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Analysis, Design and Prototypical Development of a Gamified Application to Perform Strength Training for the Health of the Human Locomotor System

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Analysis, Design and Prototypical Development of a Gamified Application to Perform Strength Training for the Health of the Human Locomotor System

DIPLOMA THESIS

submitted in partial fulfillment of the requirements for the degree of

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in

Biomedical Engineering/Medical Informatics

by

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to the Faculty of Informatics

at the TU Wien

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Daniel Boros

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Daniel Boros

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Kurzfassung

Die verringerte körperliche Aktivität in der Bevölkerung führt zu einer Vielzahl an gesundheitlichen Problemen, welche negative Folgen auf das Individuum, sowie auch auf die Gesellschaft haben. Aufgrung von gesundheitlichen Problemen sinkt die Lebensqualität des Einzelnen, und das das Gesundheitssystem is mit einer großen Herausforderung konfrontiert, insbesondere mit einer immer älter werdenden Gesellschaft.

Eine möglicher Lösungsansatz, um diese problematische Situation zu verringern, könnte darin bestehen, den Fokus mehr auf die Prävention durch Interventionen im Lebensstil des Individuums zu legen. Eines dieser Interventionen ist die regelmäßige Durchführung von Krafttraining. Viele positive gesundheitlichen Effekte werden mit dem Betreiben von Krafttraining assoziiert. Speziell im Hinblick auf den menschlichen Bewegungsapparat kann Krafttraining zum Aufbau und Erhalt von Muskelmasse, sowie zur Erhöhung der Knochenstärke beitragen. Das kann den menschlichen Bewegungsapparat widerstandsfähiger machen gegen orthopädische Probleme, welche aus Situationen mit großer mechanischen Einwirkung wie zum Beispiel beim Stürzen, oder in Alltagssituationen durch Fehlhaltungen oder auch einfach aus dem Prozess, dass Skelettmuskeln und Knochengewebe sich mit zunehmendem Alter abbauen, entstehen.

Dabei ist bei der Durchführung von Krafttraining es von großer Bedeutung eine Regelmäßigkeit aufrechtzuerhalten. Der lange Prozess der Anpassung von Skelettmuskulatur und Knochengewebe benötigt Stimuli, welche regelmäßig auf diese Gewebe ausgeübt werden. Dadurch, dass Skelettmuskulatur und Knochengewebe anpassungsfähige Gewebe darstellen, werden diese ohne genügend Stimuli schwächer. Neben der Regelmäßigkeit ist es auch wichtig einen hohen Fokus und Anstrengung in die einzelnen Trainingseinheiten zu setzen, damit der optimale gesundheitliche Nutzen erreicht wird. Das bedeutet, dass das Individuum nicht unnötig Zeit vergeudet und sich nicht während den Trainingseinheiten ablenken lassen sollte.

Deswegen wurde in dieser Thesis eine mobile Software-Applikation entwickelt, welche eine Reihe an Zielen addressieren soll. Zunächst einmal sollte durch eine Einbindung von gamifizierten Elementen und dem Aufklären über die gesundheitlichen Vorteile von Krafttraining der Nutzer dazu bewegt werden, ihr gesetztes Trainings-Frequenz Ziel zu erreichen und damit die Anzahl zu erhöhen Krafttraining zu betreiben. Eine Vielzahl an Individuen verlieren häufig die Motivation Krafttraining zu betreiben und haben ein Problem damit eine Regelmäßigkeit des Krafttrainings aufrechtzuerhalten.

Weiterhin wurde eine gamifizierte Funktion entwickelt, bei welcher die Nutzer die Pausen in den Trainingseinheiten aufzeichnen müssen, um bestimmte Vorteile in der App zu bekommen. Das entspricht dem Ziel die Trainingseinheiten zeitlich zu optimieren und somit die Trainingsdauer zu reduzieren. Diese Aufzeichnung der Pausen und Einhaltung eines zeitlichen Rahmens soll unterstützend auf den Fokus, welcher der Nutzer auf das Training legt, wirken und somit dem Nutzer es ermöglichen, qualitativ hochwertigere Trainingseinheiten mit hoher Trainingsintensität zu betreiben.

Im Entwicklungsprozess wurde das Requirements Engineering eingesetzt, um in mehreren Iterationsschritten Anforderungen zu erheben und zu verfeinern. Hierbei wurden die Nutzer der Zielgruppe früh in den Entwicklungsprozess mithilfe des User-centred Design eingebunden, wobei eine Vielzahl an Iterationsschritten durchlaufen wurden.

Keywords: *Krafttraining, Prävention, Knochenstärke, Requirements Engineering, User-centered Design*

Abstract

The reduced physical activity level in the population creates a wide range of health-related problems, which have negative consequences for the individual and also for society. For the individual the quality of life is decreased due to health issues and the health care system is confronted with a large challenge, especially in a more and more aging society.

A possible solution to reduce this problematic situation may be to place more focus on prevention through lifestyle interventions. One of these interventions is the regular performance of strength training. Many positive effects on health are associated with performing strength training. Specifically with regards to the human locomotor system, strength training can help to build and maintain muscle mass, as well as increase bone strength. This can make the human locomotor system more robust against orthopedic issues resulting from situations of large mechanical impact such as falls, or from everday life situations through bad posture, or simply from the process of the decline of skeletal muscle and bone tissue with increasing age.

Hereby the keeping up a regularity with performing strength training is of great importance. The lengthy process of having results from adaptation of skeletal muscle and bone tissue require a regular stimulus being put on these tissues. By being an adaptive tissue, skeletal musculature and bone tissue get weaker when not placing enough stimuli on them. Besides the regularity, also the amount of focus and effort put into the individual training sessions themselves are important to get the optimal health benefits. This means that the individual should not unnecessarily waste time and get distracted during the training sessions.

Therefore in this thesis a mobile software application was developed that has a set of aims it should address. First of all, through including gamified elements and raising awareness about the health benefits of strength training, the application should encourage the user to adhere to their training frequency goals and therefore increase the amount of times the user performs strength training. Many individuals lose motivation frequently and have a problem maintaining the regularity with strength training.

Furthermore a gamified feature was developed in which the user has to track the rest periods during a training session to receive certain benefits in the application. This corresponds to the aim of optimizing the training sessions in terms of time, so to reduce the training duration. This adherence to a set time frame should support the focus

put on the training and therefore enable the user to perform more qualitative training sessions with high intensity.

In the development process, requirements engineering was applied to elicit and refine requirements in several iteration steps. Hereby users of the target group were involved at an early stage with use of user-centred design, where several iteration steps were performed.

Keywords: *Strength training, prevention, bone strength, requirements engineering, user-centered design*

Contents

CHAPTER 1

Introduction

In this thesis a gamified application to promote the performance of strength training in context of health benefits and prevention is to be analyzed, designed and developed in form of a prototype. Hereby the role of exercise in form of strength training for the health of the human locomotor system and biomechanical tissues such as skeletal muscles and bone should be emphasized. In the development process of the gamified application the users should be greatly involved by applying the user-centred design and concepts of requirements engineering.

This chapter involves the description of the problem, the motivation behind the thesis, as well as the specific aims the thesis has. Furthermore the methodology used is presented and a brief overview of the structure of the thesis is given.

1.1 Problem Statement

According to a report from the World Health Organization (WHO) in 2018 it was examined in a survey that 46% of Europeans never take part in physical activities and merely 7% exercise regularly. In addition a majority of adults in Europe spend more than five hours daily with seated activities [Org18].

An inactive lifestyle is detrimental to the health of the individuals because the abscence of an adequate amount of movement can lead to health issues later in life. In particular the lack of movement influences the state of tissues involved with biomechanics and the human locomotor system which can lead to health issues and orthopedic diseases. That also often influences the ability to perform certain movements without experiencing pain. Furthermore an inactive lifestyle can make the individual susceptible to gain excess body fat. Obesity is on the rise in many countries. Obesity can lead to additional health issues and negatively influence the well-being of the individual [Wes12].

Due to the biomechanical tissues such as skeletal muscles and bone adapting to the demands placed on them, the abscence of adequate stimuli leads to a decrease in their qualities and thus are more prone to health issues. When combined with the individual being obese, the problems can further increase due to the large weight which the human skeletal system has to bear while not being adapted to adequate stimuli through exercise and abscence of enough movement [Piv18].

Many individuals have the intent to change their lifestyle regarding exercise. However most have difficulties maintaining a regular exercise schedule for a long period of time and fall back into old patterns. Hereby to receive the benefits of exercise the regularity of performing exercise is of most importance. Another issue often is that many individuals do not want to put in a lot of effort into the performance of the exercise itself. This is especially true for strength training when a lot of time is wasted in between exercise sets, as well as the individual not maintaining the appropriate focus on the performed exercise and training intensity being reduced [KJRA04].

1.2 Motivation

In many of today's societies, decreased physical activity levels combined with high obesity rates are major issues for the individuals health and for the societies. This is accompanied by an increased aging population which places an additional challenge on the healthcare system [Org18] [Wes12].

A valuable approach is to not only intervene when the problems already occured, but also to try to prevent the problems from happening in the first place. Hereby regular strength training can make a significant contribution [MRB+20].

Through strength training stimuli are set on the skeletal muscles, as well as the bones. This leads to an adaptation process in the muscles and the bones, and they become stronger. With an increased strength of skeletal muscles and bones, individuals can be more resistant against situations of high mechanical stress such as in a fall accident or in an athletic activity. But also in situations where not such high loads occur such as seated activities, stronger skeletal muscles have the ability to lead to a better posture which can prevent having certain orthopedic issues. Furthermore, due to loss of skeletal musculature and bone density with age, the application of stimuli to these biomechanical tissues is of great importance to counteract that decline [MRB+20].

There are several reasons to start and perform strength training on a regular basis at a younger age and not to only start at an older age. First of all, the training experience accumalted over the years is important to acquire knowledge of for instance how to carry out exercises with good form and how to apply a high training intensity among other learnings. Another advantage to begin at a younger age is that if mistakes were done, the body is less prone to injury and mistakes can be avoided better with age. Additonally an advantage is that this positive habit of regular strength training is built up over many years which should make it easier to maintain. Also the individual has already gone

through the long process of muscle and bone adaptation when reaching an older age and there is already a solid base of muscles and bone strength. Another issue that can be addressed with regular strength training is to prevent obesity. In addition to the expenditure of energy while performing strength training, especially the increased energy expenditure through muscle growth can make it easier to maintain a healthy weight in combination with the right nutrition. Hereby the reduction of fat mass is relevant [SS11].

As it can be seen there are many reasons to perform regular strength training and the motivation of the diploma thesis is to promote regular strength training and raise the amount of strength training performed, so that the individual's health can benefit from that and overall improve their quality of life. In addition to an abscence of motivation to perform strength training regularly, often times the training sessions themselves are not performed with enough focus and time is wasted by taking more time between exercise sets than necessary for recovery to perform the next exercise set. Many get distracted in the process. Furthermore this has a negative impact on the applied training intensity. However a high training intensity is important to improve the outcomes for the health benefits of strength training such as strengthening of the bones [GGFGC09] [KJRA04].

1.3 Aim of the Thesis

The aim of the thesis is to develop a protoype in form of a mobile application which has the goal to support the user to achieve a targeted training frequency and therefore increase the engagement in physical activity in form of strength training and maintain a training routine. Hereby raising awareness of the positive health benefits of strength training with regard to the human locomotor system should be achieved and gamification elements should be included into the application. In addition the application should support the training sessions to be performed more time efficiently through the decrease of wasting time not focusing on the training. The plan is to integrate gamified elements for the motivational aspects as well as to process data during the training session with the support of a smartphone.

The specific questions which should be answered in this diploma thesis are the following:

1. Can a gamified application, that raises awareness about the health benefits of strength training with regard to biomechanical aspects, help to achieve a targeted training frequency and thereby increase how often the user performs strength training?

2. Can the training sessions be made more time efficient through the use of the application?

3. What are the requirements for the application to achieve the adherence to a targeted training frequency, thereby increasing training frequency, and the optimization of duration of training sessions?

1.4 Methodology

The development of a software solution in form of a mobile application was performed on the basis of requirements engineering and the software methodology of user-centred design. Hereby stakeholders were involved in the development process at an early stage and took in the central role to find requirements for the solution. This involved an iterative process where requirements were elicated and further refined. The stakeholders consisted of people from the target group which are people of the age between 18 - 35 that have at least a bit of experience with strength training. The methodological approach is illustrated by visualization of the individual steps taken in the requirements engineering process in diagram 1.1.

As a first method a literature review was conducted to obtain relevant information regarding the research questions of the thesis. Furthermore a research about existing solutions related to the targeted objectives of the thesis was performed. These existing solutions were selected by specifiifed criteria from scientific publications as well as commercially available products. The relevant aspects which the developed solution in the thesis should fullfill were extracted and compared individually with all the solutions that were selected.

From the literature research, including the state of the art research, the relevant topics were defined and participants for the development process in a user-centred design were searched.

After the research analysis has been done, the first iteration in the user-centred design was conducted by means of an interview with a participant of the target group. Here the interview was used to get first ideas about the requirements to the application and mindmapping was used as a tool to gather these ideas.

Based on the literature research and on the ideas collected and documented in the mindmap, questions were formulated for an online survey. The questionnaire was hereby given to two people to test its content and structure. With the feedback of the two participants and feedback from the supervisor, the questionnaire was revised and then given to 43 people in iteration number 2 to give their answers.

From the evaluation of the online survey 15 requirements were formulated and documented in a list with prioritization based on the importance of them seen by the participants. Subsequently 5 requirements were noted for the game idea that was based on the requirement list from the online survey and own ideas of the author. In total therefore 20 requirements were collected and documented.

In iteration 3 with the list of requirements a low-fidelity prototype was developed in form of wireframes and in addition user flow diagrams were created.

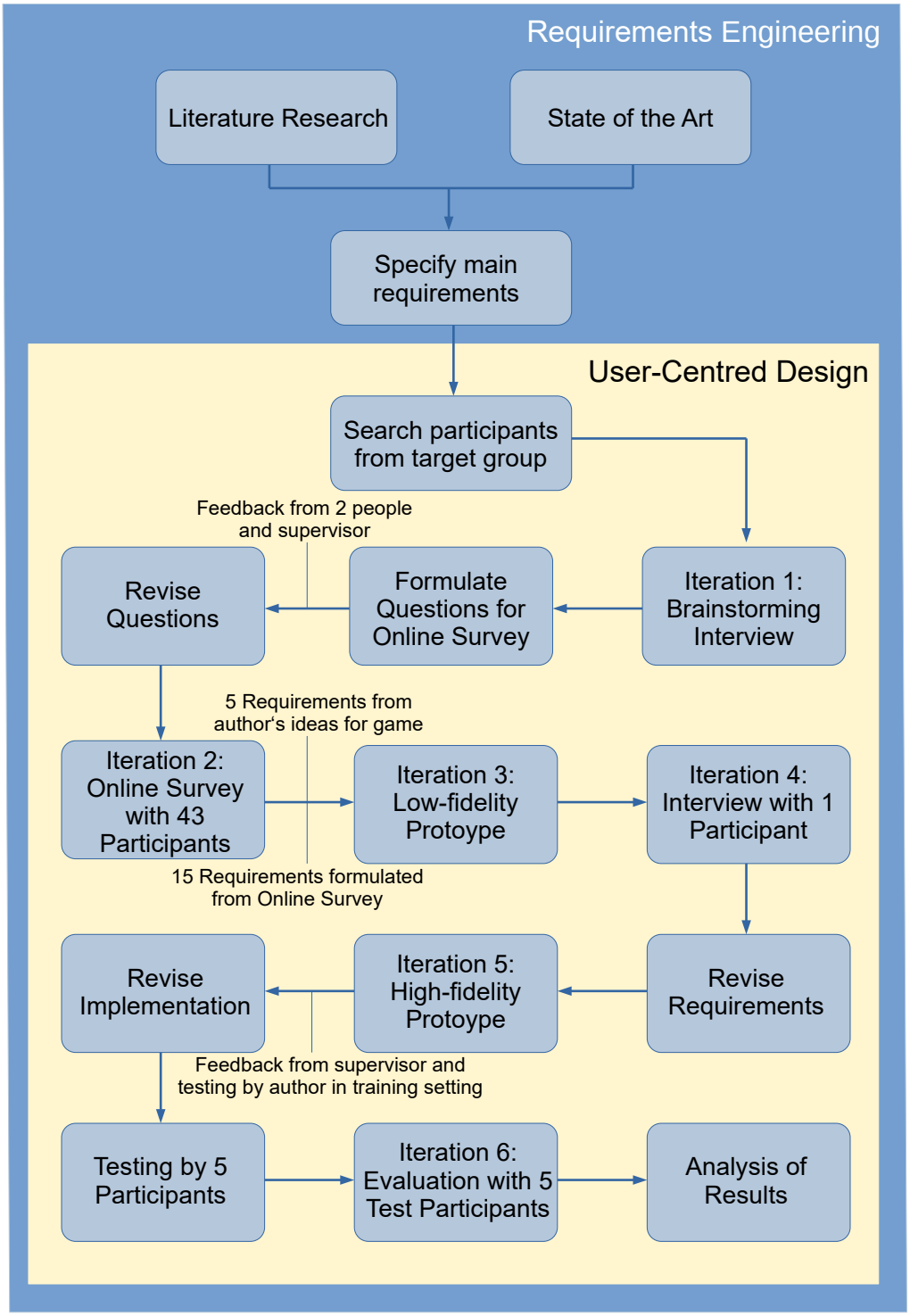


Figure 1.1: Methodology Diagram

Afterwards an interview was conducted with a participant of the target group in an iteration 4 to get feedback to the developed prototype and revise the requirements. Hereby the prototype and user flow diagrams were printed out on paper and presented to the participant to be able to directly sketch improvements in feedback on the paper prototype. Simultaneously the feedback was also captured through notation. As a result the wireframes were revised and 5 new requirements for the game were conducted. After this iteration in total 25 requirements are listed.

Based on the 25 requirements in an iteration 5 a high-fidelity prototype was developed. This was a coded prototype and took form in a mobile application on the iOS operating system. Hereby during the development process feedback was obtained from the supervisor and also the features were tested in training session settings by the author.

After the high-fidelity prototype was brought to a finished state, in an iteration 6 the prototype was given for testing to 5 participants from the target group. Herbey the application was given to them for a time period of 1-2 weeks so that they had enough time to use the prototype during their training sessions.

Subsequently the testing participants were interviewed and feedback based on the research questions and usability criteria gathered. In the process data and comparitive data were collected as a measurement. The relevant data to answer the research questions were the amount of times the testers performed strength training and if they adhered to their set training frequency goal while use of the application. Hereby the comparitive data was the amount of times the testers performed strength training two weeks before use of the app and if they adhered to their training frequency goal in that timeframe. Furthermore the data was collected of the duration of the training sessions while the application was used and as comparative data the duration of training sessions two weeks before the use of the application.

At the end of the user-centered design process the high-fidelity prototype was evaluated with the data and comparative data. Furthermore it was evaluated if the requirements developed throughout the user-centred design process were successful in fulfilling the adherence to the targeted training frequency and therefore if the application lead to an increase in training frequency. Furthermore it was evaluated if the requirements fulfilled the reduction in duration of training sessions to make the training sessions more time efficient.

1.5 Structure of the Thesis

In the following a brief overview of how the thesis is structured into its individual chapters is given.

After the introduction in this chapter was made, in chapter 2 the theoretical basics, that are relevant to the objectives dealt with in the thesis, are presented. These involve a biomechanical part where information about skeletal muscles and bones as biological tissues are presented, as well as fundamentals of strength training and its relevance to

the human health. The other part of theoretical basics involves technical fundamentals which are of importance to understand the development process of the prototype.

Afterwards in chapter 3 the state of the art is presented when it comes to similar solutions to the objectives of the thesis. For this, a selection of existing solutions from scientific publications and also from commercial products which were selected based on established criteria are presented. At the end of this chapter a summary of the selected state of the art is presented and compared with the objectives of the thesis. Here the innovation of the aims of the prototype developed in the thesis is shown.

Then in chapter 4 the results of the development process in several iteration steps are presented. This involves the elicitation of requirements and involving the target user in the process.

In a first iteration step (chapter 4.1) ideas were discussed in a semi-structured interview with a participant of the target group. This resulted in the first list of requirements which were then used for the next iteration step where an online survey was developed.

In the online survey in iteration step two (chapter 4.2) 43 people from the target group were asked specified questions consisting of open questions and multiple-choice questions. From the analysis of the results of the survey the requirements were further refined and noted.

After that based on the collected requirements a first prototype was developed in iteration three (chapter 4.3) by the author through sketching of wireframes and user flow diagrams. Then these were presented in iteration four (chapter 4.4) to another stakeholder from the target group and discussed in an interview. This resulted in feedback and refinement of the wireframes.

Subsequently the development of a high-fidelity prototype was performed in iteration five (chapter 4.5) on the basis of the requirements of the previous iteration steps and the low-fidelity prototype from the wireframes. Hereby a coded prototype was implemented and refactored in an iterative process until the finished prototype fullfilled the requirements and the functionality was given.

Then the high-fidelity prototype was given to five testusers for one to two weeks. After the participants went through the testing phase of the app, an interview was conducted with each testuser and their experience and critique were collected especially regarding the research questions of the thesis. Afterwards the results were evaluated in chapter 4.6 by the author which were then discussed in chapter 5. Finally in chapter 6 a conclusion was made and possibilites of improvements documented.

CHAPTER 2

Theoretical Basics

In this chapter the theoretical basics which are relevant to the content of the thesis are presented. This includes theory regarding biomechanical fundamentals as well as basics about strength training which are then connected through the subject of health benefits and prevention. Afterwards relevant aspects of motivational theories are described to understand what drives people to adhere to certain actions to achieve a goal. After that the subject of gamification is presented and finally the important basics of requirement engineering are shown which are essential for the prototype developed in this thesis.

2.1 Biomechanics

The health of the human locomotor system depends on the body's skeletal tissues such as muscles and bones which both have key functionalities in the biomechanical behavior of the body. Muscles are active tissues which produce movement whereas bones are passive tissues which have functions in support and protection of the body. Consequently it is immensely important to sustain strong muscles and bones. In this chapter the theoretical basics of the structure and functionality of these tissues will be presented and importantly also the impact of exercise on these tissues will be identified [KTA18] [RK13].

2.1.1 Skeletal Musculature

Muscles can be distinguished into three types: skeletal muscles, cardiac muscles and smooth muscles. Due to skeletal muscles being the relevant muscle type for the active movement of the human locomotor system, throughout the scope of this thesis when referring to muscles skeletal muscles are meant. Skeletal Muscle not only determines the ability to perform movements but also gives the human locomotor system its stability [KAH11] [Car19].

Through activation of motoneurons skeletal muscles can be contracted and transmit forces to the bones which results in their movement. These force transmissions happen through connection of the muscle to the bone by tendons [KAH11].

Structure

Muscle tissue has a hierarchical structure. A muscle consists of a large amount of muscle fibres. These fibres are mostly made up of myofibrils which are arranged in parallel to eachother and extend over the whole muscle fibre. Each myofibril consists of a large number of thinner actin filiaments and thicker myosinfiliaments which can be seen in figure 2.1. The interaction through dislocation between myosin and actin filiaments is responsible for the contraction and relaxation of the muscle and therefore leads to the movement of the corresponding body part. When the myosin and actin filiaments dislocate from eachother in contraction phase the muscle length decreases whereas in relaxation phase the muscle length increases [RK13].

Muscle fibres can be distinguished by their types namely into slow-twitch muscle fibres (type I) and fast-twitch muscle fibres (type II). Type I muscle fibres are slower in contraction capability than type II muscle fibres, but are more resistant to fatigue. Type II muscle fibres however have a faster contraction capability but also fatigue more quickly. Furthermore type II muscle fibres can be divided into types of IIa and IIb. Hereby fibre type IIa is between type I and type IIb in terms of reaching fatigue and contraction speed [Kom03].

The contraction of a muscle occurs through motoneurons that have axonal branches which innervate the muscle fibres. Herewith an individual impulse is forwarded from the motoneuron to the axonal branches where all muscle fibres provided by that motoneuron are stimulated and synchronous action potentials are generated. This leads then to a twitch of force. Each individual axon hereby innervates a single musle fibre [JHR04].

Muscle Force

The amount of isometric force which a muscle can generate is determined by its cross-sectional area. For contractions where the muscle is shortened the amount of force which can be generated is larger than for an isometric contraction of the muscle. However when a muscle is stretched and lengthened, the force which can be produced is greatly larger than that of an isometric contraction and therefore also that of a contraction where the muscle is shortened [JHR04].

Furthermore the generated force also depends on the velocity with which the muscle is shortened or stretched. When there is an increase in velocity, the magnitude of force generated for shortening of the muscle is quickly decreased and at a certain velocity no force can be sustained. With an increased velocity for stretching of the muscle, the generated force can be larger but quickly reaches the maximum force that can be sustained [JHR04].

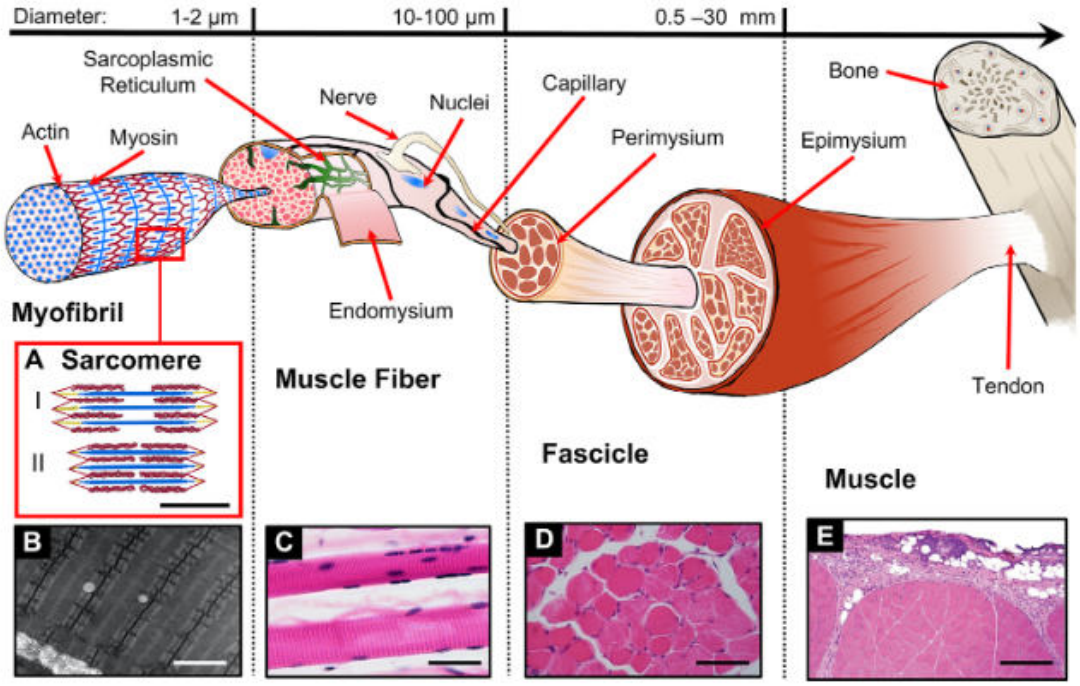


Figure 2.1: Hierarchical structure of muscle [GSZ+20]

Adaptation

Muscle adaptation occurs based on mechanical stress acting on a muscle. If a muscle is overloaded with weight, for instance through performing strength training exercises, the muscle fibres react through complex mechanisms on the cellular level with an increase in size [Kom03]. The increase in muscle size is described by hypertrophy which is the increase of cell size. In particular the muscle cell, which corresponds to the muscle fibre, increases it's cross-sectional area. An increase of cross-sectional area results to a greater force which the muscle can generate [Kom03]. The stretch-overload of the muscle leads to an increase of protein synthesis for the muscle which is larger than protein degradation which results in muscle hypertrophy. Furthermore the magnitude of hypertrophy can vary between fibre types of a muscle based on different types of strength-training methods. It has been examined that a large proportion of hypertrophy for heavy strength training occurs in type II muscle fibres [V10].

Current research suggests that in humans there is no increase in muscle cell amount which is described by hyperplasia, the increase of cell number, however this still remains controversial. When not loading the muscle with a weight according to the level of it's performance the muscle fibres react with atrophy which means the decrease in size of the cells. So the cross-sectional area of the fibres are reduced which lead to a decrease of force the muscle can exert [Kom03].

2.1.2 Bone

Bones are important building blocks of the human locomotor system. Their functionality lies in giving the body it's shape and protecting internal organs from external forces. It also facilitates movement of the body by being connected to muscles through tendons. Moreover bones are a major calcium storage and have functionalities regarding general metabolism of the body [CB00].

Structure

Bone also has a hierarchical structure and consists of organic and inorganic materials as well as water. This hierarchical structure is organized into different scale ranges in which bone can be examined. To understand the mechanical properties and functions of bone the examination of the different hierarchical levels is important and therefore shown in figure 2.2 [BA14].

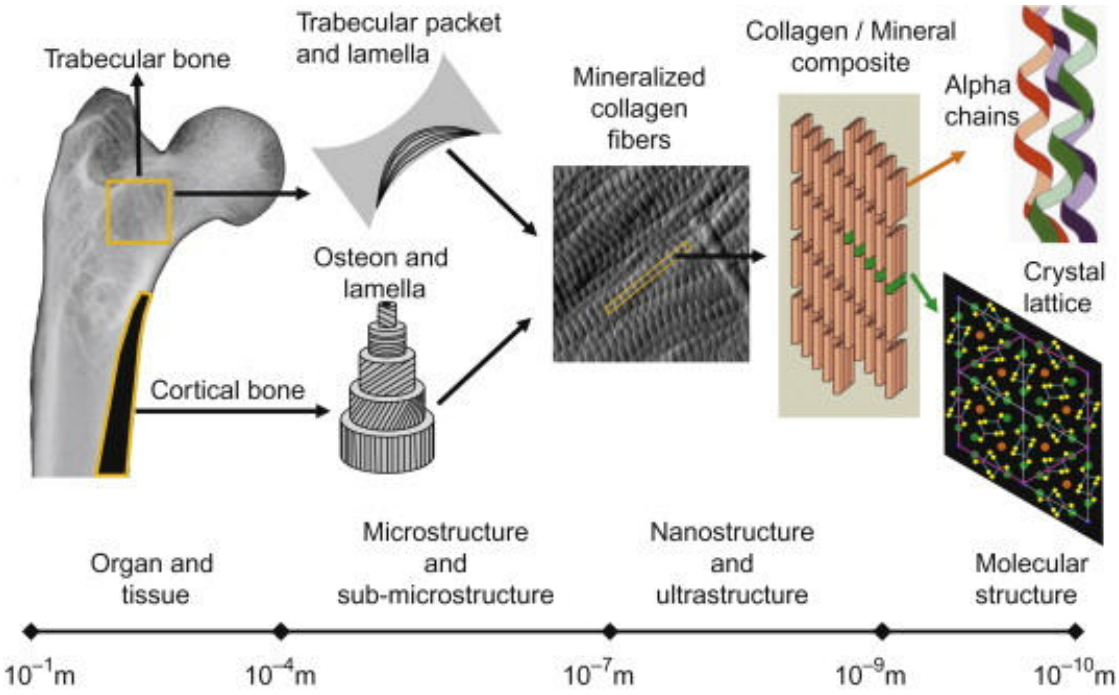


Figure 2.2: Hierarchical organization of bone in different scale ranges [BA14]

The structure on the macroscale describes the structure on the whole-bone level. Here there is a differentiation between cortical (also called compact) bone and cancellous (also called trabecular) bone. An important difference between these two type is the level of porosity the bone tissue has. Trabecular bone is much more porous and therefore also less dense than compact bone. The differntiation however needs to be done through evaluation of the microstructure. Cortical bone form a dense, outside shell whereas trabecular bone is located in the interior. Trabecular bone acts to decrease loads and

lead the forces forward to the stronger cortical bone that can withstand compressive forces. Also trabecular bones microstructure is formed in direction of lines of stress acting on it which allows for a lightweight, porous structure but still provides strength. This lightweight structure is important for balancing out the heavier cortical bone, so that the movement of bones through muscles is easier. [BA14] [RKSZ98] [DeS13].

On the microscale mineralized collagen fibers arrange into lamellar structures which are organized as planar sheets. These lamellar sheets can shape into different forms. On of these forms are osteons. An osteon is shaped as a cylinder consisting of several concentric lamellar sheets arranged around a central canal. Another microscale structure which cortical bone can take is woven bone where there is no clear pattern in which the mineralized collagen fibers are arranged. In trabecular bone a framework of lamellar sheets can be found, that arrange roughly parallel to the trabecular surface. [BA14] [RKSZ98].

The structure on the nanoscale consists of mineralized type 1 collagen fibres. This composite material shows stiffness due to the minerals and resilience and ductility due to the collagen fiber. On the microstructural level in most cases the mineralized collagen fibrils form discrete sheets, they arrange themselves in lamellae. On this scale level the organization of the bone tissue depends on the functional requirements [BA14].

Bone Strength

The resistance to bone fractures can be described by the whole-bone-strength. This is influenced by the bone mineral density (BMD), and consequently the bone mass. However also the tissue quality is of importance for bone strength, and also the bone geometry and microarchitecture of bone. Hence the way in which the bone mass is distributed in the shape of the bone plays a role in whole-bone-strength, and also the intrinsic properties of the bone matrix [JB18] [Amm09].

Bone Remodelling Process

The bone remodelling process is a lifelong process and includes bone formation, called ossification, and bone resorption. Ossification is the process of laying down new bone material by cells called osteoblasts. On the other hand bone resorption is when mature bone tissue is removed from the skeleton by cells called osteoclasts. This balance between osteoblasts and osteoclasts is responsible for the continous reshaping of bone. Naturally the bone mass of an individual decreases with age as seen in following diagram in figure 2.3 [DeS13]:

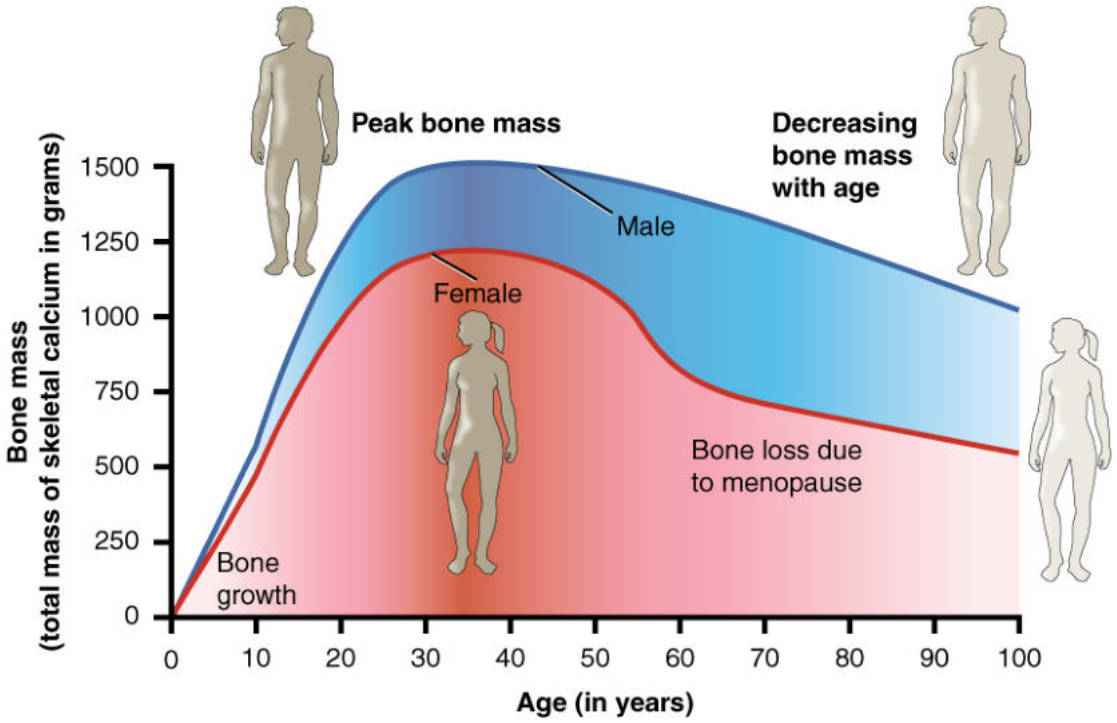


Figure 2.3: Relationship between bone mass and age [DeS13]

Humans reach their peak bone mass at the age around 30, from which it then gradually decreases with age. Hereby women have a time frame where the decrease in bone mass accelrates, which is in their menopause. The bone remodeling process is influenced by hormones that the endocrine system produces. With the menopause women produce less estrogen that stimulate bone formation. If there is an imbalance in the regulation between bone formation and resorption many metabolic bones diseases for instance osteoporosis, where the rate of bone resorption exceeds bone formation, can occur [DeS13].

The remodelling process can be influenced by injuries for instance fractures but also by functional demands regarding mechanical loading of the bone [DeS13]. With the mechanical loading of bone, the structure of bone adapts to the mechanical stimulus. This relation between bone structure and mechanical loading was described in Wolff's Law which describes the alignment of the internal trabecular structure of bone to the principal stresses acting on the bone. This could be concluded to the functional adaptation of bone to mechanical stresses. If the loads on the bone increase, it becomes stronger and more mechanically competent. However if the loading on the bone decreases, bone loss occurs. [KTA18] [Piv18].

2.2 Strength Training

After understanding the skeletal tissues muscles and bones and their functionality of adapting to mechanical loading the fundamentals of strength training to improve the health of these tissues are presented in the this chapter.

2.2.1 Maximum Strength

The maximum force a person can exert in a specific exercise can only be performed for 2-3 times successively or can only be exerted for a couple of seconds. If the exercise is continued to be performed, the force continually decreases with increasing repetitions or time period. For measuring of the maximum strength the One Repetition Maximum (1-RM) is referred to which describes the maximal possible weight a person can perform with an exercise for one single repetition. The maximum strength is an important measure to distinguish endurance training from strength training. In sports research training which is performed above 40% of the maximum force, is regarded as strength training whereas under 40% of the maximum force is classified as endurance training [SHH+17].

