CHALMERS
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Rehab Rush

- Exploring how a body controlled mobile phone game can be designed to facilitate and support rehabilitation of ACL-injuries

Master's thesis in Interaction Design & Technologies

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Cover: Final prototype of the motion controlled mobile phone game Rehab Rush

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Abstract

In this master's thesis, a high-fidelity prototype of a body controlled mobile phone game was developed, with the purpose of investigating if a mobile phone game can support and facilitate patients when executing their physiotherapeutic exercises. The targeted user group for the game was young women (16-20 years old) with ACL-injuries. The research was based on the question: *How can a body controlled mobile phone game be designed to help young women with ACL-injuries do their exercises in a correct and rewarding way?*.

To address this research question, an iterative development process was executed, which involved conducting a qualitative study to evaluate the idea and prototype with experienced physiotherapists. Seven guidelines elicited from the research, development process and qualitative study, were formulated to provide inspiration and support for further development of this game or other mobile games for physiotherapeutic purposes.

Keywords: game development, physiotherapy, interaction design, motion tracking, AR, health, mobile phone game, Unity

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Maja Kristensson & Mathilda Möller, Gothenburg, June 2023

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1
Introduction

This is a master's thesis project conducted by two interaction design students at Chalmers University of Technology. The study is meant to investigate how a body controlled mobile phone game can be constructed to facilitate and control that patients execute physiotherapeutic exercises correctly and in a more rewarding way. Video games are a popular leisure interest and 66 percent of all Americans state that they play regularly [4]. The objective of this study is to investigate if the interest in gaming can be used for a higher purpose and help people in need of physiotherapy to do their prescribed exercises. If a game can be designed to support patients when performing their physiotherapeutic exercises, that also controls that the exercises are executed correctly, they might be given the extra motivation it takes to do it. This project will focus on young women (aged 16-20) with anterior cruciate ligament (ACL) injuries.

1.1 Background

In this section, background research to the project is presented. It includes compliance in physiotherapy, how rehabilitation of ACL-injuries is conducted, together with descriptions of exercises commonly prescribed for patients with ACL-injuries.

1.1.1 Compliance in Physiotherapy

Non-compliance in healthcare is a wide spread problem, which can affect the result of the treatment [5]. Although physical therapy is one of the medical disciplines where compliance has a major impact on the outcome, there has been little research on the extent to which patients do not perform their recommended exercises. The studies that have been conducted to investigate non-compliance in physiotherapy present varying results, that between 14-70% of patients do not adhere to their rehabilitation program [5]. Even though there is a considerable variation in the results of different studies, research has been conducted to understand why people who struggle with injuries do not do their prescribed physiotherapeutic exercises [6]. This research shows that three main factors of why people do not comply with their recommended exercises are:

1. the barriers patients perceive and encounter
2. the lack of positive feedback
3. the degree of helplessness

The first item on the list, *barriers*, is exemplified with problems such as; not having enough time, forgetting to do the exercises, and economic issues. According to the study, this factor was shown to be the strongest reason for non-compliance [6]. The second factor, *feedback*, is explained by the fact that patients who were continuously supervised and received positive feedback from the therapist were more compliant than patients who did not have much contact with their therapists. The third factor, *helplessness* is defined as the patients' lack of confidence in doing the exercises and doubting if what they do makes any difference [6].

A systematic review, comparing and analyzing the results of five different studies focused on enhancing compliance among patients, presents doubtful results of the studies [7]. The studies examined if compliance could be enhanced by; (1) providing patients with recorded instructions of the exercises, (2) providing patients with personalized computer-generated printouts of the exercises, (3) a 10 minute consultation with physiotherapist before each exercise session, (4) adding a motivational training program to the prescribed rehabilitation exercises, (5) adding a motivational program including counselling focused on the importance of exercising and to address the possible barriers the patient encounters. Additionally an exercise schedule, rewards and punishment strategies was added as well as an exercise diary [7]. The conclusion of the systematic review is that motivational programs have a moderate impact on the compliance, that compliance strategies do not have any impact on the compliance of long-term physiotherapy patients, and lastly, finds conflicting results regarding short term physiotherapy patients [7].

1.1.2 Game based rehabilitation

Attempts have been made to try to improve compliance among physiotherapy patients. Some including games, some by doing adjustments of traditional physiotherapy, but none of these studies is targeting young women with ACL-injuries. Research has shown that using video games in physiotherapy has the possibility to tackle boredom and encourage the patient to do their exercises [8]. The games that have been developed for physiotherapy have used Xbox Kinect to track the patient's movement [8].

Multiple studies have been conducted using virtual reality (VR) therapy as a treatment method for children with cerebral palsy (CP) [9]. Physiotherapy for children with CP is mostly done to increase balance and walking ability [9]. Since traditional therapy at a rehabilitation center tends to be expensive and include travelling, home based VR game therapy is becoming increasingly popular due to economic and convenient reasons [9]. Some studies also suggest that VR game therapy could improve physical qualities in children with CP including strength, balance and coordination [9]. However, there are recent studies showing results that VR therapy is not more efficient than traditional physical therapy [9]. More research is needed in the field.

In one study, the serious game LAKA was used to investigate if serious gaming can contribute to health outcomes in people with chronic pain or functional somatic

syndromes [10]. This study found very small signs for this serious game, in addition to regular multidisciplinary rehabilitation, to improve physical and mental health. Even though the study did not show strong proof, they still suggest that further research should be conducted in the field of serious games in health care [10].

1.1.3 Rehabilitation for ACL-injuries

Anterior cruciate ligament (ACL) injury is one of the most common sports-related injuries treated with physical therapy [11]. In Sweden, approximately 6,000-7,000 ACL-injuries occur each year, and it has been shown that young women aged 16-20, active in sports such as football, are most at risk of being affected [11].

ACL injuries often require a knee reconstruction operation. The goal of the reconstruction is to restore the knee to homeostasis, a static physical condition, with full function and range of motion (ROM). The rehabilitation program therefore consists of two phases, preoperative and postoperative [12].

The preoperative rehabilitation is done to improve the postoperative recovery and is focused on increasing muscle strength, stabilizing the knee, regaining full ROM, and physically preparing the body for surgery [13]. Furthermore, preoperative rehabilitation is done to reduce swelling, inflammation and pain which is important for preventing postoperative disorders such as arthrofibrosis [12]. The preoperative rehabilitation phase usually lasts around 21 days before surgery [12].

The postoperative rehabilitation typically includes four stages; an early postoperative phase, a strengthening and neuromuscular control phase, an advanced strengthening phase and a final phase, focusing on making the patient ready to return to sport activities, by continued strengthening and neuromuscular control [14]. All four stages are mainly focused on improving ROM, increasing muscular strength and control, with increased intensity. It usually takes between four and nine months from the day of operation until the knee is fully recovered and the patient can go back to their regular physical activities [12].

1.1.4 Background summary

Getting patients to comply with their physiotherapy can be difficult and non-compliance is a widespread issue in healthcare. Various attempts have been made to solve this problem, including the use of video games in physiotherapy, but studies on improving compliance among patients have given mixed results. The use of video games or VR games in physiotherapy require the patients to have certain equipment in the form of consoles and their specific accessories. Since almost everyone in the target group already owns a smartphone, and they carry it with them wherever the go, a mobile phone game could be a more accessible solution. Rehabilitation of an ACL-injury includes many different exercises with focus on strength, range of motion and stabilization.

1.2 Purpose and aim

The focus of this project is to construct a body controlled mobile phone game with the purpose of helping young women with ACL-injuries perform their prescribed physiotherapeutic exercises. Our aim is to create a more accessible solution by using devices and sensors the patients already have. In Sweden, about 96-97% of all 13-18 year olds own a smartphone [15], which is why we will focus on creating a mobile phone game. Thereby it will be accessible for many users and the usage of the game will not be restricted to a specific location.

1.3 Research question

The project aims to answer the following research question:

> *How can a body controlled mobile phone game be designed to help young women with ACL-injuries do their exercises in a correct and rewarding way?*

2
Theory

This chapter presents exercises for rehabilitation of ACL-injuries, theory about app development, how motion tracking can be done with smartphone sensors, and a comparative analysis of games on the market, using motion tracking.

2.1 Rehabilitation Exercises

The exercises described below are commonly occurring in rehabilitation programs for ACL-injuries. Different programs and descriptions of exercises differ somewhat and therefore we have chosen to present some of the most basic and common exercises. The exercises occur both in the preoperative and postoperative rehabilitation.

2.1.1 Strengthening

The strengthening exercises are focused on strengthening the muscles surrounding the knee, mainly focusing on quadriceps to strengthen the front of the thigh, hamstrings to strengthen the back of the thigh, and calves [16]. By strengthening the muscles surrounding the knee the patient will be able to stabilize and increase the range of motion [16].
One common strength exercise is Isometric Quadriceps Contractions, see figure 2.1. The patient sits down with the injured leg extended, contracts the quadriceps, the muscle on front of the thigh, and then holds for 10 seconds before relaxing [16].

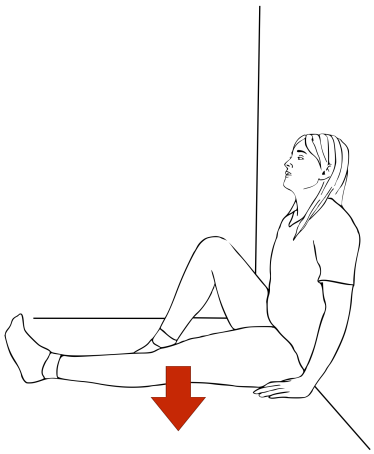


Figure 2.1: Isometric Quadriceps Contractions. Illustration by Mathilda Möller

Double-Leg Quarter Squats, or Half Squats, which can be seen in figure 2.2, is another commonly prescribed rehabilitation exercise. The patient stands up with feet shoulder-width apart, then slowly bends knees and hip, as if they were going to sit down on a chair, into a quarter or half squat before returning to starting position. The better the knee is, the lower the patient can go before standing up again [17].

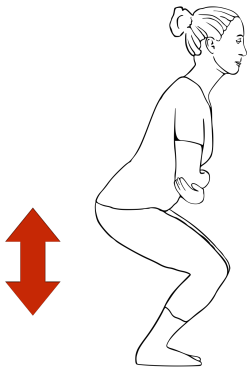


Figure 2.2: Double-Leg Quarter Squats. Illustration by Mathilda Möller

Heel Raises, shown in figure 2.3 is an exercise for strengthening the calves. The patient stands on both feet and slowly lifts the heels, standing on the tiptoes, then holds for a few seconds before slowly returning to start position. Support might be needed to hold the balance [17].

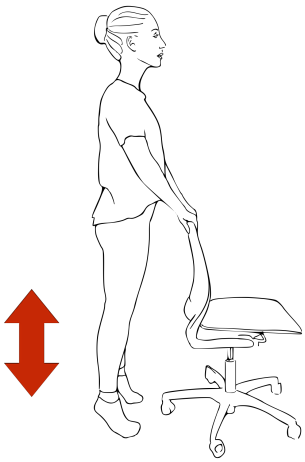


Figure 2.3: Heel Raises. Illustration by Mathilda Möller

2.1.2 Stabilizing

The stabilizing exercises are mainly based on standing on one leg. This improves the patient's balance and strengthens the muscles surrounding the knee [16]. The stabilizing exercises can be adjusted throughout the rehabilitation process by for example standing on uneven surface such as an Air pad, Bosu ball or balance board [18].

2.1.3 Range of Motion

Regaining full range om motion (ROM) is important both before and after surgery. During the preoperative phase the goal is to reduce swelling and regain full or nearly full ROM. This has to be obtained before the reconstruction operation can be done [19]. Increasing ROM is done through knee extension, straightening the joint, and flexion, bending the joint [20]. There are three types of exercises for increasing ROM; Active range of motion exercises, Active assistive range of motion exercises, and Passive range of motion exercises. Active ROM is done without assistance, no external force is applied to the movement [20]. Active assistive ROM is done with assistance of the therapist. This is done when the muscles are too weak, or when it is too painful to reach out to the joint´s extreme positions [20]. Passive ROM is when the patient is still and the joints are moved and stretched by therapist or a machine [20]. Three common ROM exercises are Heel Slides, Seated Knee Extension and Prone Knee Flexion.

Heel Slides, shown in figure 2.4, is an exercise where the patient stretches the knee without putting weight on it [16]. It is therefore a safe exercise to be done early in the rehabilitation process [16]. Heel slides are done either sitting up or laying down on the floor, with both legs outstretched. The patient should then bend the injured knee and slowly slide the foot as close to the buttocks as possible [16]. A feeling of pressure can occur in the knee but the patient should stop the movement before feeling pain. The heel should be kept in this position for 5 seconds before slowly returning to starting position [21].

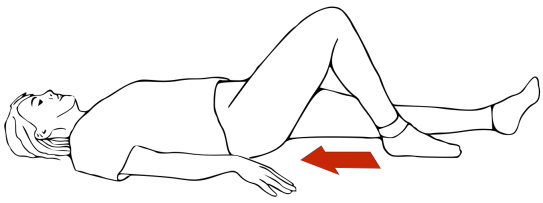


Figure 2.4: Heel Slides. Illustration by Mathilda Möller

Seated Knee Extensions, shown in figure 2.5, are done sitting on a chair with both feet on the ground. The patient should then slowly, by lifting the leg, straighten the injured knee as much as possible, hold the extended position for a second before slowly returning to the starting position [22]. This exercise can be done in multiple ways, sitting up, laying down, assisted, not assisted, with weights or without weights.

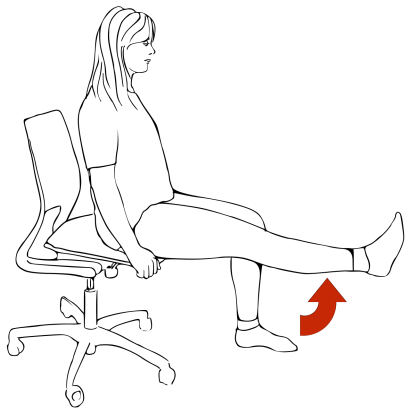


Figure 2.5: Seated Knee Extension. Illustration by Mathilda Möller

Prone Knee Flexion, shown in figure 2.6, is an exercise done laying on the stomach with both legs outstretched. The patient should then slowly flex the joint by bending the injured knee and bring the heel towards the buttocks, hold in the flexed position for a few seconds before returning to the start position [16]. This exercise is sometimes called Hamstring Curl and can be executed standing up [17].

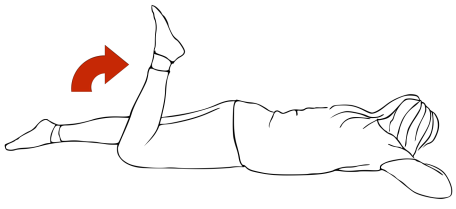


Figure 2.6: Prone Knee Flexion. Illustration by Mathilda Möller

2.2 Human Activation Recognition

Human activation recognition (HAR) is an increasing field of research. The increased relevance of the topic has come with the expanding usage of smart devices [23]. The research differentiates two kinds of HAR systems, external and wearable sensors.

Examples of external sensors are cameras in the public which recognizes activities, and intelligent homes where sensors are connected to smart devices to recognize and collect data on user's behaviour. External sensors are mainly used for security and interactive applications [23]. The usage of external sensors is limited and affected by factors such as privacy and complexity [23]. Because there are issues regarding privacy when monitoring people's behaviour in private and public spaces, wearable sensors are more commonly used for HAR systems. These wearable sensors are used with the purpose of monitoring, recognizing and assisting users' daily activities [24]. Wearable sensors are often used for measuring the user's movement, temperature and humidity in environments, and physical signals, such as heart rate [23].

2.3 Motion tracking with embedded smartphone sensors

Most smartphones today contain various embedded sensors. These sensors are for example used for tracking movement, humidity, brightness, temperature, pressure and distance, and are getting more and more accurate and powerful [25]. The advantages of using embedded smartphone sensors to detect human activity is the capability and diversity of sensors [26] and because of the accessibility. The most used sensors for tracking movement of the human body in smartphone applications are the accelerometer and the gyroscope. These two detect the acceleration and directional movement of the device [26]. Another commonly used sensor for tracking body movement in games is the image sensor, i.e. camera. This is more commonly done in video games with external devices such as Xbox Kinect, but also in augmented reality (AR) games for smartphones.

