In the first divergence-convergence iteration, the problem space was explored, which resulted in the research question. Afterward, the initial interaction was developed using the BCW and a practical framework for patient-centered goal-setting in physiotherapy. This concept was then specified to a low-fidelity wireframe to enable discussions with experts. In two short evaluation-improvement iterations, the concept was improved. The main insight in this stage was the usefulness of defining the goal-setting area according to the SMART structure. In hindsight, this change was valuable because the expert interviews of the last iteration were mostly focused on the usefulness of the long-term goal component, which might not have been the case if no long-term goal had been specified. Finally, the chance to formulate an assignment for a class of physiotherapy students resulted in many interesting directions, which future research could further specify and investigate.

By documenting the insights from each stage of the development process, researchers can pick any component or stage of the work and explore a different direction or a specific component in more detail in future research.

7.2 General strengths & limitations of the project

A strength of this thesis is the wide range of design and research aspects it covered. Many steps were covered, from a literature review, over the detailed application of a behavior-change framework, to designing, developing, and evaluating prototypes in multiple iterations. Considering the limited graduation period, this approach has a trade-off with exploring the depth of individual aspects. Especially during the application of the BCW, assumptions had to be made to manage the limited resources.

The development and design experience of the researcher enabled the development of a horizontal prototype that users can asynchronously download, test, and give feedback on. This allowed for efficient user testing in a realistic setting. The participants could download the prototype to their smartphone and test it like a real app without the direct supervision of the researcher, which enabled them to not only have discussions about specific parts but also on the concept from a high-level perspective. For example, it could be discussed whether important steps in the complex process of setting goals are missing.

Another strength was the unique evaluation opportunity to test the concept with a class of physiotherapy students and formulate an assignment for them. This resulted in high leverage of user feedback. Overall, the many employed evaluations resulted in feedback from many different angles. However, this is also a drawback since each evaluation method had a relatively low number of participants. The cause was the number of methods employed and the difficulty of finding participants. Overall, the evaluations focused more on gathering qualitative than quantitative data, limiting the findings' generalizability.

The biggest limitation is, however, that this study did not answer the question of how useful such technology is in supporting exercise adherence, self-efficacy, and patient involvement. A longer-term study would be needed for this, which was unfeasible to conduct within the scope of a master's thesis.

7.3 Conclusion

This study examined how technology can support a patient-centered goal-setting process in physiotherapy. After a literature review and a prospective survey of patients, an initial concept was developed by applying the Behavior Change Wheel and a practical framework for patient-centered goal setting in physiotherapy. Following a Research through Design approach, the concept was translated towards a wireframe, which was improved in two evaluation-improvement iterations. A mid-fidelity app was then implemented, which was evaluated by two expert interviews, an assignment for a class of physiotherapy students, and a patient-user test.

The results showed multiple promising roles for technology that might facilitate a patient-centered goal-setting process. The long-term goal component could act as an assessment of the expectation from the patient's perspective before the first therapy session, which can be used as a basis for discussion within the treatment sessions. This role would also force therapists to keep the goal-setting process patient-centered. The second role is that of a companion for the patient. An app might motivate patients by setting long- and short-term SMART goals and visualizing their progress. It is also clear that such a technology cannot fully replace the discussion therapist and patient must have about the patient's goals.

The results also indicated that such technology is only useful for a subset of patients. From the evaluations, the ideal users would be patients affine to technology, whose therapy is not short-term and includes home exercises. A first user test showed promising results in terms of acceptance of such technology. Moreover, by using the app, the goals set were significantly more measurable and timely.

This work contributed to scientific knowledge through the development of a behavior change technology following the Behavior Change Wheel and a Research through Design approach.

Furthermore, it contributed to the design space of physiotherapy by investigating the role technology can take in employing patient-centered goal setting.

However, It must be noted that because of the low number of participants in each research method, the results cannot be generalized and are also limited in terms of reliability.