2.2.2 Training Variables

To achieve physiological adaptations there are different training variables which need to be considered. These variables consist of the amount of sets and repetitions, which can be described as training volume, the exercise intensity, duration of rest periods between sets, as well as the training frequency. Also the type of exercise and the order of the exercises within the training plan can be considered as training variables [Don07].

Progression is important in strength training to move towards a certain goal. Depending on the main training goal, the training variables should be taken into consideration. For progression in resistance training progressive overload, specificity and variation are three important principles that need to be considered. Progressive overload describes the gradual increase of stimulus on the muscles, which is important for progression due to the muscles adapting to the demands put on them over time. Specificity describes that the adaptations achieved with the training are specific to the targeted training goals. Variation of training variables leads to progression because the body can adapt rather quickly to the training regiment and through altering the training variables new training stimulus can be applied [Pro09].

Training volume is an important variable that describes the amount of work done in strength training in a certain time frame. This can be in a single training session or as a sum over a longer time frame such as weeks or months. Training volume is usually described as the total amount of sets and repetitions performed as well as the volume-load, which represents the weight used over the course of all sets and repetitions (sets*repetitions*load) [NJK+21].

Training intensity is most often described by the percentage of the one repetition maximum (1RM). The smaller the percentage of the one repetition maximum used, the more

repetitions can be performed until failure [STN+21].

Furthermore an important variable are the rest periods between sets. Rest periods describe the amount of time taken to recover between sets and exercises. Hereby the rest periods depend on the training goal, the lifted relative load, the complexity of the exercise, as well as the training experience of the individual. For the applied training intensity the variable rest period is very relevant because the load lifted is influenced by the amount of time for recovery between sets and exercises. With a larger amount of rest, the individual can recover more and perform better in the next set. Thus enabling a high training intensity [Pro09] [BSTM05].

2.2.3 Training Goals

Based on the primary training goal the training routine has to be designed in an accordingly manner by considering the training variables. In sports science three main goals when dealing with resistance training can be distinguished: Strengh increase, hypertrophy and muscular endurance. Depending on the primary goal the training is designed differently in terms of intensity, which leads to different ranges in repetitions and sets as well as resting periods between those sets. There is an inverse relationship between the load, which corresponds to the training intensity, and the amount of repetitions performed. [KJRA04].

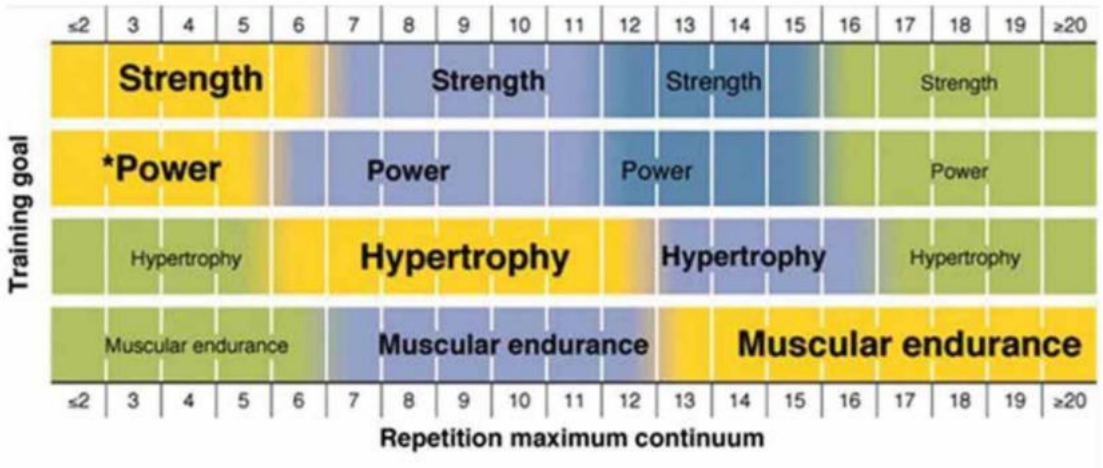


Figure 2.4: Different ranges of repetions according to the primary training goal [SWH12]

In figure 2.4 the different ranges in repetiton depending on the main objective of the training are visualized. Many studies have found that 80-85% and over 85% 1 Repetition Maximum (1RM) is the loading range which is optimal for strength increase. This means that the weight can be lifted for about 1 - 6 repetitions [KJRA04].

For muscular hypertrophy around 70-80% 1RM is said to be the optimal loading range which corresponds to 6 - 12 repetitions performed per set. That intensity range is often

used for muscular hypertrophy because it combines loading and volume in the best way. It has also been found that in the repetition range of 6 - 12, significant strength gains are made. So the strength increases are not exclusive to the repetiton ranges of 1 - 6, but for advanced lifters that loading range is superior for strength gains [Pro09] [KJRA04].

When training in a loading range that allows for a repetition range of 12 - 15 or more, muscular endurance is targeted and strength increases are rarely achieved. However for untrained individuals even in the lighter repetition range dynamic muscular strength can be increased [KJRA04] [Don07].

The training experience level plays a large role in the range where strength increases occur. It was found that individuals new to training had the largest effect on strength increase with 60% 1RM, whereas trained individuals had the greatest increase with 80% 1RM and 85% 1RM had the largest effect in strength development of athletes. It is also important to note that individuals unexperienced with strength training need to put their focus first on learning the movements of the exercises in correct form [Pro09].

There is debate about the optimal number of sets per muscle group for a training session. However it has been found that multiple sets per exercise are more effective for strength increases than single sets per exercise in a training session. Additonally in a meta-analysis it has been found that around eight sets per muscle group had the largest muscle size increase. It has to also be mentioned that above a certain point, increasing the training volume might be disadvantageous. It has been shown that moderate volume was better for strength increases than low or high training volumes when applying similar training intensities [Pro09]. Also the inverse relationship between intensity and volume should be accounted for. If the training volume is increased, it is difficult to maintain the high intensity and one also risks overtraining. So the intensity potentially has to be decreased in order to increase the training volume [KJRA04].

2.2.4 Effect on Health

In the following paragraphs, the health benefits related to strength training are unraveled and presented based on a variety of scientific studies. The benefits of strength training go beyond strenghtening of the muscles. This becomes clear when examining a meta-analysis of a large amount of studies that found that strength training was associated with a 21% reduction of all-cause mortality [SMIW+19].

For the health of the individual, including physical, metabolic and mobility health, skeletal muscle is of great importance. The fundamental intervention to increase the quality and quantity of skeletal muscle mass is performing resistance training [SCJ+20]. Performing resistance training is particularly important due to muscle mass decreasing with age [WP].

The benefits of strength training on the human locomotor system exceed building and maintaining muscle mass and strength. It furthermore can lead to stronger bones which is important to prevent fractures and many orthopedic diseases, the most prominent one

being osteoporosis [Pub]. For an increase in bone density the World Health Organisation recommends moderate-to vigorous-intensity weight-bearing endurance and resistance types of physical activity for 3-5 days per week, 30-60 minutes per training session [WHO+10].

The level of intensity seems to be important of how well the bone mineral density can be increased. It has been found that for instance walking or running has limited positive effects on bone mass increase, whereas resistance training with high intensity and elevated speed of movement has the largest impact on bone mass increase [GGFGC09]. Therefore for improving bone mass the resistance training should be designed to include heavy loads and consequently be performed with high intensity [KJRA04].

After pointing out the health benefits of strength training specifically related to biomechanics, in the next paragraph the more general health benefits of strength training are presented. There is evidence that strength training is effective in reducing some major cardiovascular risk factors. Therefore strength training can play an important role in the prevention of cardiovascular diseases [SS11].

One way in which these positive effects on the cardiovascular system take place is through the impact of strength training on weight control. Strength training leads to a raise of resting energy expenditure by increasing muscle size which makes it easier to maintain a healthy weight [SS11].

It can lead to lowering of resting blood pressure, improve cholesterol and decrease chronic inflammation, as well as improve insulin sensitivity and reduce the risk for type 2 diabetes [Bec18]. Due to the increase of muscle mass weight management can become easier for the individual because an increase in muscle mass results in a higher energy expenditure of the body so more calories are used at rest [DoHHS18].

The benefits of strength training to the brain have also been researched and it is increasingly suggested that it can improve cognition. Hereby it is thought that resistance training might lead to beneficial neurobiological processes. It has been found that resistance training lead to substantial functional brain changes, especially in the frontal lobe which were accompanied by improvements in executive functions [HTSM19].

2.3 Motivation

For the development of an application which aims at improving health of the users through motivation it is important to examine the basic concepts of motivation which are discussed in this chapter.

In motivational theory two different types of motivation can be distinguished: Intrinsic and extrinsic motivation. Intrinsic motivation describes taking action due to inner propulsions which consist of personal interests or satisfaction. Extrinsic motivation on the other hand is when people produce certain efforts because they are driven by obtaining a reward or they are driven by avoiding certain negative consequences such as punishments [DDR17].

2.3.1 Self Determination Theory

The Self Determination Theory conceptualizes qualitatively different types of extrinsic motivation, that themselves differ in terms of their relative autonomy. When someone acts in an autonomous manner the person stands behind their actions whereas when autonomy is not present the person is being influenced by an external force to behave in a specific manner [Hoy10]. So the first type of extrinsic motivation which is assumed by the self determination theory describes controlled forms of motivation. This leads to externally regulated behaviors which are performed to adhere to due to the possibility of reward or punishment administered by an external force. These controlled forms of motivation are expected to lead to short-term motivation and not to a sustained motivation over a longer period of time. The second type of extrinsic motivation described by the self-determination theory is motivation which comes from self-valued causes, so the potential outcome of the behavior is personally valued. As an example people might go exercising not because they intrinsicly want to but rather because they are driven by the desired outcome of maintaining good health [TCM+12]. Another central concept of the Self Determination Theory is that people have basic psychological needs which are of importance for autonomy-based motivations. These basic psychological needs consist of competence, connectedness and autonomy [TCM+12].

2.3.2 Achievement Goal Theory

In Achievement Goal Theory the people's conceptualization of success is the main factor for motivation. Here two distinct orientations can be named: performance goal (or ego-oriented) and mastery goal (or task-oriented). From an ego-orientated approach the motivation comes from comparing ones performance to others and finding motivation in a better performance than others. Here the goal is to build normative competence and distinguish yourself through larger success from others. The task-oriented motivation however comes not from comparing to others, but from comparing to ones self, so if the performance was a personal best or something new was learned. Here the focus lies on building self-competence, mastering the task and self-improvement [Hog20] [SP11].

2.3.3 Attribution Theory

The Attribution Theory describes the reasoning of success or failure by attributing these to certain aspects. This means in theory an attribution always comes after an outcome and these outcomes can lead to emotions depending on the outcome such as happiness or sadness. Hereby the attributions can come in different forms: Controllability, locus of causality, stability, globality and universality [San20] [SP11].

Controllability describes how much the success or failure lays in the control of the person. Locus of causality means if the cause for success or failure is dependent on oneself or on external factors. Hereby locus of causality is in relation with self-esteem because self-esteem is larger when we attribute internal reasons for success rather than external reasons such as luck or help from others. Similarly self-esteem is reduced when for failure the reason is attributed to one self rather than external reasons. Stability describes if a change can be achieved over time or not. Globality as an attribution form means if the success or failure can be applied to many situations or only one specifically. And universality describes the attribute form if the reason for success or failure can be applied to many people or only to oneself [San20] [SP11].

2.3.4 Self-Efficacy Theory

In self-efficacy theory the performance in a task depends on self-efficacy, which describes being self-confident in a particular skill. Hereby being more confident increases people's motivation in performance, whereas being in doubt to be successful has a negative impact on performance. However being too overly confident can also be bad for motivation because people then tend to not put in as much work in accomplishing their goal. Self-efficacy is furthermore specific to a task and also does not involve comparison to others [WE02] [SP11].

2.3.5 Expectancy Value Theory

The Expectancy Value Theory deals with two necessary ingredients for motivation, namely expectancies for success and subjective task value. If the individual does not have any expectancies that success can be achieved, that leads to a lack of motivation. But if the individual is sure about being successful, that leads to an increased motivation. However also the subjective task value has to be present. This means that the success or failure of a task has to be relatively attractive to the individual. If the individual does not see a value in performing a task, then the motivation is still going to be absent despite the belief that the individual would perform successfully [Wig94] [SP11].

2.4 Serious Games

In this chapter the terms serious games and gamification are explained and their different characteristics are presented.

Generally games can be distinguished between traditional games and digital games. Traditional games refer to games which do not involve any computational tools for instance card or board games. On the other hand digital games describe games which use some sort of computing machinery such as smartphones or computers as their platform [DGEW16]. In most definitions serious games are refering to digital games and due to the aim of this thesis to develop a prototype of an application the following descriptions refer to digital games.

Digital games can be divided into two categories: entertainment games and serious games. Entertainment games are games which were exclusively intended to entertain the user and provide a fun experience. On the other hand serious games go beyond the entertainment aspect of a game. There are many definitions surrounding serious games but generally the idea is that the game should not only entertain but also achieve another additional goal.

Depending on these characterizing goals the type of serious game can be determined from a list of different categories such as learning purposes or the purpose of improving health and well-being. Application fields of serious games are vast and include following fields: Games for Training and Simulation, Educational Games, Games for Health, Societal and Public Awareness Games, Pervasive Gaming, Marketing Games and several more [DGEW16]. Due to the theme of this thesis serious games in the context of health and prevention will be discussed more thoroughly than the others. Serious games in the healthcare area can be used for supporting the training of medical staff, or used in therapie for psychological and physical illnesses, or also for prevention and promotion of a healthy lifestyle [LST09]. For therapy in rehabilitation serious games can be used in the context of so-called exergames.

2.4.1 Exergames

One category of games with serious games which aim at improving health and prevention are exergames. These type of games not only have the goal to promote a healthy lifestyle but also increase the users physical fitness and can be used in a rehabilitation setting. The idea of exergames is that the user is being physically active during the game. In this realm of games it is important to measure the movements of the user as the input of the game so different types of devices have been invented to measure those movements while playing the game. One example is the Wii-Fit Balance Board which is a scale-like structure that can register the weight distributions when applying force through body weight forces. Another example is the Xbox kinect which uses a camera to register the movements of the player. And also the technologies surrounding virtual reality have opened up new possibilities of exergames [DGEW16].

2.4.2 Gamification

When designing a game as a developer it is important to distinguish between the terms serious games and gamification. The use of gamification means that the application developed is not intended to be a game per se, the intention is simply to make use of game-elements and/or game-based concepts to help achieve the intended goal of the application. These game elements can include badges, achievements, challenges and rewards. A simplified model for gamification can be described with three aspects: Goals, Meusurements and Rewards. It is important to be clear about what the aim in behavior of the user should be before designing the gamified system. Afterwards it should be thought of which actions are necessary to carry out those aims and how they can be measured. Finally the user needs to be rewarded for the action carried out [DGEW16] [Ole19].

2.4.3 Game Design

The success of a serious game or a system with gamified elements is also determined by the game design and how engaging the game is for the user. Therefore this chapter provides some information about basics of game design. A game should be designed in a way that it is fun to play for the user. Hereby different elements can be considered to make it engaging for the players. Three important aspects can be named to make the players engaged in a game: Challenge, play and story [Tra14].

Challenge includes the achievement of goals which addresses a fundamental desire of human-beings. Here it can be thought of to not only include a goal at the end of your game, but also subgoals during the path to get to the end of your game. This can make the players more likely to keep playing the game. Furthermore it is important to think about the difficulty of the desgined goals. Also it is essential to make sure that the goals are clearly defined and that they are understandable to the users [Tra14].

Another challenge aspect comes from competition. This adds a further natural challenge for the user which can happen in a multiplayer system directly against other players or indirectly through rankings or similar forms. Furthermore challenge can be driven by making interesting choices. Hereby it is important that the choices the user makes have certain consequences in the game. To increase the engagement the choices can be designed so that the decisions are difficult to make and the user has to weigh their choices against eachother [Tra14].

Play is the next important aspect to the design of a game. Play in games can be seen as the freedom of players to take action in a set of rules which give the game a rigid structure. This gives the player an opportunity to express themselves personally and give them an emanant experience. Play can take form in the user living out fantasies where the player experiences something that in reality they are not. This aspect is carried out extensively in role-playing games but can be used in other categories of games as well. Furthermore play can be driven by social interaction where in the game there is communication between players and relationships can be formed in the framework of the

game. Another powerful play aspect is exploration and discovery which makes the game experience exciting for the player to discover new things and go in unknown territories. Furthermore collection can be an enganging aspect for play. The drive of the player to collect certain items can be a further motivational factor for playing the game [Tra14].

Lastly the aspect of story can be important for designing the game. The entertainment through communicating stories to the player can lead to fascination of the players. This involves dramatic elements where the player has to overcome obstacles [Tra14].

2.5 Requirements Engineering

When developing a system an essential part of the development process is requirements engineering. Before a software project is begun it is important to make use of requirements engineering to understand the problem scope of the system to target the specific aims the project should have in a correct manner. This tries to avoid the scenario that the project misses its aim and simply does not fulfill the needs of the stakeholders which consist of users, customers, suppliers, developers or businesses [DHJ17]. Accoridng to basic definitions for ISO management system standards stakeholders can be defined as the following: "A stakeholder is a person or organization that can affect, be affected by, or perceive itself to be affected by a decision or activity." [JY20] Hereby the process is iterative and starts with initial requirement that are then refined, expanded and allocated down to designs on lower levels where specific low-level tasks can be carried out by an engineer [CAHW22].

2.5.1 Requirements

To understand the concepts of requirement engineering it is important to define what a requirement is. There are several definitions when it comes to requirements. One way to describe it is, that a requirement is a condition or ability which is needed by a user for a solution of a problem or for fulfill a goal. Another way to describe a requirement is it being a condition or ability, which a system or part of a system has to fulfill or possess to satisfy a contract, a norm, a specification or other formally set document [PR15]. For software development projects requirements can also be described as the following: "A requirement is a need, expectation, constraint or interface of any stakeholders that must be fulfilled by the proposed software product during its development" [Che13]. In software development two types of requirements can be distinguished: user requirements and software requirements. The necessities of the user for the software product are described by the user requirements. These entail the functionalities that should be met by the software and also conveniences required to improve personal performance. On the other hand there are software requirements that are distinctive to software systems such as usability, software security, user friendly design and several other aspects [Che13].

Requirements can be distinguished into two main types, namely functional and non-functional requirements. Functionality or a functional property of a system is described

by functional requirements. Hereby specifications are made with inputs and outputs, as well as a process or a behavior based on a function [WK13].

Non-functional requirements do not affect business functionality directly. However they impact the efficiency and effectiveness of an IT system for the users and the people who have the responsibility for the program support. They deal with large operational and technical areas of the system for the reliability of the application [Par17].

2.5.2 Methods

The goal of methods in requirements engineering is to support determining the requirements and knowledge of the stakeholders. There are several different types of methods which can be used in determining requirements and they should be chosen in respect to the specific use case of the system being developed [PR15].

Interviews

There are three basic interview methods which can be distinguished namely structured interviews, semi-structured interviews and unstructured interviews. Structured interviews are prepared by a set list of questions beforehand and follows a standardized process. This corresponds to a verbal questionnaire that is used in an interview in person, over the phone or through other technologies such as chats. Hereby closed questions as well as open questions are used to get information on specific topics. However often the participants get to answer through a range of numbers or multiple choice answers. The constellation of questions are usually the same for all participants and the order of questions are maintained. Structured interviews are useful when the main issues are clear and the interviewer wants to gather detailed information on those issues [Cha13].

In a semi-structured interview structured questions are given as well as the possibility for unstructured exploration. Here the interviewer can gather information about a specific issue but the participant is given the chance to mention new issues as well. For complex issues this can be a powerful interview method [Cha13].

Unstructured interviews do not follow a predefined format or detailed questions. Moreover a topic is dealt with in general and the participants are given the possibility to express their experiences with that topic. Hereby no constraints are put on the participants. Preparation for an unstructured interview is important to have a clear definition of the aim of the interview and a document called an "interview guide" can be used to have a support during the interview that entails for instance the to be covered areas as well as general questions and a checklist to have an overview on the subjects dealt with [Cha13].

Questionnaire

Questionnaires tools which appear in written, online or verbal form and are used for gathering data from individuals or groups. The data then can be analyzed by qualitative and quantitive techniques. Questionnaires can be used to gather information from a large scale of participants and the standardized questions can be used to compare the answers between several groups and products [Wil13b].

In a questionnaire both open and closed questions can be conducted. It is possible to perform this method of questioning the users online which can reach a large number of people. Through issuing questions in form of a questionnaire in a short period of time with low cost a lot of people can be targeted. Another advantage is that stakeholders, which can not formulate their answers well, have this taken care of through already predefined answer choices. Disadvantage of questionnaires are that only issues the requirements engineer has knowledge about or suspects to be important can be raised. Not having a direct contact between requirements engineer and stakeholder means that possible questions can not be issued during the process and are only seen at the end when evaluating the questionnaire [PR15].

Brainstorming

Brainstorming is a creative technique to establish ideas and solutions to problems. This technique can be performed on an individual person or on a group of people [Wil13a]. For the brainstorming session to be successful there should be someone who leads the discussion and prepares the problem to be discussed beforehand. This involves thinking of what type of stakeholder should partake in the session and maybe the discussion leader gathers information about solutions from others with a similar problem that was addressed [AD20]. At the beginning a question, topic or problem is issued and the aim is to find as many ideas as possible. After that the results can be discussed and maybe certain ideas prioritized as being more relevant to the issue at stake [Wil13a]. With brainstorming an often used supplementary technique is mindmapping where a graphical visualization of ideas is developed. Here the focus lies in visualizing the relationships between those concepts [PR15].

User Scenarios

User scenarios are narrative descriptions of how a user would interact with the system to complete a specified typical task of the system. Hereby specific type of users can be created through personas. These personas are made up of fictional individuals with a detailed description profile. Each persona then is a model that represents a certain type of user. This supports then the development process when there are no usability activities possible with the actual users and personas serve as placeholders for the end users [CB05]. User scenario descriptions happen in natural language and are written in great detail. This is a large advantage of user scenarios because people without the technical knowledge can also participate in the requirements engineering process. User

scenarios should ensure that the users can perform the functions that should be provided by the system otherwise the users will not use the system [CAHW22] [PR15].

Requirements from Prototypes

The presentation of prototypes to the stakeholders can be a valuable method for requirement elicitation. A prototype is a model of the final product. Hereby the stakeholders have a concrete form of the developed ideas shown to them which can make it clearer for the stakeholders to convey their ideas and requirements. Depending on the objectives and phase of the design process, the level of detail of the prototype can vary from a simple sketch to a highly detailed implemented coded prototype. Hereby it is important to be clear about the aim of the prototype so that the developer does not go into too much detail and also when presenting the prototype that the stakeholders do not involve themselves in the implementation itself. Another issue which can arise with a non-operational prototype is that the stakeholders would like to use it functionally where it is not intended to. In that case it should be made clear that the prototype is only an illustration of ideas [DHJ17] [AAB07].

2.5.3 Documentation of Requirements

For the success of requirements engineering it is important to document the requirements in a structured manner. A structured documentation clarifies details, makes connections clear and facilitates the access of requirements to the stakeholders [Ebe12].

The structure can be achieved through requirement specification which contains all requirements belonging to the project. This requirement specification is a document which arranges for everyone involved what should be done and constitutes the basis for additional documents composed throughout the development process [Ebe12].

There are two elementary perspectives for the specifications. Firstly there is the product requirement document which contains requirements of what and why something is done. This covers the market requirements. On the other hand there is the perspective of solution specification which describes how something should be done. This is fundamental to the contractor as a basis for the development process. These two perspectives however are not strictly divided and there can be content overlaps [Ebe12].

Before recording requirements in the specification document, the requirements have to be filtered, analyzed, evaluated and prioritized. It is important that the formulation of a requirement is exactly described so that everyone can understand its content. That is the reason why the use of natural language in the specification is not desireable due to it easily leading to missunderstandings. Individual requirements should also be as short an concise as possible. Formal notations which are close in syntax structure to those of most programming languages allow for a precise defintion but also are difficult to read. Due to both natural language and formal notation having its clear downsides, it is recommended to use semi-formal notations which should be administered with some tool. Furthermore a good organization of the requirements is essential so that relations between

requirements are clear to the reader. To record the requirements it is recommended to use templates which support keeping the structure of the specification [Ebe12].

Unified Modeling Language (UML)

A semi-formal notation can be achieved through the Unified Modeling Language (UML) which is heavily used as a modeling language for software systems. UML has a defined syntax and is standardized through the Object Management Group (OMG). With UML complex processes in the requirements are visualized through diagrams to support the understanding of the reader. Two important terms in UML are scenarios and use cases. Scenarios describe requirements based on concrete cases of how the system is used in practice. They can be part of a requirement or sum up several requirements. The advantage of describing requirements in a scenario is that the reader can more easily understand its content than if it were just listed among other requirements which can appear to be too abstract. Use cases are the notation of how to document scenarios and belong into the requirements specification. They should describe the interaction of the system with the external environment. The notation includes diagrams but also, if details are necessary, verbal descriptions. In summary scenarios describe the behavior of the participant with the system being developed on the basis of concrete cases and use cases are a way to structure these behaviors and visually show the interactions and interfaces of the system [Ebe12].

2.6 User-Centered Design

User-Centered Design (UCD) is a software design methodology for developers and designers. It puts the users and their needs as the foundation of the development process. Through feedback of the users it can observed if the system being developed meets aesthetic criterias but also how effectively the system is achieving its designed purpose [Low13].

Three essential principles can be stated for User-Centered Design. Firstly there should be an early focus on the users and the tasks. This can be achieved by getting requirements from users early on in the process by means of several different methods. The next principle is the empirical measurement of product usage. This means that the product should be easy to learn and the usage should be effective as well as absent of errors. To assess this, usability tests can be conducted with prototypes in earlier stages of the process or with the final product. Hereby users should follow a sequence of typical tasks using the product. If there are usability issues present, changes in the product can be implemented before a release is published. The third principle is that the User-Centered Design process is a iterative design. This means that several times during UCD requirements are collected, designs of the product are made, the product gets modified and put through tests. Hereby with each iteration step the product gets refined until the desired outcome is achieved [CB05].

The UCD process can be divided into four phases, as seen in figure 2.5. The first phase is to specify the context of use, so identifying the target group and the problem that is addressed with the product as well as the conditions it will be used for. The next phase is specifying requirements where the discussed methods earlier in chapter 3 are applied. After that the phase of creating design solutions is performed where the product takes it shape from a rough concept to a complete design. And as a last phase the evaluation ensures by testing the product on the user that it meets the defined goals [oHHS20].

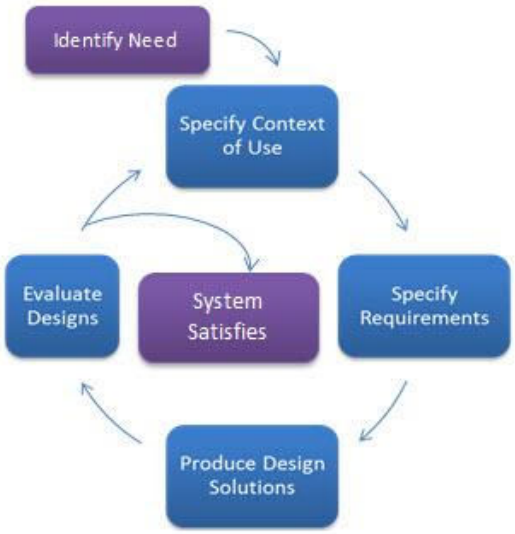


Figure 2.5: Different phases of a UCD process development cycle [oHHS20]

2.6.1 Prototyping

During the process of UCD, creating design solutions with prototypes is a helpful tool to support finding a solution to the user's needs. A prototype is generally a model of the final product which can be used in later stages in the development process. Prototyping allows for presenting software requirements visually, rather than merely describing them in words. It enables the developers to experiment and explore different solutions and finally reach the optimal solution [AAB07]. In business informatics prototypes, where a pre-version of the application system is developed, are part of the methodologies that can be applied. Hereby there are types which are prototypes for graphical interfaces, where the focus is on the user interface or prototypes which put the focus on the functionalities of the system [WH06].

The prototype can be described by its fidelity, which means how detailed the implementation is. Low-fidelity prototypes do not go into detail and are more conceptual, whereas high-fidelity prototypes display the final user interface precisely. When using a prototype there are many possible prototyping methods from which there is to choose from. Some of them will be presented in the following paragraph [AAB07].

Paper Prototype

Another prototype method is paper prototyping which consists of a paper mockup of the user interface. Here the user interface should also include functionality of the interface. Aim of paper prototyping is to perform testing on the users by showing them the different user interfaces on paper and the user navigates through manual input through the interfaces. The advantage of paper prototyping is that an idea can be easily and quickly tested, so several different approaches can be developed to solve the same issue in a short period of time. When developing a paper prototype it should be considered which user flow or specific assumption should be tested [Kat17] [AAB07].

Wireframe

The static layout of different pages throughout a digital product can be presented in wireframes. A wireframe prototype is usually created in the beginning of the design process and derived from a use case or scenario. It contains high-level sketches which should visualize basic concepts about the structure of the product and also its interactions, so that the design team can reach a consensus. A detailed design is usually not the aim of a wireframe, the design details are much rather built on it. Therefore the placement of elements on the page and the organization of the different pages are of importance and not the choice of colors or typography. Figure 2.6 shows an example for a wireframe [Kat17] [AAB07].

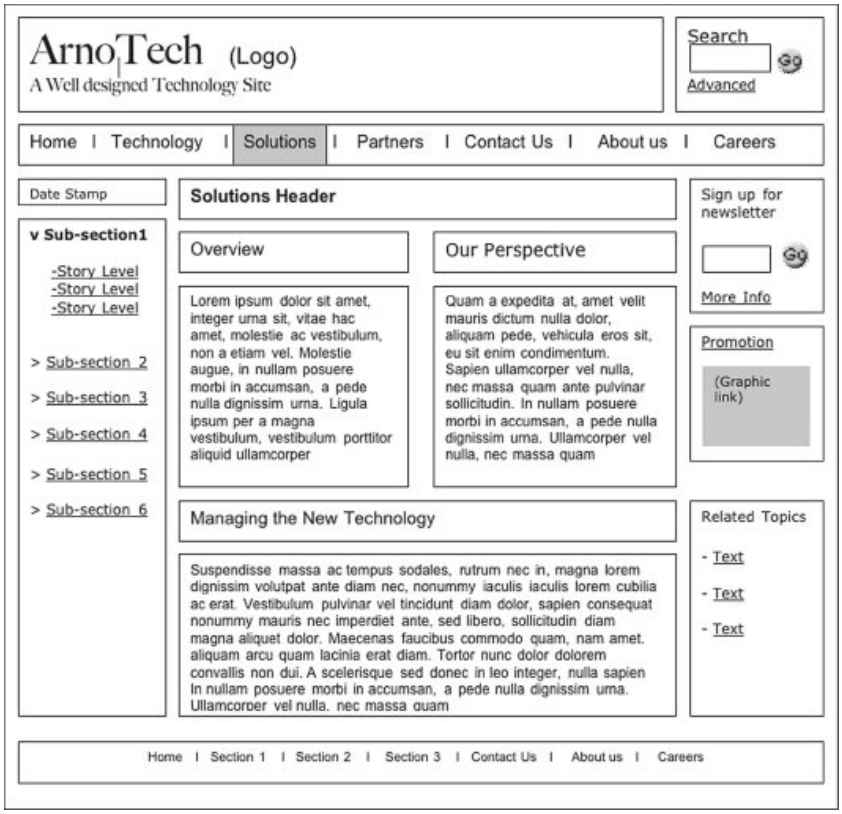


Figure 2.6: Wireframe prototype [AAB07]

Coded Prototype

A coded prototype displays an interactive prototype that is implemented in a programming or scripting language which is mostly implemented in the target programming language. The coded prototype should be considered in later iterations of prototyping and it is designed to directly result into the final product. Hereby the coded prototype is very useful for usability validation testing. Furthermore if the coded prototype is implemented in the target programming language, the code can be reused for the end product [AAB07].

2.6.2 Usability Testing

In software development the target of usability is to design a system that enables and promotes desirable experiences for its users as well as diminish any unpleasant experiences when using the software. Hereby usability assesses the quality of the system and corresponds to a nonfunctional requirement [HA14].

Usability testing is a process where specific criteria for usability are evaluated in a developed product by testing participants who are a representation of the target group. Hereby the following aspects are relevant as the target of usability testing: the product

should be useful and seen as valuable to the target group. Furthermore the product and its processes should be simple to learn. The product should support the increase in effectivness and efficiancy of the performed tasks wanted by the users. Additionally the product should be satisfying to use by the target group [JD08].

There are basic elements of usability testing that should be named. First of all not hypotheses should be developed but rather research questions or test objectives. Furthermore a sample of users which are representative for the targeted end users of the product should be involved in the usability tests. These users can hereby be randomly chosen or not. Moreover the work environment of the real work circumstances should be represented and the users should be observed how they use or review a representative version of the end product. Additionally an interview by a moderator and probing should be conducted with the testers in a controlled and occasionally extensive approach. The quantitive and qualitative performance and preferences intentions of the testers should be collected and measured. Also the testers should be given the possibility to describe improvements in the product's design [JD08].

Usability tests can be moderated or unmoderated, as well as in person or remote. If the usability test is in person and moderated, the participants are given the device for testing and shown the task they should fulfill while observing them. A usability test can also be held remotely, so that in case of moderation the users and the usability engineer are connected by a medium for remote communication and the test is being held at a agreed upon time. However a usability can also be held unmoderated and remotely which makes the usability testing more flexible. Hereby the participants are given the tools to run the tests with a prototype and they can perform the tests whenever they want without supervision. The results then get shared after the tests have been carried out by the participants [BD17].

CHAPTER 3

State of the Art

In this section initially a selection of scientific publications regarding to developed prototypes with serious games or with gamified elements connected to the aim of prevention of health issues due to a sedentary lifestyle and thereby offering motivational concepts to raise physical activity, are presented. Afterwards a selection of commercially available solutions are examined.

When examining these applications it should be made clear for each case what objective is pursued, which type of sport activities are targeted and which kind of features are included. At the end of the chapter a comparison between the examined apps and the prototype which is subject of this thesis will be made.

3.1 Scientific Publications

The mentioned objectives lead to many researched solutions in scientific publications, whereas some are more relevant for the thesis than others. The scientific publications were searched for in various online sources consisting of the online platforms "SpringerLink" [Nat21], "IEEE Electronic Library (IEL)" [IEE21] and "ACM Digital Library Complete" [fCM22] and also on the online platform of the library of TU Wien [Wie21]. Here certain search terms were applied such as "Serious Games" or "Gamification" in combination also with "Prevention" or "Sports" among others.

The selection of scientific publications was chosen by a number of criteria, which are presented in the following:

- The publication should describe a solution to raising the activity levels of the user by the means of a serious game or gamified elements.
- The developed solution should make use of motivational concepts to achieve its aim.
- Include the theme of prevention of health issues
- Solutions instead of generally increasing sport activities, specifically increase strength training.
- Does the prototype have a educational character and raise awareness about the health benefits of physical activity?
- Solutions instead of health benefits in general, specifically regarding the human locomotor system and prevention of orthopedic diseases.
- Optimize training sessions through increase of intensity or focus on the training itself.

In the following sections a few of the selected publications will be presented with more detailed descriptions. These were chosen because they together show a diverse selection of what is possible in the area of gamified prevention in combination with a healthy lifestyle and also what kind of solutions there are with targeting biomechanics.

3.1.1 Lazarus

In a scientific publication the developed prototype of an Android-based mobile application with gamified elements called Lazarus is presented. This specific prototype is of interest because it takes up the theme of prevention and the health risks from an inactive lifestyle and aims at offering a solution to the lack of motivation to perform sport activities. This solution is based on motivational concepts and the integration of a serious game [BBLG18].

Main goal of the application is to motivate inactive people to do more sport activities. This was achieved through several features. The application was not targeted at a specific sport but rather at performing exercise itself. So the user could choose a sport from a list and afterwards had to choose a sport establishment as a location on a map through GPS-functionality. Then the training type could be chosen in which way the exercise would be verified for instance by measuring the time with a stopwatch. These functionalities are shown in a screenshot of the application in figure 3.1 [BBLG18].

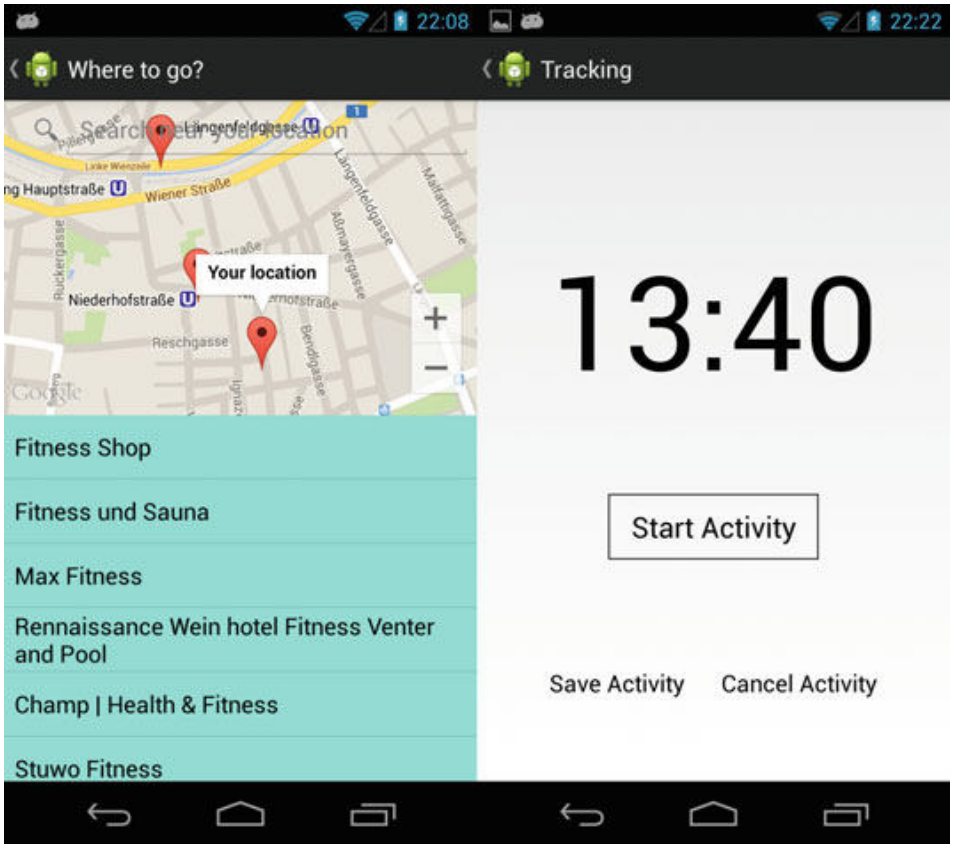


Figure 3.1: Lazarus Sports Tracking [BBLG18]

When the training session is over the user gets rewards in means of items and achievements. Items can be used for a game which is a central part of the application. Achievements are further motivators which give an exercise goal to the user and can be accomplished and collected by the user. A motivating factor is that the user can see the completed sports activities and achievements of other users [BBLG18].