2.3.1 Accelerometer and Gyroscope

The accelerometer and gyroscope are responsive sensors influenced by movement. The data from the two sensors are often grouped to accurately track human activity and is installed in most smartphones and wearables today and is utilized in medical applications and for tracking fitness [27]. When an accelerometer is connected to a smartphone it detects change of speed, if the phone is tilted, the angle of rotation, vibrations and crashes [27]. The gyroscope is used for tracking the exact orientation, position, angular motion, and direction of the phone and allows the smartphone to quantify the data [27].

2.3.2 Camera

Tracking human activity with an image sensor can be done through different techniques. The general name for these techniques is Optical Motion Capture (OMC) which in turn can be divided into sub divisions based on if they use one single camera (monocular), multiple cameras (multi-view) and whether or not it uses markers on the moving object to track the motion (marker-based/markerless) [28]. Detecting motion without markers on the object is done with various techniques such as frame

subtraction, background subtraction and optical flow [29]. These techniques are all based on a system where the camera has a fixed position.

Another kind of camera used for tracking motion in video games is the Xbox Kinect. Kinect has three types of sensors, a color camera, an infrared (IR) projector and an IR camera. By using infrared light the device can detect and locate a person in a 3D space [30].

2.4 Game genres

This section presents game genres common for mobile phone games, including serious games, platformer games and puzzle games.

2.4.1 Serious games

There are multiple definitions of serious games. One of them is the following:

> "Serious Games": any piece of software that merges a non-entertaining purpose (serious) with a video game structure (game) [31].

Unlike most games, where the only purpose is to entertain, serious games can still be entertaining but also include a higher purpose. The term Serious games can be divided into different categories, for example education and healthcare where the scope of the games includes mental or physical training [31]. These kinds of games can be a possible motivation for people to keep up with their rehabilitation and self-care and they are claimed to be promising tools for future rehabilitation [32].

2.4.2 Platformer games

Platformer games are set in environments allowing for vertical and horizontal movement[33]. They require the player to defeat enemies, catch collectibles and traverse obstacles by running and jumping. Classic platformer games include Super Mario and Donkey Kong. A subgenre of platformer games is endless runner, where the player is moving forward at a constant speed, limiting the possibility of influence by the user. Popular games in the endless runner category are Subway Surfers and Temple Run.

2.4.3 Puzzle games

Puzzle game is a genre of video games where the player is presented with puzzles or mini challenges to solve [33]. These games often include strategy and requires problem-solving skills to progress through the game. Examples of popular puzzle games are Candy Crush and Tetris. Puzzle games is a popular genre both for mobile games, consoles and computer games [33].

2.5 Comparative analysis

This section contains a selection of existing apps and other platforms that uses technology that possibly could be applied to this project.

2.5.1 Flap fit - A body tracking mobile game

Flap fit is an app developed by YUR Inc. and is available in App Store [34]. This game in claimed by the developing company to "build healthy workout habits while having fun" [34]. In this 2D game the player controls a flying bird trying to avoid obstacles. Using body tracking technology through the front camera on the iPhone the user controls the bird while moving his/her body. A squat moves the bird downwards and straightening up moves the bird upwards. If the bird run into an obstacle the game needs to be restarted. The user does this by raising his/her hands. There is no information to be found regarding whether the game is developed in collaboration with physiotherapists or doctors or only by designers and developers.

2.5.2 Stasism - therapeutic physical video games

Stasism is an online social platform for people with cerebral palsy (CP) created by HuginTech [35]. This platform includes therapeutic physical video games where the body is used to control games with the purpose of getting people to do their physical therapy. The games are controlled using web camera and/or balance board. All games on the platform are developed by professional game developers in collaboration with doctors and therapists [35]. In addition to the games, the platform includes an online community for people with CP to connect with each other.

2.5.3 Whac-A-Physio

Whac-A-Physio is a virtual reality (VR) game used in a study for neurological physiotherapy [32]. This game is played in a VR environment using the VR headset Oculus Quest (or Oculus Quest 2) and two controllers. The game is a board of white square tiles that randomly changes colour to red or blue. When a tile changes colour, the aim is to hit it with the corresponding controller. If the tile is red, the right controller should be used and if the tile is blue, the left controller should be used. This game challenges the balance of the user, both standing up and sitting down. It also engages the upper body through rotation, coordination and movement. One aim of this game is to fit a heterogeneous user group and can therefore be customized by both the users and the physiotherapists providing the game. The game can be adjusted to use only one upper limb and also to fit a more narrow range of motion in case of poor functioning of the upper limbs [32]. Whac-A-Physio was developed through a Co-design process where physiotherapists and users were involved throughout the entire process [32].

2.5.4 LAKA

LAKA is an adventure game played on a touch screen tablet computer where the player controls an avatar who encounter and interact with other characters [10]. In every encounter the player gets different options to choose from in situations like standing in line, being invited into someone's home or travel around the world. The aim for this game is to teach people to handle life by guiding them through situations that might come up [36].

> "...it aims to improve and test your skill in generosity, moral discipline, patience, energy, focus and wisdom. These are the six "paramitas" (virtues) of Mahayana buddhism" [36].

While this is not a religious game, it has taken inspiration from Buddhism [36]. The company who developed this game claim that sources of chronic pain often can be found in the environment of the patient [36]. They claim that mentally stressful situations can cause physical pain [36]. LAKA was developed by the Dutch rehabilitation company Ciran, together with the game studio, Paladin [36].

2.6 Theory Summary

There are a number of different ways to use motion tracking in smartphones, including gyroscope, accelerometer and camera. These techniques are used in a number of different mobile phone games on the market and are possible solutions to the problem presented in this project. There are multiple different game genre options for the game. What genre and technique to use will be investigated to find what aligns with both the physiotherapeutic exercises and the target demographic for the game.

3
Methods and Tools

This chapter presents relevant frameworks and methods that have been implemented or considered potentially useful throughout the project. Starting with design frameworks, presenting relevant software and design tools along with idea generation methods, development methods, testing and evaluation methods.

3.1 Design frameworks

Some organizations adopt methodologies for software and game development. There are multiple frameworks available for software design, but not as many for game design [37]. Even though many professionals use methodologies for design some claim that they should be used more as guidelines than rules [37]. If the purpose of the game is to learn, the requirement of knowledge of game design also needs to be accompanied of knowledge in instructional design [37].

3.1.1 Design thinking

Design thinking can be described as a nonlinear process for detecting and solving problems [1]. Design thinking can advantageously be applied in situations where the problem is not well defined. It has been used to develop business models and process design, but the focus in this context will be on product development. Design thinking has developed over time and has its origin in different fields like software development, engineering, arts and business. Since it has a cross disciplinary background, there are multiple models and tools to choose from within the field of design thinking. However, what a lot of the models have in common are two main phases: identifying problems and solving problems, which are visualized in figure 3.1. The first phase can be broken down into two subcategories: discover and define. In the discover mode, the goal is to find out what the user needs are and understanding their context, experiences and behaviours. In the define mode, the insights from the discover mode are translated into well-defined problems. When it comes to the create mode, the aim is to come up with solutions to the defined problems. These solutions can then be iterated over and over. The first step is to generate a lot of ideas. This can be done using methods for brainstorming and other types of idea generating methods. Prototypes are then developed based on the ideas that best meet the criteria of the insights discovered during the identify phase[1]. In the final phase of the design thinking framework, evaluate, feedback on the created prototypes is collected and evaluated based on the user needs. One way to receive

feedback is to test the prototypes on potential users [1].

As shown in figure 3.1, design thinking is not meant to be a linear process. The different modes should be iterated over multiple times.

Figure 3.1: A graphic representation of the design thinking framework [1].

3.1.2 Lean Game Development

The Lean framework has its origin from the Toyota manufacturing in the 1950s [38] and is closely related to agile methodology. The Lean method is suggested to be a systematic method for waste minimization without sacrificing productivity [2]. There is an adaption of the Lean framework to fit to the game development process suggested in [2]. Some claim that there has been a shift from agile to Lean in recent years [39] [38], even though both methodologies have a lot of similarities [40]. Since design and software development both are iterative processes, the Lean framework can be of sufficient use in a process of designing and developing [40].

> "Lean game development offers a methodological alternative to game development that can help you to eliminate waste, get results as fast as possible, strengthen and empower teamwork, and allow you to have a better view of the whole work" [2].

There are six main phases in the Lean game development process [2]. These phases are: inception, design, build, measure, analyze and iterate. Figure 3.2 shows these steps in a graphical way. The first phase, inception, include defining the goals, doing the research, brainstorming and making hypotheses to turn the ideas into measurable goals [2]. This phase can also benefit from creating personas to help visualizing the users [2]. The second phase is where the design is made and the ideas from the first stage are refined. After the design is made the coding begins to develop and test what is possible to make. When the prototype is ready it needs to be tested on the target group. This is done in the phase called measure. After the testing the results need to be analyzed to get an understanding of the usability of the prototype. As in most frameworks for product development iteration is an important part of the design process. This is done to generate new ideas and concepts [2].

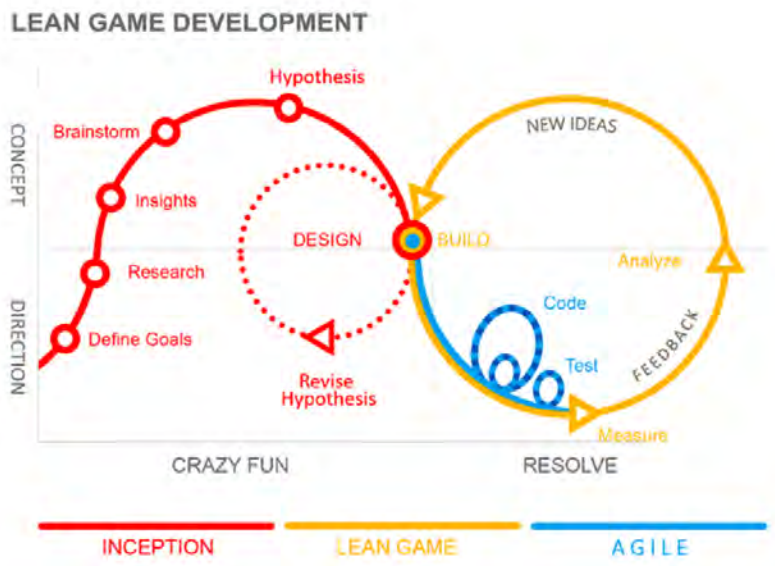


Figure 3.2: A model of the Lean development process [2].

3.1.2.1 Daily stand-up meetings

Daily stand-up meetings, also called daily scrum, is a common practice within development teams and often used within agile development processes [41]. It is used for improving communication and sharing information within the team. The daily stand-up meetings are often around 15 minutes long meetings which are held at the beginning of the working day with the focus on sharing valuable information between the team members and improving group dynamics [41].

3.2 Ideation Methods

This section introduces various methods for generating and organizing ideas. The ideation methods are primarily focused on developing multiple ideas quickly rather than spending a lot of time on individual ideas. Evaluation methods can then be combined with ideation methods for sifting and elaborating the generated ideas.

3.2.1 Mind mapping

Mind mapping is a visual, non-linear way of writing down topics and ideas to organize a problem space [42]. The main topic is written in the middle of a paper and circled. Related subjects are then written around it with lines drawn to the main topic. Ideas related to the subjects are written around them and connected by lines [42]. The mind map, and the process of creating it, allows for condensing and verifying presumptions, establishing links, and exploring other possibilities, and thereby organizing the information [42]. Mind mapping is especially useful when the relationship between topics is unclear.

3.2.2 Crazy 8

Crazy 8 is a method for rapidly generating a large number of ideas [43]. Every participant is given a piece of paper to fold into eight equal sized rectangles [43]. Eight minutes is given to draw (or write down) eight ideas, one in each rectangle on the paper. When the time is up, everyone stops drawing and the ideas are presented and discussed in the groups.

3.2.3 Brainwriting

Brainwriting is a method for creating ideas where every participant writes down ideas instead of shouting them out as in traditional brainstorming [44]. Brainwriting can be divided into two types: individual brainwriting and interactive brainwriting. In individual brainwriting every participant gets to write down their ideas on a specific topic without discussing with the other participants. After the ideas are listed they are grouped together and duplicates are eliminated. In interactive brainwriting every participant is given a specified time (usually several minutes) to write down a couple of ideas. After the idea is written, it is handed over to another person who can add new ideas with inspiration from the first one or extend on the first idea [44].

3.3 Development Methods

In this section, several methods commonly used in game development are described. It includes methods for communicating ideas and for creating prototypes.

3.3.1 Game Design Document

A Game Design Document (GDD) is a guide and reference document declaring all important details of a game [45]. The document is usually created in the beginning of the development process to set the frames of the project and facilitates for the development team to work in the same direction and provides a clear vision of the project. The GDD details aspects such as the gameplay mechanics, level design, story, characters, art style, sound, and more. The GDD is used as a tool for communication within the development team as well as with the stakeholders. The structure and content of the GDD varies between different projects and there is therefore no standard template. However, it is important to make the document clear and concise [45].

3.3.2 MoSCoW prioritization

MoSCoW is a prioritization technique where every letter stands for a category of requirement with different levels of priority[46]. M stands for *Must have*, S for *Should have*, C for *Could have* and W stands for *Won't have*. With this technique, attributes of, for example, a product or prototype are listed to clarify the order of importance.

- **Must have**
  These elements must be included if the finished result should be considered a success.
- **Should have**
  Elements on this list have high priority and should be included in the result.
- **Could have**
  Represents elements that are preferred but not essential. These could be included if there is time available to address them.
- **Won't have (this time)**
  These elements will not be included within the frame of the current version. The might, however, be included in future version.

3.3.3 Wireframing

Wireframing is a method often used in app development where structural representations and skeletons of graphical user interfaces are created [47]. The wireframes can be of varying fidelity, from skeletons to interactive prototypes. The method is used for quickly making ideas more tangible which facilitates explanation and evaluation, before the ideas are implemented [47].

3.3.4 Throwaway Prototyping

Throwaway prototyping is a development method where prototypes are quickly built to then be discarded as soon as they have served their purpose [48]. The method is often used for software development when there is a high degree of uncertainty regarding the requirements or there is a high risk associated with the project. The focus of the method is to step by step implement and test different functionalities. Multiple prototypes can be developed to address a single problem, to be evaluated, compared and finally discarded since it is a quick and simplified system with limited functionalities. The goal of throwaway prototyping is to identify and address problems and issues early in the process, before spending too much money and time on a solution. Once the prototype has been tested and evaluated it is discarded and the knowledge and insights from the process are used for development of the final prototype. The benefits of throwaway prototyping is reduced development costs and time, together with improved collaboration among team members and higher better alignment with user and customer needs [48].

3.3.5 Evolutionary Prototyping

Evolutionary prototyping is an iterative software development approach where the development team starts with building a simple initial prototype and then continuously refine and enhance it until it becomes a final, fully functional product or prototype [48]. The goal with evolutionary prototyping, in contrast to throwaway prototyping, is thereby to create the final prototype to be tested and evaluated by users and stakeholders. The feedback is then used for continuous refining and developing until the final goal of the development process has been reached. The

benefits of evolutionary prototyping is that it enables stakeholder and user engagement throughout the process which makes the final product to more likely fulfill user's need and expectations. This development approach is useful when the requirements are not well understood from the beginning of the process or when they are likely to change over time [48].

3.4 Evaluation and Analysis Methods

This section presents different evaluation and analysis methods used for evaluating, sifting, and elaborating ideas. The evaluation methods includes methods for qualitative and quantitative user studies meanwhile the analysis methods aims to structure and analyze data.

3.4.1 Dot Voting

Dot voting is an evaluation method used for prioritizing ideas, decision making within a design team, or identifying areas of issues. The method involves letting a group evaluate a number of options or ideas through voting by placing dots on their favourites. The number of dots given to each participant can vary depending on the number of options to be evaluated and the level of feedback that is desired. Dot voting can be conducted anonymously or not. The benefits of dot voting are its simplicity, flexibility, and ability to quickly rate and get insights from a diverse group of participants. However, it is important to ensure that the voting process is well-structured and clearly communicated to participants to avoid bias or confusion. Overall, dot voting is a useful evaluation method that can provide valuable feedback in various contexts, narrow down the number of ideas and to make quick group decisions [49].