Future research should further investigate the potential role of technology in assessing the patient's expectations from the therapy. One way to achieve this could be to collaborate with a physiotherapy clinic to conduct a study where a technology like this work is used in their practice.

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Appendix A

Wireframe version 1

The following figures show the first version of the wireframe prototype. The stars in the figure reference figure A.5, where different options at the respective point in time have been drafted.

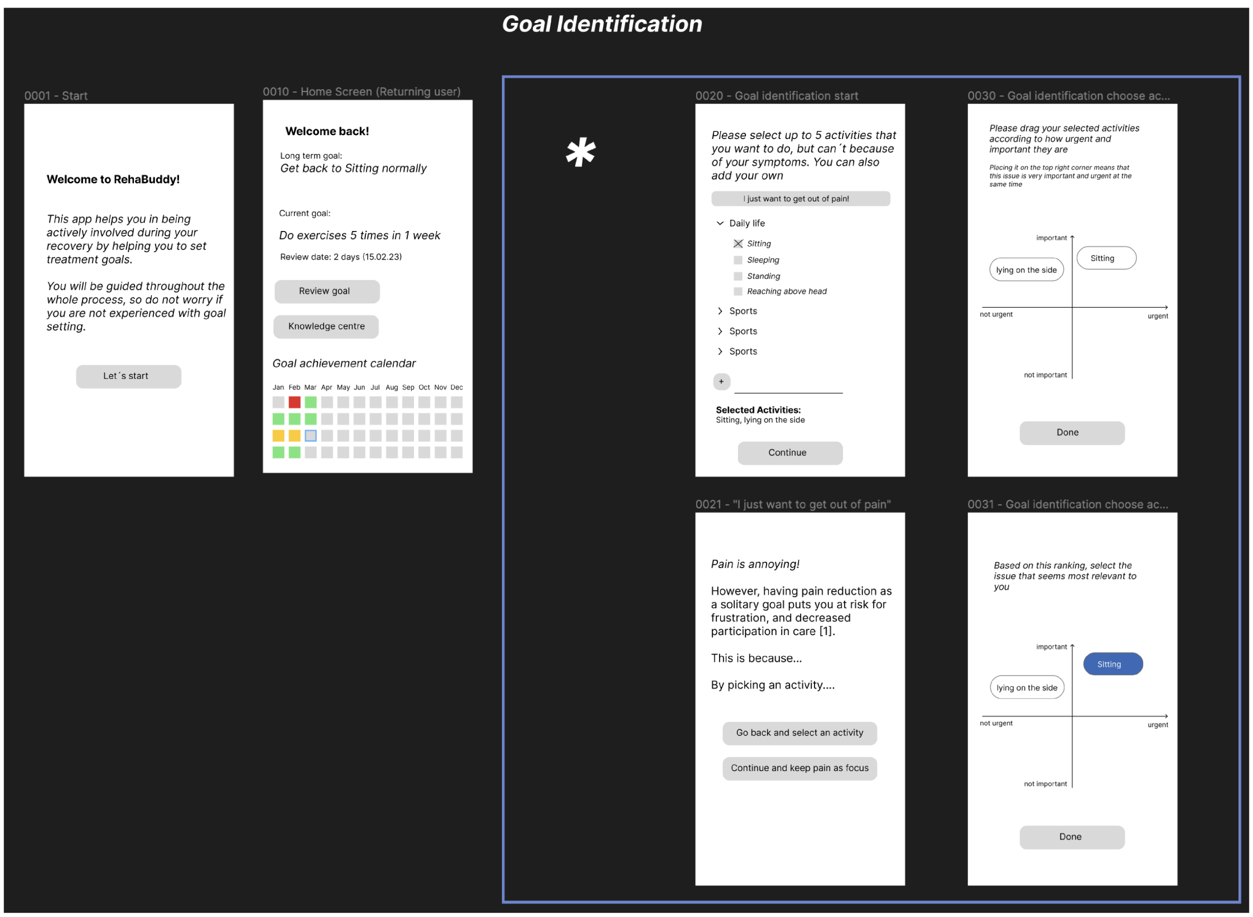


Figure A.1: Welcome screen and goal identification

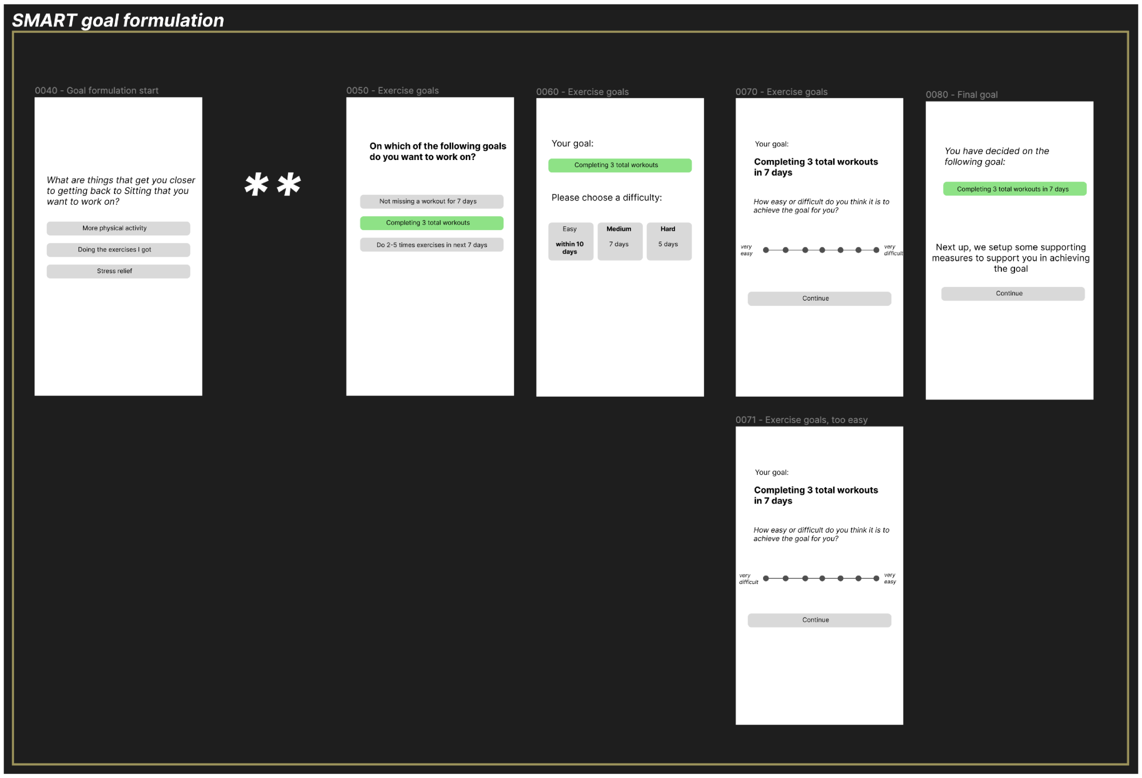


Figure A.2: SMART goal setting