The central game built into the application is a simple tactical game where the user plays against a other user or against a computer-bot. The resulting points of the games are then recorded in a highscore which makes the game competitive. A screenshot of the game is shown in figure 3.2 [BBLG18].

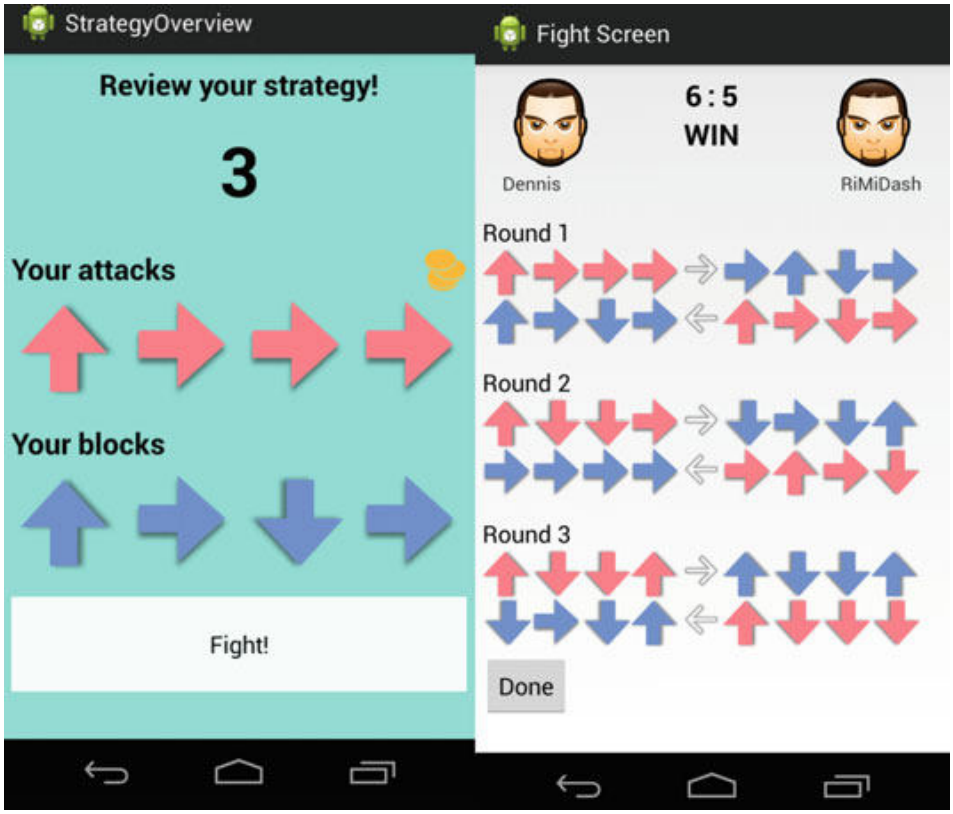


Figure 3.2: Lazarus Game Procedure [BBLG18]

3.1.2 Mobile gaming in gyms - can fitness and games join together?

The publication "Mobile gaming in gyms - can fitness and games join together?" [SHA18] is of interest due to the aim of connecting together exercising in gyms and playing games with a mobile application. Furthermore the application was designed with gamified elements to raise motivation of the user regarding fitness training. Also interesting is the fact that fitness data was recorded and used in the application to achieve the motivational concepts of the application [SHA18].

However the mobile app developed did not show any educational aspects regarding the preventative effect of fitness training and its focus laid more on increasing fun of performing fitness training. Moreover there was no mention of increasing the intensity during the training sessions and therefore optimizing the training effect itself [SHA18].

For the main objective of the developed application, to bring together gyms and playing mobile games, Siira et al. [SHA18] partnered with a mobile game company and a gym company with a newly opened gym. The whole game has a subset of different features [SHA18].

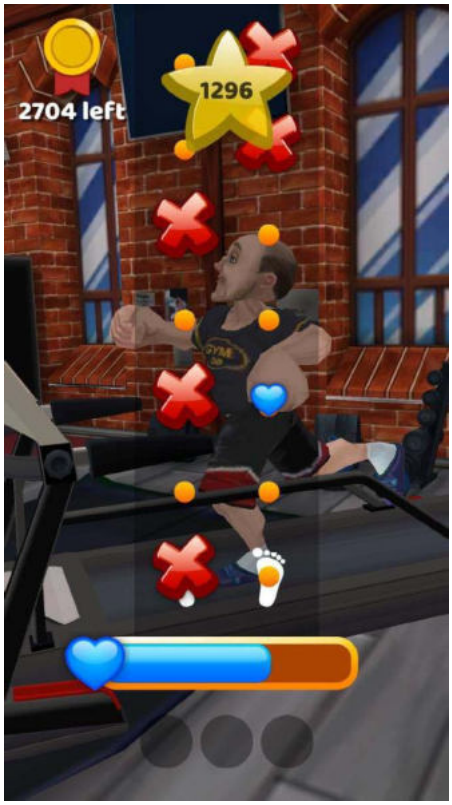


Figure 3.3: Example of a minigame in the application [SHA18]

One feature of the app is the integration of different minigames which are themed by certain gym activities such as boxing, weightlifting or using a treadmill (see figure 3.3). These minigames can be played if the user has enough points which can be earned through physically performing fitness activities [SHA18].

These fitness activities do not have to be performed in the gym because the user can feed in fitness data through several fitness devices for instance smartwatches. But there is also the option in the gym to use certain gym equipment which sends fitness data directly to the application. The minigames have the feature of being competition based between several users which consists of daily rankings and success resulting into earning in-game currency [SHA18].

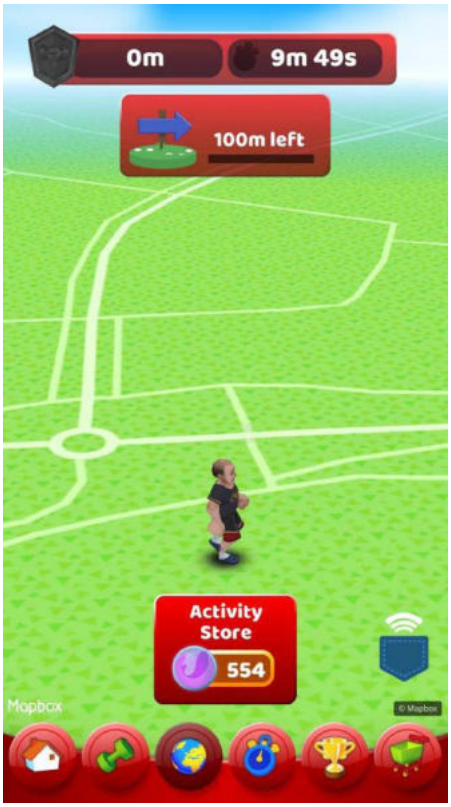


Figure 3.4: Concept of game connected to gym [SHA18]

Another way to get points is through the GO-feature of the app. The GO-feature places the user on a map which should resemble reality and track the user over the phone GPS (see figure 3.4). Here walking around and meeting certain step goals as well as fulfilling quests translate to points which can be used for the minigames [SHA18].

3.1.3 Tito Bico

The publication by Scarle et al. [SDBR+11] is of relevance because a serious game was developed to promote healthy eating and increase of physical exercise. The target group hereby were obese children. Therefore the serious game deals with prevention of health issues due to obesity and furthermore has an educational character [SDBR+11].

The developed serious game was not developed as a mobile application but rather as a video game with the input devices of the video game console Nintendo Wii. These consist of the Wii-mote controller and the Wii-fit balance board which have specific sensors to record the movement of the user. This makes it possible to integrate exercise into the game and therfore this prototype can be categorized as an exergame. However Scarle et al. [SDBR+11] stated that the physical activity during the game should only be supplementary to promoting exercise outside the game play [SDBR+11].

The main gameplay was defined by the player being a young wizard who delivers food packages to islanders which were struck by famine on the island Tito Bico. Here the player gets confronted with a 3D-puzzle with boxes of food choices (see figure 3.5). The player now should stack 3 healthy foods together and supply them to the islanders and on the other hand stack 3 unhealthy choices of foods together and throw them into a waiting bin. This stacking of boxes was carried out by the player using the Wii-mote as a magic wand. Furthermore there were minigames incorporated where the Wii input devices were used, for example the player is rowing in a coracle by doing rowing motions with the Wii-mote and through leaning in one direction steering the coracle. Supplementary health tips were displayed subtly on the players screen for instance when loading between subgames [SDBR+11].

Figure 3.5: 3D-Puzzle concept of the game in Tito Bico [SDBR+11]

As a result the developed prototype "Tito Bico" incorporated educational elements into the gameplay. Here the target group and the goal of the prototype is different to the one developed in this thesis. The aim was to reduce obesity in children by increasing physical activity in general and not specifically strength training. Furthermore the educational character was focused on healthy eating and not on the positive impact of strength training on the human locomotor system [SDBR+11].

Another difference in concept is that the prototype of Scarle et al. [SDBR+11] is an exergame whereas the developed application in this thesis is not aimed at directly performing physical exercises through a game. Furthermore in the prototype of Scarle et al. [SDBR+11] the target of optimizing the training sessions is not addressed [SDBR+11].

3.1.4 Virtual Reality Serious Game for Musculoskeletal Disorder Prevention

In another scientific publication the prevention of musculo skeletal disorders was targeted through a serious game. These musculo skeletal disorders can develop in workers which exhibit awkward postures for long periods of time, frequent bending and twisting, as well as repetitive work. Usually ergonomic interventions for these issues are necessary. In this paper the approach was taken to develop a serious game which tracks the motion of industrial workers through sensors while performing certain movements. The serious game gives feedback about awkward postures. Furthermore the game takes place in virtual reality. In figure 3.6 the setup of the game in virtual reality is shown with a user playing the game [SZO+18].

Figure 3.6: User playing Serious Game in Virtual Reality [SZO+18]

The serious game was developed as a puzzle-like game where there are gears placed on a board. Initially there are already some gears placed on the board. The user has to

complete the puzzle by placing gears into the empty gear spaces. When the user placed all the gears into the correct order, the system begins to rotate and the level is completed. The gameplay of the puzzle-like game is displayed in figure 3.7 [SZO+18].

Afterwards the user gets a score mainly based on the quality of movement and posture during the game. If this score is too low, the level has to be redone. Additional points are received for completing the puzzle in faster times. Furthermore the user gets a feedback about where the risk locations are for developing musculo skeletal disorders based on the movement and posture during the game [SZO+18].

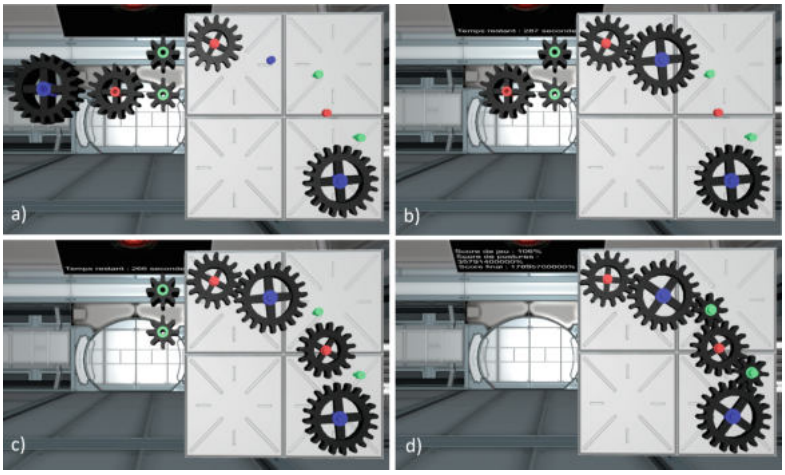


Figure 3.7: Gear Puzzle Game [SZO+18]

3.1.5 Mobile, Exercise-agnostic, Sensor-based Serious Games for Physical Rehabilitation at Home

In this paper the design of three serious for physical rehabilitation in terms of the human locomotor system is described. The games were developed for a smartphone which is connected with a wearable device. This wearable device consists of a inertial and electromyography sensor. These sensors track the movements of the user, which then lead to specific actions in the mobile game. The serious games were developed modulary and in a way that physiotherapists can adjust the game to reach certain requirements such as repetitons or contraction time. Furthermore the physiotherapists can get the data of the user after playing the game and evaluate the progress [VNCC18].

The first game developed was the Bridges Game, displayed in figure 3.8. Here the user can raise rectangular platforms when contracting a muscle. After the contraction the user needs to relax the muscle to let the circle move from the left to the right of the screen [VNCC18].

The second game developed was the Labyrinth Game, displayed in figure 3.9, where the user through contracting a muscle leads the circle to follow the path of the labyrinth.

There are certain checkpoints in the labyrinths where the user needs to relax the muscle to be able to advance forward. Also if the user doesn't hold the contraction fully until a checkpoint but rather relaxes the muscle, the circle rolls backwards [VNCC18].

In the third game developed, displayed in 3.10, the gameplay involves the opening of gates through contracting a muscle. Before reaching a gate the user needs to relax the muscle for a period of time shown in a countdown timer to ensure a relaxation period. The goal of the game is to advance the circle through the gates and finally reach the end of the level [VNCC18].

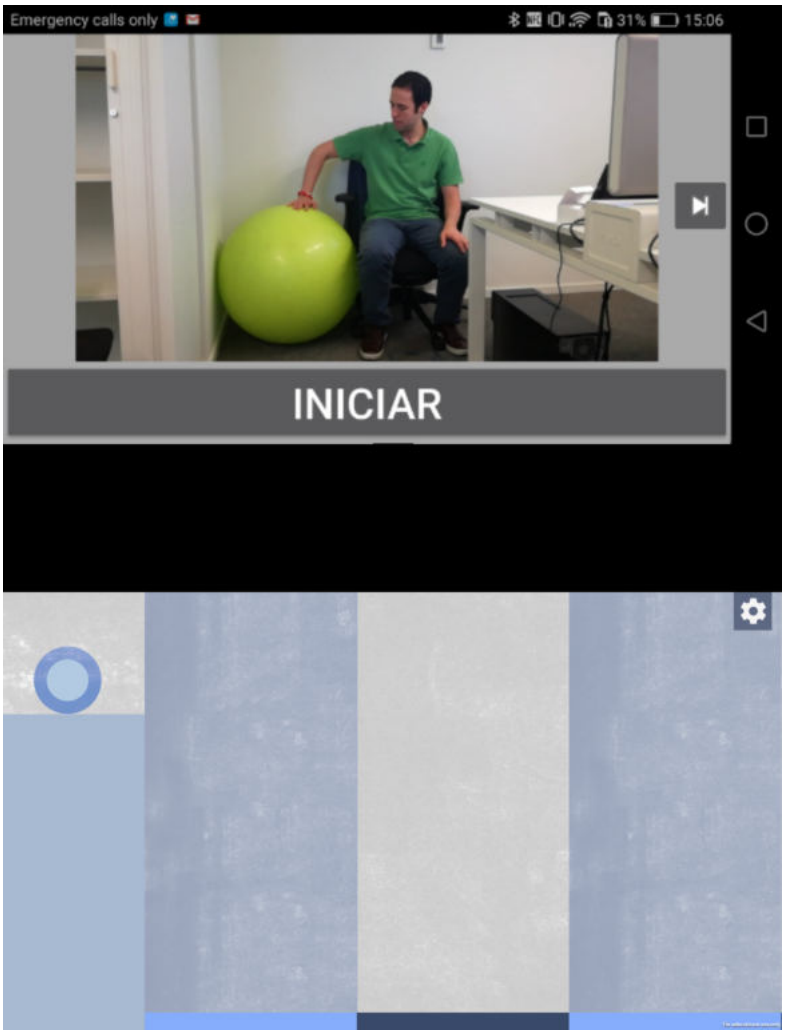


Figure 3.8: Bridge Game [VNCC18]

Figure 3.9: Labyrinth Game [VNCC18]

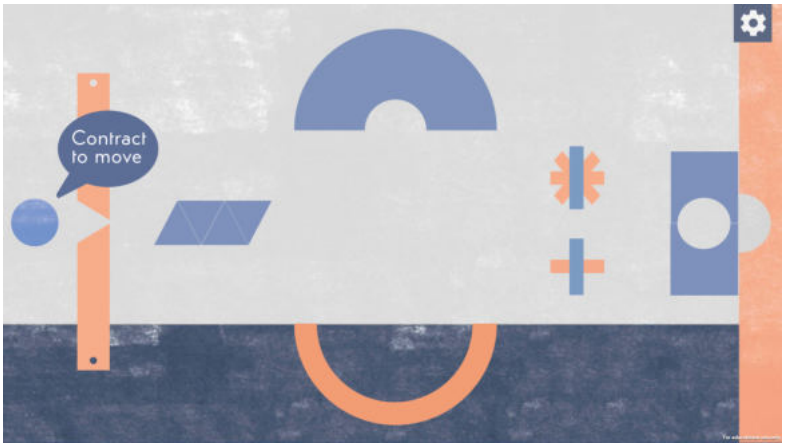


Figure 3.10: In this game the users needs to contract their muscles to open the gates and let the circle advance forward [VNCC18]

3.2 Commercially Available Solutions

After analyzing the scientific publications, it is also useful to examine solutions which are commercially available. Hereby the vast selection of applications in the app stores in the category health and fitness were browsed through with the mentioned criterias in mind. Furthermore it was also researched what kind of solutions exist beyond the mobile application realm, on other platforms such as video game consoles. For the commercially available solutions the criteria of popularity was seen as important to gain an insight to the preferences of the users. Therefore the following chosen solutions consist of being among the most popular in the area of fitness and the combination of fitness and promoting the users to perform physical activities with gamification.

3.2.1 Pokemon Go

A very popular commercially available gamified mobile application for motivation of improving health through increasing movement is Pokemon Go. The core concept of this game is searching for pokemon which are fantasy creatures and trying to catch as many as possible. In figure 3.11 the process of catching a Pokemon is displayed. The search involves the players to walk around their city or village due to pokemon being in different locations. The player is placed on a virtual map, as seen in figure 3.12, and through GPS-tracking the location of the user is recorded. Furthermore the steps of the user are recorded which also lead to benefits in the game. This game blends the reality together with the virtual world and follows the principle of augmented reality [Com22].

The approach of improving health in Pokemon Go is different to the developed prototype in this thesis due to focusing on walking as an exercise. Therefore the focus is put on a lower intensity exercise performed for a longer period of time [Com22].

Figure 3.11: Catching a Pokemon in Pokemon Go [Com22]

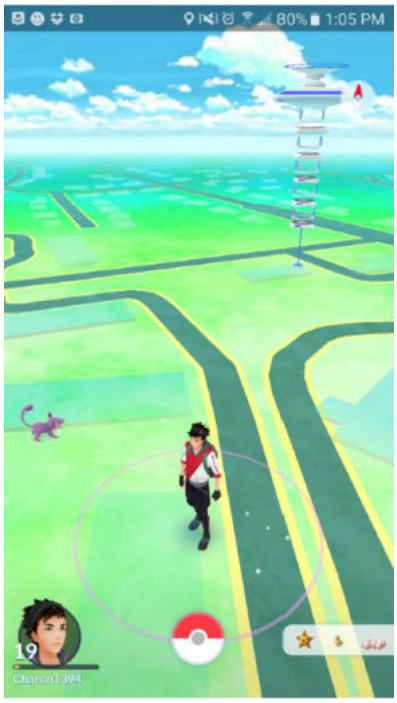


Figure 3.12: Virtual map in Pokemon Go [SK17]

3.2.2 Ring Fit Adventure

Ring Fit Adventure is an Exergame developed by Nintendo [Nin20] for the Nintendo Switch gaming platform. To measure the movements throughout the game two pieces of equipment were introduced with this game (see figure 3.13). The main piece being the Ring-Con, which resembles a pilates ring [Nin20].

Here the Ring-Con has an input for the Joy-Con, which is the joystick of the Nintendo Switch. The second piece of equipment is a leg strap where the other part of the Joy-Con is attached to. Through gyrosensors in the Joy-Con it can be measured if the movements are performed correctly which is important for the game play. The game has a main story modus and a minigame modus. The story modus consists of an RPG with levels (see figure 3.14) where different kinds of monsters appear that the user has to beat through attacks. These attacks are done when the user does a number of different exercises with the Ring-Con. Here the correct execution of the exercises is monitored through the gyrosensor of the Joy-con. If the exercise was not performed correctly, then the attack on the monster is not as effective as when peforming it correctly [Nin20].

Moving forward in the game happens through jogging in place monitored by the leg strap or in a quiet mode where moving forward happens through being in a slightly bent squat position. The player has to sometimes jump in the game which is achieved by pressing together the Ring-Con. Furthermore information and suggestions about healthy lifestyle

choices for instance about nutrition or exercise are integrated into the gameplay [Nin20].

Figure 3.13: Equipment for Ring Fit including the Ring-Con (outer) and the leg strap (inner) both with Joy-Cons attached [Nin20]

Figure 3.14: Storymodus of Ring Fit Adventure [Nin20]

3.2.3 Freeletics

The fitness mobile app Freeletics is a very popular application for exercising. The main feature is the personal coach which puts together a training plan based on the users fitness level. This happens after assessing through questions about the users experience with exercising and the goals of the user. The personal coach is hereby using artificial intelligence [Fre21].

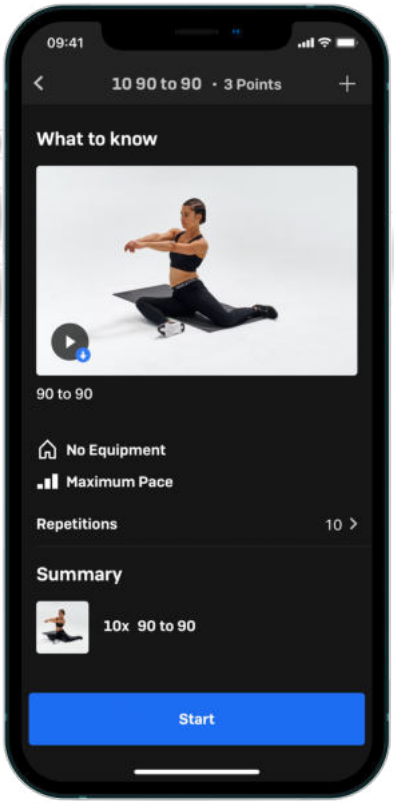


Figure 3.15: Freeletics Training Information on Exercise [Fre21]

The app furthermore shows information about the exercises and displays the given exercise in a video format to give the user a manual how to perform the exercise correctly (see figure 3.15). The training plan created by the AI is highly personalized and reacts to feedback from the user. For instance the user can enter if no equipments are available for the session or that certain body parts should be excluded (see figure 3.16) [Fre21].

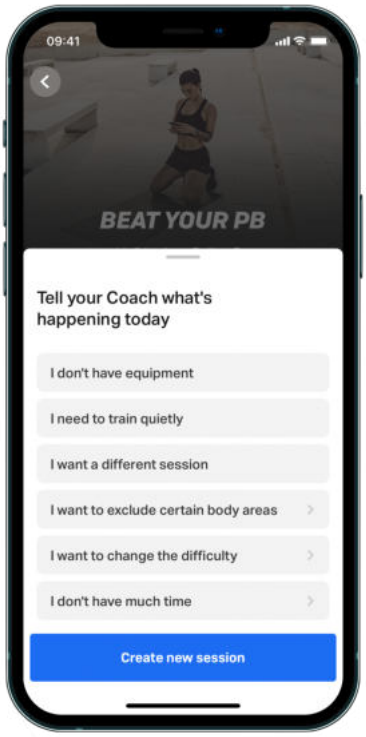


Figure 3.16: Freeletics Training Session Preferences [Fre21]

3.3 Summary and Comparison of State of the Art

After describing a subset of State of the Art which were chosen by mentioned criterias, in this chapter all looked at State of the Art for this thesis are presented in a table form, displayed in two parts, in table 3.1 and 3.2, to give an overview of the relevancy of each and also make clear the abscence of features which haven't been dealt with in this combination of features.

The selection of State of the Art was categorized in either aiming at generelly increasing exercise, which means no specific sport or exercise type was targeted, and on the other hand in solutions which were aimed specifically at strength training.

Furthermore it was looked at if the solution addressed the theme of prevention, so if an awareness about preventative effects of exercising was brought to the user. Here it was divided into raising awareness about general health benefits of the exercise peformed and into raising awareness specifically about health benefits regarding the human locomotor system and prevention of orthopedic diseases.

Moreover it was looked at if the solution involved educational elements, so if the developed prototype taught the user about for instance a healthy behavior like for example healthy food choices to make. This doesn't have to automatically align with the point of raising awareness about health benefits and prevention.

Lastly the solutions were examined if they offer a solution to increase the intensity of the exercise session itself or promote maintaining focus on training to assess the effort put into the training session.

The solutions were categorized between scientific and commercial sources and in addition also the technical devices, which the solutions consist of, were mentioned.

At the bottom of the following table the prototype of the thesis is listed and it can be seen that the categories where the prototype belongs differs in the constellation from those of the state of the art and these differences will be described in the next chapter.

Gamified Solutions	Motivational Concept	Increase Exercise (In General)	Specifically Target Strength Training	Raise Awareness for Prevention (General Health)	Raise Awareness for Prevention (Biomechanics /Orthopedics)	Increase Intensity/ Focus	Integration of Educational Elements Into Prototype	Scientific Source	Commercial Source	Technical Devices
Mobile gaming in gyms [SHA18]	Yes	Yes	Yes	No	No	No	No	Yes	No	Smartphone
Tito Bico [SDBR+11]	Yes	Yes	No	Yes	No	No	Yes	Yes	No	Video game, Input Devices (Wii-mote & Wii-fit balance board)
Improve Posture [u.a16]	Yes	No	No	No	Yes	No	Yes	Yes	No	Microsoft Kinect Camera, Personal Computer
BitRun [GMCL17]	Yes	Yes	No	No	No	No	No	Yes	No	Smartphone, Fitbit
Lazarus [BBLG18]	Yes	Yes	No	No	No	No	No	Yes	No	Smartphone
Walk the Isle [Hei18]	Yes	Yes	No	No	No	No	No	Yes	No	Smartphone
Virtual Reality MSD [SZO+18]	Yes	No	No	No	Yes	No	Yes	Yes	No	Virtual Reality Device, Motion Capture Sensors

Table 3.1: Table Comparison of State of the Art (Part 1/2)

Gamified Solutions	Motivational Concept	Increase Exercise (In General)	Specifically Target Strength Training	Raise Awareness for Prevention (General Health)	Raise Awareness for Prevention (Biomechanics /Orthopedics)	Increase Intensity/ Focus	Integration of Educational Elements Into Prototype	Scientific Source	Commer cial Source	Technical Devices
Physical Rehabilitatio n Mobile App [VNCC18]	Yes	No	Yes	No	(Yes)	No	No	Yes	No	Smartphone, Wearable Sensors
GAMEREH AB@HOME [TIP+21]	Yes	No	Yes	No	(Yes)	No	Yes	Yes	No	Inertial & Visual Sensors (Kinect Camera), Personal Computer
Low-Back Pain [BJO+13]	Yes	No	No	No	Yes	No	No	Yes	No	Microsoft Kinect
Pokemon Go [Com22]	Yes	Yes	No	No	No	No	No	No	Yes	Smartphone
RingFit [Nin20]	Yes	Yes	Yes	Yes	No	Focus: No Intensity: Yes	Yes	No	Yes	Nintendo Switch (Video Game Console)
Freeletics [Fre21]	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Smartphone
Prototype of Diploma Thesis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Smartphone

Table 3.2: Table Comparison of State of the Art (Part 2/2)

3.4 Innovation of Prototype Developed in Thesis

Finally it is shown in the following section what the innovation of the developed prototype in this thesis is compared to those of the state of the art.

There are several publications which developed a prototype with gamified elements that aim to increase the motivation to exercise more and thus promote a healthy lifestyle. However, the selection is significantly reduced when the target is to increase the motivation to perform strength training.

Associated with that is that most of the state of the art deals with the prevention of health issues in general and not with a focus on improving health of the human locomotor system and prevention of orthopedic diseases.

Many of those publications which focus on biomechanics and the human locomotor system deal with supporting rehabilitation from some orthopedic issue through development of a gamified prototype. There have been some publications also found which aim at prevention of orthopedic diseases. However those focused on the maintenance of good posture or stretching. Hereby the difference of the developed prototype in this thesis is that the prevention of orthopedic issues is targeted from the side of strengthening the different parts of the human locomotor system such as muscles and bones.

Furthermore in many publications which target the improvement of a healthy lifestyle there is an absence of an educational character. The user is guided to a more healthy lifestyle but there is no emphasis on the health benefits that this lifestyle change can bring with it. The developed prototype in this thesis is built to raise awareness of the health benefits of the changed behavior regarding exercising in particular strength training.

Another characteristic of the prototype developed in this thesis is that the users not only are being motivated to perform stength training but also to optimize their individual training sessions. This should be reached through increasing the intensity and focus on the training itself. An assessment of the effort made in a training session is therefore approached because it is of importance to also promote the quality of the training session itself.

CHAPTER 4

Results

In this chapter the results of the thesis and the conducted iteration steps in the user-centred design process and requirement elicitation are presented.

Initially the aims of the thesis were discussed in an interview (Iteration 1) with a former student colleague and several ideas were developed which were considered afterwards in the next iteration for the questionnaire.

In the mentioned next iteration (Iteration 2) an online survey was developed on basis of ideas of the author and from the brainstorming interview session. The online survey was conducted with 43 participants consisting of people from the target group of the thesis. From the evaluation of the questions several requirements with regards to the prototype were noted.

On the basis of these requirements in a next iteration step (Iteration 3) the author realized the ideas by sketching of wireframes and user-flow diagrams. Furthermore the author developed two game ideas on basis of the requirements and his experience with mobile games. As a result a low-fidelity prototype was put on paper.

This low-fidelity prototype was then presented to another participant in an interview (Iteration 4) where the ideas were refined by making notes and sketching changes during the discussion. After the interview the feedback of the participant and the results were refined by sketching of new wireframes by the author.

Afterwards based on the revised low-fidelity prototype in a next iteration step (Iteration 5) a high-fidelity prototype in form of a mobile application was implemented.

Finally the high-fidelity prototype was given to a selection of five participants from the target group in a last iteration step (Iteration 6) for testing for a time frame of one to two weeks, after which interviews with each individual were conducted. Based on the interviews from the testusers an evaluation was performed.

To give an overview the iteration steps are presented with the type of the iteration and the number of involved participants in the following table 4.1:

Iteration Nr.	Iteration Type	Number of Participants
1	Brainstorming Interview	1
2	Online Survey	43
3	Low-fidelity Prototype	-
4	Interview	1
5	High-fidelity Prototype	-
6	Evaluation	5

Table 4.1: Overview Iteration Steps

Hereby some participants were involved in multiple iteration steps and therefore in the entirety of the user-design process 45 individual participants were included. In particular the participant from iteration 1 (Brainstorming Interview) was included also in iteration 2 (Online Survey) and iteration 6 (Evaluation), the participant from iteration 4 (Interview) was also included in iteration 2 (Online Survey) and iteration 6 (Evaluation), and furthermore one participant from iteration 6 (Evaluation) was also already included in iteration 2 (Online Survey).

In the following chapters each iteration step is described in detail. Hereby the process of the elicitation of requirements for the prototype and the development of the prototype with the involvement of the users by the use of the user-centred design process and requirements engineering should be presented.

4.1 Iteration 1: Brainstorming Interview

Before extracting requirements through an online questionaire from a larger amount of people, an initial iteration was performed in form of an interview with a former classmate from Biomedical Engineering. He was at the time of the discussion in his late twenties and has longstanding experience in strength training. Due to him not living in Vienna anymore, the discussion was kept over video conference where also a mindmap could be shared through the screen-sharing functionality. The resulting mindmap from the brainstorming can be seen in figure 7.1.

As a starting point the main questions which the thesis addresses were explained and discussed. To record ideas a mindmap was used as a support in the discussion. Firstly the issue with intensity in strength training and possibilities to raise the intensity during a strength training session was examined. Before going to the point of increasing intensity it had to be clarified what is meant by intensity in the context of the thesis. As a specification it was registered what the training goal is and which proportion of the one repetition maximum should be targeted by the prototype. The training goal should not be muscular endurance but rather hypertrophie or maximizing strength. This means the training should not target low stress intensities and high repetition numbers due to the

aim being giving the muscles and bones a high enough mechanical stimulus to increase in size.

Due to the respondent regularly practicing CrossFit which is a fitness regiment that targets mostly muscular endurance, he could share his experience with heart rate monitoring and intensity. The training sessions usually involve a time frame where the participants exert maximal exercise intensity without having pauses. During this time the heart rate increases and is being held on a high level. Therefore examining the heart rate alone wouldn't make it possible to distinguish between the different training goals.

Furthermore the respondent explained that correlating the heart rate itself with intensity has several issues. The heart rate depends on the fitness level of the individual, and also on the exercise which is performed. For instance when performin a biceps curl the heart rate is assumed not to increase as much as when performing a squat due to more muscles being involved in the case of the squat exercise. Moreover the heart rate can depend on the amount of repetitions made during a set. And then there is also the issue of adaptation of the individual fitness over time. This can mean that over time the heart rate of the individual decreases even though he is making progress through increasing the weight in the exercises and therefore increasing the stimulus on the biomechanical tissues to adapt.

It was established that in context of the thesis a higher intensity should be targeted by the means of that the user does not extend his pauses between sets to a longer than necessary amount and therefore maximizes the focus on the training itself and doesn't get interrupted by long pauses.

So to measure the intensity of the training it is necessary to find out the amount of pauses made during the training session and how long the duration of pauses was. In the brainstorming interview session two ideas were established.

The first idea was that the user actively records his pauses during the training and the application guides the user through the training session by recommending the duration of pauses. The recording could happen by implementing a timer element that goes off when the user presses a button element and stops again by action of the user when the next set is about to be performed. The pause duration can be set by either choosing maximal strength training or hypertrophie or can even be entered manually by the user before the training starts.

The second idea was that rather than just looking at the heart rate itself, the course of the heart rate over the time period of the training session could be examined to figure out the pauses and their durations. It is expected that when a pause is begun the heart rate starts do decrease and increases again when a new set is performed. The duration of pauses can then be put into relation to the overall trained time which then can lead to an intensity score.

When combining both ideas it could be possible to put the manual input of the pauses by the user in relation to the course of the heart rate after the training session. This

could be evaluated in a graphical form and overlaps between the course of the heart rate and the manual input could be examined.

As another note that was established was that it can be better if the complexity of the functionality regarding manual input would be kept low, so that the user is not overwhelmed by features during the training session and can concentrate on the essential aspects. The respondant also said that in his experience with fitness apps complex features are not used that often by the user.

After this the discussion went towards the other essential question which is aim of the thesis. Hence different ideas, in terms of the prototype motivating the user to perform strength training regularly and how educating the user about the benefits in terms of biomechanical aspects can play a role in that, were considered. First of all an idea was established that the application shows the benefits of strength training in form of displaying facts to the user. Maybe when the user has followed the recommendations and got a high score in the app, the user gets a motivating message and a fact about the benefits and if the recommendations did not get followed a message in form of a negative message by informing the user what consequences a sedentary lifestyle can have. Furthermore it was established that there should be some variation of a point system where the reached frequency of performing strength training in a certain timeframe for instance in a week is taken into consideration. Also points given based on the intensity levels in from of keeping the pauses to a minimum should be regarded in the total point score. Moreover it was noted that a feature to show the success of the user in form of statistics and graphs could be important for motivation of the user.

Afterwards the discussion went furthermore towards the gamification aspect of the prototype. The respondant viewed rewards in terms of unlocking certain achievements and having certain goals positively. He mentioned that many fitness apps include achievements and in his opinion it drives motivation in the user. As another suggestion he mentioned that score boards as in highscores would be a interesting feature regarding motivation. In his view especially in the age group of the target group comparison with others is a large motivational drive. Hereby it would be possible to compare the users in different categories for instance based on the intensity score or following the frequency of the strength training regiment.

Regarding the implementation of a serious game and receiving benefits based on the scoring of the app, the respondant said that the motivational aspect of that could be more difficult. The success of the game to motivate could strongly dependend on the individuals interest in games itself and also the game has to be really engaging and fun for it to work in a motivational sense. In his perception this could involve a larger complexity than the scope of the thesis of implementing a prototype. His thought is that maybe it is not necessary to develop a whole game but rather use gamified elements as for instance achievements and score systems.

4.2 Iteration 2: Online-Survey

In a next iteration step an online survey was constructed to gather information from a larger number of people from the defined target group. The development of the survey went through several steps to get to its final form. Already in the iteration step before in the brainstorming interview, questions which could be interesting for the thesis were examined and entered in a list form into a text-document. Afterwards the text-document was handed in to the supervisor of the thesis and in a discussion improvements in regards to the formulation of some questions as well as from a content point of view were conducted.

Subsequently the improvements were made and the questions were entered into a Google Forms document. This was an important step to evaluate the structure of the survey. This involves for instance deciding which questions are mandatory, but also in which type of answer should be given. Types of answers can be for example a predefined selection of answer possibilities or allowing the respondants to answer in a text field to an open question. After conceiving the survey in Google Forms the survey was given to two people to fill out as a test round. After adapting to the feedback, the form was given to the supervisor where again improvements to the formulation and content of questions were made, but in this step also the structure of the survey was in focus of the discussion. The composition of the defined sections with questions were discussed and also a meaningful sequence was established. Also the text displayed at the beginning of the survey was discussed so that the participants of the survey know exactly which conditions should be met to answer the questions. From the feedback of the discussion the Google Forms Survey was adapted to the suggested improvements to finally have the survey in its final form.