3.4.2 Interviews

There are two primary methods for survey research suggested by [42]. One of them is interviews and the other one questionnaires. Interviews is a method of survey research where you get direct contact with the participants [42]. Interviews can be held either in person or remotely, via phone calls or video conferences for instance. There are three different types of interviews; structured, semi-structured and unstructured [50]. These three types of interviews are described below. It is suggested by [42] that interviews are best suited to be used in the middle phases of a design process. They say that it is preferred to use interviews either in the early exploration phase, in the middle of a project to evaluate early prototypes or to help generate ideas. They also mean that interviews can be helpful later in the process to get feedback on final prototypes.

3.4.2.1 Structured interviews

Structured interviews is a method where each question from a decided script is asked in the exact same way and the exact same order to every participant of the interview

study. It usually contains more closed than open-ended questions [50]. Structured interviews are suggested to be used if you want to interview a lot of people and collect more quantitative answers [50].

3.4.2.2 Semi-structured interviews

Semi-structured interviews rely on an interview guide, rather than a script that the interviewer has to stick to [50]. This guide contains open-ended questions that can be asked in either order that the interviewer prefers. Usually the interviewer can use probing questions to get more information from the interviewee [50]. Semi-structured interviews are recommended to be used if you have some problems that you specifically would like to know more about [50].

3.4.2.3 Unstructured interviews

Unstructured interviews does not contain any prepared questions. The interviewer can start with a very open question about the subject to get a better understanding and then follow up with probing questions and let the interview move forward more like a conversation. The goal of an unstructured interview is to get a better understanding of the subject. This type of interview is suggested to be used in an early stage of the research process when you know nothing or little about a subject [50].

3.4.3 Questionnaires

Just as with interviews, questionnaires is one of the two primary methods for survey research [42]. Questionnaires are tools for collecting information from different people where they fill in pre-decided questions [42]. Sometimes the answers are multiple choice and sometimes they are open for the participant to write freely. Questionnaires are suggested to consist of closed questions because open questions are harder to compile and analyze for the researcher [51]. Another argument for using closed questions is that they are easier for the respondent to answer [51]. However, caution should be taken when constructing the questions and alternatives for answering to make the questionnaires as reliable as possible [51]. According to [42], questionnaires should be used either in the exploration phase of a design project or later in the evaluation phase. They also mean that they are useful when you want to reach out to many people in a short period of time and collect a lot of answers. Questionnaires should always be used in combination with other research methods [51].

3.4.4 Focus groups

Focus groups is a qualitative research method where a small group of well chosen participants, usually with similar backgrounds, discuss a research topic [52]. The group typically consists of six to eight participants together with one moderator, the interviewer, who leads the discussion and asks questions. Focus groups are used for gathering opinions, attitudes and insights about a research topic, from a well-chosen group of people [53]. The advantage of focus groups is that the dynamics of

the group can facilitate and contribute to deeper discussions. To enhance this it is important to have a skilled moderator and an open, non-judgemental climate [53].

3.4.5 Observations

Observations can be used as an evaluation method in different phases of the design process [42]. Observations can either be semi-structured, involving a set of guiding questions but allowing for flexibility in the observation process, or structured, relying on predetermined questions, worksheets, or checklists to document the behavior of the users.

3.4.6 Affinity Diagramming

Affinity Diagramming, also known as the KJ-method, is an analysis method used to gather large amounts of qualitative data that then can be narrowed down and grouped into categories [54]. Affinity diagramming derives from anthropology and social science, but has been accepted in the field of Human Computer Interaction (HCI) [54]. The method can therefore be used when evaluating interactive prototypes with the purpose of analyzing data gathered in user studies.

3.5 Software for Game Development and Motion Tracking

This section presents software that can facilitate the development of games for mobile phones. Game engines for building games will be described along with software that enables development of a motion tracking system.

3.5.1 Game Engines

Game engines are tools for software development that facilitates the development of digital games [55]. There is a growing number of game engines available on the market, which can make it hard when choosing one engine to work with [55]. Two of the most used game engines, Unity and Unreal Engine, are presented below.

3.5.1.1 Unity

Unity game engine is developed by Unity Technology and is today one of the most used game engines in the world [55]. This engine is easy to use, with a flexible development process and simple exporting process. Unity supports scripting in C# which is simple and efficient [55]. Unity provides an extensive library of tutorials from beginner level all the way to advanced level which makes it available for a broad user group [56]. It is free for beginners and students and it is considered ideal for developing 2D and 3D games [57]. It also includes kits for AR and VR development. This engine is easy to use in cross-platform teams and can be used to develop games for computers, consoles, mobile phones and more [57].

3.5.1.2 Unreal Engine

According to the company behind Unreal engine it is "the world's most advanced real-time 3D creation tool for photoreal visuals and immersive experiences" [58]. Unreal engine works with a visual scripting Blueprint framework which is intuitive for non programmers[55] [57]. Some consider Unreal to be the top choice when working with VR and it is better for 3D games than 2D and mobile games [57].

3.5.2 Software for camera based motion tracking

There are multiple ways of using motion tracking with a camera as sensor. Some of them are explained below.

3.5.2.1 OpenCv

Open CV is an open source library containing algorithms for computer vision [59]. Unity Asset Store [60] contains a free asset called *OpenCV plus Unity* [61]. The developers of this asset have adapted "*OpenCVSharp* (open source C# port of OpenCV)" to the Unity Environment. This facilitates the process of registering footage from the webcamera and using that information to control a game.

3.5.2.2 Augmented Reality

Augmented Reality (AR) is defined as the integration between the physical world and the digital world [62]. AR combines virtual and real objects in an interactive way. There are multiple tools for developing with AR-technology. Some of them are presented in this section.

AR Foundation

ARFoundation is a Software Development Kit (SDK) provided by Unity which allows developers to create augmented reality (AR) systems and applications for iOS and Android devices. ARFoundation provides tools and features that enables development of AR experiences such as placing virtual objects in the real world, image tracking, object tracking, face tracking and body tracking. ARFoundation uses two primary technologies: ARKit for iOS devices and ARCore for Android devices [63].

Vuforia

Vuforia is a software providing a software development kit (SDK) for creating AR systems and applications [64]. The SDK integrates with Unity which enables developers to create interactive AR experiences for mobile devices, with features such as tracking real-world objects, images, targets, and 3D objects, using computer vision technology. It also provides tools for creating and managing virtual content that can be placed in real world, enabling users to interact with their surroundings through their devices [64].

3.5.2.3 Motion Tracking Cam

Motion Tracking Cam is a third party asset available for purchase in the Unity Asset Store [65]. This asset is created by SG-DIGITAL [66] and enables motion tracking by detecting change of the pixels captured by the camera. By a change of color in the pixels or by change of contrast, the moving areas on the screen are detected. This detection then translates into movement in a 3D environment in Unity. In the asset there are three pre-set ways to explore on how to control the game objects: either by moving the virtual objects to the area of the screen where the movement is detected, by moving the objects in the same direction as the detected movement in the camera, or by making a game object appear on the screen at the position of the camera detected movement.

3.5.3 Design tools

Different design tools that can be used for designing graphical user interfaces, 2D/3D models and animations for games are presented below.

3.5.3.1 Figma

Figma is an online tool for collaborative work in design and prototyping [67]. Figma is a tool that can be used in UI/UX design, brainstorming, graphic design, wire-framing etc. [67]. It allows the user to build low or high fidelity prototypes with or without interactivity. This tool is widely used among UX designers.

3.5.3.2 Procreate

Procreate is a drawing app for iPad where sketches, drawings and animations can be created [68]. These drawings can be exported and used in the game engine in the case of creating a 2D game. If the game is in 3D, drawings made in Procreate can be used for menus and pop-up signs. Procreate is a two time winner of the Apple design award, in 2013 and 2022 [68]. Procreate has an extensive library of brushes and all brushes can be customized to fit specific needs. Even more brushes can be downloaded and imported to Procreate.

3.5.3.3 Maya

Maya is a professional software for 3D animations and visual effects owned by Autodesk [69]. Maya has a wide range of tools for animation, simulation, and modeling [70]. 3D models and characters created in Maya can be imported and used in game engines like Unity or Unreal. This software is very popular in the video game industry [70]. The yearly price for a Maya license is over 2200 euros [69].

3.5.3.4 Blender

Blender is a free and open source software for 3D modelling, animation, sculpting, rendering and much more [71]. It is created by Blender foundation that is an independent public benefit organization [71]. Blender is cross-platform and runs equally

well on Linux, Windows, and Macintosh computers [71]. Blender is a customizable software that offers advanced options for editing Python scripting [70]. The purpose of this is for the users to be part of the development and allow for faster bug fixes and better usability [70]. Even though this software is free, it is still very powerful and suitable for independent learners because of a strong online community that offer many tutorials and guidance for beginners [70].

3.5.3.5 Mixamo

Mixamo is an online platform, provided by Adobe, which provides 3D characters, and animations to be used digital projects such as games and movies [72].

4
Planning

This chapter presents an overview of the project plan, including the frameworks to be used, project goals and challenges, as well as a timeline for project.

The main game design process of this project will follow the aforementioned Lean framework with its six main phases; inception, design, build, measure, analyze and iterate [2]. We consider this framework to be the most suitable for this project since its main focus is on the development rather than the user experience. The focus will be on creating the features of the system and combining motion tracking with game development. The game will be a serious game since its purpose is not only to entertain, but to have the aspect of the user's recovery in mind. The goal is to develop and then test the functionalities to make sure the system works the way it is supposed to. To test the functionality, one study will be made with physiotherapists, to make sure the exercises are made in a correct way. A secondary study will be made with people from the target group, to make sure the game is user friendly.

4.1 Targeted injury

Based on the research about ACL-injuries and its rehabilitation, we have decided to focus on Seated Knee Extension to be the exercise controlling the game. This exercise is chosen because it improves range of motion (ROM) which is crucial for rehabilitation both before and after surgery. Seated Knee Extension is an exercise that can be adjusted, with or without weights, based on the patient's condition. It can therefore be executed throughout the whole rehabilitation process, and possibly even after. Another advantage with choosing this exercise is that it is a big movement which will facilitate the development of motion tracking. The choice of exercise affects the decision of motion tracking technique which in this case will be camera based since it is not affected by the movement or position of the smartphone. Since there are different kinds of extension/flexion exercises that are based on similar movements, there is a possibility that the game can be adapted to multiple exercises.

4.2 Process plan

Below, the six phases of the Lean framework are described. These will be used for guidance throughout the design and development process.

4.2.1 Inception

In the first phase of the Lean game development process as suggested by [2], there are five sub steps; define goal, research, give insights, brainstorm and make hypotheses. These steps will be executed as described below.

4.2.1.1 Define goal

The goals of the game will be set, and to reach the goals different approaches of how to use the body as a game controller will be investigated.

4.2.1.2 Research and give insights

By means of a literature review and benchmarking we will explore what systems are possible to use and which ones already exist on the market. We will also investigate which therapeutic exercises are most frequently used to cure ACL-injuries. The focus will then be to create a game controlled by the body movements of one of the exercises. The insights gained from the research will be the basis for brainstorming possible solutions.

4.2.1.3 Brainstorm and make hypotheses

Brainstorming sessions will be held and inspired by "7 tips on better brainstorming" [2]:

- Have one conversation at a time
- Try to create as many ideas as possible.
- Build ideas over others' ideas
- Encourage crazy ideas
- Be visual
- Maintain the focus
- Don't criticize or judge

The brainstorming session will focus on enhancing creativity and generate game design ideas. We will start by using Mindmapping (3.2) to get the discussion and idea generation process started. This method will be used to define the different areas of game design that will be relevant to brainstorm around and to start the discussion. To continue enhancing creativity the Crazy 8 (3.2) method will be conducted with the purpose of quickly generating many ideas. The ideas from the Crazy 8 method will be used for recognizing patterns and define different game genres to continue generate ideas within. We will then use these game genres as starting point for a number of Brainwriting (3.2) sessions with the purpose of generating many, more detailed ideas, within each game genre. The generated ideas will then be discussed and evaluated through Dot Voting (3.4) with the purpose of narrowing down the scope and number of game ideas.

4.2.2 Design and build

After the inception phase we will create a prototype of a game appropriate for the chosen target group. The development part of the project will be an iterative process between prototyping, testing and evaluating. The initial part of the development process will focus on exploring different techniques and areas of the game separately. For this, the method Throwaway Prototyping (described in section 3.3) will be used. When insights are gained about which techniques to use and what kind of game to create, the development of a final prototype will begin. The method we are planning to use for this part of the project is Evolutionary Prototyping (3.3) with the goal of iteratively building, refining and developing a fully functional game.

Throughout the development process Unity will be used as the game engine (see section 3.5). The main advantages of Unity is that any type of game can be developed, it supports cross-platform development, it is good for creating both 2D and 3D games, that it is simple and easy to learn and has a big community with free assets and tutorials [57][55]. Another advantage of using Unity as game engine is that both group members have prior experience of creating games with this software. We will explore the possibilities of using the sensors of the phone to track body movement which in turn will control the game. When a functional prototype is developed, it will be exported and tested on mobile phones.

4.2.3 Measure, evaluate and iterate

Throughout the development process we will conduct testing carried out within our group. Through trial and error we will iterate through the development process until having a functional prototype to do user tests with.

When the main functions of the game are implemented we will have a focus group (described in section 3.4) with physiotherapists as participants to discuss important and additional aspects to implement and consider when developing the final prototype. This will be done early on in the development process to gain insights and get opinions on the idea before too much time is spent on a final prototype. The focus group will also facilitate the preparation and planning of a qualitative study which will be done to evaluate the final prototype.

The qualitative study will include user tests followed by interviews (3.4). This qualitative study will focus on evaluating the functionality of the prototype and its possibility to accurately guide the patient through the exercise. We aim to recruit a minimum of 6 participants to reach data saturation [73]. We will mainly focus on evaluating the prototype with legitimated physiotherapists to make sure the game supports the patient to do the exercise in a correct way, and to get their professional opinions of the game's effect on the rehabilitation process. Additionally, a secondary study will be conducted where we will evaluate the prototype with 6 participants from the target group (women aged 16-20 with ACL-injuries) to make sure that the game is user friendly.

The game is initially intended to be used as a replacement of one specific exercise in the patient's rehabilitation program. Further development of the game would be to include more exercises to finally include the whole rehabilitation program.

4.2.3.1 Finding Participants

To find participants to our studies we will use the following channels:

- contact physiotherapists
- advertise using social media
- contact football clubs to find participants
- contact physiotherapists to get in touch with patients

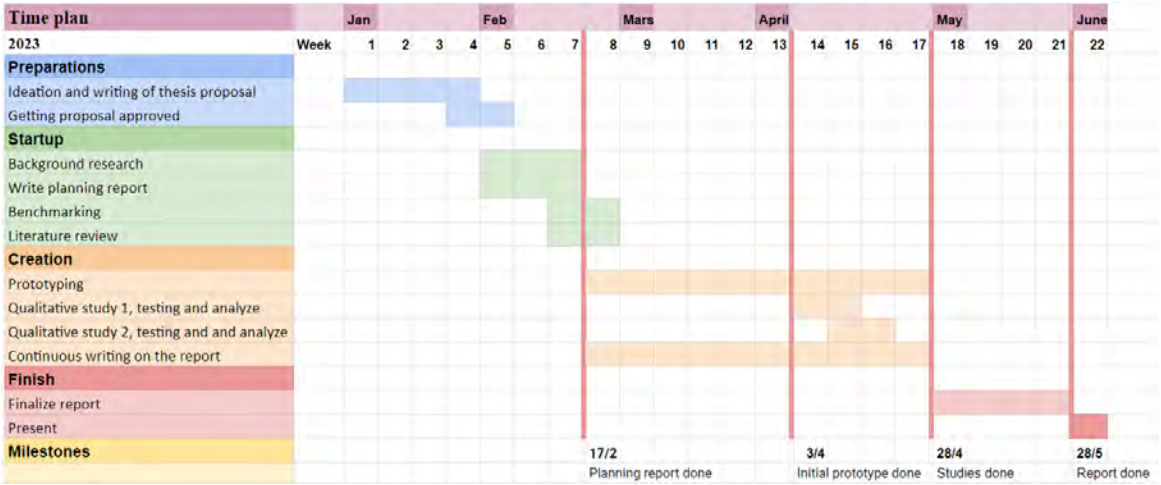
There might be problems when recruiting participants to a study for injured people because of professional secrecy if contacting physiotherapists. An easy solution could be to advertise the study through social media for people to voluntarily contact us. Since our targeted users are above 15 years old they have the legal right to give their own consent of participation [74].