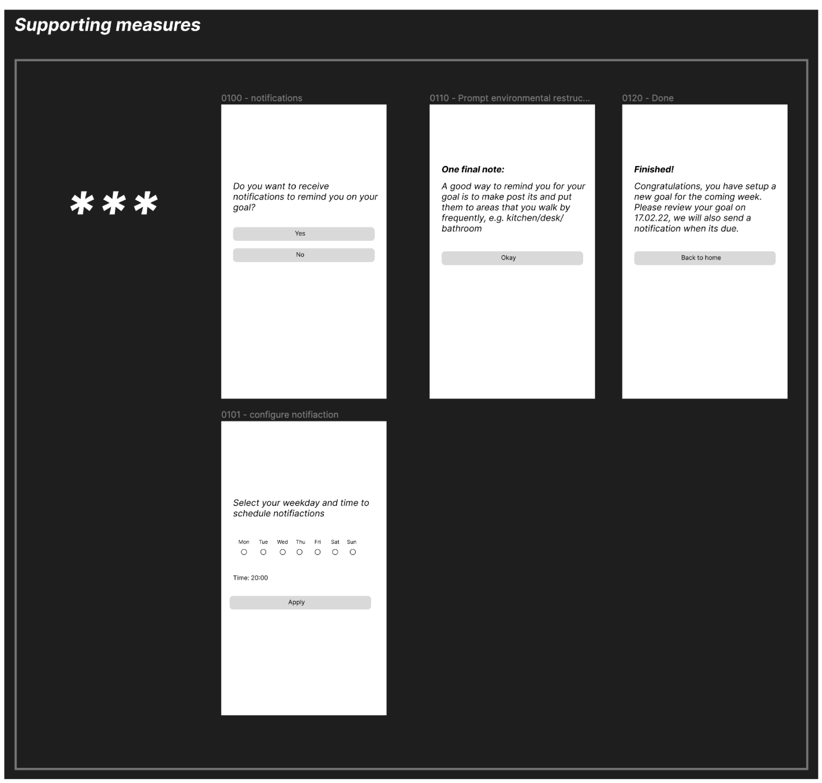


Figure A.3: Supporting measures

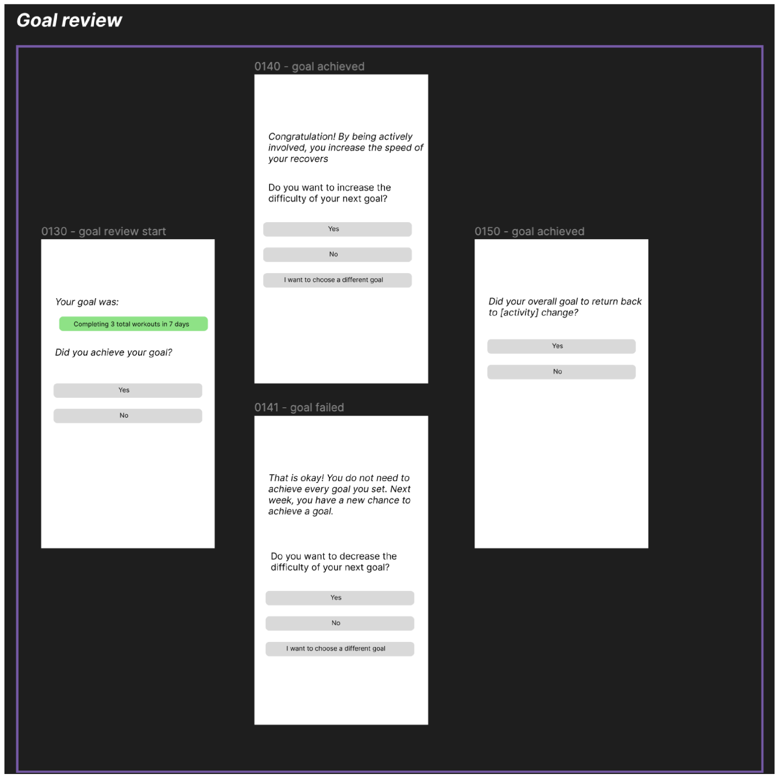


Figure A.4: Goal review & adaptation

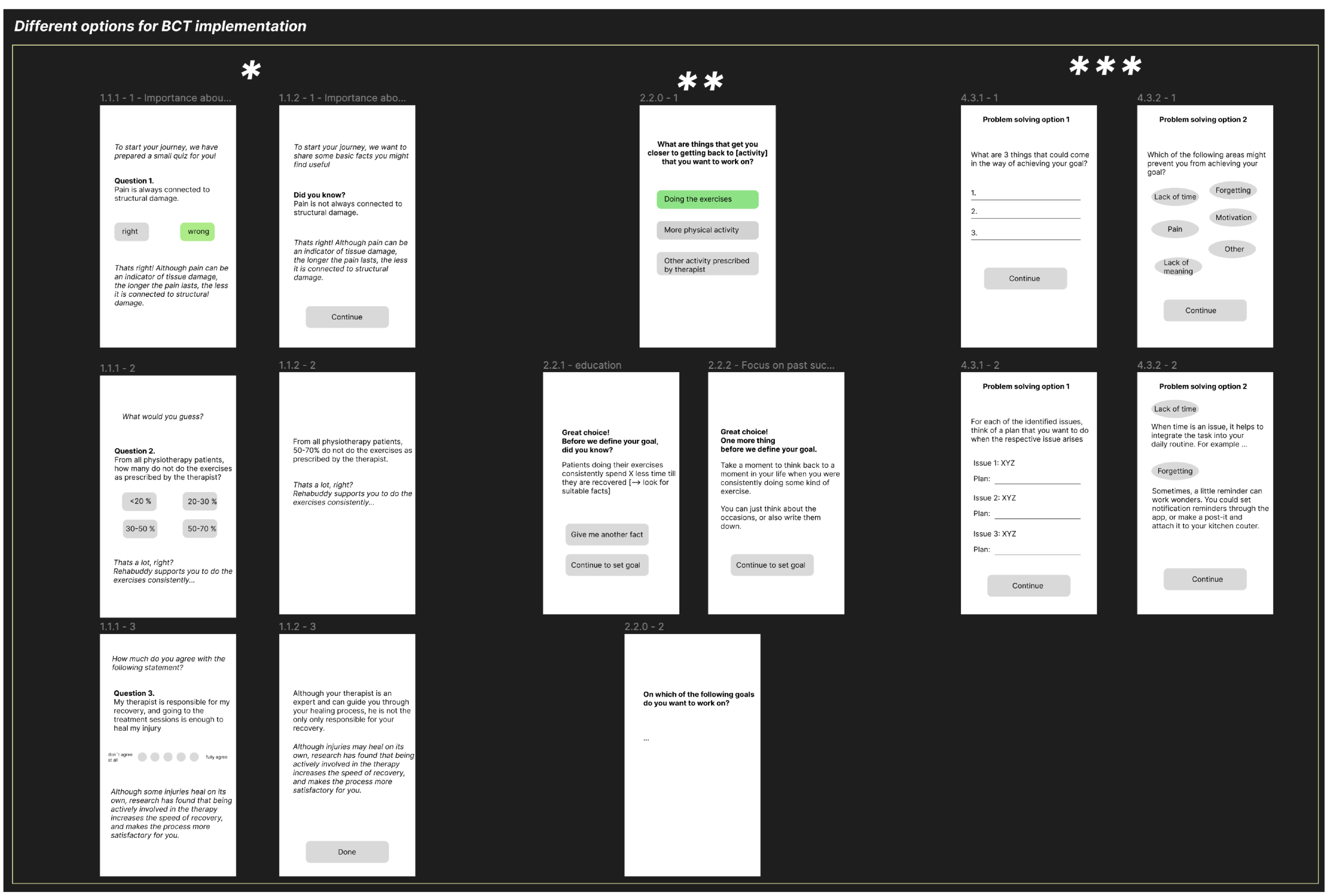
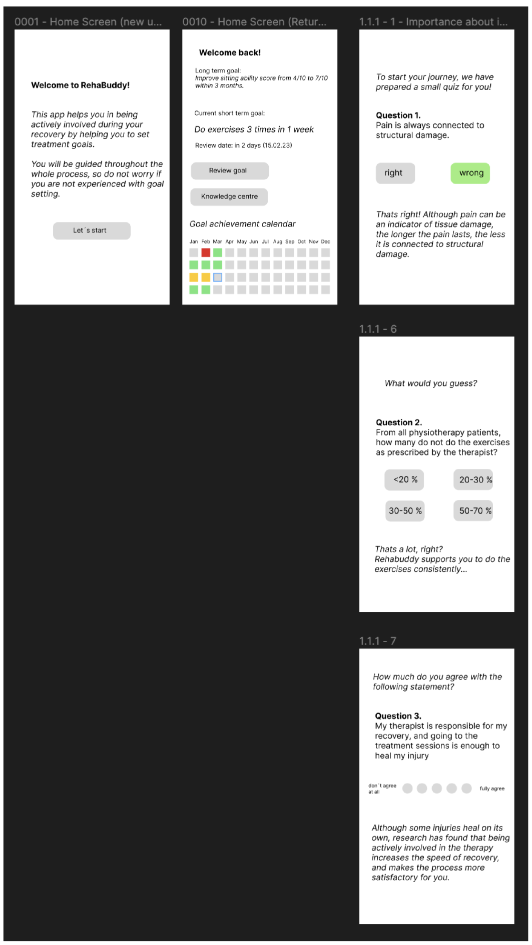