The online survey was distributed through sending the Google-Forms link of the survey and there were 43 participants which completed the survey. The participants consist of friends and acquaintances as well as participants from online forums or groups, which fulfilled the criteria of the target group. At the beginning of the survey an information text was displayed that the questions should be answered for the time period before the pandemic because that can have a significant impact on training behavior. It was also made clear that the questionnaire is aimed at people who have at least a bit of experience with strength training and it was also explained what is meant by strength training in detail. The questions of the survey with the results are listed in the appendix beginning from figure 7.2.

The survey was divided up into sections. Beginning with a section about personal information. The average age of the participants was 24 and the gender distribution, displayed in figure 4.1, was at 23 male participants (53.5%) and 20 female participants (46.5%). The employment status was divided up into three main parts, with full-time being at 14 participants (32.6%), part-time at 17 participants (39.5%) and no employment at 10 participants (23.3%).

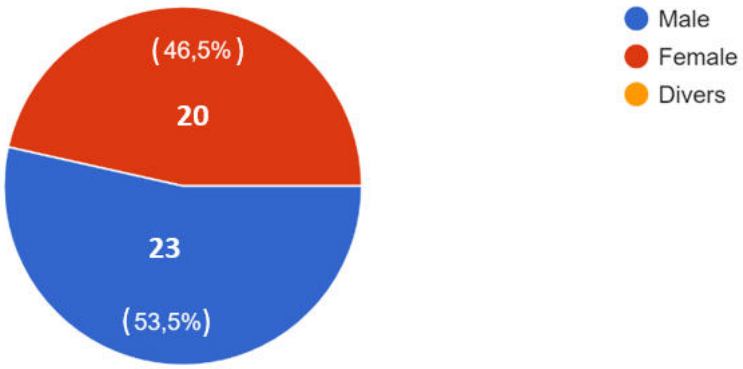


Figure 4.1: Gender Distribution of the Survey

In the following the motivation behind the conducted questions is explained. The first set of questions were conceptualized to get an overview about the fitness-level and the training behavior of the participant. This knowledge is important for the development of the prototype to get an overview about frequency and experience regarding strength training to observe the actual status of their training and where the problematic points are.

Furthermore questions about the reasons to perform strength training are important to have knowledge which motivational reasons could be the strongest to target in the application. To assess the reasons for motivation it is important for the first research question, if a gamified application, that raises awareness about the health benefits of strength training with regard to biomechanical aspects, help to achieve a targeted training frequency and thereby increase how often the user performs strength training.

Afterwards questions about the training sessions themselves were conducted because it is not only important to get an idea about the training behavior over a longer period of time, so in terms of regularity, but also about the individual training sessions themselves and how they are built. Information about the training sessions can help to achieve a strategy to optimize the sessions in terms of time and intensity which is of interest for development of the prototype and the second research question, namely can the training sessions be made more time efficient through the use of the application.

Then another important part of questions were questions dealing with the interplay between technology and strength training. Here experiences of the participants with existing apps in conjuction with strength training is helpful to learn from positively received features and implementations, as well as learn from more negatively received features. Also asking for the desired functionalities from the participants and motivational factors for strength training in context of an app can directly guide towards requirements for the prototype. This is of interest for the third research question of what the requirements are for the application to achieve the adherence to a targeted training frequency and

thereby increasing training frequency, and the optimization of the duration of the training sessions. In particular moreover it is also important here to see how well gamified aspects are received, also for the assessment of the first research question, as well as to review the popularity for the usage of supporting wearables such as fitness trackers.

4.2.1 Section: Fitness Level

To get an indication about the physical activity level of the participant, it was asked how many hours of sports the participant does in a week. Only 2 participants (4.65%) answered zero hours, most people answered one to three hours with 19 participants (44.19%), 15 participants (34.89%) answered four to six hours and 7 participants (16.3%) answered the highest answer possibility with seven hours or more. Therefore most people with 41 participants (95.35%) perform at least a bit of sports in a week.

4.2.2 Section: Information Regarding Training Behavior

The next section deals with information regarding training behavior. In this section the first question is how long their experience is with strength training and the results are displayed in figure 4.2.

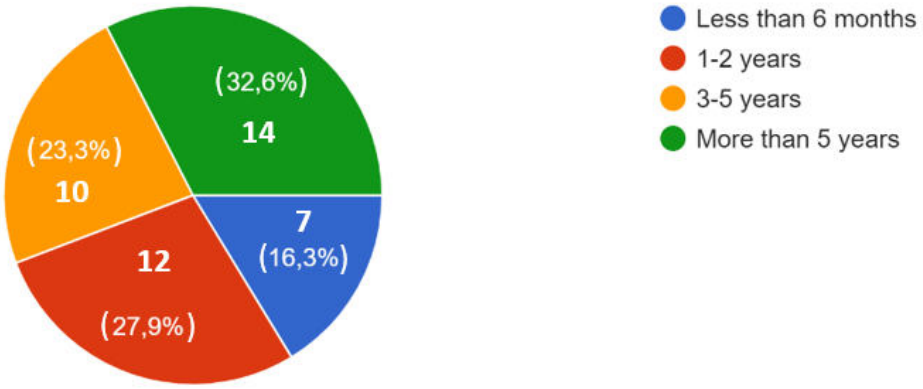


Figure 4.2: Strength Training Experience

7 participants (16.3%) are beginners and answered that they have less than six months experience, 12 participants (27.9%) answered they have one to two years experience, 10 participants (23.3%) answered they have three to five years experience and 14 participants (32.6%) answered that hey have more than five years of training experience. The next question unveiled the utility of making an app for motivation to perform strength training because only 22 participants (51.2%) answered that they perform strength training regularly and 21 participants (48.8%) don't perform strength training regularly. To get the full benefit of strength training maintaining a regularity is of great importance. From

the group of people who answered that they perform strength training regularly, most of them with 10 participants (45.5%) do strength training three times a week. Only 2 participants (9.1%) perform their training once a week, 5 participants (22.7%) two days a week and 5 participants (22.7%) even more than three times a week. Furthermore 15 participants (68.2%) perform their strength training sessions in a fitness studio and 12 participants (54.5%) at home.

In a next question the question was raised to the participants who don't do strength training regularly what the reasons for that are. By far the reason people answered the most with 11 participants (52.4%) was that they do not have enough time. This is an aspect where the prototype can be useful in terms of keeping the duration of the training session low due to achieving a focus on the training and keeping pauses as short as necessary for recovery. The next two reasons people answered were equally often marked with 7 participants (33.3%) each. The first one was that they are too lazy to perform strength training regularly and the second one was that it is not fun to them. These two reasons also indicate the value of developing a mobile application. The aim of the app to motivate people to do strength training ties in with the aspect of laziness and can provide support to overcome this unmotivated condition. The other reason of strength training not being fun can maybe be improved through involving gamification elements in the mobile application.

In a next question the participants were asked to rate their success with strength training and the results are displayed in figure 4.3. Here most people saw moderate success with 21 participants (48.84%), then as the second largest group high success with 14 participants (32.56%). Only 2 participants (4.65%) saw a very low success rate whereas 5 participants (11.63%) answered with a low success rate.

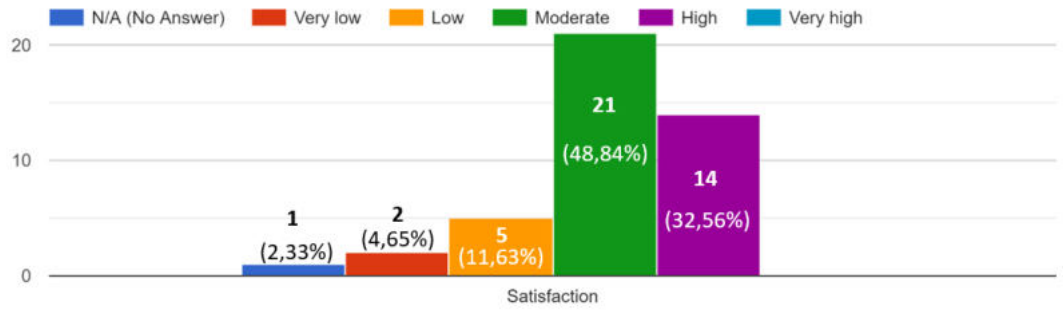


Figure 4.3: Question: How do you rate your success you have had so far with strength training?

A similar distribution in answers, displayed in figure 4.4, can be found in the subsequent question, where the participants were asked to rate their knowledge about strength training. This indicates that the amount of knowledge a person has with strength training correlates with the success they have with strength training which seems plausible.

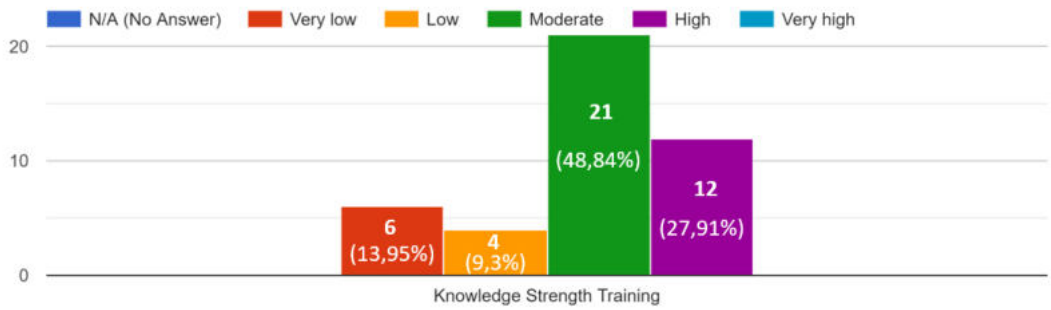


Figure 4.4: Question: How do you rate your knowledge about strength training?

Most participants with 25 participants (71.43%), which answered this question, reported that they get their knowledge about strength training from the internet for instance from the video platform Youtube or from some form of videos or applications. Several people with 6 participants (17.14%) answered that they get their information from friends and others with 15 participants (42.86%) answered that they get informed by trainers or sport courses. These findings indicate that the majority of people from the target group with 25 participants (71.43%), which answered the question, get their information regarding strength training from the internet or other technological means and therefore use technology for mediation of knowledge. This proves that mobile apps can be seen positively by most people for transfer of knowledge regarding strength training and raising awareness about the preventive role strength training can have.

In a next question reasons for carrying out strength training were asked. By far the most answered reason was health with 35 participants (81.4%), significantly above the second-most answered reason which was appearance with 23 participants (53.5%). Furthermore 22 participants (51.2%) answered the reason for performing strength training with improving strength or performance and 16 participants (37.2%) answered having fun while training as a reason. Here it can be seen that improvement of health is the largest motivational factor to perform strength training which fits perfectly well into the subject of prevention dealt with in the development of the app in context of the thesis.

In the last question of this section the question was raised, what bothers the participants the most with their strength training. A lot of people, which answered this question, with 8 participants (25%) answered lack of time for strength training being an issue or that the training sessions are too long. Several with 6 participants (18.75%) answered that the success of the training is not apparent or that success only develops slowly over time and therefore it is difficult to build up a regularity of performing strength training. Therefore an app which supports the user by displaying the positive effects of adhering to their strength training regiment can be of great value for the user.

4.2.3 Section: All About Training

Afterwards the section "All About Training" was started with posing the question how long a training session usually takes for the participant. Here there was a wide range of answers from a couple of minutes to 120 minutes.

The next question was if and which kind of primary training strategy is being pursued by the respondant with their strength training and the results are displayed in figure 4.5. In fact most people answered with 14 participants (32.6%) that they don't follow any strategy. The second most answered strategy was strength endurance (High repetitions, lower weights) with 12 participants (27.9%) and hypertrophy with 8 participants (18.6%). Maximizing strength was only answered by 5 participants (11.6%). An explanation why hypertrophy was answered not so often could be that people associate hypertophy with the typical bodybuilder physiques portrayed in the media. However the appearance achieved with professional bodybuilding or people who take maximizing muscle mass very seriously can not be equated with hypertrophy as a general training goal.

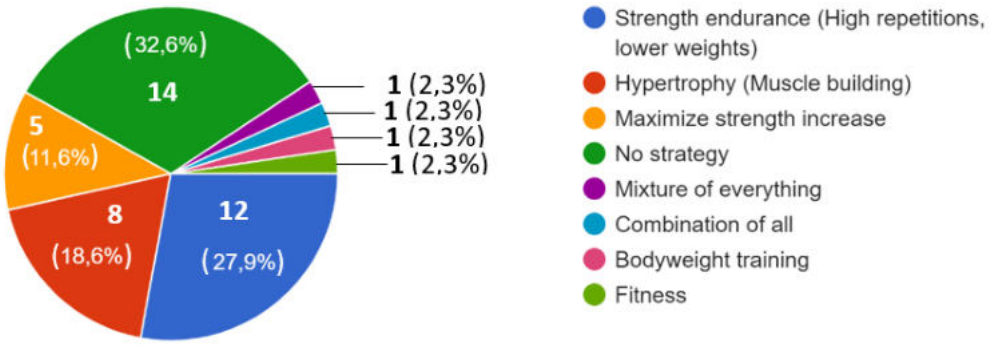


Figure 4.5: Question: Which primary strategy do you follow with your strength training?

In a next question the training intesity was evaluated by the question if the participant breaks a sweat during their training and the results are displayed in figure 4.6. Here the most answered "a little bit" with 17 participants (39.5%), followed by "yes, a lot" with 15 participants (34.9%) and "yes moderately" with 11 participants (25.6%). Consequently there is potential in increasing training intensity in a majority of participants with 28 participants (65.1%) not answering "yes, a lot".

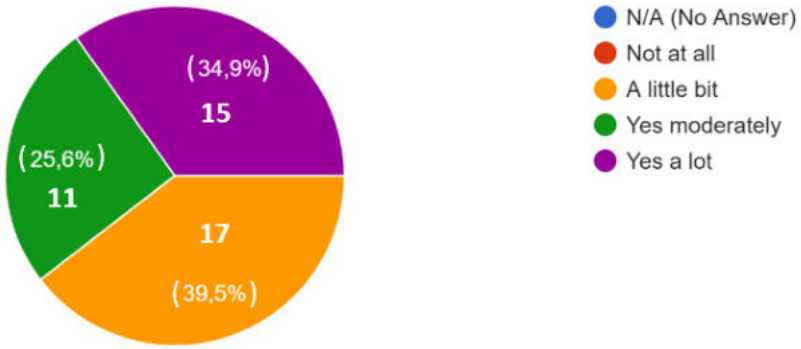


Figure 4.6: Question: Do you break a sweat during your training? (as an indicator for the intensity you train with)

The next question dealt with the fact if the respondant documents their training sessions and the results of the question are displayed in figure 4.7. Predominantly most people with 30 participants (69.8%) answered that they don't document anything. And in the subsequent question, if the pauses in between training sets are documented, even more people with 36 participants (83.7%) answered that they don't document the pauses. A documentation can be a large supportive measure to adhere to goals. Hence there can be a large potential for an app, which for instance through documentation of the adherence to certain pause lengths, can lead to a more efficient organization of strength training.

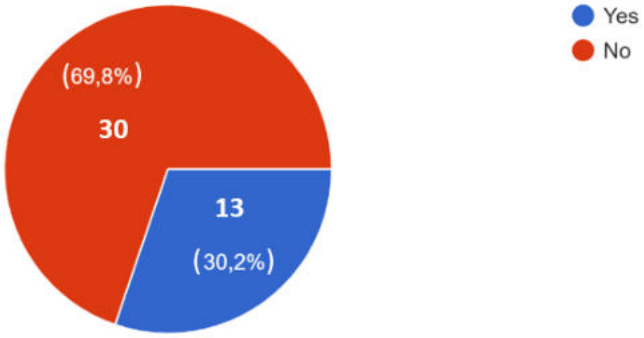


Figure 4.7: Question: Do you document your training sessions?

The respondants which document their pauses were asked how long they do pauses in between their training sets. The results of the question are displayed in figure 4.8. Respectively 3 participants (42.9%) answered "less than one minute" or rather "one to two minutes". 1 participant (14.3%) answered "more than five minutes".

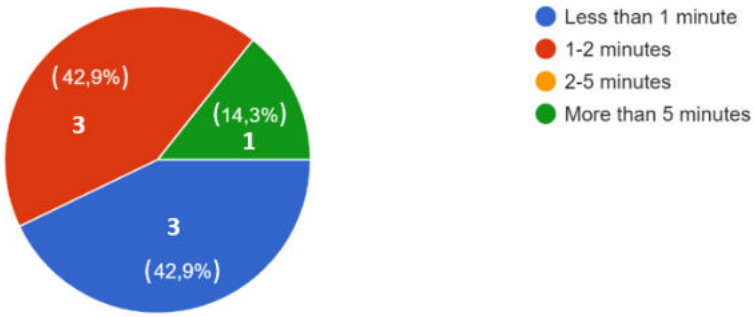


Figure 4.8: Question: How long do you do pauses in between the training sets of the exercises?

The respondants who don't document their pauses were asked to estimate the length of pauses they make in between training sets. The results of the question are displayed in figure 4.9. Most of them with 21 participants (58.3%) answered that their pauses are one to two minutes long. Respectively 7 participants (19.4%) answered that they do pauses for one minute or rather two to five minutes. Only 1 participant (2.8%) of them estimated their pauses are longer than five minutes.

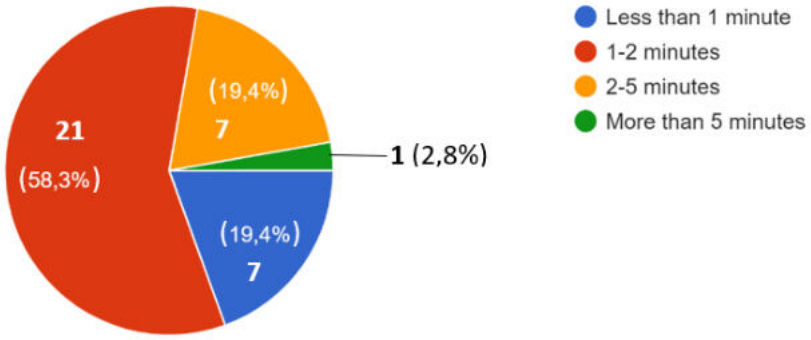


Figure 4.9: Question: What do you estimate, how long do you do pauses in between training sets of the exercises?

In a next question the respondants were asked if they are easily distracted during training. The majority with 31 participants (72.1%) said that they are not easily distracted during their training. However 12 participants (27.9%) answered that they get easily distracted. Of those who get easily distracted it was asked due to what they get distracted. Here the most answered reason with 5 participants (41.67%) of whom answered this question was their smartphone. But also other influences for instance noises and other people with 3 participants (25%) were mentioned.

The question if the participants use wearables for example a smartwatch or fitness tracker for their strength training was asked and the results of the question were displayed in figure 4.10. Most respondants with 32 participants (74.4%) stated that they don't use fitness trackers or smartwatches. The other 11 participants (25.6%) were asked which kind of fitness tracker they use. Here a wide range of different smartwatches and fitness trackers were mentioned for example the Apple Watch or a Fitbit device. Those who said that they don't wear any wearables such as fitness trackers were asked for the reason why they don't use one. A large portion with 14 participants (43.75%) indicated that they see them as unnecessary and have no interest in them.

Therefore one should consider when developing the app to give the possibility to use it also without a wearable. Maybe the possibility of the integration of a wearable should be an add-on in the app which does not have to be utilized. This could certainly be possible because measuring the pauses can also happen through manual input of the user. The feature of extracting the pauses and their length from the heart rate data could be optional for users who want to use a wearable.

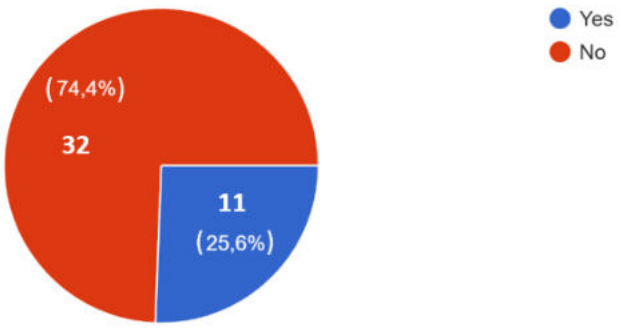


Figure 4.10: Question: Do you use wearables for example a smartwatch or fitness tracker for your strength training?

4.2.4 Section: Use of Technology in Strength Training

In the next section "Use of Technology in Strength Training" the first question dealt with the question if the respondant uses any apps for their strength training. Most people with 31 participants (72.1%) answered that they don't use any apps. To get a picture of which apps the respondants use, those who answered that they use apps for their strength training were asked to name the specific apps that they were using.

Afterwards those which use apps were asked which functionalities they use for their strength training. Here it is noticeable that the majority uses apps for exercise instructions with 9 participants (75%) and planing of their strength training regiment with 7 participants (58.3%). Fewer respondants stated that they use apps for motivation with 4

participants (33.3%) and only 1 participant (8.3%) answered that a timer-functionality for the training was used. So here it could be that for the last two aspects stated namely motivation and integration of a timer element there aren't any satisfactory applications in this context available. Therefore there could be a large potential to be tapped into with these features.

The next question was posed to everyone, namely what the respondants would want from an app which supports them with their strength training. In fact a lot of people with 9 participants (20.93%) stated that they would like to get motivated through an app. Futhermore many with 7 participants (16.28%) would like to have a timer component or some kind of time monitoring for their training. Some people with 6 participants (13.95%) answered that they want a guidance how to do the exercises correctly. Moreover some respondants with 3 participants (6.98%) answered that they would prefer a simple design with an easy handling. Then there were also 3 participants (6.98%) who would want some kind of monitoring or display of calories burned during training.

After that the respondants were asked if they are interested in games and the results of the question are displayed in figure 4.11. A large majority with 30 participants (69.8%) answered that they are insterested in games.

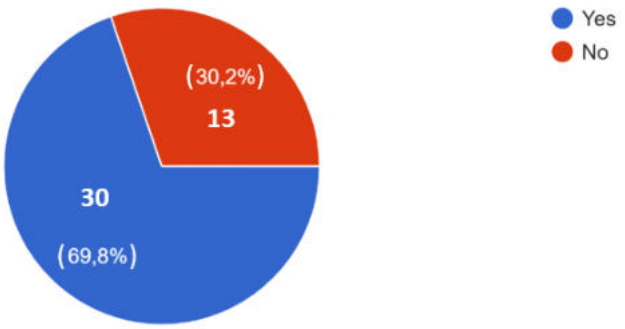


Figure 4.11: Question: Are you interested in games?

In a following question it was asked if the participant likes to play on their mobile phone. Here the group which answered yes was a bit less than in the question before with 18 participants (41.9%) of the respondants, but this is still a major group. Hence it would be suitable to integrate gamified elements into the app and furthermore it seems as if a serious game would be interesting for a large group of people as well.

In the last question of this section and therefore also of the survey, several ideas for increasing motivation in context of an application were displayed to the participants which they should rate, if it would lead them to be motivated to perform strength training or not (results displayed in figure 4.12). The most positively received idea with

31 participants (72.1%) stating yes and 10 participants (23.26%) stating maybe to the idea was to show the health benefits of strength training to the user.

Related to that idea the idea of raising awareness of the preventative effect of strength training regarding orthopedic diseases was seen also positively with 20 participants (46.51%) answering yes and with 17participants (39.53%) answering maybe. Only very few answered with no with 6 participants (13.95%).

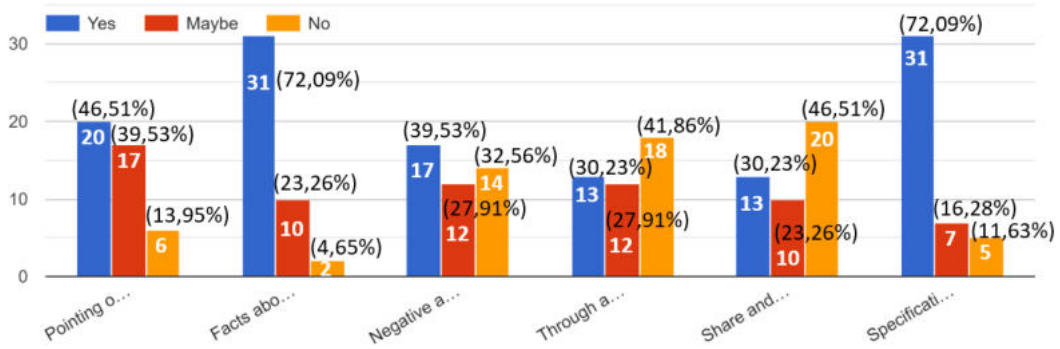


Figure 4.12: Question: Which of the following things in the context of an app could motivate you to do strength training? 1: Pointing out preventative effect against orthopedic diseases ; 2: Facts about health benefits ; 3: Negative aspects of an inactive lifestyle ; 4: Through achieving goals receiving benefits in a mobile game ; 5: Share and compare progress with others ; 6: Specification of certain targets for example adhering to training plan for a month

This can be interpreted that many people might not be aware of the preventative effect of strength training regarding the human locomotor system. Hence there could be a large potential to be filled with an app raising awareness about that to the user. Furthermore the idea which got a lot of positive votes 31 participants (72.1%) stating yes and 7 participants (16.28%) stating maybe, was to integrate setting goals by the app which the user can achieve. This could be implemented in an app through achievement elements. Less clearly positively received, with 17 participants (39.53%) stating yes and 12 participants (27.9%) stating maybe, was the idea of displaying the negative effects of an inactive lifestyle by the respondants.

Therefore it has to be seen if this idea should be implemented into the app or if it is better to stick to displaying the positive effects of strength training. Significantly rejected was the idea of comparing and sharing the success and results with others with only 13 participants (30.23%) stating yes but also 20 participants (46.51%) stating no. Also the idea of receiving benefits in a mobile game for achieving training goals was negated by a large amount of respondants with 18 participants (41.86%) stating no and only 13 participants (30.23%) stating yes, however also a lot answered with maybe with 12

participants (27.9%), so the three possibilities of answers were rather equally balanced between eachother. The uncertainty about this idea could come from the fact that this concept of serious games and motivation for strength training is a rather unknown concept and maybe many can't really imagine how this would be realized.

4.2.5 Requirements

After displaying and analyzing the results of the online survey, requirements for the development of the protoype were extracted through clustering the answers into meaningful groups and summarizing them into a list of requirements. The presented requirements were holistically stated with different frequencies, and are ordered in the following table 4.2 with number one being the most stated requirement to number 15 being the least stated requirement. To each requirement an associated priority was assigned with less important meaning that only a few individuals stated those aspects, important meaning that more than only a few individuals saw those aspects as essential and very important meaning that a large amount of participants stated that aspect to be important to them.

Subsequently to the presented table the basis on which the individual requirements were formulated, is described.

Nr.	Id	Requirement	Priority
1	R1	Illustrate Health Benefits of Strength Training	Very Important
2	R2	Specification of Training Goals which the User Can Achieve	Very Important
3	R3	Raise Awareness about Prevention, Especially Regarding Orthopaedic Diseases	Very Important
4	R4	Optimize duration of Training Session	Very Important
5	R5	Improve Focus on Training	Very Important
6	R6	Include Tracking of Time (Timer-Element)	Very Important
7	R7	Motivational Concept	Very Important
8	R8	Possibility to also use without wearables	Very Important
9	R9	Aim to Increase Fun Factor of Strength Training	Important
10	R10	Including Gamified Elements	Important
11	R11	Rating of Training Intensity	Important
12	R12	Ability for Documentation of Training Especially Pauses	Important
13	R13	Evaluation and Display of Results (Tracking Progress)	Important
14	R14	Simple Design and Easy Handling	Less Important
15	R15	Free and Without Advertisements	Less Important

Table 4.2: Requirements extracted from the analysis of the conducted online survey

A very important issue for most participants was the aspect of health benefits through strength training. When asked for the reasons of performing strength training the vast majority with 35 participants (81.4 %) answered with health being the driving factor. Also in the question about assessing the magnitude of motivational impact to perform strength training, very well received was the idea of displaying facts about health benefits

of strength training. Therefore raising the awareness about the positive impact of strength training on the individuals health was extracted as the most important requirement for the app, displayed as requirement number one.

Also a very important requirement is the capability of the prototype to specify certain training goals which the user can achieve. Here achievement elements can be integrated which the user can then unlock if successfully meeting certain goals. This idea of specification of certain targets for example adhering to training plan for a month was seen very positively by almost three quarters of participants with 31 participants (72.09 %) and therefore formulated into a requirement with a high priority.

Another especially important requirement is raising awareness of prevention especially in terms of orthopedic diseases. This requirement was extracted from the high rating of the idea of pointing out the preventative effects regarding orthopedic diseases in an app. Here only 6 participants (13.95 %) answered that it wouldn't motivate them to perform strength training, whereas 20 participants (46.51 %) answered with yes and 17 participants (39.53 %)with maybe.

A further greatly important issue with strength training which was named several times when asked what bothers them the most about their strength training, was the time it takes to perform their training sessions with 8 participants (25 %) of the answers to this question stated this issue. Furthermore the most answered reason for the participants to not do strength training regularly with 11 participants (52.4 %), which answered the question, was that they don't have enough time. So time seems to be a large issue with the success of keeping a regularity in strength training. Therefore the requirement of optimizing the duration of the training sessions was formulated as being important.

Connected to the former requirement is the requirement of improving focus while training. If the focus is kept on the training and the person is not distracted, then not only the duration of the training session can be optimized but also the training intensity can be increased. At least more than a quarter of respondants with 12 participants (27.9 %) answered that they get easily distracted while training.

Also a notably important requirement is to include tracking of time during training with a timer element. This requirement was extracted partly also from the reasons for the requirement of optimizing the duration of training sessions, so that a lack of time is seen as a very important factor for not performing strength training. But also furthermore specifically from a few people with 7 participants (16.28 %), when asked in an open question what the respondant would want from the prototype, said that they would like to have a timer integrated which then can monitor the time. This could be specifically helpful for monitoring the length of pauses in between training sets.

Furthemore of great importance is that the prototype should be designed to have a motivational concept because the issue of absence of motivation to perform strength training is prevelant in a lot of respondants and especially the motivation to perform strength training regularly is an issue where almost half of the respondants with 21 participants (48.8 %) answered that they don't perform strength training regularly.

Requirement number eight, the possibility to use the app also without wearables, was extracted from the questions about wearables. Firstly due to the question of usage of wearables where 32 participants (74.4 %) and therefore the vast majority said that they do not use any wearables for their strength training. But also in the subsequent question about the reasons for not using wearables and many participants with 14 participants (43.75 %) stating that they believe they are unnecessary lead to the idea of having the possibility of using wearables but making it not mandatory for the usage of the app. It could be seen more as an add-on feature for those who would like to use it.

Trying to increase the fun factor of strength training was extracted from the specification that a large portion of people with 7 participants (33%) from the group which do not perform strength training regularly answered when asked for the reasons for not keeping up that regularity, with that strength training is not fun. Furthermore when all participants were asked for reasons of performing strength training, 16 participants (37.2 %) answered because of it being fun. Consequently it can be seen that having fun with strength training is a priority for many people and therefore the requirement of aiming to increase the fun factor of strength training was enlisted as a requirement with high priority.

Including gamified elements was also seen as an important requirement and was obtained from a set of questions regarding games. First of all more than two third of respondants with 30 participants (69.8 %) are interested in games and in a subsequent question a bit less than half with 18 participants (41.9 %) stated that they play mobile games. So it seems that in this target group gamified elements could be well-received even though in a question about rating motivational impact of the idea of getting benefits in a mobile game through achieving training goals was getting mixed ratings. The reception of this idea positively and negatively were roughly in the same amount with 13 participants (30.23 %) answering yes and 18 participants (41.86 %) answering no, whereas also roughly the same amount with 12 participants (27.9 %) was unsure about the idea. Anyway this is still a significant portion of the respondants which see the idea positively and especially with the questions regarding interest in games has shown to have great potential for including gamified elements in the prototype.

Another important requirement which can be extracted from the questions about intensity and avoiding distractions is to give a training intensity rating which could for instance be calculated from the length of the pauses or could be manually inserted by the user of how intense the user felt the training session was.

A further requirement is providing the ability to document the results one has from their strength training especially in terms of duration, intensity and pause length. This could happen manually through the input of the user and certain statistics could be calculated from said input. This requirement was extracted by the fact that more than two thirds of the respondants with 30 participants (69.8 %) don't document their training sessions at all and even more with 36 participants (83.7 %) don't document their pauses in between training sets. This could lead to a large potential to give the user a framework and a clearer plan of what the user is doing.

Connected to the requirement of documentation of training it was also seen as important to display the results of the training to the user. This requirement was extracted from the fact that the rating of the respondants with regards to the success with their strength training showed that many are not as satisfied as they could be with almost half of the participants with 21 participants (48.84 %) rating their success as moderate. When results of training are displayed to the user there can be a clearer sense of achievement which can then lead to a continuation of their regular strength training routine. Furthermore in a question to users who already use apps for their strength training 6 respondants (50 %) answered that they utilize the functionality of tracking of progress.

Also an issue which was mentioned by 3 participants (6.98 %) when asked for what they would want from the app was being user-friendly. Therefore the requirement of the prototype having a simple design and easy handling was included with a medium priority rating.

As a less frequently desired issue but also seen as import enough to state as a requirement is that the application should be free to download and it should also be free from advertisments. This was stated a couple of times with 3 participants (6.98 %) when asked for what the respondants would want from the app and the part about having no advertisments supports also the requirement of having a user friendly design, so that the user is not distracted by advertisments being displayed.

4.3 Iteration 3: Low-fidelity Prototype

On the basis of the requirements obtained so far, in a next step the development of a low-fidelity prototype was carried out. Thereby the main components and features of the prototype which a user should be able to do were established. The execution of these main features by the user were firstly presented in a user flow diagram. Afterwards the screens the user interacts with were outlined in wireframes to present the layout of the app whereby the focus layed on the functionality of the app and not on designing the elements.

4.3.1 User Flow Diagram

First of all based on the requirements the main sections of the app the user should interact with were established. Central component of the app is the home screen. On the home screen the other sections of the app can be reached through a navigation bar at the bottom of the screen.

The user flow diagram for starting the game is displayed in figure 4.13. When clicking on the button to navigate to the game section a screen opens where for instance a picture of the game and a button "Play Game" is displayed. It was decided to not immediately start the game after navigating to the game section because maybe the user just accidently pushed that button. Also the intermediate screen makes the game more integrated to the context of the whole app. After the user clicks on "Play Game", the game starts launching and can be played by the user.

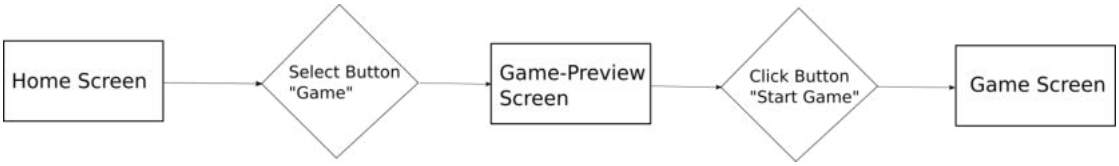


Figure 4.13: User Flow Diagram for Starting the Game

The next main feature is the Achievement screen which can be reached by clicking on the button in the navigation bar. The user flow diagram for the achievements features are displayed in figure 4.14. There all the achievement-badges are displayed which themselves can be clicked on to get more information about it. When clicked on it a further screen opens where some specifications about that achievement are displayed. By clicking a button to quit that page, the user gets taken back to the overview of achievements.

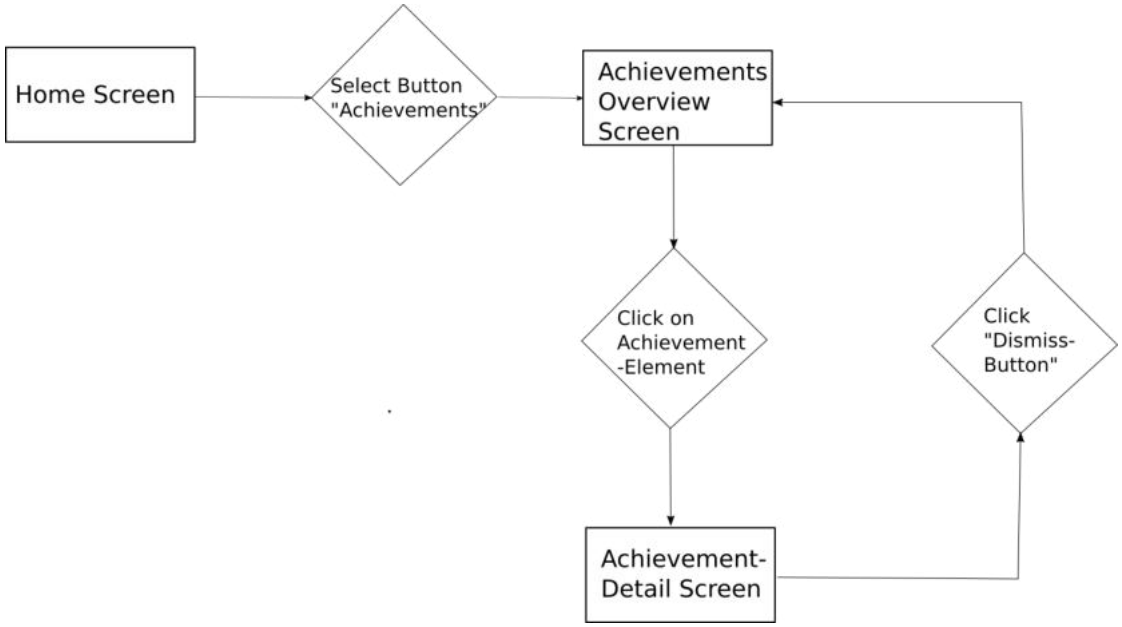


Figure 4.14: User Flow Diagram for Achievements

Another central part of the app is the training section and its user flow diagram is displayed in figure 4.15. When clicked on the specific button in the navigation bar, the "Training Preparation Screen" opens up where the user can give specifications about certain things for the training session which will be carried out. There should also be the possibility to create a new template for a training session, so that it is possible to load up settings from previously defined training sessions. When clicking on a button for creating a new training template, a popup element should appear where the user can enter the training specifications.