4.3 Documentation during the development process

Throughout the design process, a project diary will be maintained to be used as support for writing the project report. The report will be written continuously during the whole design and development process. Alongside these two documents a game design document (GDD) (3.3) will be created to specify the attributes of the game.

4.4 Time plan

To keep track of the time frame of the project a plan will be used as a guide for our work. Milestones are used to make sure we stick to our decided plan. This plan will be followed up during weekly meetings with the project supervisor.



5
Execution and Process

This chapter presents the execution and process based on the Lean framework, which includes the phases of inception, design, build, measure, analyze, and iterate. The process is described chronologically, starting from the inception phase to the final iteration of the final prototype. The chapter take its starting point with research and goals defined, which involve designing a smartphone game controlled with the physiotherapeutic exercise Seated Knee Extension, using the device's camera as the sensor and Unity as the game engine.

5.1 Inception

The inception phase of the process included research on what kind of motion tracking systems existed and how they could be applied to this project. The systems explored were Open CV, AR in Unity and Motion Tracking Cam. The process of exploring them is described in the section below. After we acquired a basic knowledge of motion tracking, idea generation sessions were conducted. The following sections provide a description of these as well.

5.1.1 Exploring motion tracking

In the first stage of the process we explored different ways of using the movement captured by the camera to control motion in Unity. Three different motion tracking systems were explored, the first one was using Open CV to track and follow movement in the camera, the second was exploring a marker-based AR system in Unity, and the third was exploring a Unity asset called Motion Tracking Cam. The process and results of exploring the three motion tracking systems will be presented in the following section.

5.1.1.1 OpenCV plus Unity

The asset, *OpenCV plus Unity* [61] was used to create a frame that displays the objects captured by the camera and creates multiple falling spheres that collides with the objects, see Figure 5.1. The creating of this project was inspired by a tutorial on youtube: *Unity + OpenCV Interactive Webcam Video Tutorial* [75]. The system create outlines around contrasting objects captured in the camera. These outlines are vectorized and used as colliders in the 2D game view. Once the spheres collides with a vector it bounces.

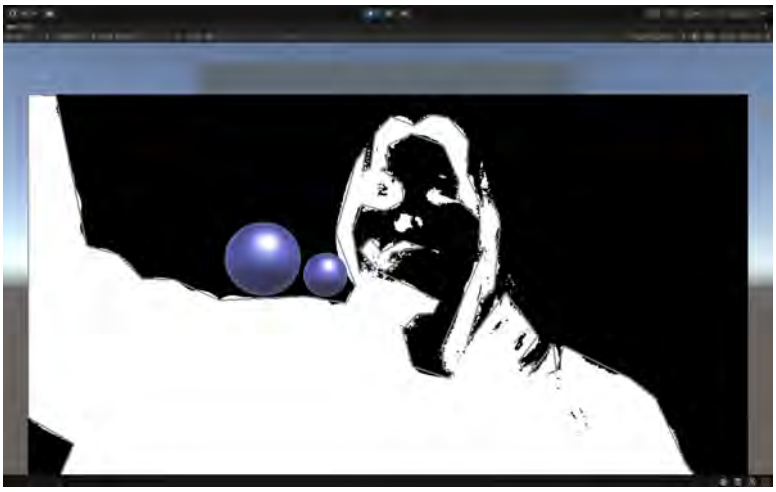


Figure 5.1: OpenCV motion tracking system

5.1.1.2 AR in Unity

The second motion tracking system that was explored was a marker-based AR system. This was done by following an example project from Unity's own learning database, Unity Learn. The example project is called Create a marker-based AR app and the tutorial collection includes both setup of an AR environment, building for Android- and iOS-smartphones, adding markers and AR objects, and creating UI to interact with the AR objects [76]. The project was built upon a downloaded project template with the AR environment included and the functionality of the app was to make a game object appear when scanning a marker with the smartphone camera, see Figure 5.2. The functionality of the buttons was to spin the AR object in the scene. For this project we explored building and exporting applications for iOS devices which demands an extra step in the building process, exporting to Xcode, an integrated development environment for Apple's platforms, before being able to open it on the device. The main issue encountered while exploring this motion tracking technique was related to the building process where several errors occurred. The experienced advantages of using marker-based AR for motion tracking are that it is a relatively simple way of tracking an object and there are many tutorials and guides online for creating AR systems.

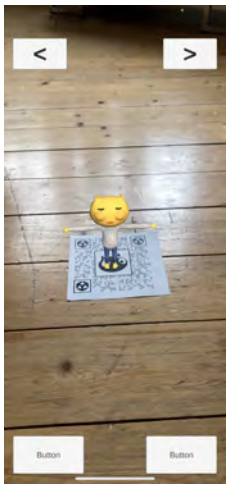


Figure 5.2: AR application for iOS device

5.1.1.3 Motion Tracking Cam

Motion Tracking Cam enables motion tracking by detecting change of the pixels captured by the camera (see 3.5). This asset was explored through a couple of preset example projects available in the asset. One of the examples was a game called Breakout, see figure 5.3, where the motion of the box at the bottom of the game is controlled by the vertical movement captured by the camera of the computer. The vertical movement in the camera decides the direction of movement of the box.

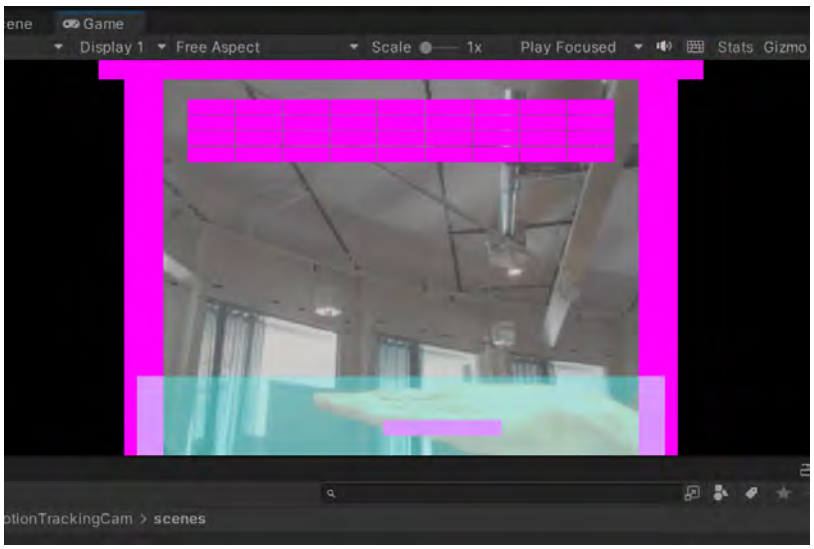


Figure 5.3: A motion controlled version of the game Breakout in the Unity asset, Motion Tracking Cam

5.1.2 Idea generation

The idea generation was focused on generating gameplay ideas. In this process, the functionalities and technical aspects of the game were put aside to enable exploration of a wider solution space. Throughout the idea generation, all ideas were

welcome, whether they were realistic or not. To facilitate the idea-generating stage, we used a selection of brainstorming methods, including *Mindmapping*, *Crazy 8* and *Brainwriting*, described in 3.2. Paper and pen were used for all methods, which were executed by the two group members. To finally evaluate and scale down the scope of the output of the idea generation process, the *Dot Voting* method, described in 3.4, was performed. The process and ideas generated are presented in the following section.

5.1.2.1 Mindmapping

To start the idea generation process a mind map was made (see appendix A), exploring different game genres, how motion tracking could be used in different types of games, and explored different existing inspirational games. The purpose of this method was to get inspired and we started thinking about new solutions and ideas. The movement of the selected exercise was mapped and combined with possible player movement in the game. For example, raising the leg up could translate to the player jumping or moving upwards. The motion tracking input could also be combined with other forms of input like swiping on the phone, pressing touch screen buttons or tilting the phone. Another result of the mindmapping was the idea of having a personalized start menu where the user can input the number of repetitions, the length to hold, and the number of sets for a specific exercise. This input could then affect the game mechanics to fit the user's specific needs. Different game genres were listed, such as *Platformer*, *Puzzle*, *Quiz*, *Shooter*, *Sandbox*, *Real Time Strategy (RTS)*, among others. The ideas and genres were discussed, and the most appealing and feasible ones were highlighted based on the target group and expected level of difficulty for the development process. The most appealing and feasible genres were *Puzzle* and *Platformer*. Thinking about platformer games also generated the idea of making an endless runner game. With these genres and ideas, and insights in mind we proceeded to the next idea generation method, Crazy 8.

5.1.2.2 Crazy 8

After the mindmapping session, the Crazy 8 method was conducted to quickly generate many ideas, whether feasible or not. Each group member was given a pen and paper, which was divided into eight sections, one for each idea. Then, a timer was set for one minute, during which time the person had to come up with, draw, and explain each idea. This was repeated eight times until the papers were filled with eight different game ideas each. The result can be seen in appendix A. The different ideas were then explained, discussed, and grouped into different genres. Most of the generated ideas were endless runner games, some were puzzle games, and some were 2D platformer games. The outcome of this method was inspiration, along with the three game genres that were highlighted and used as a basis for the following idea generation method, Brainwriting.

5.1.2.3 Brainwriting

Based on the results from the previous idea generation method, Crazy 8, a third ideation method was conducted, *Brainwriting*. This method was conducted to explore the solution space within each game genre. The session was thereby divided into three sets, based on the game genres highlighted in the Crazy 8 method: *Endless Runner*, *2D Platformer* and *Puzzle*. For each genre, both group members were given three post-it notes to write down three ideas. Two minutes were given for writing down each idea. When all three ideas were written down, the timer was started again, and two more minutes were given to elaborate on the other person's idea. This was repeated until both group members had contributed to each idea. The session resulted in 18 different ideas that both group members had developed together. An overall view of the ideas can be seen in figure 5.4, and more detailed in appendix A.

Figure 5.4: Ideas generated using the Brainwriting method, divided in to three game genres.

5.1.2.4 Dot Voting

As a final step of the idea generation process, with the purpose of narrowing down the scope and number of ideas generated from the Brainwriting session, the Dot Voting method was conducted. The three collections of ideas, seen in Figure 5.4, were gathered in a Figma document. Then, both team members were given three dots each to place on their top three favourite ideas without discussion. The results of the Dot Voting method clearly indicated that Endless Runner and 2D Platformer were the highest prioritized and winning genres, whereas the Puzzle game ideas did not receive any votes.

5.2 Design and build

This section presents the methods used for building the initial and final prototypes of the game. As a result of the brainstorming sessions it was decided that the focus of the development process would be on endless runner games. To explore the features of Unity Engine and the process of making this type of game, multiple prototypes were made using Throwaway Prototyping (described in section 3.3). The final prototype was then developed through Evolutionary Prototyping (described in section 3.3). Throughout the design and build phase, a game design document (GDD) (3.3) was developed to outline the key aspects of the game. This GDD also includes a functionality prioritization list, which was created using the MoSCoW-technique (3.3). For the full GDD, see Appendix E.

5.2.1 Throwaway Prototyping

The initial part of the design and build phase focused on exploring different techniques and functionalities of endless runner games and motion tracking. Several prototypes were created for each aspect to compare and evaluate different techniques. Once a function was implemented in the prototype, tested and evaluated internally in the team, the prototype was discarded. Strategies for building various functionalities and insights gained from prototyping were documented and saved for later stages of the development process. This process was divided into two separate parts: exploring different approaches of building endless runner games and investigating various techniques of building motion tracking systems, primarily marker based AR systems, in Unity.

Building Endless runner games

To explore different approaches and features of endless runner games, multiple prototypes were created. Using throwaway prototyping, features such as player movement, spawning of objects and ground sections, and implementation of characters and animations were explored. The prototypes were of differing fidelities, from simple environments focusing on the functionalities and movements see figure 5.5, to prototypes of higher fidelity exploring both player motion, level design, characters and animations see figure 5.6. Once insights of functionality and prototyping strategies had been gained, the building of motion tracking systems could be explored.

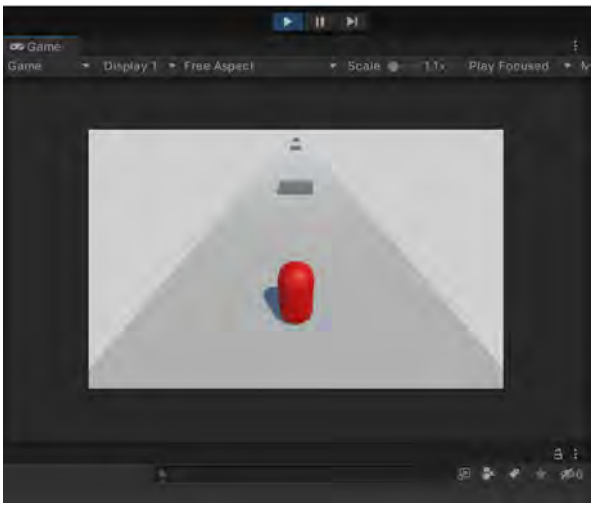


Figure 5.5: An early prototype of an endless runner game showing the player approaching obstacles

Figure 5.6: A prototype of an endless runner game, based on tutorial by Jimmy Vegas [3], showing the character and level design in Unity

Building motion tracking systems

The second part, building motion tracking systems in Unity was also explored through throwaway prototyping. Based on the research and insights gained during the inception phase, where different motion tracking systems were explored, the decision was made to continue with building a marker-based AR system. The advantages of this technique are the amount of documentation and tutorials available, for example through Unity's library, Unity Learn. This technique was considered easy to understand and enabled more accuracy to the motion tracking than other techniques explored during the inception phase.

Two software development kits, AR Foundation and Vuforia (described in 3.5) along with two different ways of controlling the game were explored. Using Vuforia, a static marker was placed on the ground. In this system the marker was used as a virtual button (figure 5.7), which, when pressed, triggered the jump action of the game

character. In the case of using a marker as a virtual button, the marker is serving as an interaction element rather than a tracking marker, and the system therefore might not be considered a motion tracking system. It is used to trigger a specific action or input within the AR system rather than tracking the movement of the marker itself. But within the scope of this project the functionality of using a virtual button achieves the same functionality as a pure motion tracking system. The system using Vuforia will therefore continue to be referred to as one of the motion tracking systems.

The second approach, using ARFoundation, controlled the character by moving the marker. When the marker crossed a vertical threshold the player jumped. Both approaches were then merged together with a simple endless runner game, developed in the previous phase of the development process, to test the motion tracking functionality together with the game mechanics.

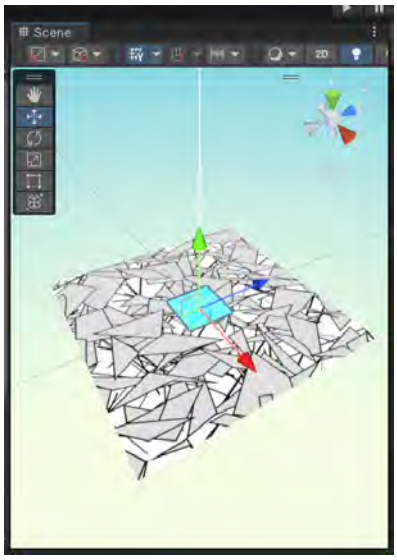


Figure 5.7: An AR marker in Unity using Vuforia to create a virtual button

5.2.2 Evolutionary prototyping

To further explore the promising motion tracking systems together with the endless runner game ideas explored through Throwaway Prototyping (3.3), a new, initial prototype of an endless runner game was created. This time through Evolutionary prototyping (3.3), with the intention of evolving into the final prototype of the game. The two motion tracking systems, one using a static marker and the other a moving marker, were kept and continuously elaborated. The technique using a moving marker in ARFoundation was once again connected to the game character where the character followed the upwards and downwards movement of the physical moving marker. The static marker developed with Vuforia was again used to be placed on the floor and a press on the virtual button triggered the jump of the game character. To evaluate both ideas in an equal manner, the two different ways of using the AR marker were connected to the exact same game. Both systems were

implemented in a simple endless runner prototype with the main functionalities implemented. The endless runner game was set in a grayscale environment where the game character was a grey capsule. The reason for this was to be able to evaluate the both motion tracking systems on the same basis, without letting the aesthetics or level of fidelity impact the evaluation of the techniques. The two prototypes were brought for evaluation in the focus group presented in the following section.