Figure A.5: BCT different options for implementation

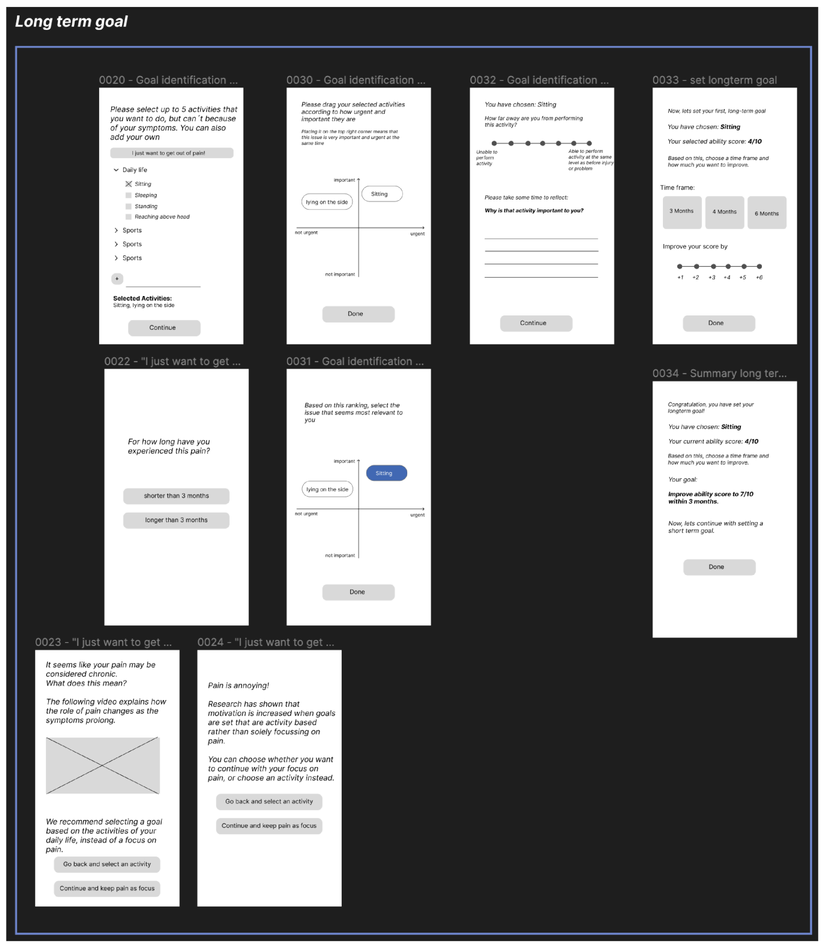
Appendix B

Wireframe version 2

The following figures show the second version of the wireframe prototype.