After the settings have been done on the "Training Preparation Screen" the user can click on the "Start" button which takes them to the "Timer Screen". On that screen the guidance for the training session takes place. Here the monitoring of the pauses should be carried out by a Timer-Element. The User should be able to Start the Timer and Stop the Timer by clicking on a button. When the training session is over, the user should be able to click on a button to finish the training session which then takes the user to a "Congratulations Screen". On that screen some short information about the absolved training session should be displayed. By clicking on a button, the user should be taken back to the "Home Screen".

The remaining two main sections consist of a "Statistics Section" and a "Settings Section". These sections of the app have a straight-forward user flow and are therefore not displayed in a diagram. The user can simply reach these two sections by clicking on a corresponding button in the navigation bar and then remain on that page for the features given by that section.

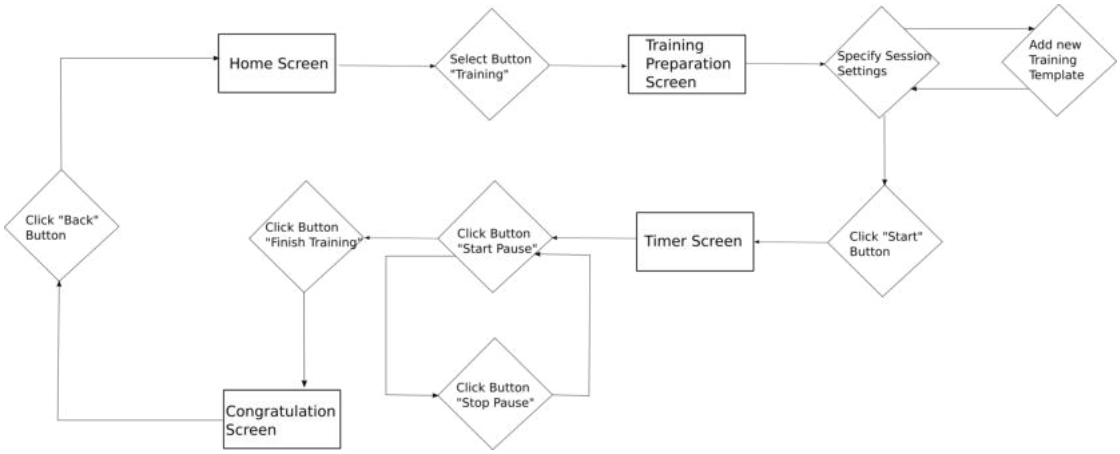


Figure 4.15: User Flow Diagram for Training

4.3.2 Wireframes

In a following step the screen layouts of the main components and features were outlined with wireframes. Here the focus was put on the functionality of the app rather than the design. Therefore the wireframes are kept without coloring and the design does not go into great detail.

Starting point of the app is the Home Screen, where the user gets directed to after loading up the app and seeing a Launch Screen. Integrating registration and login of the user was deliberately omitted, since this function is not necessary due to finding out through the previous step that the comparison between the users accomplishments is not a desired requirement. Leaving out this feature can lead to an improved user experience in context of the aims of the app and cuts out a further layer of complexity, by signing up and logging in, which could be a barrier to the user to actually use the app. After all, in the evaluation of the questionaire the requirement of simplicity and easy handling was recorded.

In most cases throughout the app the screens can be divided into three parts: an area for a top navigation bar, where the name of the app or the section can be displayed. On the bottom of the screen a tab bar is displayed which contains buttons to direct the user to the main sections of the app when the user clicks on them. In the area in between the navigation bar and the tab bar, the actual main content of the screen is displayed.

On the Home Screen, displayed in wireframe figure 4.16, there could be a large image which represents the app and makes the app look nice. Also there should be a display of the users score which is a central part of the gamification aspect of the app. Underneath the picture there should be some kind of integration of displaying information about the health benefits of strength training, so that the topic of prevention is placed as an important element of the app. This idea was developed from the two requirements, namely requirement R1 to illustrate health benefits of strength training, as well as requirement

R3 to raise awareness about prevention, especially regarding orthopedic diseases. This feature of displaying health benefits of strength training should raise awareness and support the user to perform strength training. This is therefore one important idea which was developed to deal with the first research question, if a gamified application, that raises awareness about the health benefits of strength training with regard to biomechanical aspects, can help to achieve a targeted training frequency and thereby increase how often the user performs strength training.

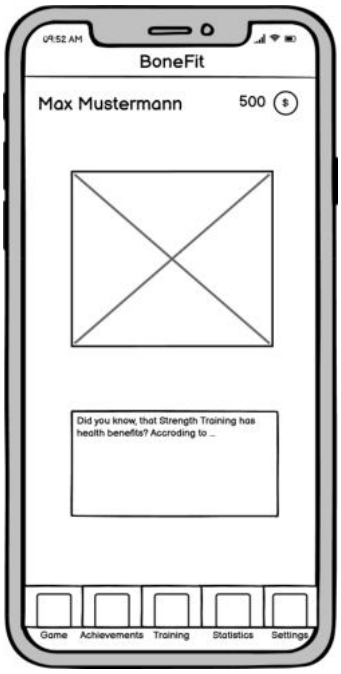


Figure 4.16: Wireframe of Home Screen

The next wireframe (4.17) deals with the "Game Preview Screen" where the user gets taken after the game section was clicked in the tab bar. Here some visual information about the game should be displayed by means of a picture for instance. Underneath there should be a button which takes the user to the actual game. Also it would be important to display the current score of the user, before the user has entered the game. Hereby the requirement R10 to include gamified elements was considered. The game should play a role in motivating the user to perform strength training through receiving benefits in the game by performing strength training. This is therefore a further motivational concept, elicitated in requirement R7, which was considered. After the wireframes of the main sections of the app are presented, the developed game ideas are presented in detail.

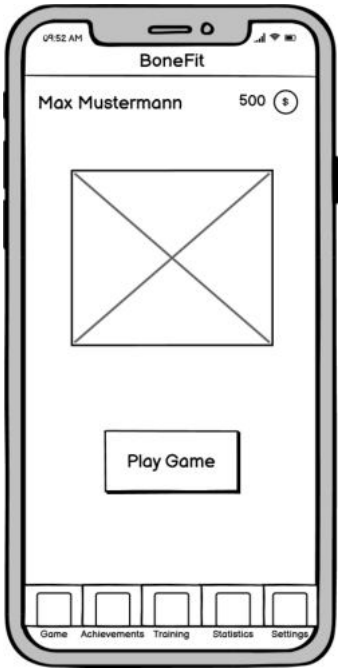


Figure 4.17: Wireframe of Game Preview Screen

In the achievements section of the app the user gets taken to the "Achievements Overview Screen", which is displayed in wireframe figure 4.18. The wireframe was designed as such, that a list of achievement elements are displayed. These elements should be different images, that represent the achievement unlocked by the user when the described goal has been accomplished. The idea is to also not show the whole list of possible achievements, but rather gray out some which will be shown when the user already unlocked a certain amount of achievements. The development of the idea of achievements was a realisation of requirement R10 to include gamified elements, as well as to have specified training goals which the user can achieve, which was elicitated in requirement R2. Furthermore the idea of requirement R7 to include a motivational concept and also the idea of requirement R9 to aim to increase the fun factor of strength training were thought about when developing the idea of including achievement elements.

When the user clicks on a achievement element a new screen opens, the "Achievement Detail Screen", displayed in the wireframe shown in figure 4.19. Here the title of the achievement should be displayed with the image of it in a larger size. Furthermore there should be some information about it, as in a desription of the necessary requirements to fulfill the goals of that achievement. Lastly there should be a button which takes the user back to the "Achievement Overview Screen".

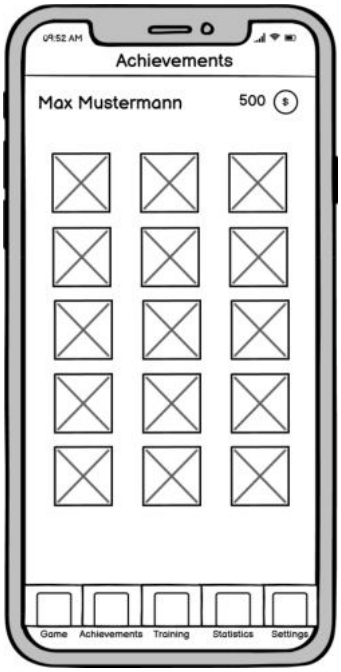


Figure 4.18: Wireframe of Achievement Overview Screen

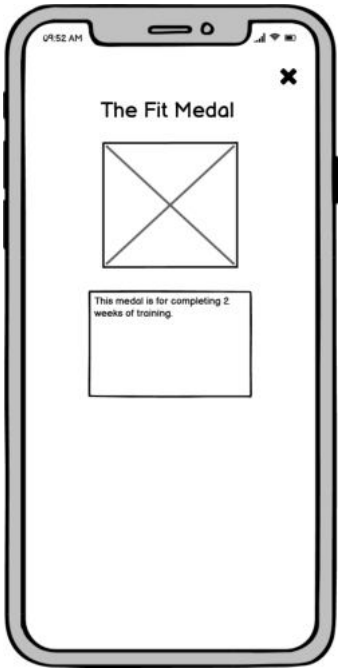


Figure 4.19: Wireframe of Achievement Detail Screen

The next central feature to the app is the Training Section. Firstly the user gets taken to the "Training Preparation Screen", displayed as a wireframe in figure 4.20. Here the main input the user has to provide is the number of individual sets, the user is going to perform in the training session. The information about the number of sets is important to keep track of the pauses in an interactive manner. There should be the possibility to either enter the number of sets manually or load it from templates which the user has created by clicking on the respective workout template from a list of created templates. By clicking on a button to add a new template, a popup appears where the user can enter the name of the workout and the number of sets it consists of. After confirming the entered values by pressing the save button, the newly created template appears in the list of training templates and can be selected. After providing the information about the number of sets, the user can press a button to start the training and gets taken to the "Training Timer Screen", displayed as a wireframe in figure 4.21.

Figure 4.20: Wireframe of Training Preparation Screen

The central element of the Training Timer Screen is the timer element which is positioned in the middle of the screen. Underneath there is a button which serves as the control of the timer. The user can tap the button to start the timer when his training set is over and the pause begins. This is a realisation of the requirements elicitated in R6 to include tracking of time (timer-element), as well as in R12, the ability for documentation of training especially pauses.

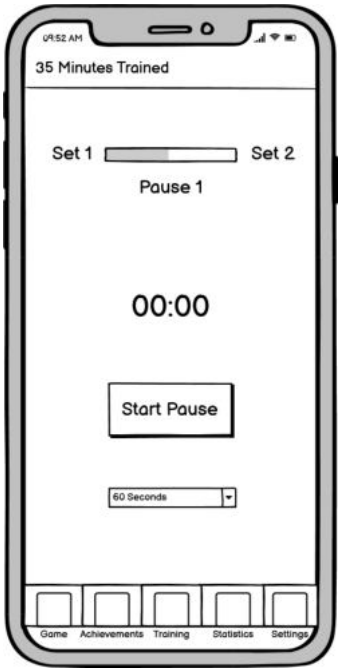


Figure 4.21: Wireframe of Training Timer Screen

There should also be a possibility present to select the duration of the pause by a dropdown menu or a slider element. This element should be preset with the duration which the user has deposited in the settings area of the app. It was decided to be able to set the duration of the pause directly in the Timer Screen for reasons of flexibility. So the user can set the pause to a bit higher or lower number depending on the condition of the user on that specific timing of the session. But also more importantly the possibility of setting a different value from a preset one is important due to the fact that during sets with the same equipment one might want shorter pauses and in between sets of different equipment where the user has to prepare the training device for instance search the needed components and restack weights. Through this choice it is also possible to include people who also do supersets which are basically multiple sets consisiting of different exercises executed right after eachother. Here the user might enter the superset simply as one set when setting up the training session, or the user can simply choose an option no pause or zero seconds and skip to the next set. Furthermore there should be a section on the top area of the screen where the duration of the remaining pause is displayed. This can be achieved through a progress bar with labels showing the sets the pause is in between of and the number of pause of the training session. The expiration of progress bar showing the targeted length of the pause can differ to the manually recorded pause the user actually has done. So for instance it can happen that the targeted pause length was one minute, but the recorded pause by the user was 90 seconds. This feature should make the users accountable to adhere to their set pause length and therefore aim to optimize the duration of the training session, elicitated in requirement R4, and

also support the focus put on the training, elicitated in requirement R5 to improve the focus on training. The described feature with tracking of pauses is therefore furthermore essential for the implementation of the second research question, if the training sessions can be made more time efficient through the use of the application.

This possibility for discrepancy is basically the basis for the calculation of the intensity score. The larger the discrepancy the lower the intensity score becomes. This therefore follows a motivational concept, which involves requirement R7, and tries to involve requirement R11 to include a rating of training intensity.

Another useful feature would be to display the number of minutes which have passed since the training session has been started, to give the user an oversight of the training length. This can be displayed in text form in the navigation bar on the top of the screen for instance. After the user has reached the last set of the training session the button where the user has control over the pauses turns into a button labeled with finishing the training session.

When the last set is done the user can push that button and the user gets taken to the "Training Results Screen", which is displayed by the wireframe in figure 4.22.

Figure 4.22: Wireframe of Training Results Screen

On the Training Results Screen there should be a text congratulating the user about absolving the training session. Furthermore there should be a list of statistics shown for instance the number of minutes trained and number of sets performed. Based on the adherence to the target pause durations, which the user set, an intensity score can

be calculated and displayed on the screen. The user should get a number of points or in-game currency according to the composed assessment by the intensity score and the completion of the training session. This in-game currency amount should then go to the account of the user where the in-game currency can be collected to get benefits in the game of the app, but also maybe unlock certain achievements. Finally there is a button which takes the user back to the home screen. These elements included in the Training Results Screen should motivate the user to perform strength training and have a good performance adhereing to the pauses. This therefore follows a motivational concept, which is content of requirement R7. Furthermore through the presentation of statistics and score requirement R13, the evaluation and display of results (tracking progress) is realized. Also the results from the training session in combination with a score to be collected for benefits in the game are a way to target research question one, if a gamified application, that raises awareness about the health benefits of strength training with regard to biomechanical aspects can help to achieve a targeted training frequency and thereby increase how often the user performs strength training. Furthermore the motivation to collect in-game coins to perform well in adhereing to the pauses is a way to target the research question, if the training sessions can be made more time efficient through the use of the application.

The next part of the app deals with the statistics feature. This area consists of one screen where the content can be scrolled in vertical direction, displayed in wireframe seen in figure 4.23. The content is hereby divided into meaningful sections. There can be a section about the frequency of how often the user performed strength training during a time frame selected by a dropdown menu. The data can be visualized by various diagram forms. Further there can be a section about Intensity of the individual workout sessions. Information in text form can be displayed for instance how long the average pause length was and how much discrepancy was present in average between the actual pauses and the target pause lengths. These statistics are mainly a result from requirement R13, the evaluation and display of results (tracking progress). However also the statistics should motivate the user and therefore this concept follows requirement R7 of a motivational concept. Furthermore requirement R12, the ability for documentation of training especially pauses, is implemented in this statistics section.

The last part of the app is the settings feature which is displayed on a single screen, presented as a wireframe in figure 4.24. Here it is thought of that the user can enter some personal information for example name and age. Then important settings are regarding the aims of the user such as a frequency aim of how often the user plans on performing strength training in a week. This is important for assessing a score for the compliance with the training frequency. Hereby requirement R2, the specification of training goals which the user can achieve, was considered when developing the idea. Hereby it was seen as essential that the user specifies the target frequency because everyone has different time schedules and fitness levels, so flexibility is regarded as an important point. The user can also for instance give a default pause length which then prefills the slider in the Training Timer Screen. Further there should be an area where the user can adjust the

game settings.

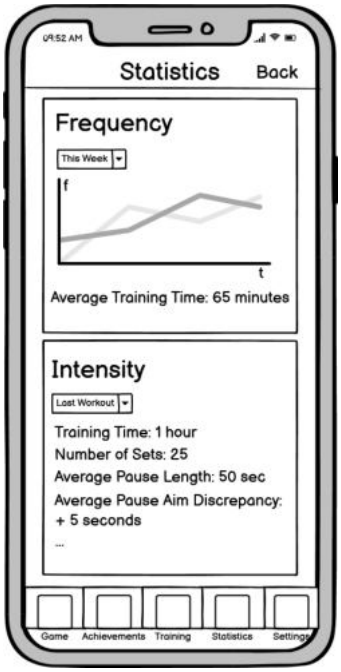


Figure 4.23: Wireframe of Statistics Screen

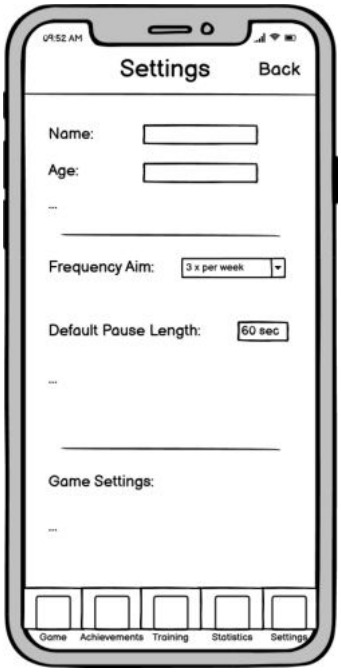


Figure 4.24: Wireframe of Settings Screen

Game Ideas

As already presented it was decided to integrate a game into the app as an important gamification aspect. Therefore this is a result of requirement R10 of including gamified elements. The aim is to have a game which motivates the user to perform strength training through the user getting benefits from performing strength training. This should therefore also result from requirement R7 to include a motivational concept and also R7 to aim to increase the fun factor of strength training.

The game should hereby also support the target of the first research question, if a gamified application, that raises awareness about the health benefits of strength training with regard to biomechanical aspects, can help to achieve a targeted training frequency and thereby increase how often the user performs strength training. Also through a score based on training performance by adhereing to set pause goals, the user should get benefits in the game and therefore support the implementation regarding the second research question, if the training sessions can be made more time efficient through the use of the application. In the following two game ideas are presented which were developed on the basis of the requirements from the questionnaire and further requirements that were stated in the following table 4.3:

Id	Requirement	Source
GA1	Integrate the theme of biomechanics (f.eg. bones/muscles/strength training)	Own Idea
GA2	Points collected from training should result in some benefit in the game	Requirement List
GA3	Level-based system	Own Idea
GA4	Include score to be collected	Own Idea
GA5	Straightforward game mechanics	Own Idea

Table 4.3: Requirements for game ideas

Hereby the two game ideas were developed after trying out several popular 2D-games from the Apple App-Store as well as the authors experience with playing mobile games in the past. In the authors opinion it was important to include the theme of biomechanics in some form to enhance the learning effect of the preventative benefits of strength training for the user. Furthermore the author considered the neccessity to keep the game as simple as possible but engaging to not overwhealm the user with complexity considering a lot of users are probably not playing games that often. Furthermore it was seen as important to include the possibility to collect points to keep track of how well the user played the game which is the central piece of motivation. Also a level-based system seemed to be interesting so there is some kind of progress and variety for the user.

In a first game idea (G1), outlined in figure 4.25, a bone avatar has to be maneuvered from the left side of the screen to the right side of the screen. Here the bone avatar has to cross an area of moving obstacles which move from the top of the screen to the bottom of the screen. These moving obstacles have to be avoided otherwise the bone avatar receives damage and either has to start again from the left side again or looses the whole game alltogether. It is thought that one screen represents one level and after reaching the right side of the screen to the finish line, the user proceeds to the next level with different obstacle compositions. The game idea is respecting requirement GA1 through taking up biomechanical elements such as the bone avatar and certain items for instance dumbbells or others. Also the gameplay should symbolize the remodeling phase of bone in a way that on the left side of the screen the initial state of the bone is that it has small microcracks which then need to be brought to the right side of the screen to the finish line which should represent the area where bone remodeling then takes place. So if left on the left side of the screen, the bone would atrophy and only after going around the obstacles and collecting certain items the bone gets remodeled and becomes stronger. Maybe the idea is also that the bone becomes stronger from level to level as well. An idea is also the possibility to use different avatars for instance different kind of bones. Depending on the size, the maneuver of the obstacles could become easier or more diffcult. This could be an area where the benefits of receiving points from the strength training allow for unlocking certain avatars or maybe avatar skins (for instance a golden bone).

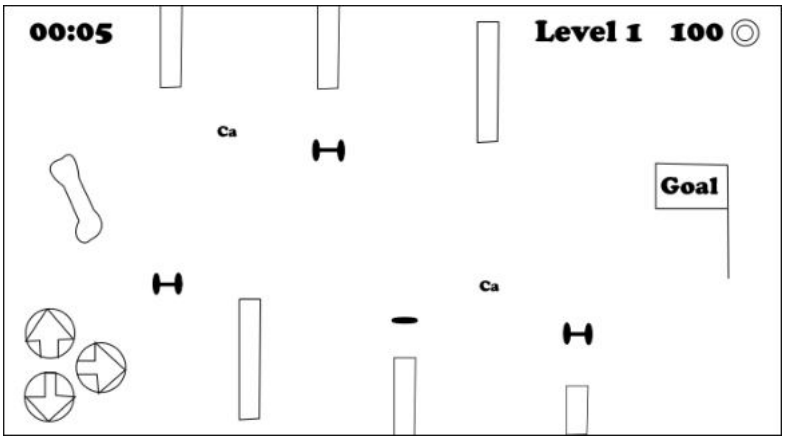


Figure 4.25: Wireframe of Game Idea 1

In a second game idea (G2), outlined in figure 4.26, a bone avatar is placed on the bottom of the screen. It can be moved to the left and to the right by the user. The idea is that items fall down from the top of the screen to the bottom of the screen and the bone avatar needs to either collect beneficial items or avoid damaging items. The gameplay should consist of a level-based system where each level can have different composition of items or different speeds at which the items fall down for instance. Through collecting beneficial items the users score increases which should also be displayed on the screen. Furthermore it is thought that there is some tracking of time which might also play a role in how fast the user completes certain scores.

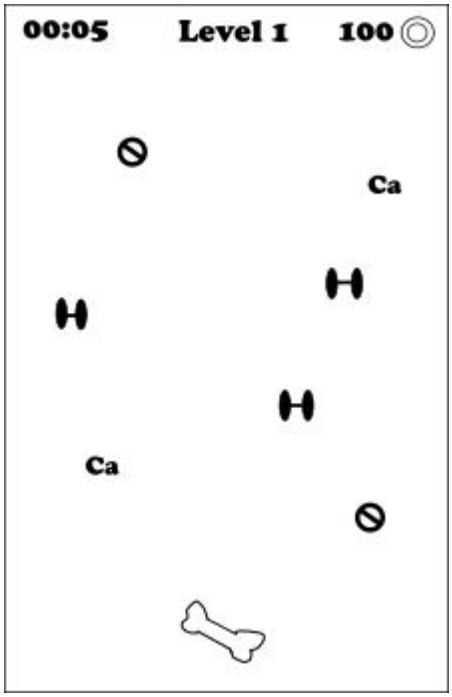


Figure 4.26: Wireframe of Game Idea 2

An idea is that the bone avatar has a certain amount of strength percentage which then declines as time goes on, which should symbolize the atrophy of bone. If the strength percentage reaches zero, then the game is over. Hereby the bone avatar can load up the strength when collecting beneficial items but can also lose further strength percentage if touching a damaging item. This strength percentage can for instance be displayed in a progress bar on the top of the screen. The benefit the user can get from the points gathered from the training sessions can be used to unlock certain avatars. These avatars might have different levels of strength and different sizes or speeds at which they can be moved. Further maybe the avatars can also have different avatar skins which could be unlocked and also different backgrounds for the game which could be unlocked.

4.4 Iteration 4: Interview

In a next iteration the outlined low-fidelity prototype was presented to a former classmate from Biomedical Engineering in an in person interview. Here the user flow diagrams as well as the wireframes were printed out to allow for ideas and feedback to be directly noted on paper. The interviewed person was at the time of the interview in his late twenties and had many years of experience in strength training. Furthermore he has experience in quality assurance of mobile applications due to his occupation as a software tester.

As a starting point the aims of the thesis and the requirements of the last iteration steps were presented to give an overview. Afterwards the wireframe of the home screen was discussed as the starting point of the application. Here a central point which was discussed was how the information about the preventative effects can be presented to the user optimally. In the wireframe an area for this information was planned as a rectangular section with text displaying the health benefits. In the discussion the interviewed had an idea to present the health benefit facts in form of several rectangular notes which appear on the screen over eachother and they can individually be tapped on to open them (displayed in wireframe in figure 4.27). When they are opened, they have a specific information regarding the preventative effects of strength training and for reading it, the user can receive points by tapping on a button (wireframe displayed in figure 4.28). This can make the information displayed more interactive for the user and also less prone to be overlooked or ignored. Furthermore it was agreed on that the home screen should be reached from all sections of the app through a button on the top area of the application.

As a next step the user flow of the achievement section was shown and the wireframes of that section presented. The idea of firstly having a list of achievement elements and that after clicking on an individual element a detailed view is opened was received positively. Here the interviewed said that unlocking the achievements is good but it should be possible to get a detailed description of what the user has to do to unlock that specific element. This can be done through clicking on it and opening a further view element. Also he said that achievements which already have been completed can go to the bottom of the achievement list, so that the user always sees the relevant achievements first. Another thing which was discussed and brought up by the interviewed is that instead of achievements there could also be challenges. In the discussion it was concluded that challenges are actively started by the user whereas achievements are collected automatically when certain goals are met. Moreover an example achievement being "Complete your workout regiment for two weeks" was looked at and discussed what should be displayed.

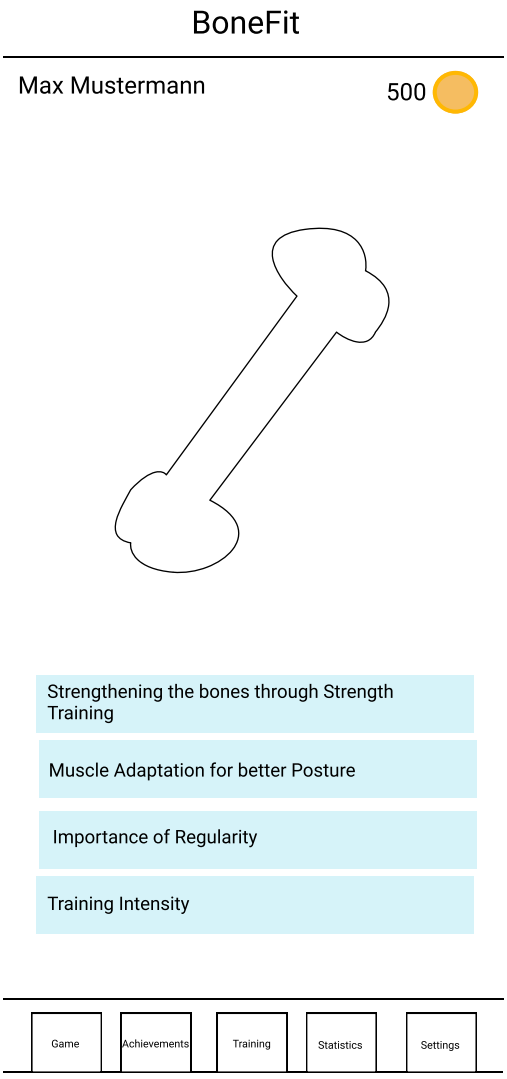


Figure 4.27: Wireframe of Home Screen Redesigned after the Interview

It was made clear by the participant of the interview that in a detailed view of the achievement while still not fully completed the task there should be a display of the progress of the user, so for instance in the example achievement from above, the last 14 days should be shown to the user and how often the user has performed a strength training session.

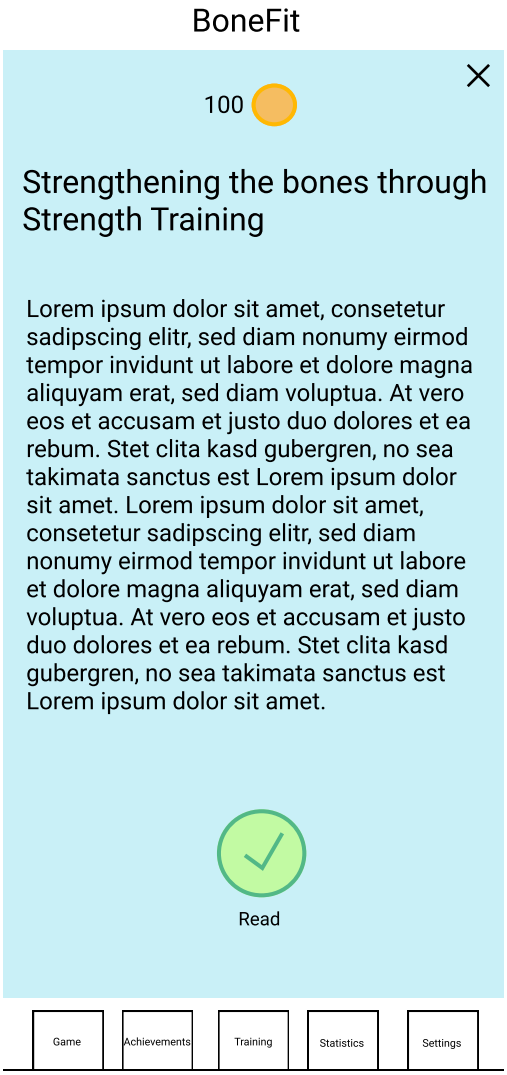


Figure 4.28: Wireframe of Prevention Note

Furthermore the training section was presented by showing the user flow and the wireframes to visualize the idea behind it. The participant saw the idea of assessing the training intensity through adherence to setting certain pause goals positively. Also the idea of giving points based on the adherence to the goal pause was positively received.

Here the interviewed made clear that it should also be important that the user should also receive less points if the user does less pause duration as intended. Additionally it was mentioned that a senseful grading of points to the discrepancy from aimed pause length has to be found and from a certain time discrepancy no intensity points should be given. When presenting the interviewed the training preparation screen from figure 4.20 the importance of registering the number of sets the user will perform was clarified. The idea that the sets are important to guide the user through the training when recording the pauses in an interactive manner was understood by the interviewed and seen positively.

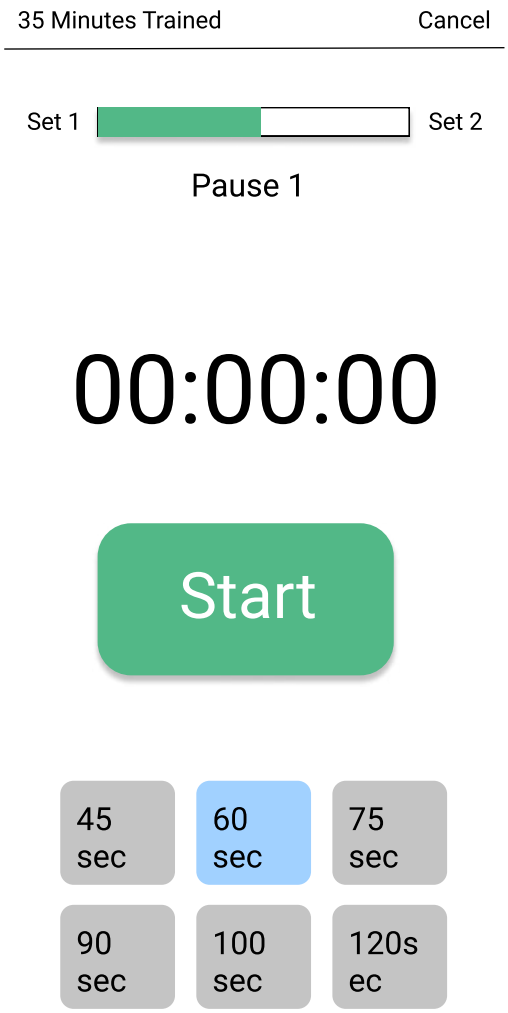


Figure 4.29: Wireframe of Training Timer Screen Redesigned after the Interview

Moreover the interview participant mentioned further improvements in the user interface of the training timer screen for instance that in a training view the navigation bar element on the bottom is not necessary to be shown and just takes away space and attention from the main task. It should further be possible to cancel the training if wanted by the user on top of the screen which takes the user back to the home screen. In that case the training session is canceled and the user does not receive any collected points. Also an other way to set the goal pause length than through a dropdown was mentioned due to a dropdown being more user-interactions before reaching the desired outcome of setting the targeted pause length. He mentioned there could simply be a number of button elements preset with pause duration values which can be set by the user in the settings otherwise those buttons can be set with default values. It was asked by the interviewed if the duration of the training displayed on the top includes the pauses, which it was intended to do so. Therefore maybe that should be made more clearly to the user. The gathered information from the discussion was realized in a wireframe shown in figure 4.29.

Further in the discussion the question of the possibility to use a different button than on the screen of the phone to start and stop the timer was raised by the interviewed. In the discussion this was seen as potentially difficult to implement due to accessibility reasons and only having a small amount of buttons in modern smartphones. Here it has to be examined if the smartphone allows for this possibilty without any side-effects. After finishing the training, the training results screen from figure 4.22 was shown which was seen positively and the interview participant liked the display of the users score and coins which the user earned from the training session.

Afterwards in the statistics section, presented as a wireframe from figure 4.23, it was examined which information should be displayed to the user and in which form. The frequency of training was seen as important to show to the user. However the interviewed pointed out that a graph is not the best way to show this information in his opinion. He said for weight loss for instance a graph is helpful but for the frequency it is not fitting. Here his idea was to introduce rectangular boxes which represent the times the user set the goal to perform strength training per time intervall. A sketch of the idea is seen in figure 4.30. So for instance if the goal is to perform strength training three times a week, then there should be three boxes which should be filled up with the days the user performed strength training. If the user did not perform strength training three times in the last seven days, but for instance two times, then only two boxes are marked as fulfilled for instance in green color and one box is marked as unfulfilled for instance in red color. Hereby it was also seen as better to display the statistics of the last seven days and not by defintion weeks so that there are no misunderstandings of when the weeks begin and when they end.

Additionally the area for displaying statistics about the assessment of intensity of the training sessions was seen as important to give the user an overview of the users progress. Here it should be possible to look at the statistics for the assessment of training intensity by the number of previous workouts performed.

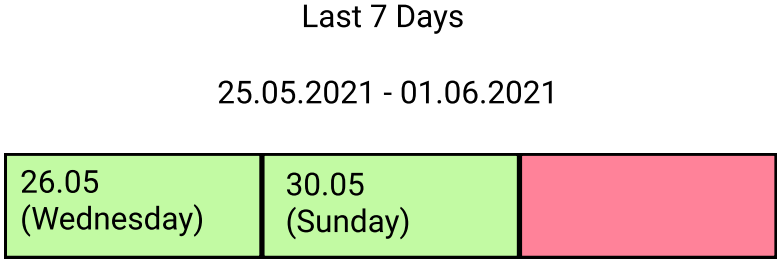


Figure 4.30: Idea to visualize Training Frequency

Subsequently the settings section was examined where the wireframe displayed in figure 4.24 was presented and the interview participant gave his opinion which settings are important for the application. At first the general settings for instance name and age were seen as nice to have to give the user some personal information to enter but for example it was discussed if the weight of the user should be entered into the app. It was concluded that the weight of the user should not be entered because the application is not aimed at weight tracking or weight loss. Then it was examined how the user should enter the frequency in which the user performs strength training. Here the result of the discussion was that the user should enter the times per week that the user aims at performing strength training and does not have to provide information on which days in the week the user does strength training to keep the settings as simple as possible. When evaluating if the goal of training frequency has been met, the logic should be implemented in a manner that it will evaluate the last seven days and does not care on which specific days the user set the training sessions to be performed. This gives the user flexibility throughout the week to adjust the days to adhere to their training frequency goal. Furthermore it was seen as important to allow for setting more than one predefined default pause length. As concluded in the discussion about the training section, there should be up to six box elements where different pause lengths are predefined to make the handling of switching pause lengths during training if necessary easier. In the settings it should be possible to set these box elements and also adjust how many of these box elements should be shown for instance only one box element or up to six box elements.

Lastly the two game ideas for the prototype based on the requirements displayed in table 4.3, were presented to the interviewed by showing the wireframe displayed in figure 4.25

and figure 4.26. The second game idea (G2) was appealing to the interviewed and was prefered to the game idea one (G1). It was agreed that the second game idea (G2) is more engaging because of the contionous flow through items coming towards the avatar and therefore also seems more dynamic. Also the game handling seems to be more simple and intuitive by swiping the bone avatar from left to right and right to left. The steering of the bone avatar in game idea one (G1) through tapping on the arrows was not received that well by the interviewed because the handling of the avatar seemed to be unnecessarily more complex. Therefore the game idea two (G2) was looked at and the idea was developed further in the discussion. The results of the discussion were noted and after the interview the wireframe was redesigned and can be seen in figure 4.31.

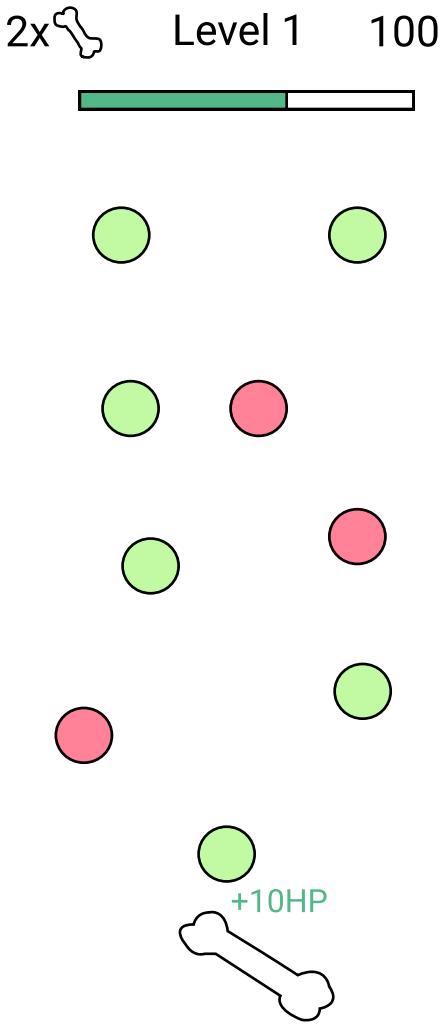


Figure 4.31: Wireframe of Gameplay of chosen Game Idea

The idea of having to collect certain items coming towards the avatar was seen as a good idea and also that there are certain objects the user has to avoid otherwise the user gets negative points. The interview participant said that a display of the time is not necessary and a highscore is enough because the highscore increases with time anyway and the display of time does not give further benefits. The idea is to make it through the levels which have a certain duration so there is no competition of the user completing a level in a faster time period. Furthermore the idea of the avatar having a certain health bar that declines with time was seen as a good idea and the interview participant further added that this health bar can also dynamically swing back and forth through beneficial items giving extra health points and the bar gets fuller whereas touching bad items leads to subtraction of health points and the health bar getting emptier. The game is over when the health bar of the avatar is completely empty. The idea of the health bar symbolizing the health of the bone and the decline of health bar representing the atrophy of bone was seen as a good analogy taking up the theme of prevention regarding biomechanics. It was concluded that the game should be a level based system where there has to be some kind of uptake in difficulty as time goes on and as higher the levels become. Here it was thought about making the approaching of items towards the avatar faster and also the constellation of beneficial and bad items to be be manipulated so that there are more bad items and less of the beneficial items.