5.3 Measure, evaluate and iterate

To evaluate the first prototype and discuss the general idea and functionalities of the game, a focus group (described in 3.4) with physiotherapists was conducted. After iterations and reconstruction of the prototype, a qualitative study was conducted, once again with physiotherapists.

5.3.1 Focus group

As a preparation for the following user studies and to get initial guidelines and connect with physiotherapists, a focus group (3.4) was conducted. The focus group consisted of three physiotherapists and one other employee at the physiotherapeutic clinic and was held by the two group members. The focus group started with a presentation of the prototype and was followed up with an unstructured discussion about the concept and the functionalities of the game. The initial impression of the general idea was mixed in the group where some thought it was a great idea to make a game out of rehabilitation and some thought it would possibly work for some people and definitely not for others. The choice of focus exercise was well received, since they claimed seated knee extension to be one of the most common exercised to be prescribed when rehabilitating an ACL-injury. When discussing the arrangement of the game they said that there is no standard amount of exercise repetitions, since this needs to be adjusted based on the individual patient and the stage of rehabilitation. However, if they had to pick a number they all agreed that three sets of ten repetitions with a rest in between was a good starting point. A proposal made by a member of the focus group was to incorporate a sports theme into the game.

5.3.2 Constructing the final prototype

For the final prototype a lot of elements that were created during the process of throwaway prototyping and evolutionary prototyping were reused and further developed. The objective for the final prototype was to enhance its overall resemblance to an actual game, in contrast to the grayscale wireframes used during the early development phase.
Since we discovered more accuracy when using AR with Vuforia and a virtual button than with a moving marker in ARFoundation, the initial prototype based on this system was used as foundation and through continued evolutionary prototyping, developed into the final prototype. Through internal testing, it was discovered that a higher accuracy of the jump of the game character was reached when the AR

marker was placed on the wall in front of the person playing than when placed on the floor.

The game environment was constructed to resemble a football field in order to have a connection to the target group. The collectibles and obstacles used in the game were downloaded from Unity Asset Store. The game character, including its animations were downloaded from Mixamo (3.5). The user interfaces, such as menu, settings page and end level screen, were implemented in the prototype. All UI-elements were initially designed in Figma (3.5), before being implemented in Unity. The reason for designing in Figma instead of Unity is that it is a good and flexible tool for wireframing (described in section 3.3), so that ideas can be quickly built and evaluated, which makes the implementation process in Unity more effective. In the next chapter, the final prototype is presented in detail.

6
Results

In this chapter the results of the study are presented. Firstly, detailing the final prototype of the game, Rehab Rush, including the gameplay mechanics and various sections of the game design. Secondly, a description of the qualitative study is provided, encompassing the preparation, execution, evaluation, and analysis of user tests and interviews. Lastly, guidelines for designing a mobile phone game to support physiotherapy are presented.

6.1 Rehab Rush

Rehab Rush (see figure 6.1) is a mobile phone game, inspired by endless runner games, which combines motion tracking through AR with a traditional platformer game. The main purpose of the game is to facilitate the execution of physiotherapeutic exercises in a correct and more rewarding way. The game focuses on the physiotherapeutic exercise Seated Knee Extension, which is described in 1.1.3 and the player's motion while performing the exercise controls the movement of the character in the game. The following sections present the gameplay and game design, while a more comprehensive description of the game can be found in the game design document, see Appendix E.

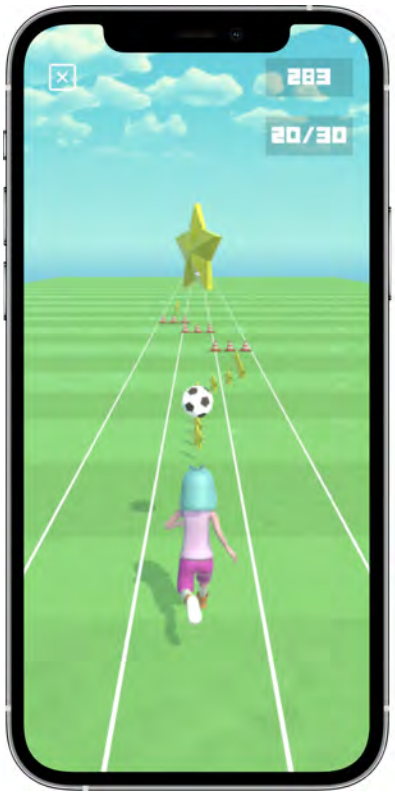


Figure 6.1: Game view of the Rehab Rush prototype

6.1.1 Gameplay

The character is a football player running on a football field, with the main task of hitting footballs in the air, collecting stars and avoiding obstacles, see figure 6.1. The goal is to complete the level and reach the end with as many hits and stars as possible. The theme of the game environment and character is inspired by the target group for the game, young women (aged 16-20) with ACL injuries. The player can move the game character sideways, by tapping either the left or right side of the screen, to collect stars and avoid obstacles and jump to hit the footballs. The jump action is triggered by the player's movement in the real world, tracked through an AR camera. The game character collects stars by colliding with them. Each star

gives one point and when colliding with an obstacle, 10 points are lost. By hitting a football a "reps point" is gained which logs how many repetitions of the exercise the player has successfully completed.

6.1.2 Game Design

In this section a more detailed description of the game design is given. It provides a description of the level design, how the game is controlled by the player and the game interface.

6.1.2.1 Level Design

The level is divided into five sections (see figure 6.2) based on the standard number of sets as suggested by the physiotherapists in the focus group (5.3). Every other section represents the sets with repetitions and every other represents the time where the player rests the leg. The ground of the level is divided into three lanes that can be reached using sideways movement. The first section consist of 10 collectibles in the shape of footballs that are collected by making the character jump. The footballs are placed in the middle lane, so no sideways movement is needed in the first section. The second section represents the period of rest between sets and consists of collectibles in the shape of stars that are placed on the ground and can be collected by making the game character run into them. There are also obstacles to avoid in the second section shaped as road cones. The collectibles add points to the point counter when they are caught and the obstacles subtracts points when they are run into. The third section is another number of sets where 10 footballs are placed at the same height level as in the first section and scattered over the three lanes. The forth section is constructed in the same way as the second one, so a rest section with start collectibles and cone obstacles. The fifth and last section is the most complex one involving all of the attributes of the four sections before, star collectibles, football collectibles and cone obstacles placed in all three lanes. The goal is a large star that when reached triggers an end screen presenting the points generated by all the collectibles caught during the level.

Figure 6.2: The five sections of the level. From the left: set 1, rest 1, set 2, rest 2, set 3.

6.1.2.2 Player control

The game character moves forward at a constant speed while the player can move the character sideways between three different lanes and jump. Sideways movement is controlled by pressing the left or right side of the screen. A motion tracking system is used to track the player's movement and trigger the jump action. The system utilizes a marker-based tracking, as described in section 2.3, using Vuforia (3.5) to create an AR marker with a virtual button (see figure 6.3). Pressing the virtual button, by extending the leg in front of the AR-marker attached to the wall, causes the game character to jump.

Figure 6.3: AR-marker on the wall that works as a virtual button

To play the game, the player should be seated on a chair facing a wall. The marker should be positioned on the wall in front of the player at a height where the middle of the marker is being covered by the foot when the leg is in an extended position (shown in figure 6.4). It is thereby the jump action that is connected to the physiotherapeutic exercise, seated knee extension (1.1.3), since the game character jumps when the player's leg is in an extended position. The marker is an image saved in the Vuforia database and printed on paper, allowing easy adjustment to the player's conditions and range of motion (ROM). By keeping the marker within the view of the phone's rear camera, the system can detect when the marker is covered and that the button thereby is being pressed.

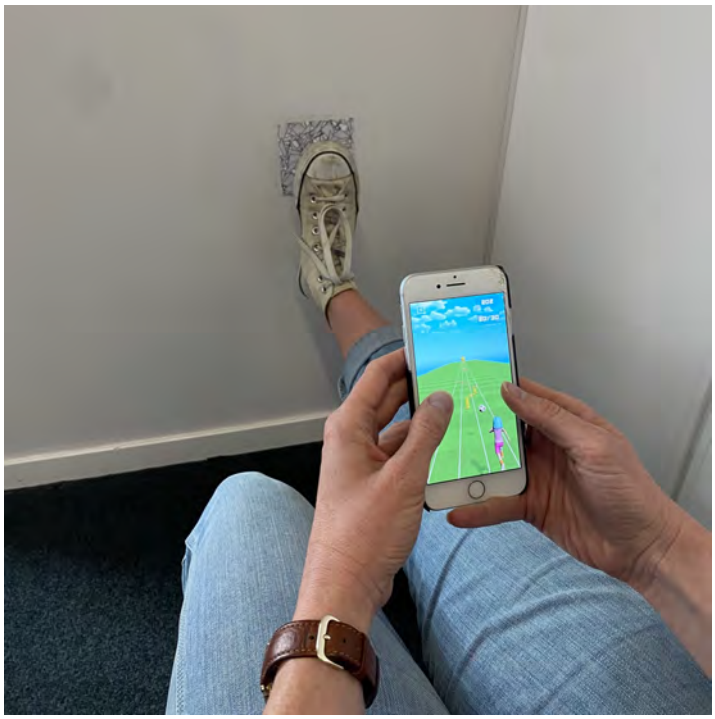


Figure 6.4: Marker placed on the wall, when extending the leg, the character jumps

6.1.2.3 Game Interface

The game interface is an important part of the game since it includes all the interactive and visual elements of the game. In the prototype wireframes for the start page, settings and progress pages are implemented to present the visual layout and structure of the interface.

Gameplay Elements
Due to the focus needed for playing this type of game, combined with the focus needed to execute the physiotherapeutic exercise in a correct way, the interface of the game view is minimalistic and simple. As can be seen in figure 6.5, there is one element representing the score which increases when collecting stars and decreases when running in to obstacles. Below the score-counter is an element representing and counting the repetitions of the exercise. When hitting a football, the count increases by one. Additionally, there are popups appearing on the screen (see figure 6.5) when running in to obstacles and hitting footballs. Together with the popups there are individual sounds connected to the game objects, which are played on collision with the game character. This multi sensory feedback is implemented to highlight the event and its impact in the game.

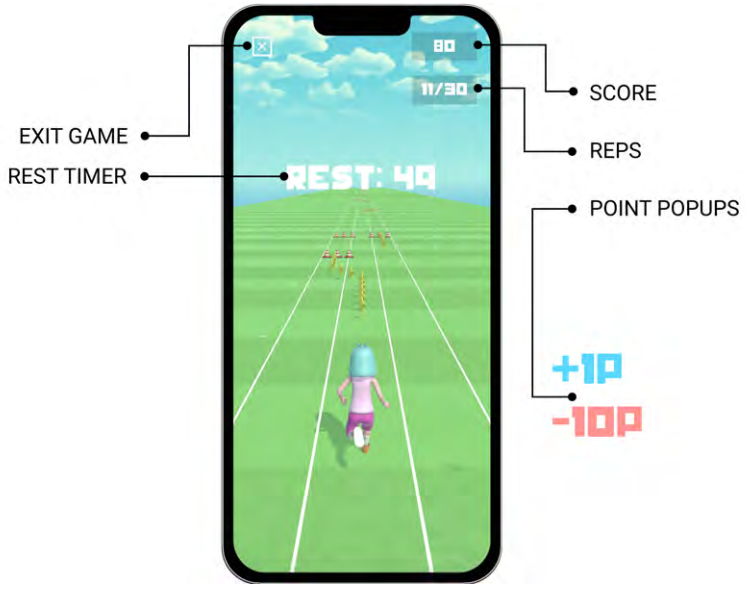


Figure 6.5: Gameplay elements

End-level screen
When reaching the goal, an end-level screen appears (see figure 6.6). The screen presents the final result of the played level, containing the final score, successfully completed repetitions of the exercise together with the number of completed sets which is based on the number of completed repetitions. This data is then saved and logged to the history and progress which can be accessed from the start page.

Figure 6.6: End-level screen

Settings
Figure 6.7 shows the wireframes representing the *startpage*, *settings page* and *progress page* of the game. Under settings, the player can adjust the number of sets and repetitions (reps), length of rest and the speed of the game character. The idea of this

is that the player can customize the game according to the rehab plan given by the physiotherapist. These settings are not implemented to be adjustable in the prototype, but shown as a wireframe to be evaluated as a concept through user testing. The number of sets decides the number of sections in the game that contains football collectibles that are caught by jumping. The number of reps decides the number of footballs in each set. The rest number determines the length, in seconds, of the rest section. The speed determines how fast the game character moves forward. In addition to the rehab settings, the settings page includes regular game settings such as sound and language settings. At the bottom of the settings page there is a switch button for activating a tutorial or not. The tutorial is a feature which provides a step-by-step walkthrough of the game. It guides the player on how to set up the marker, how to jump and how to play the game. This is done through hints and descriptions when new things are happening in the game. This tutorial is automatically activated the first time the game is played and then automatically deactivated. The switch button allows the player to manually activate this function again to get the guided walk through of the game when needed.

Figure 6.7: The wireframes of the game, from left to right: start screen, settings page, progress page.

Progress

The idea of the progress page is to monitor the player's game progression and thereby the rehabilitation progress. It provides information on how many footballs have been caught as well as the highest number of points the player has gained by playing the game. Additionally, it displays a streak number, representing the consecutive number of days the game has been played. This function allows the users to keep track of their daily rehabilitation activities and showcase their progress to their physiotherapist. The player can get a weekly, monthly or yearly overview of their rehabilitation

progress and set up weekly goals which will be considered full achievement, 100%, of the statistics. This page is a wireframe built to be evaluated on an idea basis.

6.2 Qualitative study

The prototype presented above was used in a qualitative study with physiotherapists. The study was conducted to evaluate the game and gain insights that can be valuable when designing a game with the purpose of making rehab in a correct and rewarding way. In this section the qualitative study is presented, including preparation, execution, analysis and results of the study.

6.2.1 Preparation

Based on the insights gained during the focus group conducted with physiotherapists an interview template was created. Different clinics with physiotherapists were contacted to get access to competent users for testing. The response was positive and we were invited to conduct the user testing at a physiotherapeutic clinic.

6.2.2 Test setup

The tests were conducted in a meeting room at the physiotherapeutic clinic. Equipment needed for the test was a chair, an AR-marker, a mobile phone with the game, Rehab Rush, installed and two additional mobile phones, one for recording sound and one for filming the tests. The AR-marker was printed on paper and attached to the wall using sticky tape. Every test started by adjusting the height of the marker to fit the height of the player's foot with the leg fully extended.

6.2.3 Execution

The user testing was conducted during a day of internal training for the physiotherapists at the clinic. An introductory, 10 minute presentation was performed where the idea and purpose of the game was explained to all of the participants at the same time. We also described how the game is played and how the tests would be conducted. After the presentation the tests were conducted in the meeting room. Eight tests and interviews were performed in the room, and one interview was done via Zoom. Each participant, except the one on Zoom, was presented with a phone containing the game. Some of the participants finished the whole level and some of them played for a shorter amount of time, but all of them played at least the first set and the first rest sections of the game. With permission from the participants, the testing was filmed. After the testing a semi-structured interview was conducted. The interviews were audio recorded using a smartphone. An interview template with questions was used to support the structure of the interview. Although, depending on the direction of the discussion, and how much time each participant had, the interview was adjusted. The interview template was constructed to make the interview last around 20-30 minutes, but due to some of the participants time

restriction, it had to be modified. All interviews were conducted in Swedish, since that was the native language of most of the participants.

6.2.4 Participants

All participants except one (participant 1) were physiotherapists with working experience between 1.5 and 10 years. Table 6.1 lists the participant in the order the tests were conducted. It also displays the length of every interview, including testing of the game, and how many years they have worked as physiotherapists.

Table 6.1: Participants in user testing

Participant	Time (min)	Active years
1 (Pilot)	10:23	Not a physiotherapist
2	23:45	10
3	14:50	6
4	13:48	7
5	17:15	2
6 (Online)	07:52	3
7 (combined with 8)	17:24	7
8 (combined with 7)	17:24	1.5
9	13:12	6

6.2.5 Analysis

To analyze the results of the user testing all interview recordings were transcribed using Microsoft Word's automatic transcribing function and then manually corrected. From the transcriptions, all statements regarding the game, the game functionality, the exercise and rehabilitation process were gathered on digital post-its in Figma. They were then grouped using affinity diagramming (described in section 3.4) and each group were labelled according to the common theme. This method was used to facilitate the organization and analysis of the data.