(a) Welcome screen and goal identification



(b) Long-term goal setting

Figure B.1

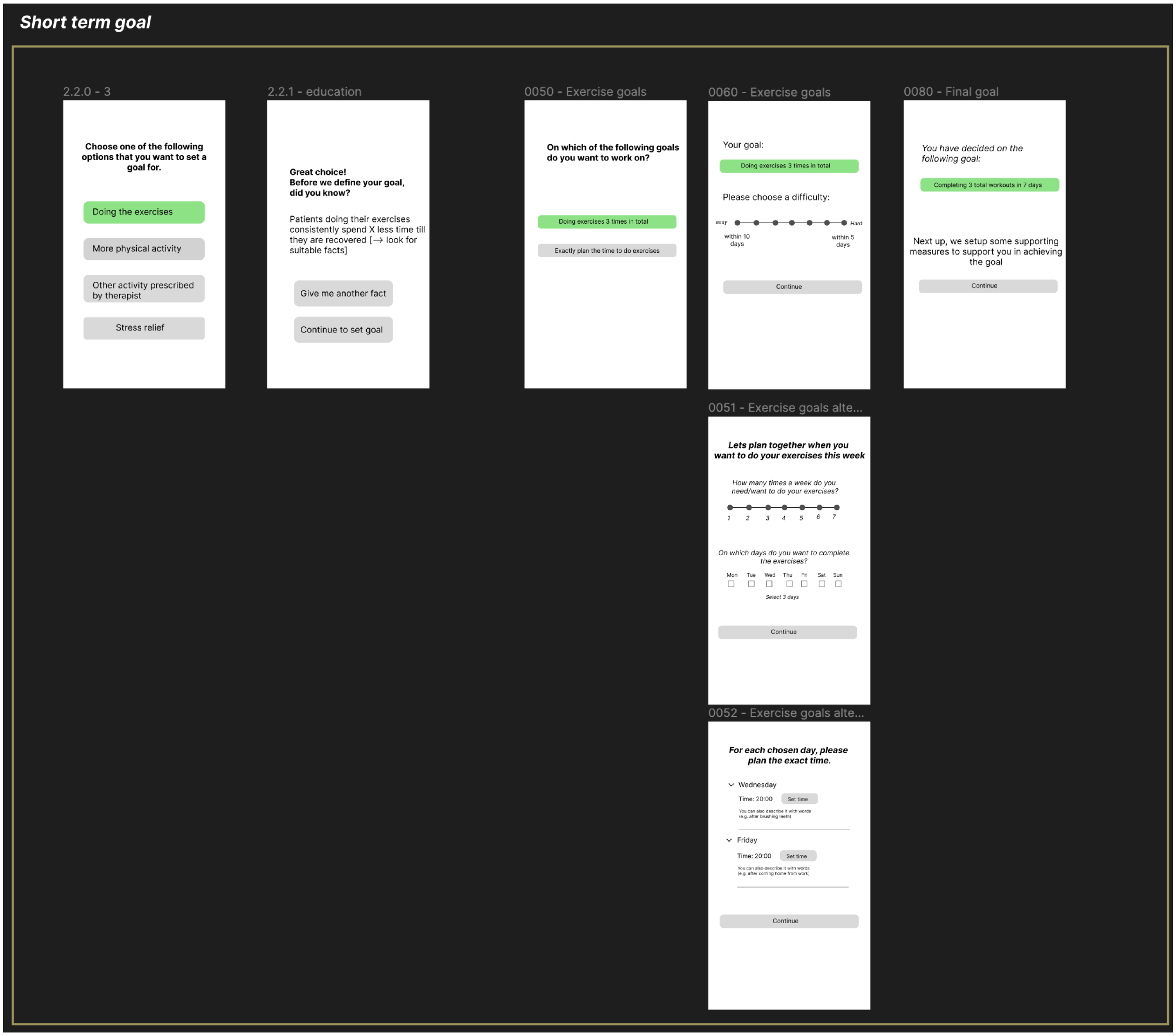


Figure B.2: Short-term goal setting

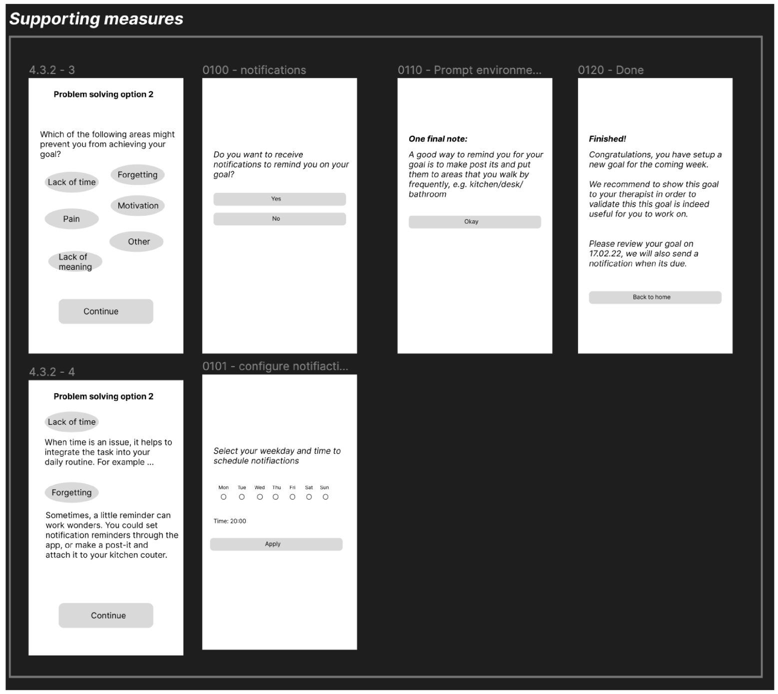


Figure B.3: Supporting measures

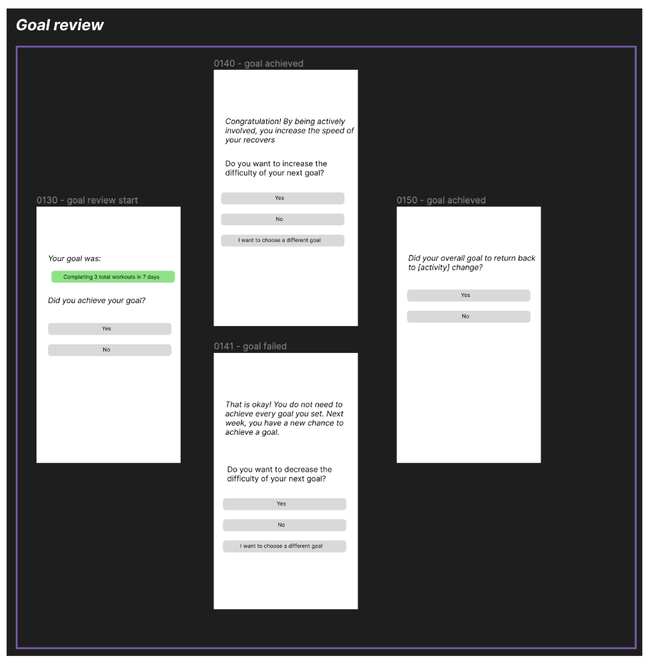


Figure B.4: Goal review & adaptation

Annex

1. Explanation of how to download the prototype
2. Worksheets for the Behavior Change Wheel
3. Participant information sheet
4. Consent form - physiotherapy students and patients
5. Consent form - (therapist) interviews
6. Instructions for patients (final evaluation)
7. Survey - final patient evaluation
8. Instructions physiotherpay student assignment (German)
9. Survey - physiotherapy students
10. Survey - formative patient evaluation