Afterwards it was discussed how the benefits for the game through the collection of virtual coins in the training section and from the prevention notes in the application should be implemented. First of all a certain amount of coins should give the user the possibility to continue the level despite the health bar reaching zero which would lead the game to be over. So the possibility to have more avatar lives through trading in a certain amount of coins should be made possible. A further benefit from the coins collected in the appication should be that there is the possibility to unlock certain avatars. In the discussion the interview participant stated that to keep the gameplay straightforward and clear to the user, playing with the different avatars should not result in certain abilities for instance higher speed in handling or smaller area of the avatar to be maneuvered through the items. The avatars should have the same area which interacts with the objects otherwise the gameplay can quickly become more complicated and it is not clear what is of an advantage. For instance the question came up, if a smaller avatar is advantageous or disadvantageous because it is easier to maneuver past bad items but it is also more difficult to collect beneficial items. There should be a section before starting the game where the user can observe which type of avatars can be unlocked and at which amount of coins they get unlocked. This feature can be displayed in a wireframe in figure 4.32. Furthermore this idea could be furthered by allowing to unlock also certain appearance modifications as different color features and different backgrounds. In conclusion it was agreed that the unlocking of different avatars can be a motivational factor to collect coins in the application.

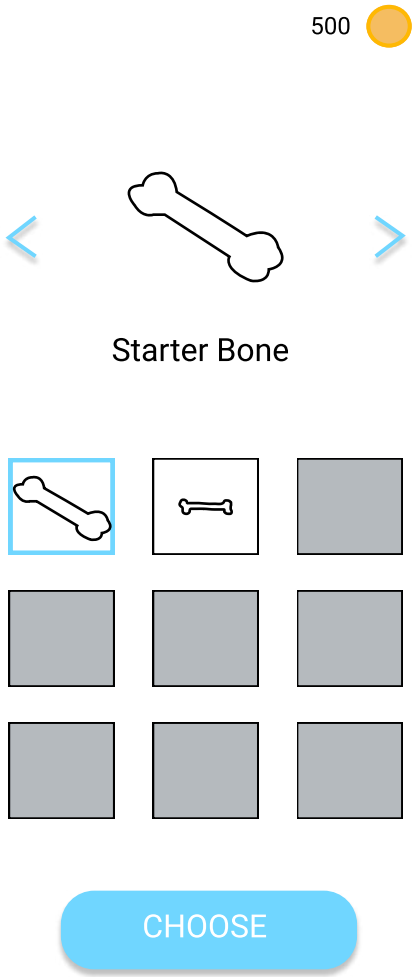


Figure 4.32: Wireframe of Unlocking Characters of chosen Game Idea

After the development of the game idea chosen and the feedback through the interview the requirements for the game from table 4.3 were revised and completed in the following table 4.4:

Id	Requirement	Source	Recency
GA1	Integrate the theme of biomechanics (f.eg. bones/muscles/strength training)	Own Idea	Prior
GA2	Points collected from training should result in some benefit in the game	Requirement List	Prior
GA3	Level-based system	Own Idea	Prior
GA4	Include score to be collected	Own Idea	Prior
GA5	Straightforward game mechanics	Own Idea	Prior
GA6	Easy steering of avatar	Interview	New
GA7	Ensuring difficulty increase with levels	Interview	New
GA8	Include highscore rather than timer	Interview	New
GA9	Include multiple avatar lives	Interview	New
GA10	Unlocking new characters only visual and no advantage making game easier	Interview	New

Table 4.4: Requirement List for Game after Interview

4.5 Iteration 5: High-fidelity Prototype

After the development of a low-fidelity prototype which sets the basic functionalities for the technical realisation of the mobile application, a high-fidelity prototype can be implemented.

4.5.1 Technical Architecture

As a technical device for the implementation of the prototype the mobile device Iphone from the company Apple was chosen. Therefore the iOS Software Developer Kit (iOS SDK) was used which is provided free of charge from Apple to download. The iOS SDK includes a range of tools which can be used for developing an application on the operation system iOS which is the operating system of the Iphone.

The iOS SDK supplies four abstraction layers which enable the application to access the device's hardware. The abstraction layers consist of Cocoa Touch, Media, Core Services and Core OS. The base layer consists of the Core OS layer which is the lowest-level layer that traversed by the other layers for accessing the hardware. On top of the Core OS layer, the Core Services layer gives access to certain features such as local storage of data with Core Data and SQLite. One layer above the Media layer provides application programming interfaces that are related to graphics, video and audio technologies. The highest-level of abstraction is the Cocoa Touch layer that provides the primary class libraries for the development. The Foundation Framework and the UIKit framework are among the most important libraries the Cocoa Touch layer provides. In the Foundation Framework a wide range of standard programming topics are addressed. Hereby lower-level C functions are wrapped with higherlevel Objective-C classes. The UIKit framework deals with the interface of the device and enables the developer to implement the user

interface. [Gru17] [BW11]. Furthermore Spritekit, which is a 2d game framework from Apple, was used to implement the game in the mobile app.

For the implementation of the high-fidelity prototype the Integrated Development Environment (IDE) Xcode was used and the implementation was done in the programming language Swift. During development to test the app, on the one hand the simulator which is built into Xcode was used, but mainly a physical device, namely the iPhone 12 was used.

4.5.2 Implementation

In the following section the prototype is presented by the individual features divided into sections. Furthermore the implementations of the requirements relevant to the individual features are described. The navigation throughout the app is realized through a tab bar where the user can click and is brought to the specific page.

Setting of Training Frequency Target

When the users starts the app for the first time, the training frequency screen, which is displayed in figure 4.33, is shown and they are asked to input the amount of training sessions they would like to perform per week as a target for the next four weeks. This then represents the frequency goal, which provides one of the criteria for the success of the user in the app. This provides important information about training goals for the implementation of requirement R2 (Specification of Training Goals Which The User Can Achieve). Furthermore the setting of the frequency goal is important for the implementation of requirement R13 (Evaluation and Display of Results (Tracking Progress)).

If the user needs more information or assistance in deciding how often to train per week, they can click on a button titled "Show Information" and be provided with information and recommendations on a new page. After deciding on a frequency target, the user can click on the save button and is taken to the app's home screen. At the end of the four weeks, after opening the app the user is asked again to input the training frequency target for the next four weeks.

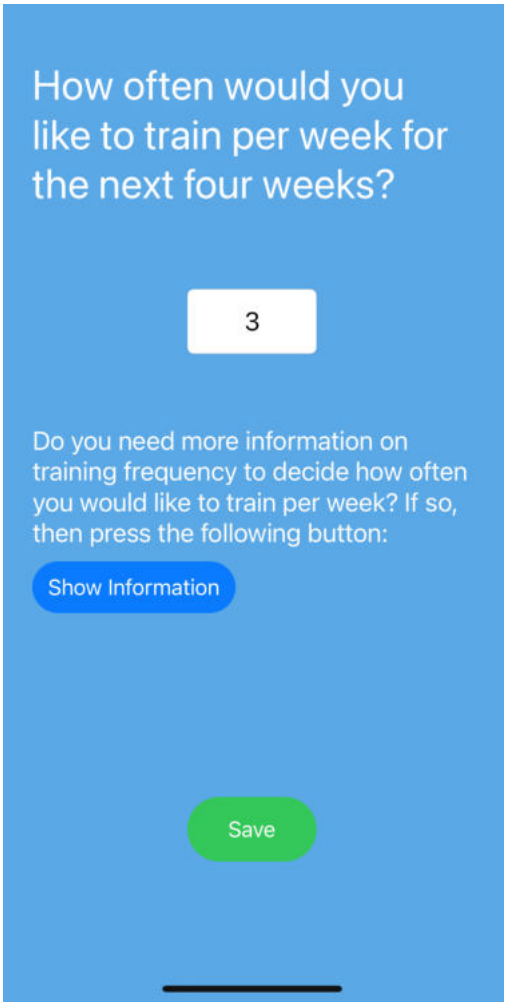


Figure 4.33: Training Frequency Setting

Home Screen / Prevention Notes

The home screen, displayed in figure 4.34 on the left side, serves as the starting point of the app, where the user is taken to after opening the app or, in case of opening the app for the first time, after setting the training frequency target.

On the home page, at the top of the screen, there is a navigation bar displaying a number and an image of a coin. This number indicates how many in-game coins named "BoneFit-Coins" the user has been able to collect thus far. There are several ways to collect coins, all of which are described in this chapter. The main way is to follow the training targets regarding frequency and pauses between training sets, which are explained in detail in the subchapter dealing with the training section of the app.

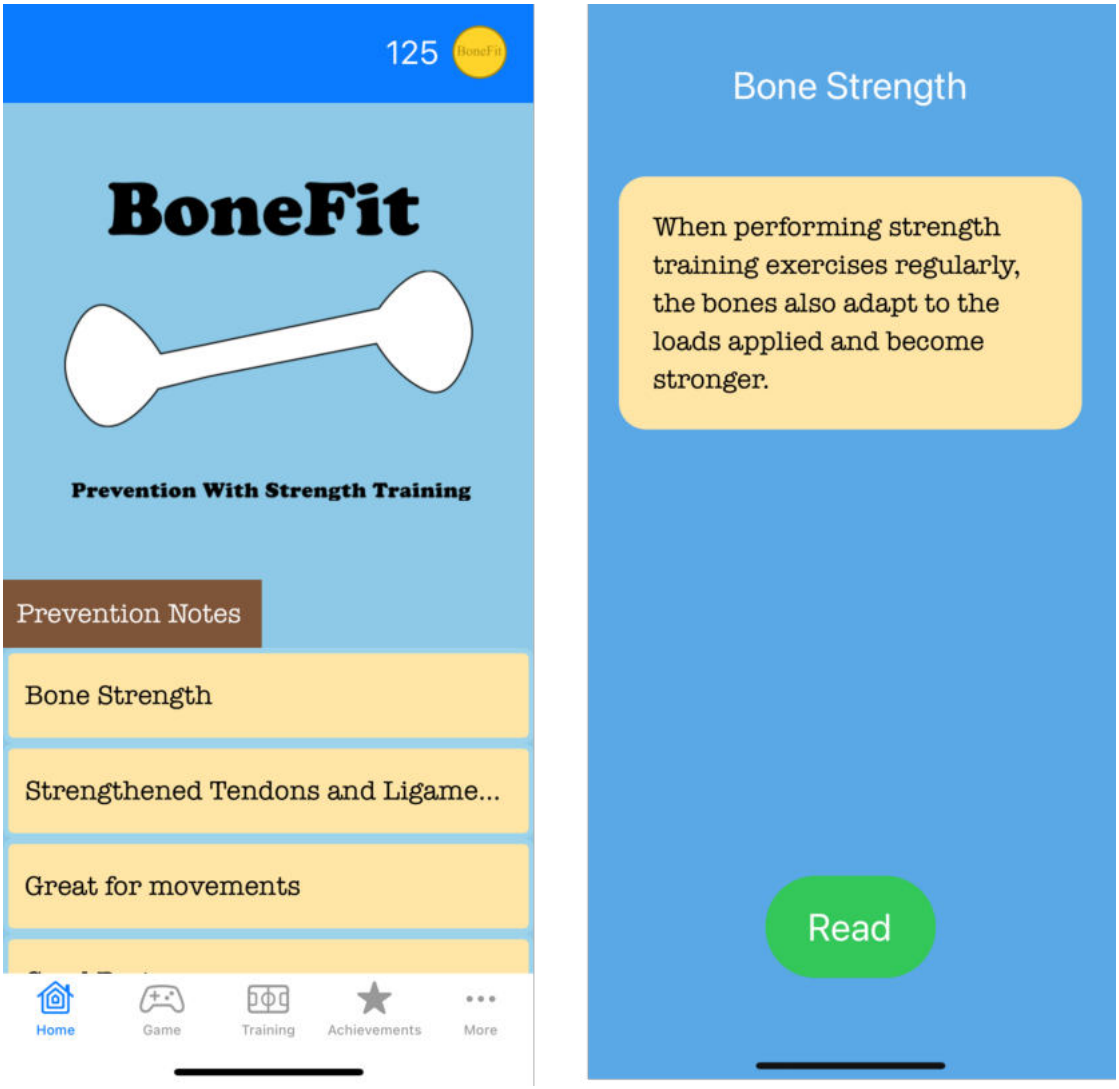


Figure 4.34: Home Screen (on the left) and prevention note details (on the right)

Another way to collect in-game coins is to read prevention notes. These can be seen on the home screen under the area where the BoneFit image is displayed. The prevention notes are displayed on a rectangular element in a list, with the the title of the individual prevention note. Prevention notes are a way to educate the user about the preventative effects on strenght training.

This feature represents the realization of the highly prioritized requirements R1 (Illustrate Health Benefits of Strength Training) and R3 (Raise Awareness about Prevention, Especially Regarding Othopedic Diseases). Furthermore the prevention notes feature should aim at motivating the user to perform strength training through conveying the health benefits in a gamified manner. Thus this provides a key aspect of the app to

help the user to achieve the targeted training frequency and increase how often the user performs strength training, which is described in the first research question of the thesis.

When the user clicks on the rectangular element, a new page opens, displayed on the right side in figure 4.34, where more detailed information about the selected preventive effect of strength training is displayed. Below this information element is a button with the title "Read", which, when clicked, symbolizes that the information has been read by the user. The user is then credited with 25 BoneFit-Coins and returned to the home screen.

The prevention notes can be read at any time as they accumulate in a list. Each day the user logs in, two new prevention notes are added to the list, which are thus ready for reading. If all of the prevention notes have been read from the list, the user will be informed that there are no more notes available for the day.

Game

When the user selects the Game-tab, the user gets taken to a screen, displayed in figure 4.35, where an avatar for the game can be chosen before the game is started. The avatar is displayed in a rectangular view with the name underneath. By pressing the arrow buttons, the user can look at the several avatars which can be chosen from. Hereby avatars which have not been unlocked yet are displayed with an overlay and a text "Not Unlocked Yet" appears on the screen instead of a button titled "Start Game".

To unlock a avatar the user can press the "Exchange Coins" Button which takes the user to a new screen where all the available avatars are shown. If the user selects an avatar, the price to unlock it is shown and the user can acquire that avatar if the user has enough coins. After the user has acquired an avatar, the user gets taken back to the game overview screen and can now choose the acquired avatar for the game. Consequently the user is rewarded for their training achievements and for reading prevention notes with an in-game reward. Hence this ability to exchange BoneFit-Coins with unlocking of avatars is an implementation of requirement R10 (Including Gamified Elements) and also more specifically requirement GA2 (Points collected from training should result in some benefit in the game).

These avatars are visually different from eachother but do not have different abilities so the gameplay does not change when using other avatars. The difficulty of the game therefore remains the same. This corresponds to the implementation of requirement GA10 (Unlocking new characters only visual and no advantage making game easier).

On the upper left corner there is furthermore a button titled "About" located, which takes the user to another screen where the basics of the game are explained. After the user has chosen an avatar and is ready, the user can press the start button and the game begins.

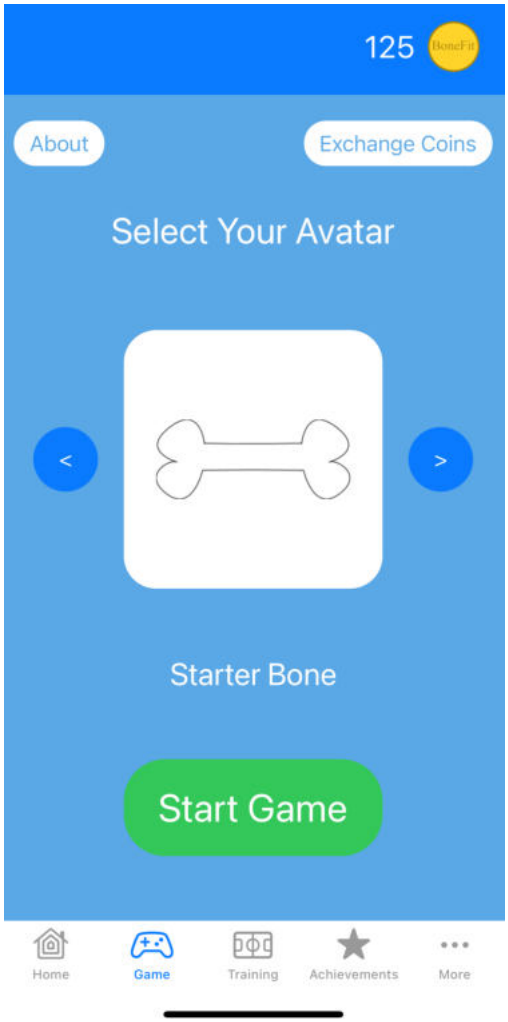


Figure 4.35: Game Overview Screen

The game mechanics consist of the user maneuvering the chosen avatar from left to right and vice versa by a swiping gesture on the touch screen. A display of the gameplay can be observed in figure 4.36. The game mechanics presents a simple handling of the avatar and is a realization of requirement GA6 (Easy steering of avatar). In the upper left corner there is a colored bar located that shows the strength of the avatar. The strength of the avatar declines automatically as time passes, which should symbolize the decline of strength in biomechanical tissues with time if being not active. However the player has to possibility to increase the avatars' strength by collecting training items coming towards the avatar. This should symbolize the importance of strength training for the strengthening of biomechanical tissues. On the other hand, various objects approach the avatar from above which in case of a collision decline the avatar's strength. The theme of biomechanics has been integrated as described and therefore requirement GA1 has been

fulfilled. The game is level-based, and a score increases steadily over time. Therefore requirement GA3 of a level-based system and GA4 to include a score to be collected have been realized. Likewise, at set intervals the level increases and with every level the difficulty of the game increases through the constellation of beneficial items and enemies, as well as the items and enemies approaching the avatar with a larger speed. In this way the requirement GA7 to ensure difficulty increase with levels has been realized. Thus, the goal of the game is to achieve the highest possible level before the strength bar is empty and the game is over. Moreover the described game mechanics was implemented with the idea of requirement GA5 to have straightforward game mechanics.

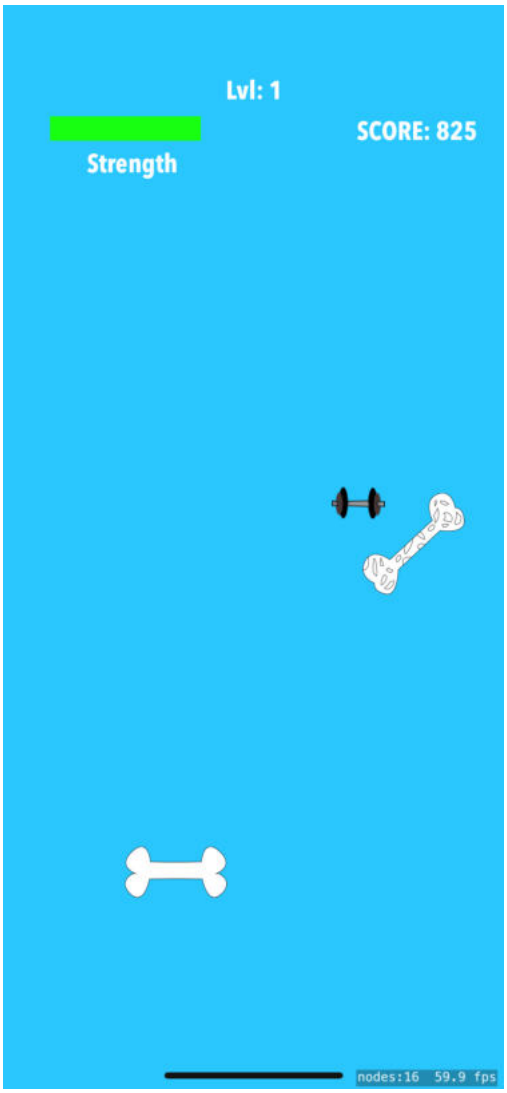


Figure 4.36: Game Screen

When the strength bar reaches zero and the user has enough BoneFit-Coins, the user

is asked if he wants to exchange 100 BoneFit-Coins to restore the full strength bar and to continue the game from the point the user left it. This gamification feature has also been added to reward the user for performing well in the strength training section as well as for reading prevention notes. This is therefore a realization of requirement R10 (Including Gamified Elements) and also the requirement for the game to include multiple avatar lives (GA9). If the user does not have enough BoneFit-Coins or does not want to use his BoneFit-Coins, the game is finished and the user is taken to a new screen. Here the achieved score gets displayed. Furthermore the user has three possibilites to chose from. The user can restart the game and try again from the beginning. Furthermore the user can exit the game and consequently gets taken back to the game overview screen. And the user can also press a button which takes him to a screen where the highscore consisting of the best achieved scores are displayed. Therefore requirement GA8 to include a highscore rather than an a timer has been implemented.

Training Settings

Before using the application for performing a training session, the user has to make a few settings. These settings are made in the Training Preparation Screen, which is displayed in figure 4.37. There is the possibility to select an already created workout by the user or add a new one and then select that one. When the user presses the button titled "Add", the user will be redirected to a new screen where a new workout plan can be created. First of all, the user has to define a name for the workout in a text field at the top of the screen. After that it is possible to add exercises by pressing a button with a plus-symbol. Here the user has to specify three things: the name of the exercise, the number of sets, and the targeted length of the pauses between the sets. The setting of the targeted pause lengths is crucial for the requirement R2 to specify training goals that the user can achieve, because in the training section this data will be used as a measure for the pause evaluation.

When creating the exercises, the user must pay attention to the order in which the exercises are created because the exercises will appear in that order during the training session in the app. After all exercises, which the user would like to have in his workout, have been created, pressing the save button will take the user back to the Training Preparation Screen where the created training session appears in the list of training sessions which can be selected. It is furthermore possible to edit and also delete a training session from the list. There is also a possibility to view the training history of the last performed training session by pressing on a button titled "View". Then a screen opens where each set of exercises of the selected training session are listed with the performed number of repetitions and the used weight in the previous workout. Hereby it is necessary that the user has documented the repetitions and weight in the previous workout.

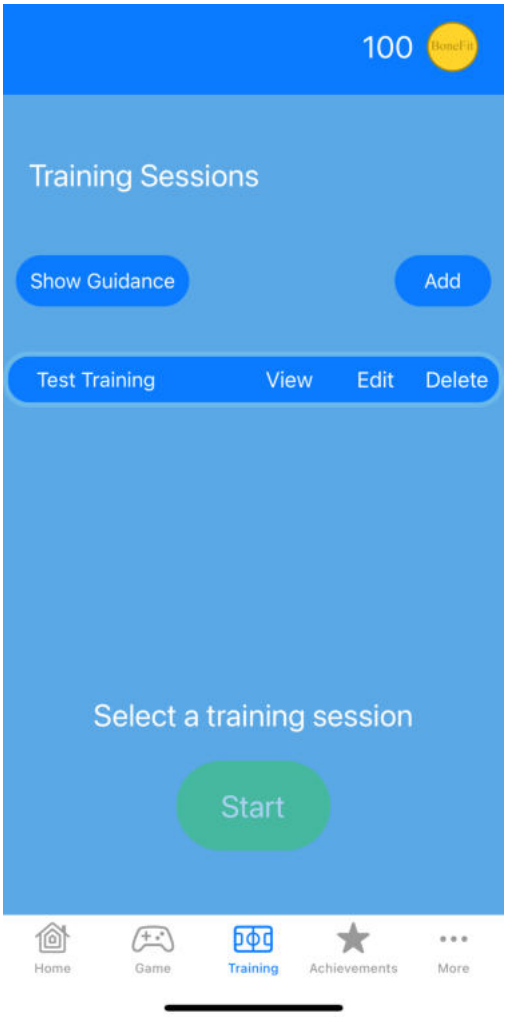


Figure 4.37: Training Preparation Screen

In the training preparation section there is also a button titled "Show Guidance", which leads the user to another screen, which is displayed in figure 4.38.

Here it is explained that the performance is displayed to the user in the training section of the app by means of a colored evaluation icon in the colors green and red. Green corresponds to the best rating whereas red to the worst rating. Additionally it is explained that the rating is based on the length of the pauses taken and on the adherence to the pause lengths predefined by the user.

If the user wants more information about the evaluation criteria and why these two factors are considered important for the benefit of the training, the user can press the two buttons at the bottom of the screen.

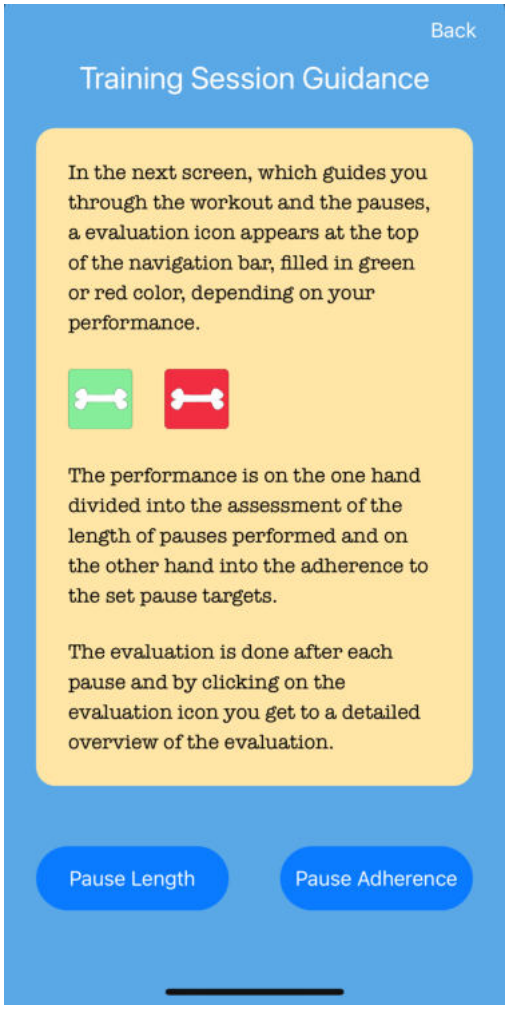


Figure 4.38: Training Session Guidance

In the explanation screen for the pause lengths, the user is presented with the connection between pause length and training intensity. On the one hand, a minimum length should be adhered to, so that the muscles can regenerate enough to be able to apply the full training intensity to the next set. On the other hand, a certain pause length should not be exceeded, so that the user does not lose focus on the training and the training session does not drag on unnecessarily, which can affect the applied intensity. A recommendation is given that the pause should be held between one minute up until five minutes. Here, for isolation exercises where not many muscles are involved, such as a biceps curl, the users should orient themselves on the lower end of the recommendation. For compound exercises where a lot of muscles are involved, such as a squat, the users should orient themselves more on the middle range or upper end of the recommendation.

In the explanation screen for the adherence to the predefined pause lengths, the user is

introduced to the fact that for the success of strength training and the accompanying health benefits it is necessary to adjust the loads on the muscles over time to maintain a high training intensity. That is the reason why tracking the weights, repetitions and sets is important. Another important variable is the rest period between sets, where the adherence to defined pause lengths can support the overall progress and favor the intensity to be applied in a given set. On the one hand, it makes you responsible to keep a time frame and not lose focus, and on the other hand, keeping this time frame makes it easier to compare the other variables such as weights and repetitions over the training sessions. A recommendation was given of keeping the held pauses within +- 15 second of the pause target length.

Training

After the user has selected a training session and pressed the start button, the user is be redirected to the training section and therefore the training screen, which is displayed in figure 4.39. In the training section, the goal is to guide the user through the pauses between sets and provide an evaluation of performance based on the held pause length and the adherence to the set pause length target. This should make the user accountable to track the rest periods between sets and aim at reducing time wasted between exercise sets, which should provide a solution to realize the requirement R4 to optimize the duration of training session. Furthermore this should aim at improving the focus of the user put on the training, which was elicitated in requirement R5 to improve the focus on training. In this implemented training feature, presented in this chapter, the research question if the training sessions can be made more time efficient is dealt with and tried to be achieved.

At the top of the screen a navigation bar can be found. There the duration of the training session is displayed, as well as the evaluation of the user's performance by a color-coded evaluation icon. In addition, there is an exit button to cancel the training session and switch back to the training session. No data of an unfinished training session is saved.

Below the navigation bar it is shown which pause is held next if the start button has not been pressed yet or which pause is being held at that moment if recording has already started. On the left side the number of the set before the pause is displayed, whereas on the right side the number of the set coming after the pause is shown. Underneath these labels, a progress bar has been implemented, which visualizes the expiration of the time to adhere to the predefined pause length.

Beneath the previous set label and the progress bar, the name of the exercise from the previous set and the noted number of repetitions and weight are displayed. Here it is possible to note the completed number of repetitions and weight in the previous set, while waiting in the pause for the next set. This possibility of documentation is an implementation of requirement R12 (Ability for Documentation of Training, Especially Pauses). When starting the timer for the pause with the large button titled "Start", an edit button appears next to the number of repetitions and weight. The user can press

the edit button to open a modal-window which lets him document the repetions and weight. These entered values are saved in the training history and can be viewed after the workout in the training preparation screen. On the right side, under the label of the next set and the progress bar, the name of the exercise of the upcoming set, as well as the values for number of repetitions and weight, which were saved in the previous workout, are displayed. So the user was given a way to use the time during his rest periods and track the two training variables of number of repetitions and weight. For the progress of the training, the tracking of those training variables is enormously important. By adaptation of the muscles to the loads, it is necessary to increase the loads over time in order to maintain a high intensity and provide stimuli to the muscles.

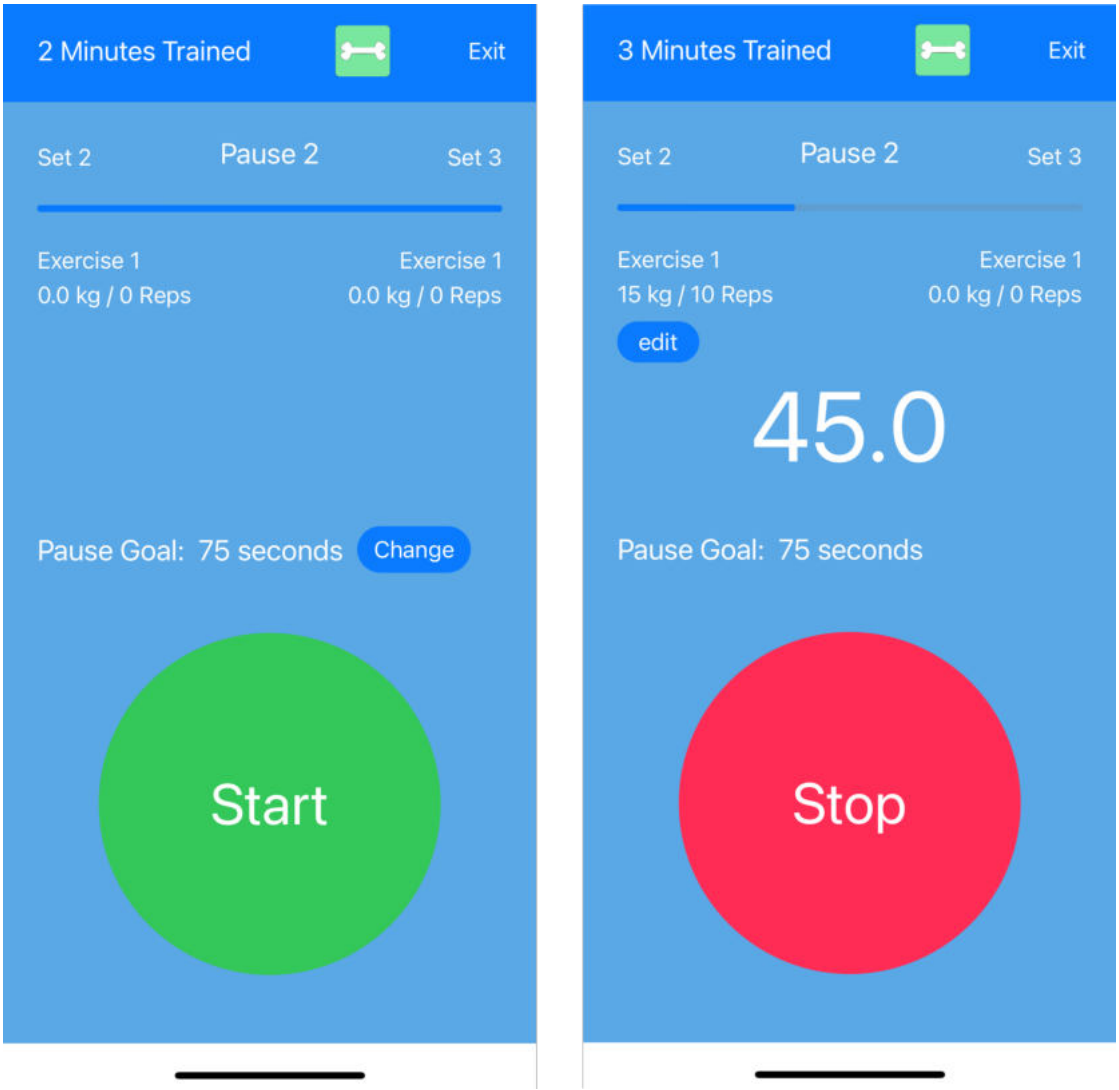


Figure 4.39: Training Screen

Figure 4.40: Training Evaluation

The recording of the rest periods was implemented by a timer that can be controlled via a large button. As a result the requirement R6 to include tracking of time (timer-element) has been implemented. The user presses the button appearing in green and titled "Start" to start the pause, meaning after a set of an exercise has been performed. The timer appears on the screen and starts counting. At the same time the button has turned red and the title has changed to "Stop". Above the button the pause length target is displayed, which was set by the user when creating the training session. When the user is done with the pause, the user presses the button and can start the next training set.

At the same time, an evaluation of the held pause is made and presented to the user by the color-coded evaluation icon in the navigation bar. This direct feedback after a pause should motivate the user to adhere to predefined pauses. Therefore this evaluation feature fulfills requirement R7 of a motivational concept and furthermore requirement R13 to evaluate and display results (tracking progress). Additionally the evaluation

feature also can be viewed as a gamification feature which adds to the implementations of requirement R10 of including gamified elements throughout the application. Connected to that, the gamification feature aims at increasing the enjoyment of the user to perform strength training, which should present a realisation of requirement R9 to increase the fun factor of strength training.

If the user wants to read more about the evaluation, the icon can be pressed which then opens a new screen, displayed in figure 4.40. The evaluation contains a short evaluation and an explanation why it is important to adhere to the given recommendations. Afterwards the recommendation gets displayed. This happens for the held pause length and for the discrepancy betweend held pause length and set pause length target. In the navigation bar the evaluation icon appears with a green icon if both of these evaluation criteria are met according to the recommendations, otherwise it appears with a red icon.

The app was designed so that no pauses are recorded between an exercise change. Instead, the button displays the title "Ready" and a text explaining, that the user should press the button when the user has finished setting up the next exercise, is presented above the button. When changing exercises, it can be difficult to maintain a pause length, as the duration of setting up the next exercise can vary depending on the weight or, for instance time spent searching for a certain equipment. Furthermore it can happen that if training in a fitness center, the equipment or machine is occupied for a while and the user has to wait.

Another feature that has been added is that during the training you have the possibility to change the predefined pause length target for the performed training session. This can only be done for the upcoming pause, if the start button hasn't been pressed yet. For the change a button titled "Change" next to the pause goal appears and has to be pressed. This feature was added for flexibility. For example, the user may notice that he is more fatigued than usual that day and needs to increase the length of the pauses accordingly.

Finally, when the last set of the training session has been performed, the title "Finished" appears on the large control button and a text is presented to the user that the user can still document the last set before finishing the training. In addition to that, the user can view the evaluation of the last set by pressing the evaluation icon. When the user is ready, the button titled "Finish" should be pressed, which takes the user to a training results page.

Training Results

In the training results screen, the evaluation of the entire training is completed and a score is calculated. This score system should provide a realization of requirement R13 to evaluate and display results (tracking progress), as well as motivate the user, an implementation of requirement R7 (Motivational Concept), and increase the fun factor of strength training, an implementation of requirement R9. The score is calculated from the length of the held pauses, the adherence to the predefined pause lengths, as well as the training frequency. Hereby the points related to the pauses are evaluated after every pause and at the end of the training session the average of the achieved points for the pause length and adherence to the predefined pause lengths are given to the user. The point system is as the following:

- Keeping the held pause length between 1 to 5 minutes accounts to + 50 points
- Keeping the pauses +- 15 seconds within the pause length target accounts to + 50 points
- For accomplishing the training session, the user gets + 100 points
- If the user achieves a set training frequency target that was set between 2 to 5 times a week, the user gets an extra + 250 points
- If the user achieves a set training frequency target that was set to 1 or 6 times a week, the user gets an extra + 150 points

So the maximal score which can be achieved in a given training session is 450 points. Under the display of achieved points, there is a brief note with a benefit of performing strength training to additionally motivate the user. Finally, the user has to press a button titled "Collect", located at the bottom of the screen, to receive the earned points and get taken back to the training preparation screen. These points are then converted into BoneFit Coins and added to the user's account. This was implemented as a realization of requirement R10 to include gamified elements.