6.2.6 Results of qualitative study

The results from the qualitative study are statements made by the participating physiotherapists. Some of the questions from the interview template were asked to all participants and their answers were gathered in table 6.2. The questions asked were *"Do you included seated knee extension in you rehab program for people with ACL-injuries?"* (Q1) and *"Do you find this type of game suitable for this exercise"?* (Q2). All original statements made during the testing and interviewing that were used in the affinity diagram can be viewed in its entirety in Appendix D. A selection of the statements will be presented in this section. To fit the format of the report, all statements were translated from Swedish to English.

Table 6.2: Answers to the questions *"Do you included seated knee extension in you rehab program for people with ACL-injuries?"* (Q1) and "*Do you find this type of game suitable for this exercise"*? (Q2)

Participant	Q1	Q2
2	Yes	Yes
3	Yes	Yes
4	Yes	Yes
5	Yes	No
6	Yes	Yes
7	Yes	Yes
8	Yes	Yes
9	Yes	Yes

All participants in the qualitative study claimed that they prescribe seated knee extensions in rehabilitation programs for people with ACL-injuries. As can be seen in table 6.2, seven out of eight physiotherapists were positive regarding the use of the game to encourage patients to do their exercises and thought that this type of game is suitable for this exercise. However, they had a lot of suggestions of improvements which are presented in the Affinity Diagram (see Appendix D). The labels created with inspiration of the gathered insights from the affinity diagram are displayed in table 6.3.

Table 6.3: Themes generated through affinity diagramming

Theme
Compliance
Feedback
Functionality
Gameplay
Gamification
Highscore
Marketing
Number of repetitions
Other exercises
Progress
Seated knee extension
Settings
Target group
Timing

Compliance
Participant 1 had experience as a patient and claimed that *"I'm not keeping up with my rehab. When you are good enough, it reduces"* and participant 2 said *"It is as*

easy as anything to get a patient to do their home exercise once. Twice maybe even. After that it gets difficult".

Feedback
Participant 9 said that *"I didn't think I got any visual feedback really that I'm picking up the stars"* regarding the star collectibles. When the question *"Do you think the game gives clear feedback that the patient is doing their exercise correctly"*? was asked, participant 9 answered *"you can't measure the quality, it only measures whether I pick them (the footballs) up or not, so no, it can't"*. To the same question, participant 5 answered *"I think so, provided you hit the ball, then you understand. You can consider whether you should have a vibration or something else to see it as well"*.

Functionality
Two of the participants (2 and 3) mentioned that they had a lot of focus on how to hold the phone and aim the camera in a correct way towards the AR-marker. This was also observed during the testing with other participants and might be a reason why the jump did not work every time the leg was raised. Participant 3 said *"I think that in the beginning there is lot of focus on holding the camera right and where you are in the game so that there will not be so much focus on contracting the thigh"*. This was said when talking about the importance of contracting the thigh to perform the exercise in a correct way. Participant 4 did not perform the exercise in a correct way and held the leg half extended right under the marker to better time the jump. Participant 4 also commented on this during the interview and said *"I stood with my leg like this, (showing a half extended leg) waiting for me to just jump up, because then suddenly the focus is no longer the exercise, but the focus is on completing the task on the phone"*.

Gameplay
There were opposing views on the gameplay by some of the participants. Participant 7 said *"This is very fun"* and participant 4 said *"The game is brain dead"*. Participant 4 explains that the game is too repetitive and explains it by saying "*Maybe that the player always moves exactly the same way and the music is always the same and the track is always the same"*. Participant 1 said *"A football every twenty seconds is not so stimulating"* and participant 6 suggested *"maybe new paths or new steps that you can climb to"*.

Gamification
Just as the discussion regarding a high score or leader board, the comments on gamification varied. Participant 1 was very positive to the idea and said both *"gamifying is great"* and *"it's great to make a game out of life"*. Participant 3 said *"it's a fun idea to try to make rehab a little more fun because, as I said, it's not so much fun initially and it's very clever to try to make the player jump when you stretch your leg"*. Participant 9 is a little sceptical when suggesting that *"there is a risk that the competitive person will come in, that you will do everything possible just to get points"*.

High score
The opinions regarding a high score differs between the respondents. Participant 6 said *"there would be some kind of leader board as well"* and *"to bring this with kind of community in that if it's a certain type of injury you could meet other people in it too, with the same type of injury and compete against them in some way"*. Participant 9 said *"if you are injured, you may not want to compare yourself to others and feel bad. Maybe something you need to activate in that case"*. Participant 7 said *"for those who become a bit competitive, especially if there is some kind of leader board, that perhaps you should put a limit on how many times per day you are allowed to play"* when suggesting that a leader board could make some people overdo their rehab.

Marketing
Participant 2 talked about marketing the game and suggested that *"I think you gain a lot if you can get a representative for it in some way, that is to say actually talk to a club or a football player or someone like a role model in that. You will gain a lot from that."* Participant 1 said.

Number of repetitions
Some of the participants suggested that 3 times 10 repetitions is too little when it comes to movement training. Participant 5 said that *"3 times 10, I think that represents some form of strength training"*. Participant 5 also said that *"if I had given this to a patient, I would have said to do between 20 and 50, then you do it 5-6 times a day"*. Participant 9 said *"when it's early rehab, you want them to do it 3-5 times a day maybe, then maybe it's 2-3 sets per round with 20 in each. There is a lot of circulation that you want to get done."*

Other exercises
There were suggestions during the interviews that this game could be used for more exercises than seated knee extension and that it could be expanded to include the whole rehabilitation program. Participant 8 said *"I'm thinking of all the straight leg lifts you do in the beginning at home, it should work for them, right?"*. Participant 1 was very optimistic and suggested that *"just look at every single exercise they do and you can make a game out of it"*. Participant 7 said *"it's really only the imagination that limits what you put the marker on and you can certainly use it for a lot of different things"*.

Progress
When shown the progress page in the prototype everyone were positive to have a tracking system. Participant 3 and 6 thought the "streak" was a good thing to have. Participant 3 expressed *"I think it's good to have streak for people who want to maintain the streak so it will stimulate"* and participant 6 said *"streak is very good"*. Participant 6 also said *"I think then there might be some way to follow up for the physiotherapist"*, when talking about that the client could show the progress page to report what has been done since their last meeting. Everyone was asked if

there was something they missed on the progress page and participant 7 suggested adding "load" as a parameter if the game was going to be used during rehabilitation with increasing weights. Participant 4 thought it could be *"nice to know in the end how many times you have actually done it. So how many knee stretches there will be in the end"*.

One participant suggested that a further development for this game could be to connect it to the clinic so the physiotherapist could keep track of the patient's progress. Participant 2 said *"the next step is somehow connecting it to the physiotherapist. So that I, as a physiotherapist, can get the feedback that a patient also gets in the form of how much has been done and things like that"*. In the same context it was suggested that *"the big and important thing is that it is good enough in terms of confidentiality, that is the important thing"* (participant 2). Participant 6 said *"it would have been a way to be able to follow along, especially if it's a little younger people, then maybe me, or just that you show later when you get there"*

Seated knee extension
Regarding what to think about when doing the exercise, all respondents agreed that it is important to achieve a full extension of the leg and tension in the thigh. *"Getting full stretch is often the most important thing"*, *"it is important to stretch the knee and not lift the leg"*, *"what is important is always to fully extend the knee"* and *"the most important thing really is to get an extension in the knee"* are some of the answers to the question *"What is important to think about when doing seated knee extension?"*. These answers came from participant 5, 9, 4 and 3. Some also suggested that they sometimes prescribes the patients to hold the extension for a couple of seconds. Participant 6 said *"maybe work a little more statically instead, during longer activation. So you work longer up and longer down or hold statically"*.

Settings
When asked what they thought about the settings page, many of the respondents thought that it was a nice feature to be able to adjust sets, repetitions and rest time. Participant 2 said *"in physiotherapy, the most important thing is sets, reps and rest"*. Speed, however was confusing to some of them. *"What is speed?"* (participant 2) and *"Speed, what is that?"* (participant 3) were two questions asked during the interviews when they had a look at the settings page. Participant 3 suggested to add a variable to adjust time with the leg fully extended and also said that *"speed is not that important"*, but *"on the other hand, being able to lower the speed would be good"*.

Target group
No questions regarding the target group (women aged 16-20) were asked during the interview. Despite this, it was mentioned during three of the interviews (4, 6 and 9) that they thought this game would be more suited for a younger and/or older audience. Participant 9 suggested that it might fit people between 12-16 and participant 4 thought it would be appropriate for people between 8-10 or over 65. Participant 6 said *"I really think it would suit the slightly younger generation, or really older"*

Timing
All participants experienced difficulties in timing the jump of the game character. Observations made during the tests discovered that the extension of the leg in almost every case was done too late. This was also confirmed during the interviews were it was stated that *"Now I kick when the ball is already over the player's head"* /Participant 4. Towards the end of every test, when the user was getting used to the game, it seemed like the timing was getting better and there was a positive learning curve for all participants.

6.3 Guidelines for making a mobile phone game for physiotherapy

Inspired by the themes created during affinity diagramming and the development process, several guidelines for designing a mobile phone game for physiotherapy were formulated. These guidelines, presented in table 6.4 are meant to be used as inspiration and support for further development of this or other body controlled mobile phone games for physiotherapy.

Table 6.4: Guidelines derived from the development process and qualitative study

Theme	**Guideline**
Feedback	Important to give clear feedback connected to the game mechanics
Functionality	Ensure that the user can focus on the exercise, rather than on technical aspects and limitations of the system
Functionality	Construct the game to encourage patients to perform the exercise correctly
Gameplay	The game should be engaging and entertaining
Highscore	If a competitive comparison between players is included, make sure it is optional and consider the potential negative effects
Number of repetitions	The game should be adaptable for various rehabilitation focuses
Other exercises	Design the game to allow for expansion to include more exercises and fit the whole rehabilitation program
Progress	Enable tracking of the progress
Progress	If a tracking system for the physiotherapist is available, ensure it complies with patient confidentiality

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Theme	Guideline
Settings	Allow for customization based on the specific requirements of the exercise
Target group	Conduct user testing with the chosen target group
Timing	Clearly indicate when the exercise should be performed and track repetitions regardless of the timing of the movement

Important to give clear feedback connected to the game mechanics
To ensure the user understands the outcome of their actions, the game interface should be designed with clear visual feedback. Incorporating audible and haptic feedback could also enhance the user's interpretation of the gameplay.

Ensure that the user can focus on the exercise, rather than on technical aspects and limitations of the system
It is important to not let the motion tracking system and its limitations require too much of the user's focus, and thereby risking a negative impact on the quality of the performed exercise.

Construct the game to encourage patients to perform the exercise correctly
For the game to facilitate and support the user while performing the physiotherapeutic exercise, it is important to consider all important factors of the exercise. For seated knee extension it is important to fully extend the knee, tighten quadriceps, not lift the thigh and sometimes hold the extension for a few seconds. It is thereby desirable to include tracking of the quality and technique of the user's movement in the system. If the system is designed with these factors in mind, it can effectively support and facilitate the user through their rehabilitation process.

The game should be engaging and entertaining
In order to increase compliance and make users continuously play the game and perform their exercises, the game has to be engaging and entertaining.

If a competitive comparison between players is included, make sure it is optional and consider the potential negative effects
To be connected to other players online might enhance the engagement and enjoyment of the game for some people. However, it is important to consider that this may not be the case for everyone, as some may find that online interactions might

add an enhanced, stressful feature to the game. Thus, while online connectivity has the potential to enhance the overall gaming experience, it is important to consider the varying preferences and needs of different individuals.

The game should be adaptable for various rehabilitation focuses
Since a rehabilitation process often extends over a long period of time, the focus of the training changes throughout this period. For ACL injuries, the focus shifts between improving range of motion (ROM), strength, and stabilization. Seated knee extension is used to improve both ROM and strength and should therefore be adaptable to both of these focuses.

Design the game to allow for expansion to include more exercises and fit the whole rehabilitation program
Since an ACL-injury rehabilitation program usually involves multiple exercises, the ideal game would be designed to accommodate all of these.

Enable tracking of the progress
An important feature when doing rehabilitation is to be consistent and perform the exercises regularly. Tracking the progress in the game could therefore be an advantage. Both for the purpose of positive reinforcement, and also to be able to show the development to the physiotherapist.

If a tracking system for the physiotherapist is available, ensure it complies with patient confidentiality
When working with health care, there are numerous directives and rules regarding patient confidentiality to take in to account. Therefore, if the game includes a system for the physiotherapist to track the patient's progress, it is important to ensure it is safe and approved for medical use.

Allow for customization based on the specific requirements of the exercise
To ensure inclusiveness for a wide range of users and to make it useful for a coherent amount of time it is crucial to enable customisation of the exercise, and thus of the game. Different individuals may have varying requirements based on their injury and stage of rehabilitation. By enabling customization, the game can better accommodate these unique needs.

Conduct user testing with the chosen target group
To make sure that the game will be appreciated and continuously used by the intended target group it is important to conduct user testing with that group. Only through such testing can conclusions be drawn regarding the engagement and enjoyment of the game. The results from the qualitative study, which was done with physiotherapists, can only evaluate the idea and functionality of the game in relation to the physiotherapeutic exercise, and not its appeal to the end-users.

Clearly indicate when the exercise should be performed and track

repetitions regardless of the timing of the movement
When the timing of the movement has an importance for the gameplay, it is important to clearly indicate when the movement should begin for successful player control. Another important factor to consider regarding the timing is that it is important to track and log the repetitions no matter when the repetition is executed. This, for the user to obtain accurate statistics on their rehabilitation and to eliminate frustration associated with the gameplay.

7
Discussion

In this section, the findings of the Rehab Rush development process are discussed. Suggestions for improvement and ideas for future development are presented, along with a critical analysis of the development process, user tests and motion tracking technique being used.

7.1 Design solutions

This section presents design changes and solutions which emerged from a selection of the guidelines presented in the results chapter 6.3. These suggestions are intended to inspire and guide future development of the game.

Important to give clear feedback connected to the game mechanics
In the current version of Rehab Rush the feedback provided when catching collectibles is points added to the point counter (see the left side of figure 7.1), the collectible disappearing and a sound effect. An example of a GUI that could provide clearer feedback is added icons next to the point counter (to the right in figure 7.1). Another example is to change the points given for every collectible. A higher score would impact the speed of the point counter, which would create more activity on the screen. In addition to visual and audible feedback, haptic feedback could be incorporated. One idea is to add a vibrating feature when running into collectibles or obstacles. The risk when using haptic feedback on every collectible is that it might cause an overload of feedback and not give the positive effect it is intended to have.

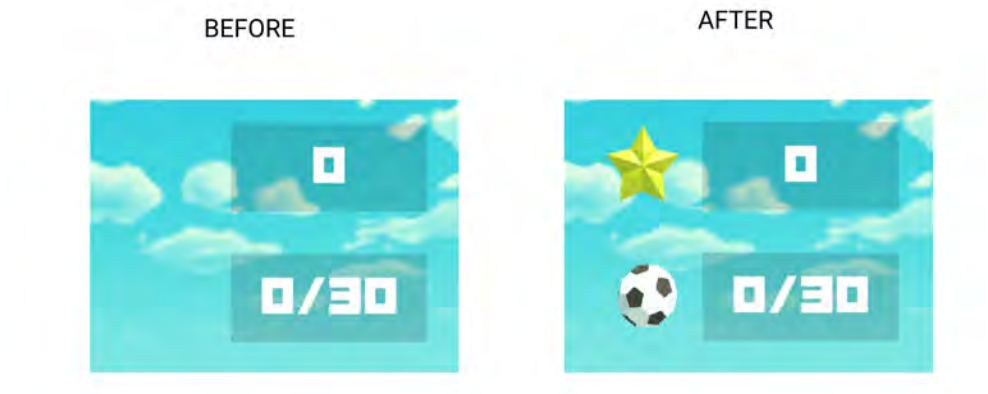

Figure 7.1: One potential solution to provide clearer feedback

Ensure that the user can focus on the exercise, rather than on technical aspects and limitations of the system
In Rehab Rush, the user needs to keep the camera of the phone focused on an AR marker attached to the wall. Some participants in the user study found this overwhelming and shifted the focus away from the game. To avoid having to keep the focus on the camera and the AR marker the game could be developed using a different technique than marker based AR. Motion tracking using pixel movement detection 3.5 or a system that recognizes the movement of the foot without a marker might reduce the focus on the technical constraints of playing the game. A different approach could be to set the camera to wide angle to increase the captured area and make the movement of the phone more forgiving.

Construct the game to encourage patients to perform the exercise correctly
The motion tracking system implemented in Rehab Rush only takes the height of the leg extension into consideration, not the quality of the movement. One solution to solve this could be to instead of using only one marker with a virtual button, multiple buttons could be used to track different parts of the leg for a more accurate tracking of the movement in the exercise.

As some of the participants in the user testing suggested, it is sometimes ordinated to hold the leg extended for a longer period of time when doing seated knee extensions. To make the user hold the extension longer there are several possible solutions. One way could be to adapt the game in the way of placing the collectibles to only be reached when the game character is jumping. The virtual button is set to keep the character in the air for as long as it is pressed. Placing more collectibles in the air (see figure 7.2), might encourage the user to hold the button pressed for a longer period of time and thereby hold the leg extended longer. Another way could be to add a timer that is counting down while the button is pressed and the score is only received if the full time is reached.

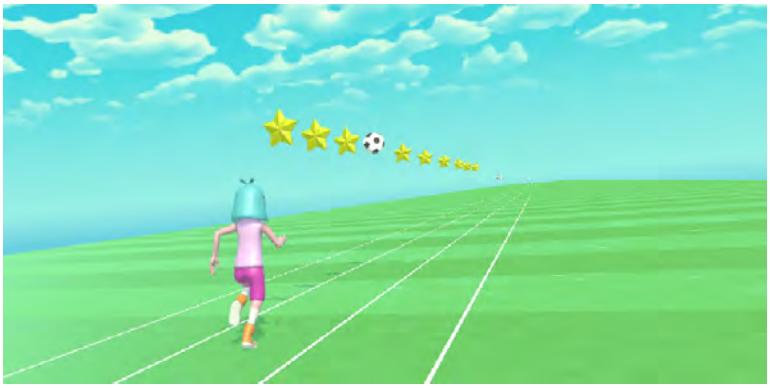

Figure 7.2: One potential solution to encourage the user to hold the leg extension for a longer period of time is to put multiple collectibles in the air

The game should be engaging and entertaining
Some of the participants in the user study seemed to like the gameplay of Rehab

Rush, while others found it too repetitive and monotonous. To make the game more engaging, adding more features to enhance the variety of the gameplay could be a probable solution. Decreasing the distance between the football collectibles could not only enhance the entertainment value of the game, but also be more suitable for performing the exercise in a correct way. Incorporating additional star collectibles and different obstacles could also make the game more challenging and thereby more interesting.

Figure 7.3: One potential solution to provide a more engaging gameplay

The game should be adaptable for various rehabilitation focuses
During rehabilitation of an ACL injury, the focus of the different phases of the rehab shifts between range of motion (ROM), strength and stabilization. The current state of Rehab Rush is constructed to primarily work when training ROM. An important aspect during rehabilitation of ACL injuries is to increase the resistance and put on weights. To make the game adaptable for the whole rehabilitation process it could be designed to work in different contexts, both at home and when using gym machines, for example leg raise machines. For the game to be more mobile, it could be based on AR using a moving marker attached to the foot, or by a markerless motion tracking system.

Design the game to allow for expansion to include more exercises and fit the whole rehabilitation program
When rehabilitating an ACL-injury, the program consists of multiple exercises with different focus. To provide a cohesive game experience and rehabilitation process, a future development for a game like Rehab Rush could include the whole rehabilitation program. This could be done either by creating separate games for each exercise within the app, or by designing one single game that can be adapted and

controlled by multiple exercises.

Enable tracking of the progress
Tracking could be done as in Rehab Rush with a progress page displaying exercise statistics, streaks, and high scores. There are both advantages and disadvantages with tracking the progress of the game. To see the statistics of performed exercises might provide a positive reinforcement to the user and help maintain the persistence of the rehabilitation. A tracking of the streak could encourage some people to perform their exercises on a daily basis. However, it could also have a negative effect, where the loss of a streak could result in a decline in their persistence.

Allow for customization based on the specific requirements of the exercise
In the prototype, the settings enables customization of the repetition, sets and rest composition as well as the forward speed of the game character. However, a more extensive list of exercise settings could be beneficial, including:

- number of sets
- number of reps
- length of rest section
- time between repetitions
- time for lifting leg
- time to hold in extended position
- time for lowering the leg
- player speed

In the prototype, footballs representing the repetitions appear in a fixed rate. One solution to allow customization of this feature could be to implement a calibration round where the user completes a set in their own pace, while filming the leg. The system can then measure and automatically adapt the settings related to pace of movement and time between repetitions. These settings can be adjusted at any time, and a new calibration round can be conducted when needed if the settings become inaccurate.

Clearly indicate when the exercise should be performed and track repetitions regardless of the timing of the movement
In the example of Rehab Rush, timing indications could be implemented through markings in the ground or by arranging the collectibles in a way that helps player with the timing. In figure 7.4, these design ideas have been implemented. In the left frame, a ground marker has been added as a discrete indication of when the player should start lifting their leg. In the right frame, the stars have been arranged in a bow to indicate the jumping movement of the player.

Figure 7.4: Two solutions for a clear indication when to perform the exercise

To track and log the repetitions no matter when the repetition is executed could be implemented by always incrementing the reps-count by one each time the virtual button is being pressed, regardless of the timing. The two scoring systems could then be separated so that all collectibles, both stars and footballs, contribute to the game score. This means that the timing only affects the score of the level, but the exercise is being tracked no matter the timing of the movement.

7.2 Marker based motion tracking

The marker based motion tracking system was perceived as a feasible way of showing a proof of concept. For the purpose of evaluating the idea of a motion controlled mobile phone game, getting the functionality in place was important. The accuracy achieved when using a static AR marker was enough for testing, but not optimal for the purpose of creating a fully functioning game. Since some of the test participants experienced problem with getting the character to jump, the functionality of the motion tracking needs to be further developed. If the game would be released in its current state, the app interface would have required the inclusion of an AR marker that needs to be printed by the user. This additional step takes away some of the simplicity of just having a smartphone to play the game. Having to print the marker yourself might lead to a higher threshold and for people not to try out the game in the first place. A markerless motion tracking solution might be better for a final game and minimize the amount of equipment needed to play the game. This might be possible to achieve using Open CV or Motion Tracking Cam, described in 3.5.

If continuing to work with a marker based motion tracking system, adjustments to the marker, the virtual button and the interface are needed. The goal is for the game character to jump every time the leg is raised between the marker and the camera of the phone. This happened in most cases, but not every time, possibly depending on circumstances around the testing. Possible influencing factors of the accuracy are marker placement, length of the user's legs and thus the distance between the phone and the marker, and lighting in the room where the game is played. One possible factor for success with accuracy could also be experience. When setting up the game for the user testing the two group members were successful every time. During the development process, we have played and tested the game extensively

which has made us familiar with how the motion tracking system works and how to trigger the jump action with the virtual button.

7.3 User testing

The user tests conducted in the qualitative study (6.2) were carried out with physiotherapists and executed at one location, and within one company. In this section we discuss what impact the choice of participants and the level design of the prototype might have had on the result.

7.3.1 Testing prototype

The prototype used for the user testing was developed with consideration that the participants were beginners and never tested the motion tracking system before. Therefore, the level was designed to increase in difficulty, but starting on a very simple level to enable full focus on the exercise. This was needed for the participants to become familiar with the system, learn how to control the player, and gradually introduce more elements to the gameplay. The length of the level was designed to align with standard exercise recommendations, consisting of 3 sets of 10 repetitions with 60 seconds of rest between each set. The simplicity of the gameplay, in combination with the length of the level might have affected the results of the testing, potentially giving the impression that the game was slow and boring. However, since it was not the gameplay that was evaluated in the study, a shorter and more engaging testing prototype combined with a short tutorial as introduction could have been beneficial to effectively demonstrate the proof of concept and obtain a fairer evaluation of the game.

7.3.2 Participants

The user tests were conducted during one afternoon at a rehabilitation clinic. A few participants in the study had limited time between patients whilst others had a lot of time and no stress during the testing and interview sessions. The participant's stress levels impacted the duration of the tests: those with sufficient time played the entire game from beginning to end, while those with time constraints only tested the first section of the game level and did not experience the full gameplay. The duration of the tests might have affected the results and the participants' attitudes towards the idea, especially considering that the initial part of the game level was intentionally designed to be simple.

To ensure more comparable results, a more structured testing environment with the same amount of time for each participant, and everyone on site for the interview, would have been beneficial. This could have been solved by building a shorter test version of the level so that all participants would have had time to play the entire game, and to only conducting tests only with participants who were not under time pressure. However, the number of tests and interviews were considered more important than the length of each session, since the purpose of the qualitative study

was to evaluate the idea and the motion tracking system in combination with the chosen exercise, rather than the gameplay. The purpose of the testing part was thereby to explain the idea and make sure the participants got an understanding of the system rather than testing for evaluating the game.

7.4 Development process

The main focus in this project was on the development of the functionality of the game. Therefore the start phase of the whole project was shorter than necessary. Initial studies with physiotherapists and with the target group, women aged 16-20 years old, where needs and requirements of the users could have been specified, might have facilitated the process of deciding the functionalities of the game in an early stage.

The gameplay was created to fit the properties of the technical aspects of the motion tracking system. More technical challenges were encountered when creating the motion tracking system than when creating the game world. Therefore, this sequence to perform the tasks worked well for this project.

The overall process for developing this game prototype worked well, since the functionalities of the game worked to show the main idea of the concept.

7.5 Ethical issues

In order to ensure a fair assessment of the prototype, it is important to conduct testing with the intended target group. Since the target group consists of people with ACL-injuries, caution should be taken. Questions of responsibility may arise if this game in any way could have a negative impact on the healing process during the rehabilitation or possibly even aggravate the existing injury further. Consulting physiotherapists during further development could also be considered a potential idea to prevent the game from making the users perform the exercise in the wrong way.

Since the intended use of this prototype is for rehabilitating an ACL-injury, there are certain aspects to consider when designing it. One important factor is that the design of the game should match the intended time spent on rehabilitation every day. There is a possibility for a game to become addictive. If the game is very entertaining, the risk of overuse might be a problem and can lead to over strain that could hinder the healing process and maybe even cause other injuries. This issue might be solved using limitations in the game, possibly a timer or warning signs.

As suggested during the user testing with physiotherapists, there were suggestions to have an online community implemented in the application for people with the same injury to connect and compete against each other. If a score board would be implemented in future development, considerations should be taken around the

ethical factors regarding competing against each other when injured. In the same manner as an addictive game could cause over strain, incorporating the competitive element may aggravate the injury in a similar fashion. To prevent possible overuse because of, for example, a user's intent to reach a higher score than another user and therefore play more than suggested by a physiotherapist, limitations could be implemented. For example a function that only allows the first attempt every day to be registered for the score board.

7.6 Generalizability

The guidelines for designing a mobile phone game to support physiotherapy, presented in 6.3 have been developed with a target group of women aged 16-20 years old in mind, and the game has been developed with focus on one exercise, seated knee extension. The guidelines are general and can also be applied when developing a mobile phone game for other target groups. They can also be used for other injuries than ACL-injuries, even though that was the focus of this thesis.

Rehab Rush, in its current version, also works for more exercises than seated knee extension. Since the AR technology of the game uses a virtual button where the "press of the button" triggers the jump of the game character, many more exercises besides seated knee extension could potentially be used to control the game. The only requirement to trigger the jump action is to cover the AR marker, which makes the game usable with other leg exercises where a part of the leg is moved between the phone's camera and the AR marker. The side movement of the game character is controlled with touch buttons and is easier to play using two hands, but it could potentially work even with only one hand. This fact may also open up the possibility of using the game for arm and hand rehabilitation, or perhaps even rehabilitating other body parts. However, these possibilities have not been explored within the scope of this thesis.

7.7 Future Work

This section discusses important aspects to consider and include in future development of the game, including further evaluation and future development of the gameplay.

7.7.1 Further evaluation of the game

To ensure that the game Rehab Rush will be a desirable product on the market, it is necessary to conduct user testing with the target group. It is important to gain insights from the people intended to play the game. The scope for this report is *"how a body controlled mobile phone game could be designed to help young women with ACL-injuries do their exercises in a correct and rewarding way"*, therefore it does not consider the factor of compliance, which is important during rehabilitation. The overarching goal of a game like Rehab Rush is to make rehabilitation fun and

help patients in maintaining compliance. When further development of the game is made including adding more levels and creating an engaging gameplay, a study regarding compliance would be interesting to conduct. This study could run over several months and consist of two groups, one group that have access to the game and one control group doing rehabilitation in the conventional way.

7.7.2 Developing the gameplay

The argument presented in the game design document (appendix E) for what makes this game fun is the motion control aspect between the player and the game character. The concept of making a game out of rehab can add playfulness to an otherwise boring practice. The AR control of the game is a unique selling point for the current version of Rehab Rush. However, to be successful in the long run, the gameplay needs further development. In its current state it is quite monotonous and lacks certain important aspects that make an engaging game. Further investigation is needed to explore the elements that contribute to an engaging gameplay experience and motivate players to continue playing for an extended period.

7.7.3 Explore a more accurate motion tracking system

In the current version of the game, a simple and effective solution is employed to track the player's motion. While this system serves its purpose well, there is potential for incorporating more precise motion tracking systems, such as skeleton tracking. This could be beneficial for evaluating and track the quality of the movement. However, more research is required to evaluate and develop the optimal motion tracking system for a mobile phone game for physiotherapy.

8

Conclusion

This thesis has explored whether games can be used in physiotherapy with the purpose of facilitating, supporting and making it more fun for the users to do their physiotherapeutic exercises. The research question of the project was: *How can a body controlled mobile phone game be designed to help young women with ACL-injuries do their exercises in a correct and rewarding way?* The research and development process, which included a qualitative study with physiotherapists, resulted in a set of guidelines for designing a mobile phone game for physiotherapy. Seven of the guidelines were directly connected to the research question. These guidelines are presented below.

- The user should be able to perform the rehabilitation exercises correctly. The aspect of holding a phone whilst doing them should provide assistance rather than undermine. Therefore is is important to **ensure that the user can focus on the exercise, rather than on technical aspects and limitations of the system**.

- **Construct the game to encourage patients to perform the exercise correctly**. If the game is designed in a way that might lead the patients to perform the exercise the wrong way there is a possibility that this could prevent healing of the injury or cause more harm.

- Rehabilitation of an ACL-injury is commonly performed in different steps with different purposes. The different purposes are strength, range of motion (ROM) and stabilization. **The game should be adaptable for various rehabilitation focuses.**

- An application designed to work with only one exercise might not be particularly useful when doing rehabilitation of an injury. Usually, rehabilitation programs consist of multiple exercises. This is why it is suggested to **design the game to allow for expansion to include more exercises and fit the whole rehabilitation program.**

- For the user to get encouragement and affirmation, and be able to show the progress for the physiotherapist, it is good to **enable tracking of the progress.**

- The requirements for physiotherapeutic exercises, in terms of how many rep-

etitions, sets and rest time, differ throughout the rehabilitation process, depending on the individual and the state of the injury, therefore it is important to **allow for customization based on the specific requirements of the exercise.**

- To ensure that the user can focus on the exercise and be rewarded for the repetition no matter the success in the game it is suggested to **clearly indicate when the exercise should be performed and track repetitions regardless of the timing of the movement.**

The guidelines provided are intended to inspire and support further development of this or any other body controlled mobile phone games for physiotherapy. However, it is important to note that additional research, and evaluation with the targeted user group, is necessary to ensure positive results and assess the game's effect on the users' rehabilitation process.