Achievements

In the app there is the possibility to unlock a number of achievements. These are displayed in the achievements screen, which is displayed in figure 4.41 on the left side, where the individual achievements are represented by images. These images are provided with a transparency if they have not yet been unlocked. However, if an achievement has been unlocked, this transparency is removed and the image is visible in its entirety.

These achievement elements should provide one further solution to requirement R2 (Specification of Training Goals Which The User Can Achieve). Also the achievement feature pursues a motivational concept to the user, which corresponds to requirement R7. Furthermore the achievement elements try to increase the fun factor of strength training

to the user, implementing requirement R9, and with that to include further gamified elements, which is an implementation of requirement R10.

The user has the possibility to press on an image of an individual achievement which then opens another screen, which is displayed in figure 4.41 on the right side, that provides detailed information about that achievement. In this view, the title of the achievement is displayed with a larger version of the image. Furthermore a detailed description of what needs to be achieved to unlock the achievement is presented underneath the image.

The following achievements can be unlocked in the app:

- The user accomplished adhereing to the training routine for one week
- The user accomplished adhereing to the training routine for four weeks
- The user accomplished adhereing to the training routine for twelve weeks
- The user received the highest evaluation in the pause length and pause adherence score in five training sessions in a row
- The user received the highest evaluation in the pause length and pause adherence score in ten training sessions in a row
- The user received the highest evaluation in the pause length and pause adherence score in fifteen training sessions in a row
- The user has read ten prevention notes
- The user has read all prevention notes once

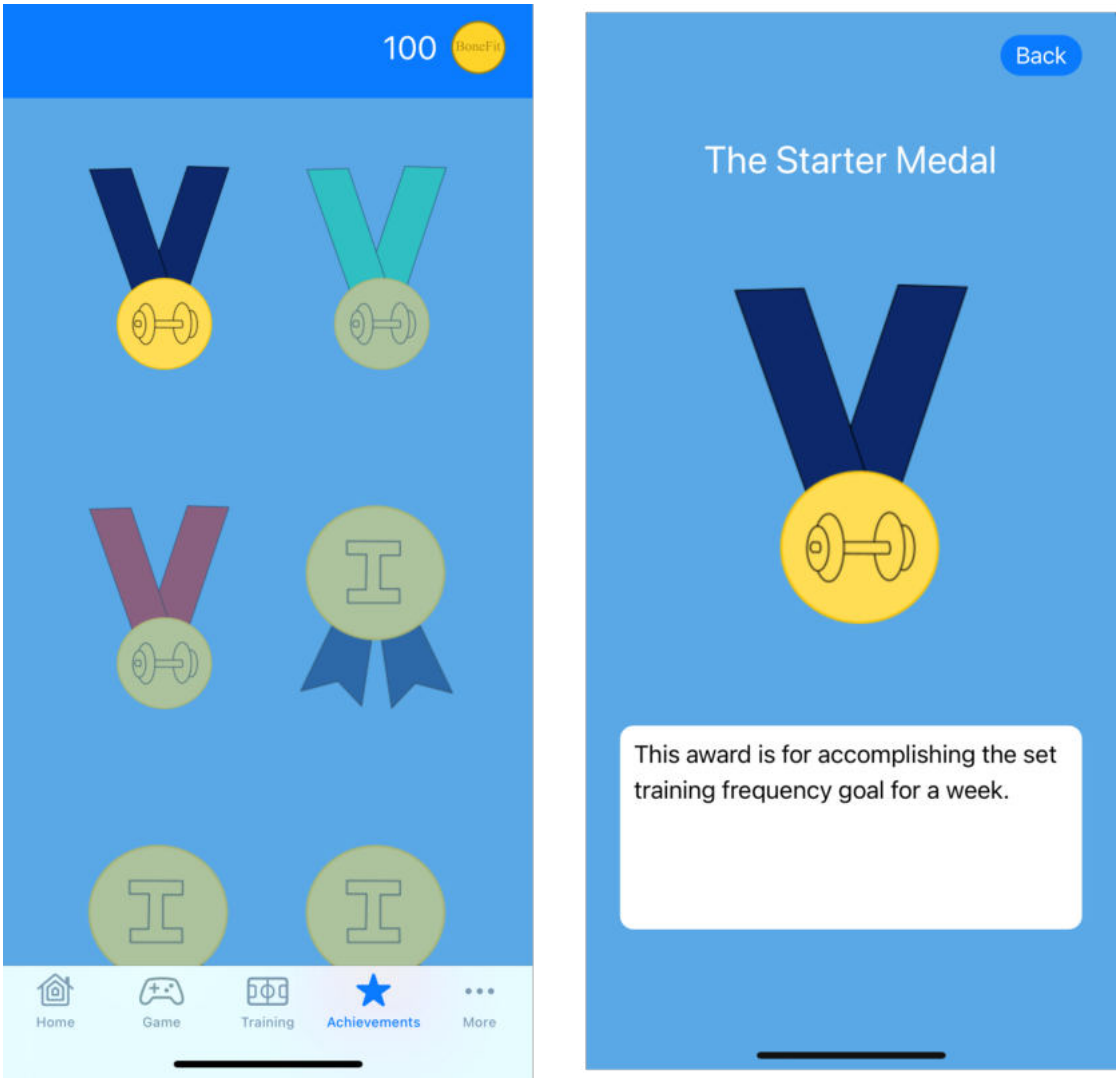


Figure 4.41: Achievements

Settings

In the app there is also a section where the user can adjust certain settings in a settings screen, which is displayed in figure 4.42. First of all, the user can change the username. This username is used to display the user's score in the game for the highscore table. Another useful setting possibility is to reset the user's training frequency goal. In principle, the app is designed so that the first time the user opens the app, the user is asked to input a target for the training frequency per week for the next four weeks. After those four weeks expire, the user is automatically asked, the first time the user opens the app since the expiration of the four weeks, to input a training frequency target for again four weeks. So generally every four weeks the user has the chance to adjust the frequency goal

without resetting any statistics. But in the settings the user can change the frequency goal at any time, although it is not recommended because the user should be motivated to build a routine and adhere to a set goal. A resetting of the frequency goal also affects all the statistics about the completed workouts which also get resetted. If the user decides to reset the frequency, a new screen will appear, reminding the user that this change will reset the statistics and the counting of the frequency would start from the current day. By pressing the button titled with "yes", the user gets taken to a new screen where the new training frequency goal can be set.

Furthermore, there is the possibility to turn the sound on or off. This applies to the reminder sound in the training section, where the user gets notified five seconds before the pause timer expires.

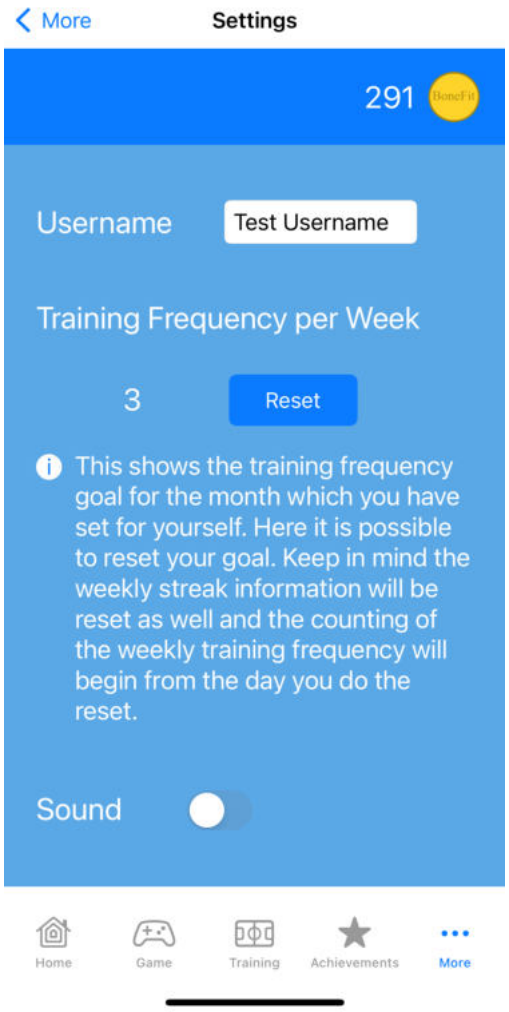


Figure 4.42: Settings Screen

Statistics

Statistics regarding the training can be viewed by the user in the statistics section of the app and the statistics screen is displayed in figure 4.43, where on the left side the top of the statistics screen is displayed and on the right side the statistics scrolled more towards the bottom of the screen are displayed. This allows the user to get an overview of the goals achieved so far and to monitor the progress over the course of the training sessions. This pursues a motivational concept, which corresponds to requirement R7. Moreover the achievement of specified training goals, defined in requirement R2, can be observed by the user in this section.

First, the progress towards reaching the target training frequency for the current week is visualized. Below the title "Weekly Training Frequency", the start date of the counting of the current week is displayed. Then a number of entry elements are generated, whereas one entry represents a training session. The number of generated entry elements depends on the number of days the user set to perform strength training in a week. Before a training session is completed in the current week, the elements appear with a red background and the placeholder text "DD.MM" representing a date. If the user has completed a training session, then the background of an element is changed from red to green and marked with the date, that training session has been done. The weekly training frequency statistic is hereby an important data point to evaluate the answer the first research question if the targeted training frequency could be achieved and thereby also if there was an increase in training frequency from the user through the implemented gamified application.

If the user needs an explanation of the individual statistics, next to the statistics title the user can press on a button titled "i", which opens up a screen where more information about the observed statistic can be found.

The next statistics is the average duration of a training session in the current week. This is an interesting statistic for the user to have an overview of the actual time spent in a training, which also can make the user accountable to not waste time. Therefore this statistic supports the implementation of the requirement R4 to optimize the duration of the training sessions and can also help to make the user aware of putting more focus on the training, which is a requirement elicitated in R5. Furthermore the user can identify and observe if the duration of a training session got reduced or increased over the course of training sessions. This data point is important to evaluate and answer the second research question if the training sessions can be made more time efficient through the use of the application.

Afterwards the weekly streak, of how many weeks in a row the user has adhered to the set frequency goal, is presented. This statistic is also used for unlocking certain achievements. The weekly streak is set back to zero, if the user misses out on adhereing to the set frequency target in a week or if the user resets the training frequency target, outside of the automatic update possibility after four weeks, in the settings. This statistic can be a great motivation to adhere to the training frequency goal, because otherwise the user

loses the progress in this statistic. Furthermore there is a section in the statistics titled "BoneFit Evaluation" which deals with the evaluation of the training sessions in terms of training frequency and evaluation of the pauses.

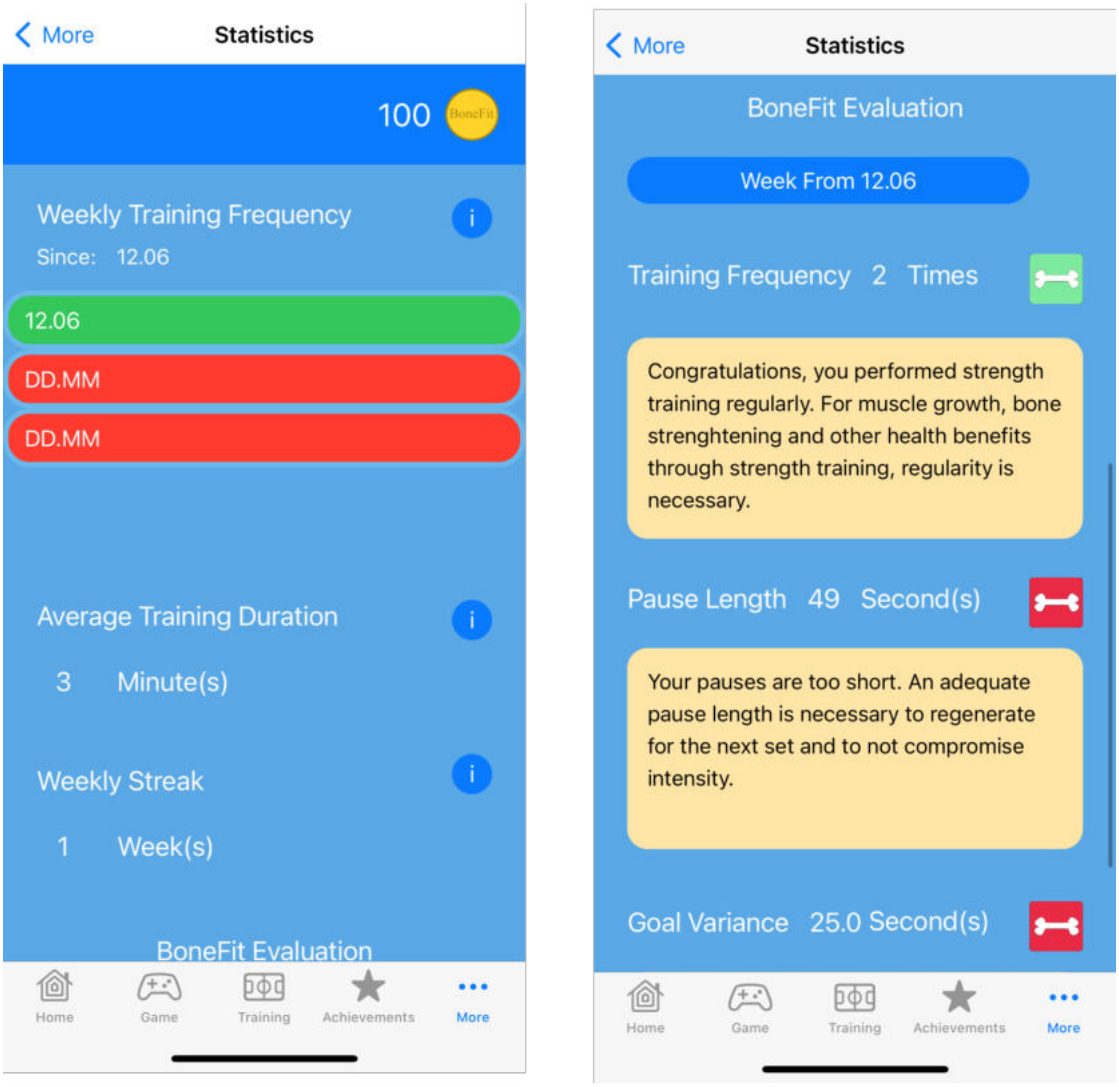


Figure 4.43: Statistics

Here the user can select a timeframe in which these statistics should be presented. Timeframe options are the latest workout, the current week, the week before or the month before the current evaluation week. This implements the requirement R13 of the evaluation and display of results (tracking progress). The three evaluation sections are presented with a calculated evaluation data next to the title. For the training frequency, this is the number of times the user performed strength training in the selected timeframe. For the pause length, the average time of the held pauses in the selected timeframe is

calculated. Similarly for the pause goal variance, the average discrepancy of time between set pause target and held pause length over the course of the selected time frame is calculated. Next to the calculated evaluation, the evaluation icon is displayed based on the recommendations for the individual statistics. Additionally underneath that in a rectangular evaluation box, a short evaluation text is presented to the user. Through the feedback in the individual statistics with the evaluation icon and the evaluation text the user can be encouraged to get a positive evaluation and hereby also requirement R7 of a motivational concept is implemented.

4.6 Iteration 6: Evaluation

In a further iteration the high-fidelity prototype was given to a number of people from the target group for testing. In particular the particpants were selected in a wide range in the age group of the defined target group, the youngest participant being 20 years old and the oldest participant being 34 years old at the time of the evaluation testing.

Furthermore a wide range of training experience was selected, from beginner levels, with 1 year of training experience, over intermediate training levels, with 4 years of training experience to more advanced lifters with 7 or 8 years of training experience.

An overview of the users is given in the following table 4.5, where the gender, age, training experience and in which iteration steps the test users participated in, are displayed.

Id	Gender	Age	Training Experience	Participant of Iteration Steps
T1	Male	20	1 year	Iteration 6
T2	Male	29	7 years	Iteration 2, Iteration 4, Iteration 6
T3	Male	30	8 years	Iteration 1, Iteration 2, Iteration 6
T4	Male	21	2 years	Iteration 6
T5	Male	34	4 years	Iteration 2, Iteration 6

Table 4.5: Test Users Overview

It was decided to involve users from previous iteration steps as well because of their expertise in strength training and further also software applications. Furthermore it was seen as valuable that they already were familar with the topic and could evaluate what evolved from previous iteration steps to the high-fidelity prototype. The selected testuser 2 participated in iteration 2 in the online survey and was involved in the interview regarding the development of a low-fidelity prototype in iteration 4. The selected testuser 3 was involved in the early stage of the development process when in iteration 1 an interview was conducted and ideas collected and also participated in iteration 2 in the online survey. Testuser 5 also participated in iteration 2 in the online survey.

The selected participants were given the task to test the whole application with all its features. The time frame for testing was set to one to two weeks with the aim to use the application for several training sessions. For users which had an iPhone device, a download link was sent out. For others which did not have an iPhone device, the author provided an iPhone 11 device for the time of testing.

After the users tested the app for the given time frame, each user was interviewed in a semi-structured interview and an evaluation of the high-fidelity prototype was developed. In the interview specifically the experience and results regarding the research questions of the thesis were given the most attention. However all the different sections and functionalities were gone through and the experience of the users noted. Hereby feedback was given and improvements suggested, not only regarding the functionalities itselves but also user experience aspects.

First, the participants were asked what weekly training frequency goal they chose and if they adhered to that goal or not. Furthermore it was asked which aspects of the application were the most motivational for them to adhere to the frequency goal. If the goal has not been achieved, the participants were asked to give the reasons behind that. Afterwards it was asked how often in a week the partcipants performed strength training two weeks before the use of the application to get comparison data.

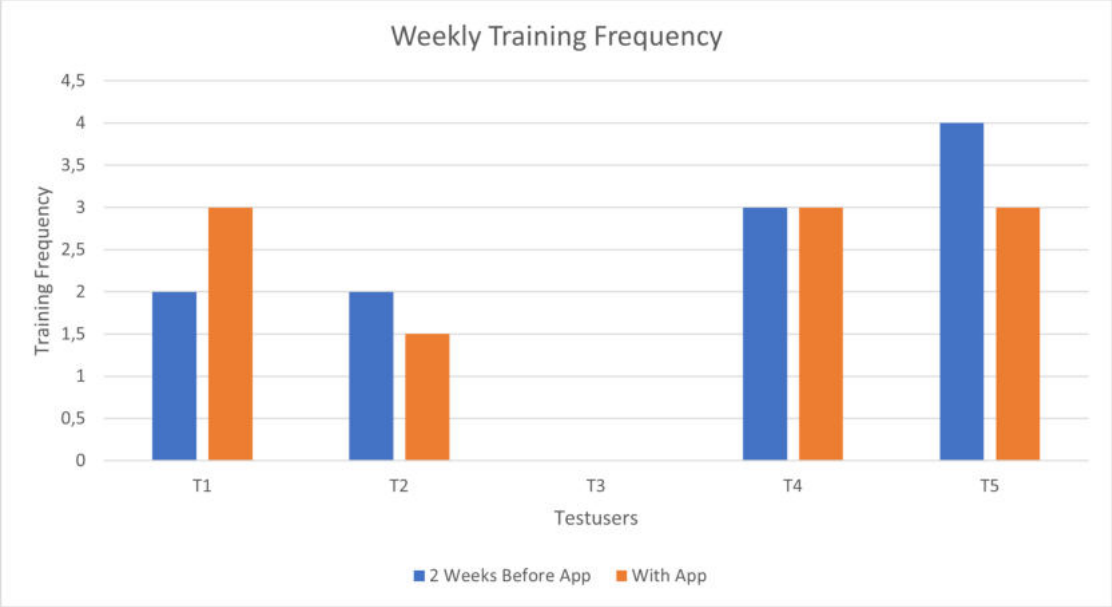


Figure 4.44: Weekly Frequency

In figure 4.44 the mean values of the training frequency per week the user performed 2 weeks before the app is displayed in blue, and the mean values of the training frequency with the use of the app are displayed in orange. Hereby depending on if the user tested the prototype for one or two weeks, in case of two weeks the mean values were calculated.

The participants had varied results when adhereing to their set target frequency goal and different aspects of the app motivated them.

Testuser 1 met his training frequency target. He mentioned that the statistics section of the application, in particular adhereing to the set goals and potential dissapointment of not achieving the weekly frequency target was seen as the most motivational aspect.

Testuser 2 met his frequency goal of three times in the first week using the app and in the second week he did not go to the gym. He mentioned that the reason for not adhereing to the frequency goal was that his week was really busy. In the weeks before he performed strength training twice a week, so also not as often as his targeted frequency goal. He mentioned that the most motivational factors in the app were having predefined workouts and the documentation of weights and repetitions of sets. Furthermore the

adherence to the pauses made his workouts really compact and shorter which was seen as a large motivational factor.

Testuser 3 used the training feature in the application only once in the testing timeframe and otherwise performed his strength training without the application. He elaborated that it was not clear to him that he had to adhere to a certain weekly frequency goal with usage of the training feature in the app to get benefits in the application. As a result the application did not have an impact on the training frequency for testuser 3, as he carried out his training regiment as before given the application. Therefore in the diagram there are no training frequency values displayed that make sense to be compared for testuser 3. Furthermore he mentioned that for him to use such an application he would need several improvements in the training feature. However if those improvements were made, he would see the main function of the application to track the training sessions as the most motivational to use the application. It must be said that T3 has a high level of expertise in strength training and is an advanced lifter.

Testuser 4 met his weekly frequency goal of training three times a week with the app, but also without the app in the weeks before. So there was no change in weekly training frequency with the app. However he mentioned that the most motivational aspect to train with the app was to reach a good outcome in the statistics section of the prototype. Furthermore collecting virtual coins was seen as another motivational aspect.

Testuser 5 did not meet his weekly frequency goal of four times a week strength training with the app. He exercised three times a week with the app, whereas in the week before he exercised four times a week. He mentioned that the most motivational aspect of the app for him to use it when performing his strength training routines, was the accomplishing of a good evaluation (green evaluation bone icon) and not a bad evaluation (red evaluation bone icon) in the training feature.

In summary it can be concluded, that the prototype did not lead to an increase in training frequency with the testusers and the adherence to a set training frequency goal did not improve with the use of the app. Therefore the research question Nr.1, if a gamified application, that raises awareness about the health benefits of strength training with regard to biomechanical aspects, can help to achieve a targeted training frequency and thereby increase how often the user performs strength training, has to be answered with, that the developed prototype could not lead to the adherence to a set training frequency and therefore did not raise the training frequency of the users. However there were a series of features that were motivational to the users to perform strength training, which should be examined.

The most motivational aspects which can be elaborated from the testusers answers of the most motivational aspects of the app, which are presented in table 4.6, revolved around the display of statistics around the accomplished training sessions, combined with also the ability to document the training session. Therefore as result it can be concluded that the focus of the attention of the users layed on the training feature and how well they performed.

Test User Id	Most motivational aspects of the app
T1	Statistics, adhering to set goals
T2	Documentation of predefined workouts, shorter workouts
T3	Tracking of training session
T4	Collecting virtual coins, statistics
T5	Getting a positive pause evaluation

Table 4.6: Most motivational aspects of the app for test users

The prototype met the requirement R7 of integrating a motivational concept, even if certain aspects implemented did not lead to the desired outcomes of motivating the user to perform strength training, other aspects did get acknowledged as motivational for the users.

Requirement R2 of specification of training goals which the user can achieve was implemented into the prototype by the user setting their goal of how often they would like to train per week and getting feedback about if they achieved the weekly training frequency. This was displayed in the statistics section and was seen as one of the most motivational aspect. An implementation of R2 was also reached through achievement elements, where certain goals around training were defined. However the unlocking of achievements was not seen as a major motivational aspect, but as a nice side feature.

Associated with R2 additionally requirement R13, the evaluation and display of results (tracking progress), was implemented and took a large role as a motivational aspect. This was implemented through the mentioned implementations of R2, but also through the evaluation of pauses through display of the bone icon with the added evaluation information in the training sessions which were then also displayed in the statistics section.

Another requirement which turned out to be greatly motivational for the users was the implementation of requirement R12 with the ability for documentation of training especially pauses. Hereby not only the documentation of pauses through the timer element was implemented, but also the possibility of documenting the performed repetitions and weight lifted in a given exercise set. This documentation was a further motivation to use the app because to make progress in strength training it is necessary to track the amount of weight lifted and the performed repetitions and if it is integrated into an app it makes the app further useful.

The two greatly prioritized requirements, requirement R1 to illustrate health benefits of strength training, and requirement R3 to raise awareness about prevention, especially regarding orthopedic diseases, were both mainly implemented through the feature with the prevention notes. Noticeable was that for the users prevention notes were not seen as a large motivational factor. Some partcipants mentioned that the information was already known. Also it was mentioned that the display of prevention notes as simple text was quite boring to read. Here it was said that maybe one could involve more

prevention statistics with precise numbers from studies, as well as display the information with support of diagrams or images. However overall the way of showing prevention information and health benefits of strength training through the gamification of collecting coins by reading prevention notes was seen as a good means to raise awareness about those topics. If the content was made more interesting and the display of information was improved, the implementation of requirements R1 and R3 could add further motivation to the user to perform strength training.

The game was generally seen as entertaining and simple to understand. The requirements GA5 of straightforward game mechanics and GA6 of easy steering of avatar was implemented into the game and were received as well implemented by the testusers. Also the implementation of requirement GA1 to integrate the theme of biomechanics (f.eg. bones/muscles/strength training) was seen as a nice concept by the testusers.

The including of gamified elements was successful through the game in combination with exchanging virtual coins, that could be collected through the training sessions or reading of prevention notes, for receiving benefits in the game. Therefore the requirement GA2 of points collected from training should result in some benefit in the game was fullfilled.

These benefits were the possibility to unlock new avatars which could be then selected to play with, as well as the possibility to exchange virtual coins for an additonal life after the user would have lost the game, which then allows the user to continue the game from where the game was left at. The requirement GA9 to include multiple avatar lives was therefore met in the implementation and seen as a good feature by the testusers. Furthermore the requirement GA10 of unlocking new characters only visual and no advantage making game easier was fullfilled in the implementation and was also seen by testusers as successfully implemented.

It was mentioned by most testusers that collecting virtual coins in the training session was moderately motivational to perform a training session with good performance. Hence this gamification feature was not seen as one of the major motivational factors to perform strength training. Hereby there were a variety of ideas of how this feature could be made more motivational.

Some participants mentioned the idea that they would have been more inclined to play the game if they could also collect virtual coins in the game itself, but maybe only unlock certain features with accomplishments from the peformance in training sessions.

Furthermore an idea was mentioned that maybe it would have been more motivational if there would have been a gamified element of a training level which could be increased through results from training sessions and would be independent from the in-game coins and the game.

The requirement GA3 of a level based system was implemented in form of increasing levels with set time intervals. Hereby a score is earned by the continous increase of score as time goes on until the game is over. Therefore the requirement GA4 to include score to be collected was successfully integrated into the game. Also the requirement GA7 of

ensuring difficulty increase with levels was implemented by adjusting the amount and types of enemies the player has to avoid and also the amount of beneficial items becoming more sparse with the level increases.

The level-based system and continuous increase of score with increasing levels were seen positively by the testusers and as great game concepts for making the game entertaining. Thus it can be concluded that the requirements GA3 and GA4 were well implemented into the game. The testusers also mentioned the idea of difficulty increase with increase of level as important feature and also experienced the implementation of how the difficulty manifests itself as well implemented. However one testuser mentioned that the game becomes too difficult from a certain level, and furthermore another testuser said that the difficulty at the beginning levels could be set lower. Therefore it can be said that requirement GA7 was in the way the difficulty increase makes the game more difficult was met, however the magnitude of difficulty can be further improved and the constellation of enemies and beneficial items can be adjusted to ensure to make the game more enjoyable, challenging and engageing at any stage in the game.

Moreover the requirement GA8 to include highscore rather than timer into the game was implemented by not directly measuring and showing time until the game is over, but an increasing score which depends on time. Also at the end of the game a screen with a highscore was implemented, which showed the previously reached score of the user. The testusers found the highscore to be an engageing feature of the game, although some mentioned that they found it not as entertaining only seeing the highscores of themselves, but would like to see a highscore where other players also participate and there is a competition between players.

Requirement R10 of including gamified elements was successfully implemented into the protoype with the game and the possibility to earn virtual coins with training performance and reading prevention information. Despite the fact that it was not a major motivational contributor to the testusers to perform strength training, it had certain aspects which made it more enjoyable to use the application and with improvements, that got mentioned by the testusers, could play a larger role in motivation to perform strength training for the user.

Furthermore the gamified elements were implemented by the achievement elements which did not contribute a lot to the motivation but was seen as a nice feature to have. The gamification of the training section itself was implemented through the timer element and the evaluation of the pauses with the evaluation icon, that changed colors based on the perfomance. This was seen by most testusers as motivational to get a good evaluation and contributed wanting them to use the application during their training sessions and adhere to their pauses. Hereby it was not mentioned explicitly that their strength training sessions were more fun. Therefore it can not be said that the implementations lead to the achievement of requirement R9, the aim to increase fun factor of strength training. However the gamification of the training section itself with the evaluation icon did lead to motivation and engagement of the user.

Subsequently, the individual training sessions were examined and the average training duration of a training session was documented. To get a comparative value, the testuser was asked for the duration of an average training session two weeks before the use of the app.

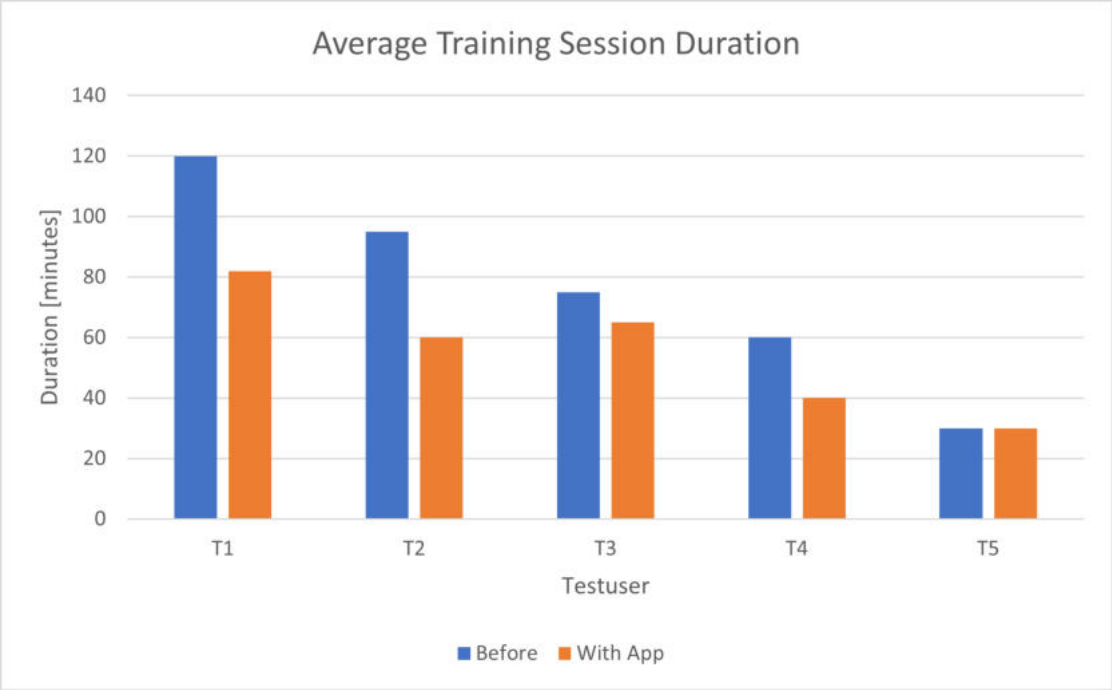


Figure 4.45: Average Training Session Duration

In figure 4.45 it can be seen that in almost all cases there was a decrease in training duration with the use of the application.

Testuser 1 had an average training duration before using the app of 120 minutes, whereas with the use of the app the training duration got reduced to 82 minutes. Also Testuser 2 experienced a strong decrease in training duration from an average of 95 minutes before using the app to 60 minutes with using the app. Furthermore Testuser 3 experienced a slight decrease in training duration from a training session being on average 75 minutes before using the app and 65 minutes with using the app. Testuser 4 experienced a 20 minutes reduction of training duration from an average of 60 minutes before using the app to 40 minutes with the use of the app. Only in one case the training duration stayed the same with testuser 5 where before the use of the app and with the use of the app a training session was on average 30 minutes long. This can be explained by the training design of Testuser 5 where he performs bodyweight exercises with one set per exercise for a given amount of minutes and then pause in between exercises for a specific pause length which he already has tracked in before using the application.

Therefore it can be observed that the implementation regarding requirement R4 (Optimizing duration of training session) was successfull. Furthermore the application met the expectations of the research question if the training sessions can be made more time efficient through the use of the application.

Along with the reduction of training duration through the tracking of the pauses, most partcipants experienced an increase in the intensity they brought to the training session due to being accountable to adhere to a set time frame. Also many participants said that they were less distracted during the training sessions and had a better focus on the training itself. Hence it can be concluded that requirement R5 to improve focus on training could be achieved through the implementations in the prototype.

CHAPTER 5

Discussion

In this chapter the most important findings are discussed based on the research questions of the thesis and the performed requirement engineering in the user-centered design process. Hereby it is discussed how the objectives of the thesis were met by the developed prototype.

Research Question 1: Can a gamified application, that raises awareness about the health benefits of strength training with regard to biomechanical aspects, help to achieve a targeted training frequency and thereby increase how often the user performs strength training?

Overall the application could not support the testusers to adhere to their set training frequency goal and therefore did not raise their training frequency. In the application numerous features were implemented that targeted motivation. Hereby some elements were able to motivate the user more than others. In motivation theory with intrinsic motivation the individual does something out of enjoyment or desire and with extrinsic motivation the individual does something because of a certain outcome. For extrinsic motivation the amount of value the individual puts on the outcome plays a large role of how strong a motivator that is.

The collection of coins through performing strength training with the app aimed at the extrinsic motivation to get benefits in the game. Simalarly the unlocking of achievements aims at the external motivation of collecting certain virtual medals and badges. This built-in gamification aspects seemed to not be a large enough motivational factor for the users to adhere to the set training frequency. In part this could be explained from the fact that some people do not play games regularly in general and therefore do not see a large value in the outcome of collecting coins. But in part it can also be that the game designed in the prototype was not as entertaining and fun as it could be. The game in the prototype was seen as entertaining by the users, but the implemented game was defined by simplicity and could be further improved.

Furthermore the aspect of raising awareness about the preventative effects of strength training could not lead to a strong motivation to perform strength training. The aim to raise awareness about the health benefits was to make the users value the health aspect of strength training more, which could lead the user to develop the amount of value of the health benefits of strength training and serve as an extrinsic motivation with self-value. At first one could think that the reason for that is that the people from the target group were between 18 - 35 years old and in that age group prevention does not play an important role for them. Additionally it could be seen that maybe many people do not think much about the health benefits of lifestyle interventions until there are problems. It is important to mention that the intention of implementing these lifestyle adjustments at a young age is of great benefit and was intentionally targeted in this thesis. However during the requirements engineering and the user-centred design process two requirements connected to this were seen as very important. They were to illustrate the health benefits of strength training and to raise awareness about prevention, especially regarding orthopedic diseases. The reason of why the prevention notes in the prototype did not pose a great motivator to the users can be explained by the fact that most testusers found the means of prevention note elements and collecting of coins by reading them as good but the content of those notes were seen as unexciting and often times already known information. Hereby it was mentioned that the display of a short text was not interesting enough and that there could be more statistics in numbers involved, as well as diagrams or images.

The strongest motivator seen throughout the testing was the statistics from the training sessions and tracking or documentation of the training itself. The central part of the application that gives the users a value in using the app is the training feature. If the user experiences a more fun or structured training session through the use of the app, then this can develop the user to have more enjoyment when training and this would target intrinsic motivation which is a strong motivator. Similarly if the user experiences, that over a longer period of time the training sessions get more time efficient and enable them to focus more or develop more intense training sessions which then can lead to more progress and results, the user can develop more intrinsic motivation to perform strength training. The gamification of the training feature through the evaluation icons and adhereing to pauses, as well as getting a feedback and a score at the end of the training sessions can hereby support making the use of the training session more enjoyable.

Research Question 2: Can the training sessions be made more time efficient through the use of the application?

The aim of reducing the duration of the training sessions was accomplished by the prototype in almost all cases. This supports the idea that many people take longer pauses between exercise sets than they intend to and exceed the time which is necessary for regeneration. The adherence to the pauses thereby ensures that unnecessary time spent between exercises due to distractions or because the individual does not want to train with more effort is reduced.

To optimize the application in the magnitude of intensity and focus in the training session,

this adherence to set pause lengths can be very beneficial which was also confirmed by most testusers. Almost all participants stated that their training intensity seemed higher than without the application and that the focus was increased. Even if the intensity is difficult to measure objectively, the subjective intensity is a good indication of how intense a workout was.

The measurement of reduced training session durations itself can be a large improvement to long term motivation of strength training because it addresses an issue which many people mention when it comes to why they do not train more regularly. This issue is that they state that they do not have enough time. By reducing the duration of training sessions whilst keeping the same amount of training volume as before, time can be saved. Coupled with the benefit of enabling the possibility of performing training with higher intensity and therefore over a long period of time making more progress, can be a large long term motivation for the users.

Another value in tracking the pauses for the overall progress with strength training is, that through the prototype from training session to training session the pause lengths are kept approximately the same and the progress made in weight and repetition is more comparable. As an example it does not happen as quickly that in a training session the pause length is doubled and the individual can then lift substantially more weight and repetitions than in the compared previous training session. So the overall progress can be monitored more easily which is important for development of muscles and strengthening of bones due to them adapting to the loads.

Research Question 3: What are the requirements for the application to achieve the adherence to a targeted training frequency, thereby increasing training frequency, and the optimization of duration of training sessions?

During the User-Centered Design the requirements for the prototype to achieve the adherence to a targeted training frequency were elicated. Here it was interesting that the majority of stakeholders mentioned that the health benefits of strength training should be illustrated as well as awareness should be raised about prevention, especially regarding orthopedic diseases.

This shows that there is also in the younger age group between 18-35 an interest in promoting health benefits. Thus this strengthens the argument that the information provided in the application about prevention was not that interesting or that the means of simple text information was too unexciting to get the users attention.