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A

Appendix: Idea generation

Figure A.1: Mindmap

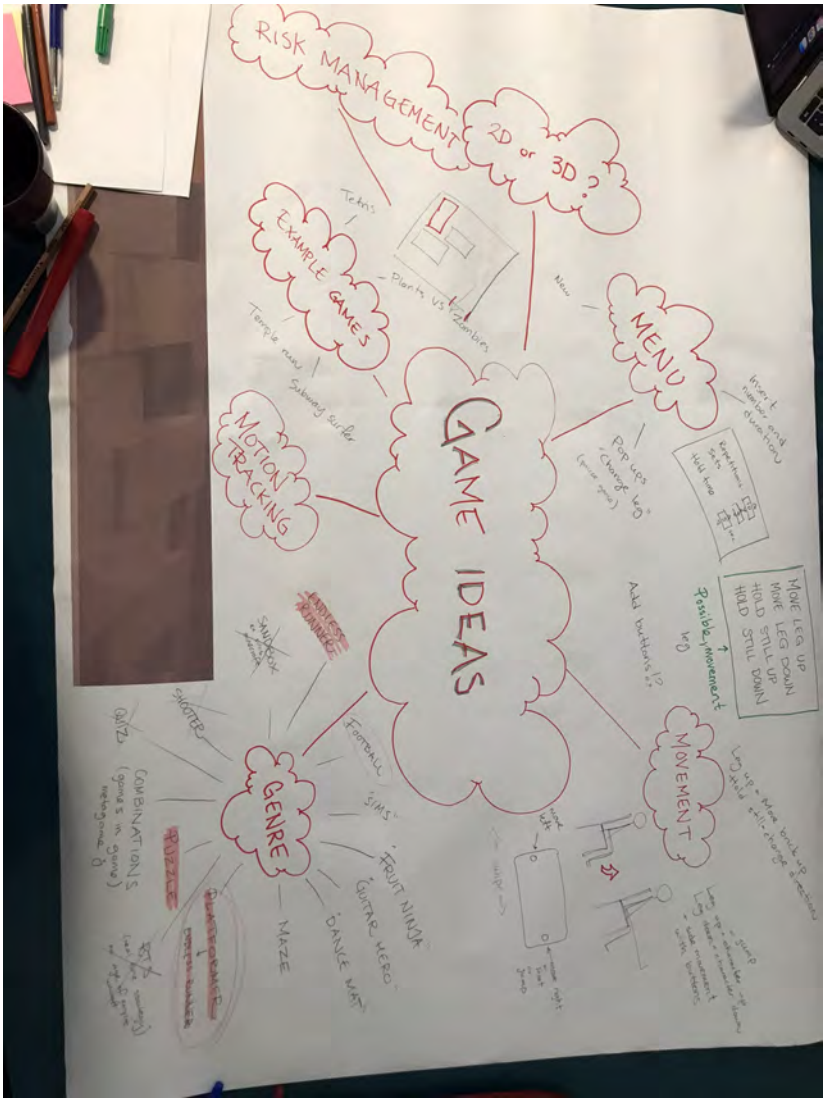
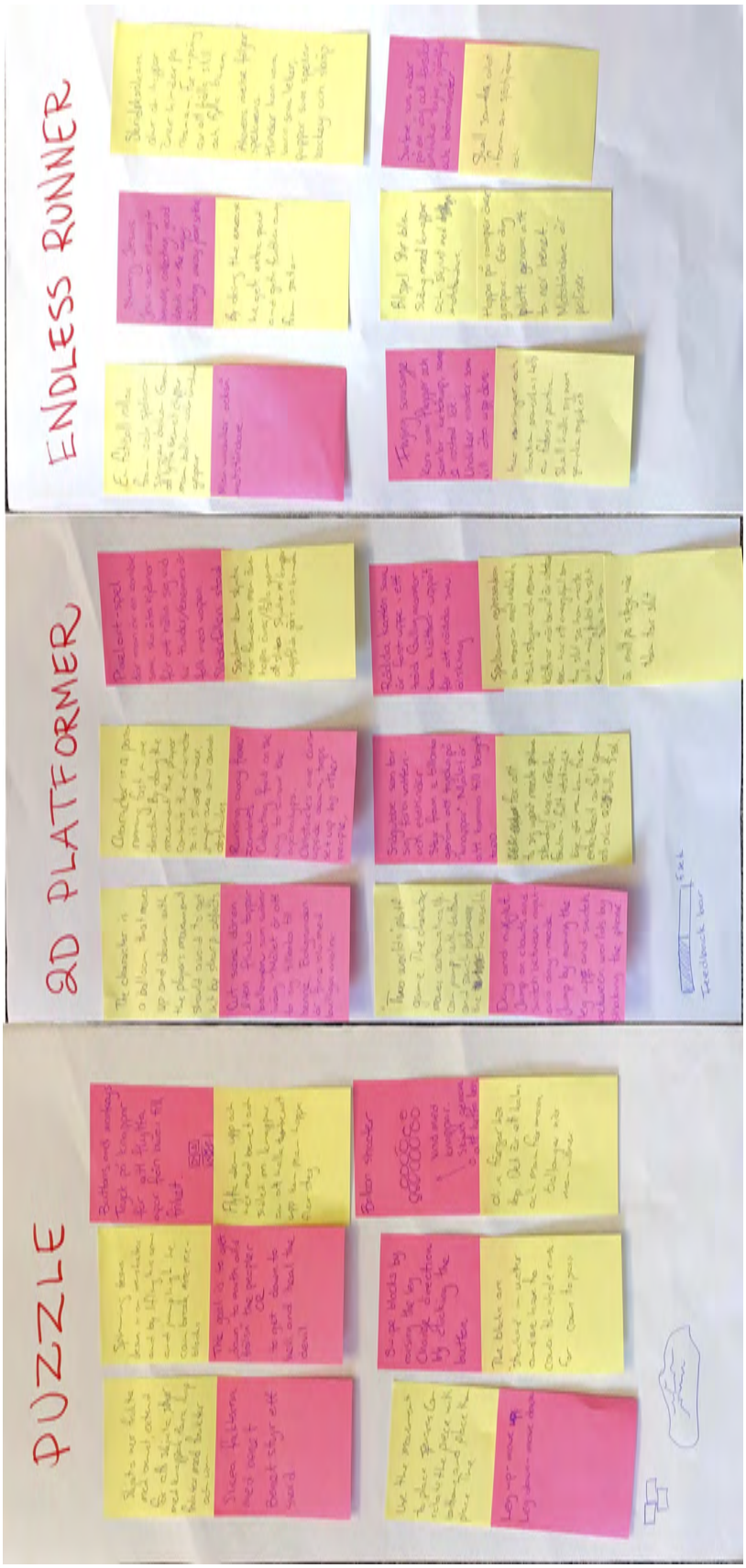


Figure A.2: Crazy 8

Figure A.3: Crazy 8

Figure A.4: Brainwriting



B

Appendix: Interview Template

Intervjumall - 25/4

Övningen:

- **Hur länge har du jobbat som fysioterapeut?**
- **Brukar du inkludera sittande knäextension (benspark) som övning för dina patienter med främre korsbandsskada?**
- **Vad är viktigt att tänka på när man gör denna övning?**
    - **Tid att hålla i utsträckt läge?**
    - **Hastighet på rörelsen?**
    - **Vila mellan sets?**
    - **med/utan belastning?**
- **I nuvarande version av spelet fokuserar vi på hemmaträning. Ser du att spelet kan fylla en funktion i detta syfte?**

Spelet:

- **Vad är din allmänna åsikt om konceptet?**
- **När du spelade spelet, kunde du utföra övningen på rätt sätt?**
    - **Varför / Varför inte?**
- **Tycker du att den valda typen av spel är lämplig för denna övning (sittande knäextension)?**
    - **Varför / Varför inte?**
    - **Om inte, vilken annan typ av spel skulle du föreslå och varför?**
- **Har du några förbättringsförslag på spelets funktionalitet?**
- **Tycker du att spelet ger tydlig feedback på att patienten gör sin övning på ett korrekt sätt?**
    - **Varför? / Varför inte?**
    - **Förslag på förbättringar**

Menyer och inställningar:

- **Tycker du att det saknas någon inställning?**
    - **något mer patienten kan tänkas vilja ha kontroll över när det kommer till övningen?**
- **Vår Progress-sida är till för att patienten skall kunna kolla tillbaka på sin statistik och sätta upp delmål på vägen. Är det något du tycker vi saknar eller borde ha med när det kommer till statistikdelen av appen?**

Andra tankar:
Har du övriga synpunkter på spelet?

C

Appendix: Consent Form

Consent form

Ditt deltagande i denna studie är frivilligt. Du har rätt att avbryta när som helst. Testet och tillhörande intervju kommer ta cirka 20 minuter att genomföra. Dina svar kommer att anonymiseras. Med din tillåtelse kommer ljudupptagning och videoinspelning ske under testet/intervjun. Dessa ljud och video-inspelningar kommer endast att ses/höras av de två testledarna för att sedan raderas.

Samtycker du till att delta i denna studie och att dina svar kommer att lagras för analysändamål?

- ☐ *Jag samtycker till ovanstående*
- ☐ *Jag samtycker till att ljudupptagning görs under intervjun*
- ☐ *Jag samtycker till videoinspelning under intervjun*

_____ _____

Underskrift **Namnförtydligande**

_____

Plats och datum

D

Appendix: Affinity Diagram

The diagram can be found online here:

Affinity Diagram

E

Appendix: Game Design Document

General

Game Name: Rehab Rush
Genre: Serious game + Platformer (endless runner)
Player: Single player
Target group: Females aged 16-20 years old

Technical specifications

Technical Form: 3D graphics
View: Third person
Platform: iOS and Android
Language: C#
Device: Smartphone

Prioritization through MoSCoW

Must have

- Motion control
- Connection to the physiotherapeutic exercise
- Repetition counter

Should have

- Game theme appropriate for the target group

Could have

- Original, self-constructed 3D models
- An engaging gameplay
- Multiple levels

Won't have (this time)

- Adaption to the whole rehabilitation program

Purpose

This is a body controlled mobile phone game that should help young women with ACL-injuries do their physiotherapeutic exercises in a correct and rewarding way.

Game play

The football player runs across the football field with the goal of hitting as many footballs as possible. The footballs are hanging in the air and she needs to jump up to get them. On her way she is collecting stars on the ground and avoids traffic cones that are blocking the path.

Game Play Outline

Opening the game application

When entering the application, a start screen appears, see E.1. Here, the game logo *Rehab Rush* is shown and there are three buttons that will take the player either directly to start playing the game, or to go to settings or progress.

Figure E.1: The start screen of Rehab Rush.

Game options

On the settings page (E.2), the player has the opportunity to modify the game. Since the game is based on rehabilitation, the player can adjust the number of sets, repetitions (reps), rest time and player speed.

Figure E.2: The settings page of Rehab Rush.

The number of sets decides how many sections of the game containing football collectibles. The number of reps decides how many footballs there are in each set. The rest time sets the length of the rest sections and speed sets the speed of the game character's forward movement.

Game elements

Collectibles
Stars: 1 point
Footballs: 1 reps point

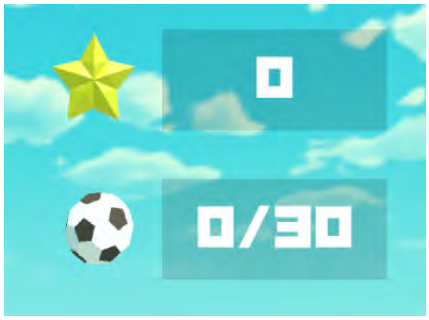


Figure E.3: Collectibles

Obstacles
Traffic cones: -10 points

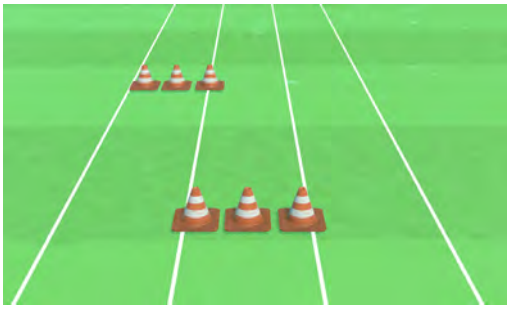


Figure E.4: Obstacles

Game boundaries

The game level consist of three lanes delimited by white lines. The character cannot move outside of these lines.

Game levels

The game consist of one game level divided into five different sections.
Section 1: Set 1 10 football collectibles placed in the middle row **Section2: Rest** Star collectibles and traffic cone obstacles **Section 3: Set 2** 10 footballs spread out over the three lanes **Section 4: Rest** Star collectibles and traffic cone obstacles **Section 5: Set 3** 10 footballs, star collectibles and traffic cone obstacles
(see E.5

Figure E.5: The five sections of the level. From the left: set 1, rest 1, set 2, rest 2, set 3.

Player's controls

Move left: An invisible touch button covering the left half of the screen. One tap moves the game character one lane to the left
Move right: An invisible touch button covering the right half of the screen. One

tap moves the game character one lane to the right
Jump: Cover the AR marker in the real world. Covering the marker makes the character jump. Keeping the marker covered keeps the character in the air

Winning

The player wins when the game character reaches the goal at the end of the third repetition section. The score of the level is presented together with the number of successfully completed repetitions and sets.

Losing

The player can't lose, just reach the goal with more or less points/repetitions completed.

Why is all this fun?

The physical connection between the player and the game character is what makes the current version of the game fun. To see the character's action triggered by your physical movement, which isn't the usual player control input. It adds a playfulness to an otherwise boring practice.

Game Design

Game Flowchart

The flowchart below, see figure E.6, presents the navigation between the wireframes of the game.

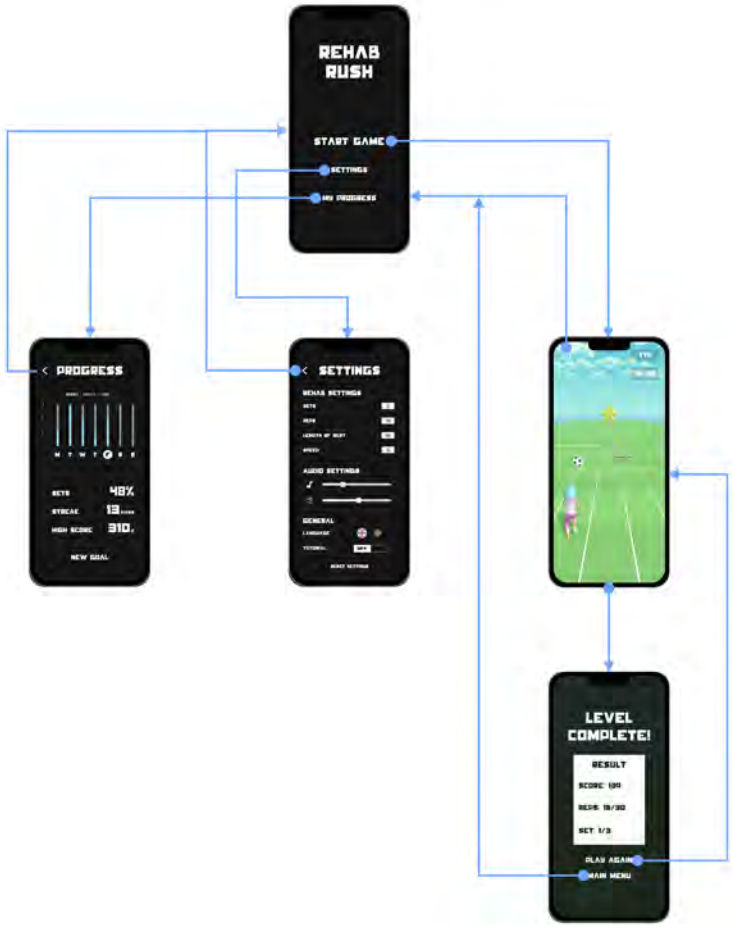


Figure E.6: Game Flowchart

User Interface

Gameplay elements

The gameplay elements can be seen in figure E.7. Beyond the elements presented in the figure, there are two invisible buttons covering the left and right side of the screen which allows for side way movement of the game character.

Start page, Settings and Progress

Figure E.8 presents the wireframes of the start page, settings page and progress page of the game. The settings page includes Rehab Settings, where the user can adjust the level design depending on their prescribed rehab program, together with settings for the audio, language and a switch button for activating a tutorial mode. The tutorial is a feature which provides a step-by-step walkthrough of the game. It guides the player on how to set up the marker, how to jump and how to play the game. This is done through hints and descriptions when new things are happening in the game. It is automatically activated and deactivated the first time the game is being played, and can after that manually be activated using the switch button.

The progress page, seen in figure E.8, shows the player history and rehab progress. Here the player can set up weekly goals and see the statistics of the game.

Figure E.7: Gameplay elements

Figure E.8: The wireframes of the game, from left to right: start screen, settings page, progress page.