A further very important requirement was seen in the ability to specify training goals which the user can achieve. This requirement was implemented throughout the prototype for instance in the statistics section the training frequency set by the user could be seen if it was met and how many weeks in a row it was met. This statistics feature was mentioned as most motivational by one of the testusers. Furthermore this was implemented through the setting of pause lengths and feedback through the bonefit evaluation icons. This was also seen as the most motivational by an other testuser. The realization of prescribed

training goals through achievements elements was somewhat successful. It was seen by most testusers as a nice to have but not a primary motivator for them.

Furthermore the requirements to optimize the duration of training sessions was seen as very important, as well as integrating the tracking of time with a timer element. In addition to that the requirement to support the improvement of focus on the training was seen as a very important requirement. These were implemented into the prototype and brought a significant optimization in training duration by including a timer element into the training functionality by tracking the pauses. Furthermore the focus was subjectively improved by these means when the testusers were asked in the evaluation phase.

Also a very important requirement to the prototype was elicitated that there should be a motivational concept. Hereby several motivational elements were integrated into the app which were already mentioned such as display of statistics, evaluation of pauses, collecting coins, achievements, benefits for the game through coins and so on. As discussed before, some of which were more motivational than others which also depended on the individual tester.

For the prototype it was also seen as very important to be able to use the application also without the use of wearables such as fitness trackers because that would be a further device needed and also maybe make the whole technical setup more complex.

Further requirements were elicated that the prototype should aim at increaseing the fun factor of strength training and also include gamified elements. Gamified elements were included into the prototype. These elements consisted of an in-game coin system that the user could collect coins when performing strength training and being successful in adhereing to the set pause lengths, as well as through reading of prevention notes.

Another gamified element was the integration of several achievements that were connected to a certain goal the user had to accomplish to unlock. The coins collected then could be used in the game for unlocking new avatars which the user could play with, as well as exchange coins for an extra life in the game when the game would have been over. Also the integration of an evaluation through the bone evaluation icon throughout the training sessions had a gamification aspect to it, as well as the adherence to a set pause length through tracking the pauses with a timer button.

Another requirement elaborated was the rating of training intensity. This was not implemented directly, but the approach was taken that it was rated and evaluated how well the user adhered to the set pause lengths which should enable the user to bring an increased training intensity. When tracking training sessions the rest periods are often overlooked next to the training variables such as training intensity and volume.

Moreover it was seen as important to be able to document the training especially the pauses and also to evaluate and display results, so to track the progress. Hereby it was implemented that the aimed at pause lengths could be set and then through the timer element during training the pauses could be tracked. Also the pause lengths and

discrepancy to the aimed at length were evaluated and documented in the statistics feature.

Also it was implemented that the weight and repetitions which were used in the previous set during the waiting of the pause could be documented and all statistics of weight and repetitions of the last workout could be seen in a list in the training preparation screen. The tracking of progress was also implemented in the statistics feature where the time frame could be chosen where the evaluation statistics of the training sessions could be seen. Further the weekly streak of how many weeks in a row the user adhered to their set training frequency was implemented.

Some less important requirements were elicitated that the application should have a simple design and easy handling, as well as be free to use without any advertisements.

Regarding the game there were additional requirements elicitated during the user-centered design process. Hereby there should be the possibility to get some kind of benefit in the game for points collected from training. These benefits were implemented in the prototype in the form of exchanging virtual coins to unlock new avatars which made it possible to play with other avatars for the user. Hereby the avatars were only visually different but the behavior in the game was the same, so there was no difference in difficulty. Another benefit from virtual coins was that if the user lost the game, the user could exchange in-game coins for an extra life of the avatar, so that from the same point in the game the user could continue. These benefits were reviewed positively from the participants in the testing phase of the app.

Furthermore the requirement of a level-based system was given and that a score should be included. Also to make the game fit into the theme of biomechanics and prevention the game should be designed to include elements related to biomechanics such as bones, muscles or strength training. Another requirement was to have straightforward game mechanics and make the steering of the avatar easy to handle. The steering of the avatar was implemented through a simple swipe-mechanism and the game mechanics were kept simple by items and enemies coming towards the avatar and the avatar having to collect items or avoid enemies. This then resulted in a decrease of strength or an increase of strength of the avatar whereas the strength decreased with time linearly and the game was over when it reached zero.

Moreover there should be an increase in difficulty with the increase of levels to make the game challenging. This was implemented through making the items and enemies fall with a larger velocity towards the avatar. Another requirement was to include a highscore rather than a simple timer, so rather have points reached than seconds until game over. The requirement of multiple avatar lives was implemented through exchange of in-game coins for avatar lives and the requirement that the unlocking of new avatars should only result in visual change and not in an advantage of making the game easier was also implemented.

CHAPTER 6

Conclusion and Future Work

To motivate someone to increase their physical activities in performing strength training brings many challenges. Each individual has its own life circumstances and values certain things more than others. If there is no intrinsic motivation, so the individual does not exercise out of fun or inner desire, but rather through extrinsic motivation simply to reach a certain external goal or outcome, it is more difficult to motivate somebody. However hereby there are also extrinsic motivators that can lead to a strong motivation if the outcome is valued by the individual such as valueing the improvement of health.

Therefore the motivational concept of an application should address the support of intrinsic motivation or extrinsic motivation with self-value to reach the users increase in motivation. Hereby different approaches in the implementation of motivational concepts into the app were made. However considering the results from the testusers, the app couldn't achieve the aim to help the users adhere to their set training frequency goal and therefore couldn't raise the training frequency. Some approaches to raise motivation appeared to hereby be more successful than others and some might need some modifications to reach their aims of leading to an increased motivation.

Raising awareness about health benefits and integrating them into the prototype can meet the development of assigning value to the fact that the user is doing something good for their health. In the developed prototype the desired outcome to make the user assign more value to performing strength training because of its health benefits especially regarding the human locomotor system and its preventative effects against orthopedic diseases did not increase substantially.

In the evaluation of results it was clear that the means of how the health and prevention information was presented was unexciting and also the content was mostly already known. The information was hereby implemented to be presented in text form. As an improvement in a possible further development the information could be presented with diagrams or images. For instance diagrams of how bone loss occurs with increasing age or

images of healthy bone compared to osteoporotic bone. It can also be imagined that the prevention information would be put into a short video that would have to be watched before getting the virtual coin benefits. Especially in times of social media and the often assigned connection to short attention spans of younger people, short video-formats could be a good way to present information.

Despite the prevention notes not being a large motivator in the prototype, it is worth noting that the idea of raising awareness about the health benefits and prevention of orthopedic diseases was elicitated as very important requirements in the user-centred design process. Therefore in future work it makes sense to not discard this aspect, but rather build upon it and make further improvements.

The collecting of coins to get in-game benefits might not be of enough value for a large number of people which makes the motivational aspect not as strong for most people. That mentioned, the gamified elements can be enjoyable for the user and spark motivation for the user, and thereby support in addition to other motivational factors the user to perform regular strength training. Important hereby is to make the gamified elements as enjoyable as possible. In the developed prototype many ideas were seen as enjoyable and made the users want to collect coins. The basic idea of getting coins for good performance in strength training and exchanging those coins for certain benefits were generally seen as a good idea. However the game idea could be further developed to make it more entertaining for the user.

An idea that was mentioned was that maybe there could also be independant from the game a training level which increases with training session performance and is independent of the virtual coins or the game. A further improvement that could be made for the prototype game would be to adjust the difficulty and make the difficulty start lower and ensure that the game can be played until higher levels, so that it is not as easy to reach a certain point where there could be a plateau. Another improvement which would make the achievement elements more interesting would be to not be able to unlock certain avatars with virtual coins but rather with the unlocking of specific achievement elements.

Furthermore an interesting development would be to further implement the highscore to be able to compete against other players. In the prototype the player only plays against the highscore on the device and there is no competition against potential other players that would also download the app. This could raise the entertainment value for the game by a lot because the competitive factor can be a strong motivator for people.

To develop the intrinsic motivation in the users the aim of the application should focus on making the training sessions as enjoyable as possible and also support them to make progress. Therefore the training feature of the prototype and the statistics should be focused on. This coincides with the users stating in the evaluation interviews their most motivational aspects of the prototype being in the training statistics and the documentation of the training sessions. It is also clear that the user will only care about the other motivational aspects implemented in the application if the training feature is enjoyable to use or gives a large enough value to their training session.

The documentation of pauses and the evaluation achieved its aim to reduce the training session duration which was seen as an added value to most of the users. The value in that was that the same amount of training volume could be achieved in less time and time could be saved. Furthermore the value was in that the users experienced a higher level of focus and felt that they could maintain a higher training intensity.

However, there might be some people that find it too uncomfortable to track their pauses in an app in each training session because it is an extra dedication to be accountable for and they enjoy more a loose training form. Maybe they are fine with less focus and intensity and cannot measurably view the potential progress which those aspects could lead to. There are people who also view the gym for instance as a more social place to meet or go with friends and take their time, so that gym sessions can get very long in duration. The implemented app for these types of potential users can hereby show the way of more compact workouts with accountability for rest periods enabling more focus and training intensity, but it can be more difficult to change the way of training for them. If they perform strength training regularly, then that is beneficial and training progress can be made. However if they don't experience further progress in their training performance and physique, it can lead to a significant decrease in motivation and disturb the regularity of strength training.

There are a few further improvements that could be made for the prototype. First of all it would be desireable to focus on making the training feature as user-friendly as possible. It should be clear to the user in every stage throughout the workout, in which pause and exercise set the users is and what actions the user has to take. It can also be considered, if it could be possible to make it easier to start and stop the timer to record the pauses without having to open the app and manually press the timer button. Hereby at the request of the stakeholders in the requirements elicitation it was stated that no additional wearables such as fitness trackers should be needed to use the app. However with the integration of wearables the tracking of pauses could be implemented through for instance touch events on the wearable device and the smartphone would not have to be opened every time a pause is held.

Another useful feature, especially for users who exercise in a gym, would be to allow to complete the exercises of a training session in any order as they would like. So there would not be as in the developed prototype a fixed order in which the exercises have to be performed. This would provide flexibility to the user to switch the order of exercise during the training session, if an exercise equipment is in use and would need a long time to wait for to be unoccupied.

Moreover when creating a new training session, it could be useful to also have the possibility to choose from an exercise library the exercises a user would like to perform. Here the benefit would be that, for the individual exercise a more exact pause recommendation could be given based on, if the exercise is a compound exercise which involves a lot of muscles or if the exercise is an isolation exercise which only involves a few muscles. The more muscles are involved the longer rest periods should be taken to recover fully for the next exercise set.

One further valuable feature improvement could be to not only track the pauses, but also the time spent during performing the exercise. This would give additional information to the user about the amount of time the muscle is placed under tension and the statistics could be extended by comparing the pause lengths to the actual time exercising the muscle. This would reveal the actual time spent exercising and potentially show the user if too much time is wasted.

Furthermore the tracking of weight and repetitions could be improved by also setting a weight and repetition goal to support the progressiv overload which is needed for muscle and bone mass adaptation. The set weight and repetiton goal could then be compared against the documentation of actual performed repetitions with the amount of weight. This could then give further evaluation possibilites and statistics that could motivate the user even more. Also the data about the amount of weight and repetitions documented in a given training session could be also saved and displayed for each training session completed and not only for the last workout. This would be useful for the user to see over the course of each training session how much progress the user has made. As a result the statistics could be extended by for instance displaying the increase in weight lifted in a selected exercise over a defined period of time, making the progressiv overload visible for the user.

CHAPTER 7

Appendix

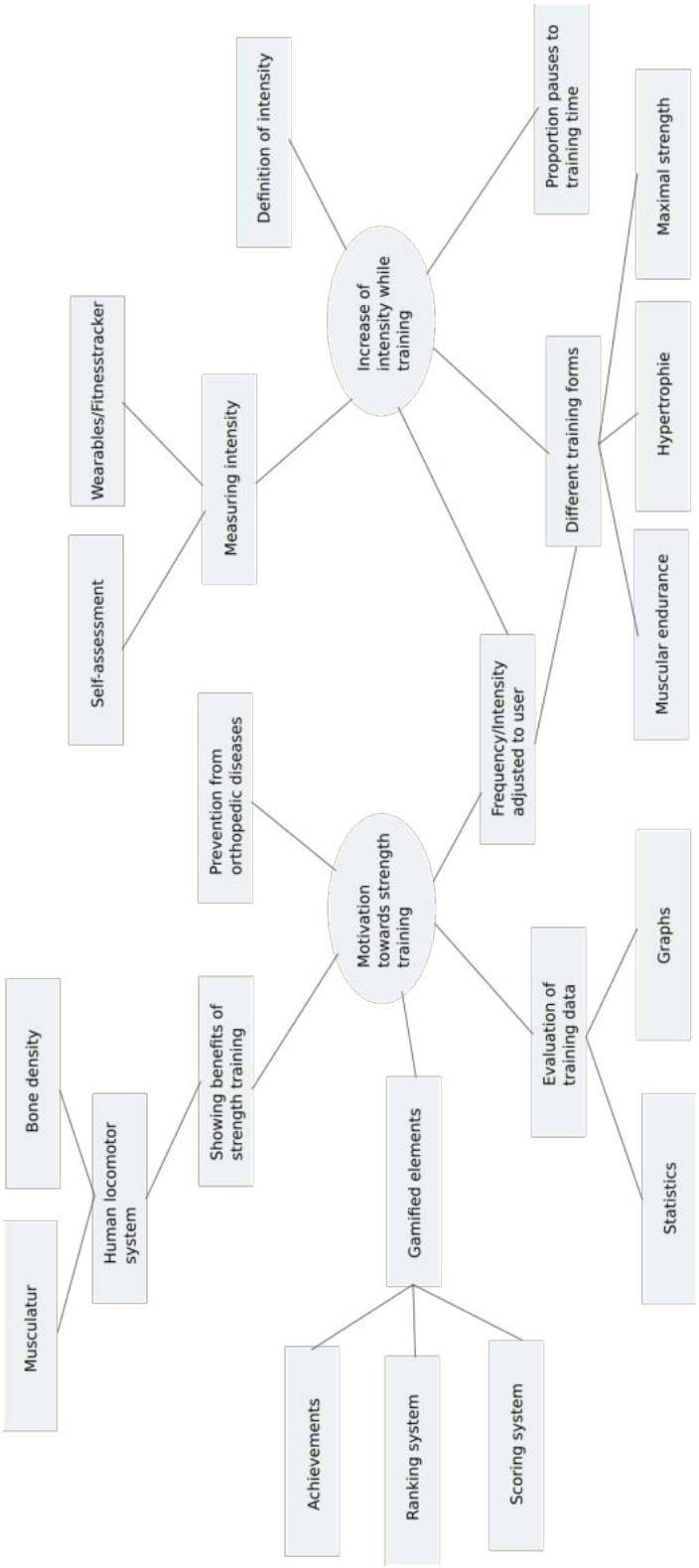
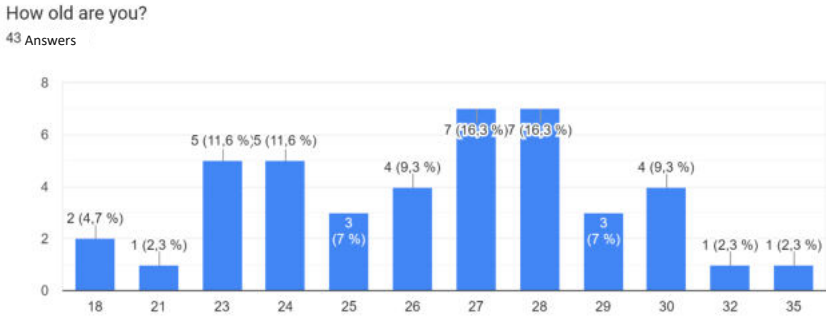
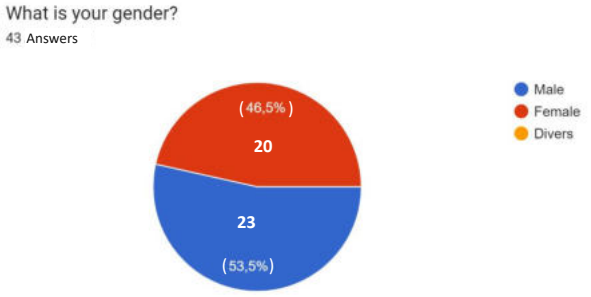


Figure 7.1: Mindmap of Interview in Iteration 1

Personal Information





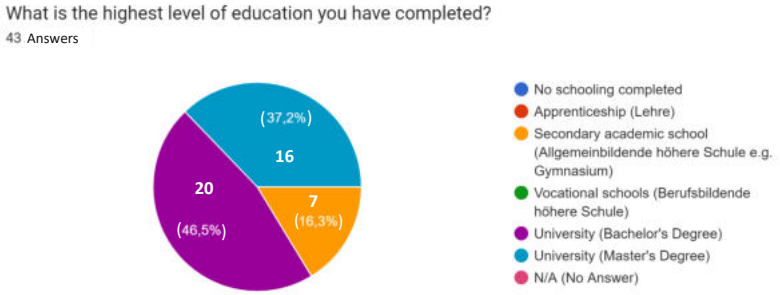
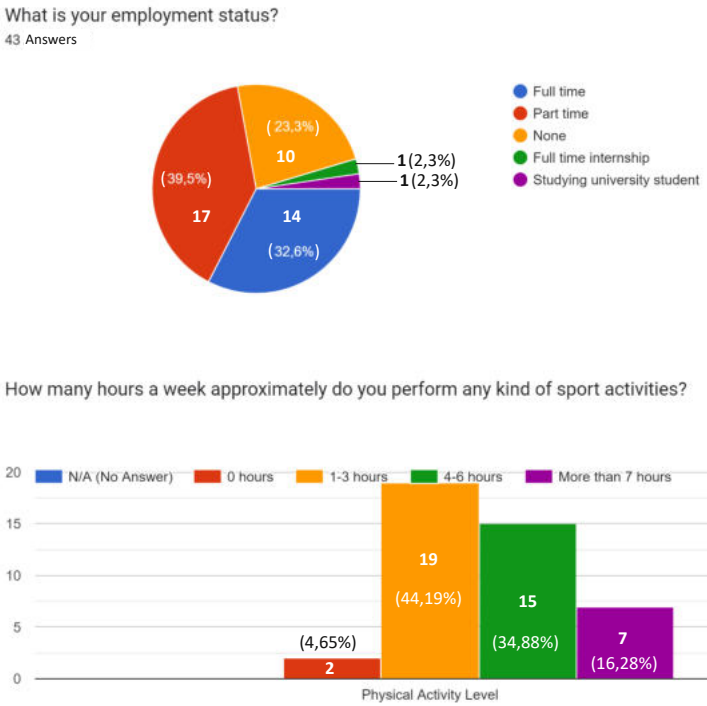


Figure 7.2: Online Survey Results 1/22



Information Regarding Training Behavior

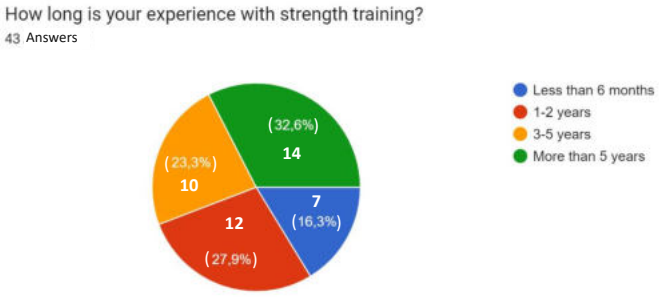


Figure 7.3: Fragebogen Antworten 2/22

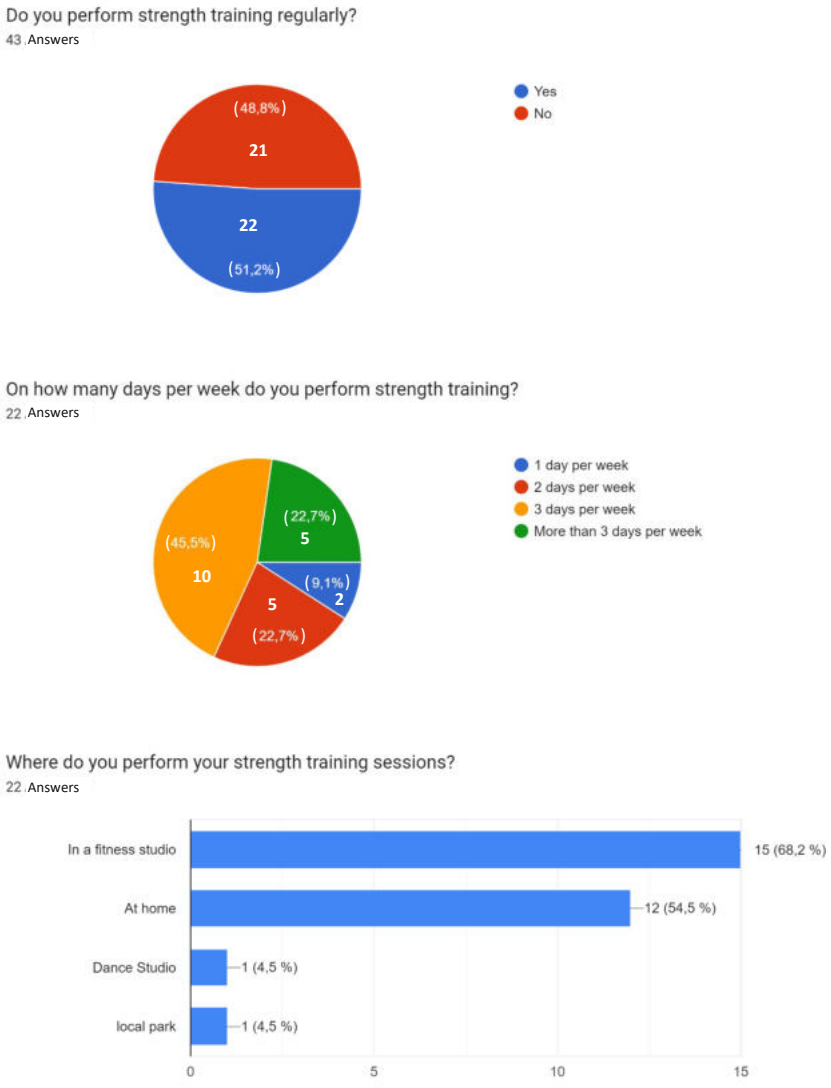


Figure 7.4: Fragebogen Antworten 3/22

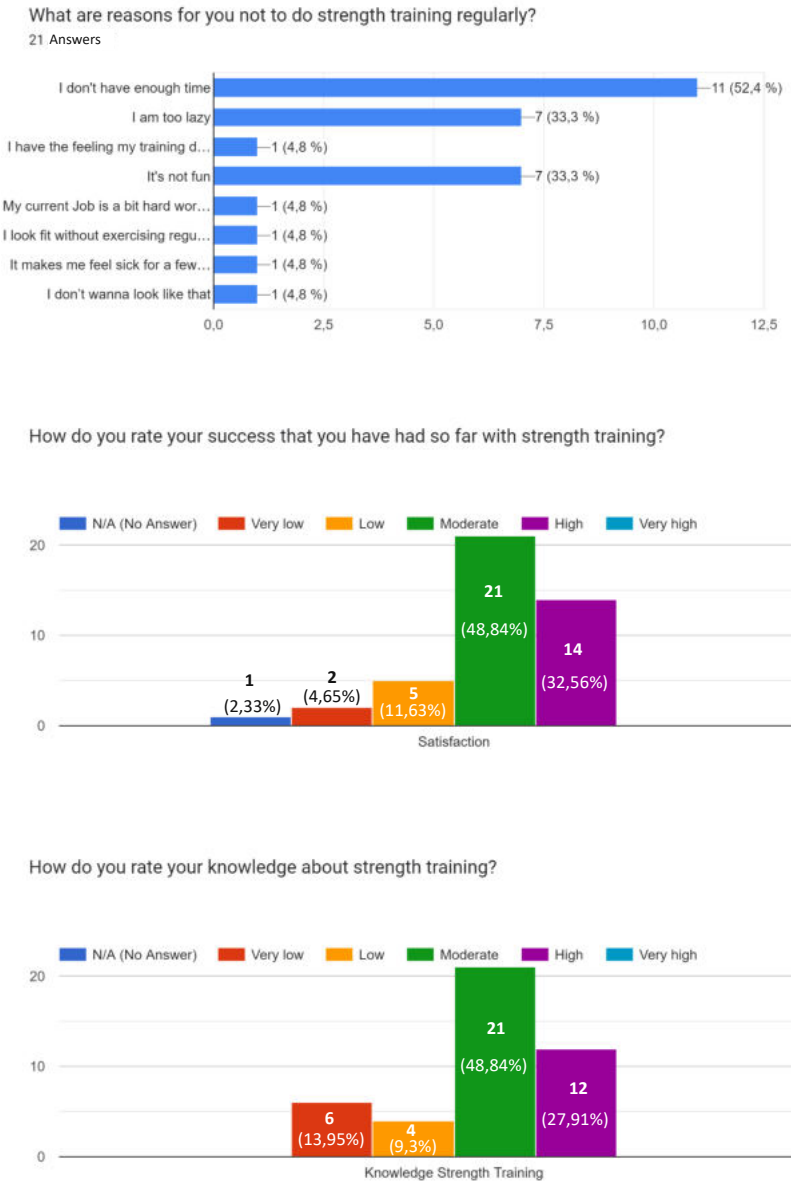


Figure 7.5: Fragebogen Antworten 4/22

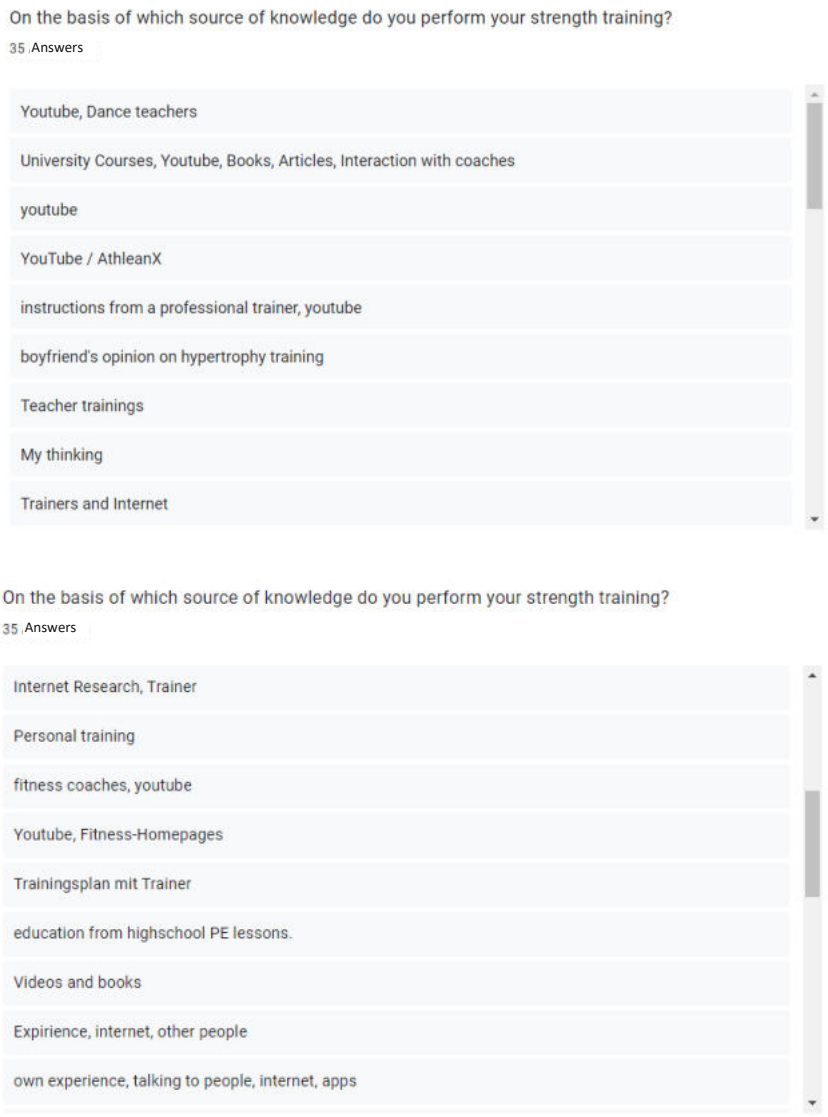


Figure 7.6: Fragebogen Antworten 5/22

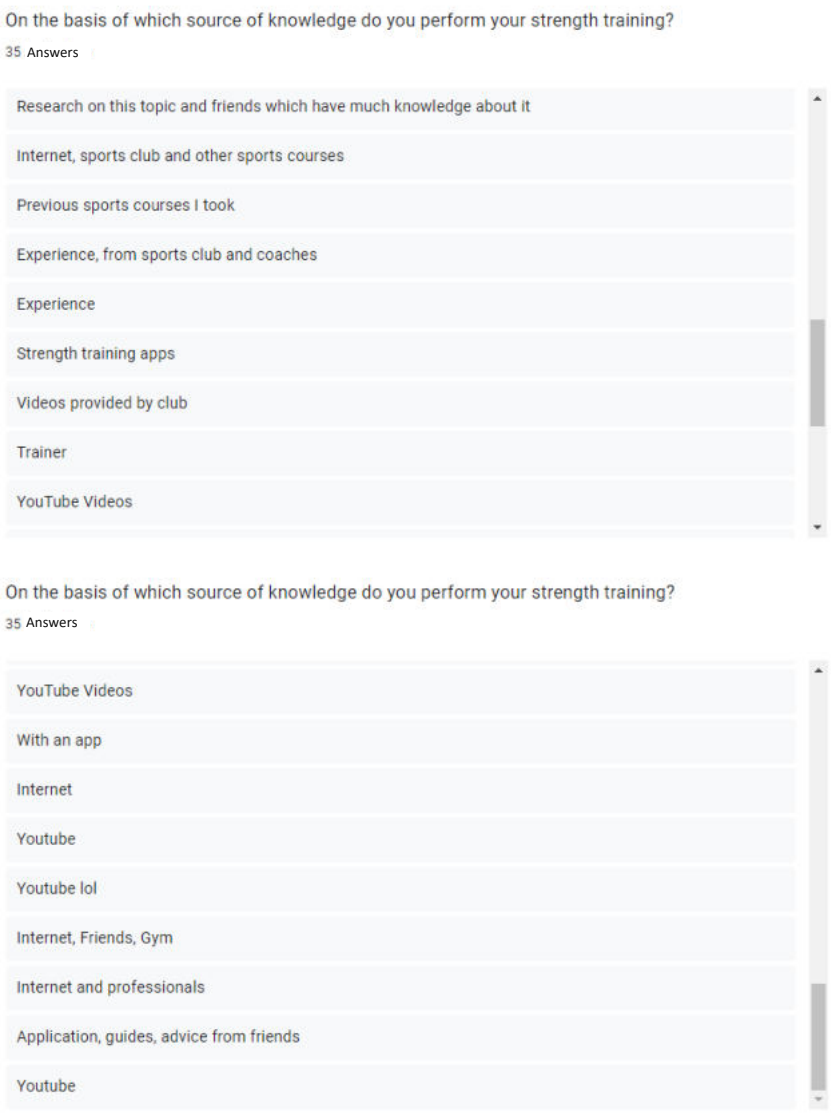


Figure 7.7: Fragebogen Antworten 6/22

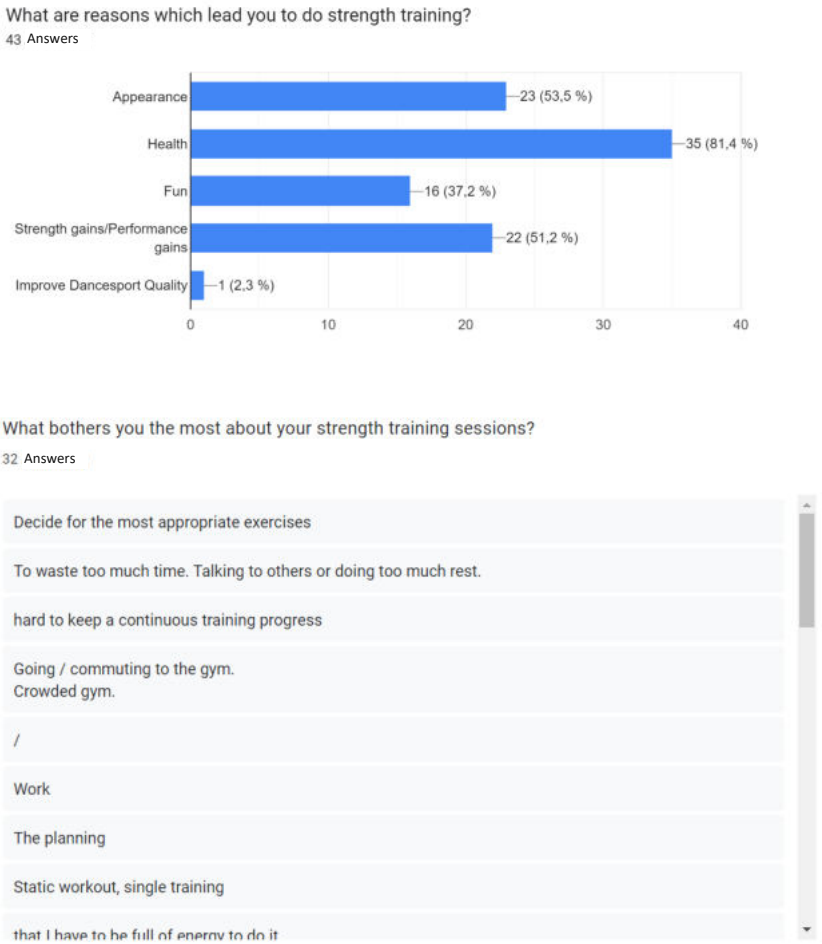


Figure 7.8: Fragebogen Antworten 7/22

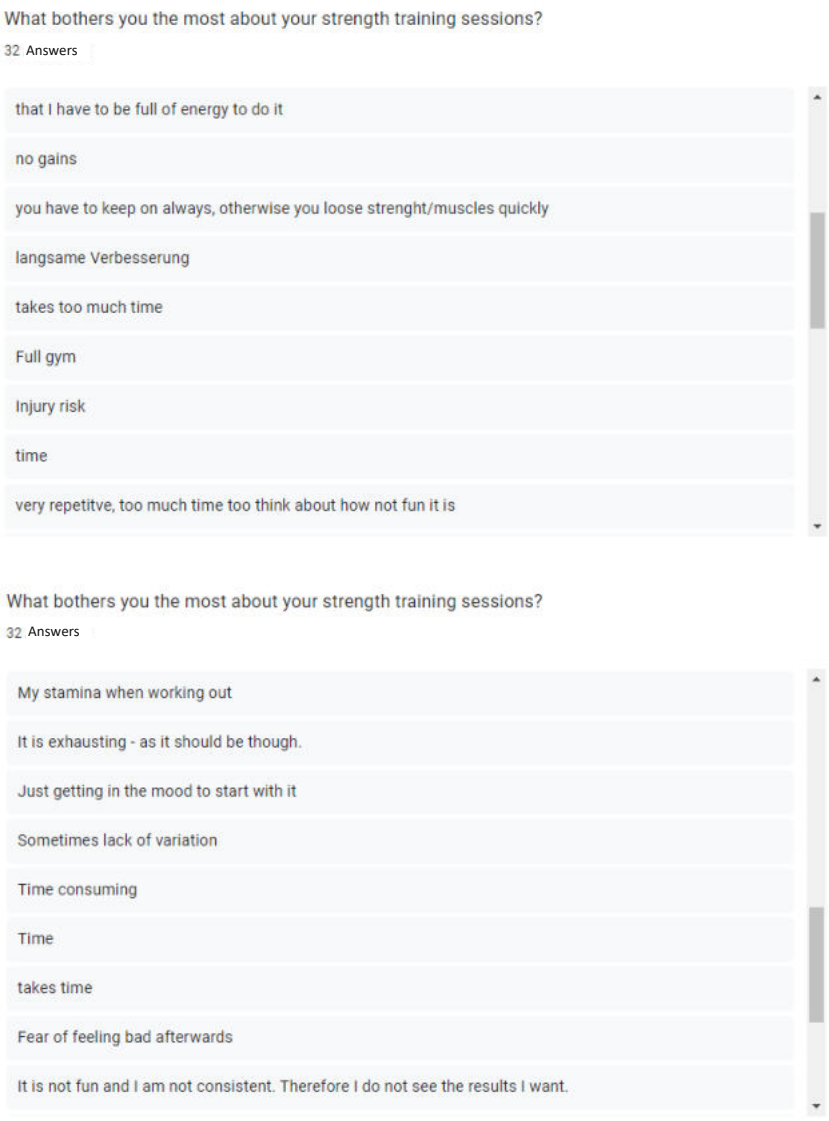
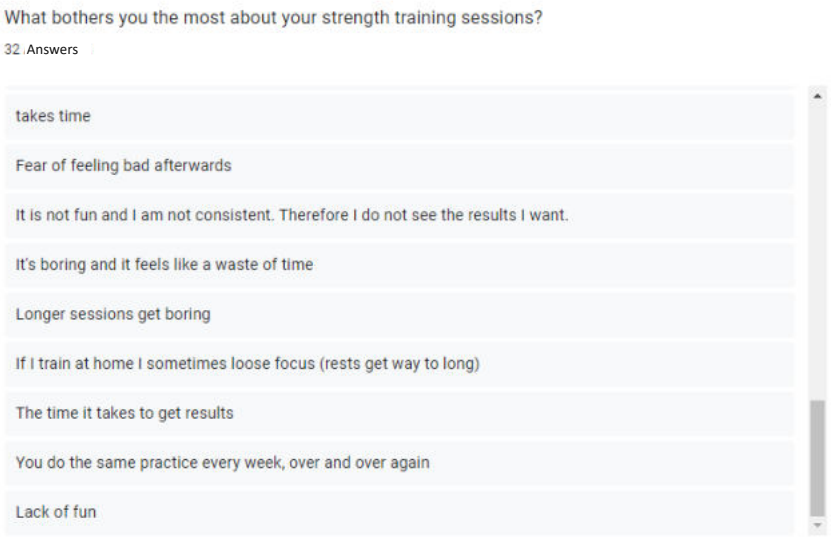


Figure 7.9: Fragebogen Antworten 8/22



All about training

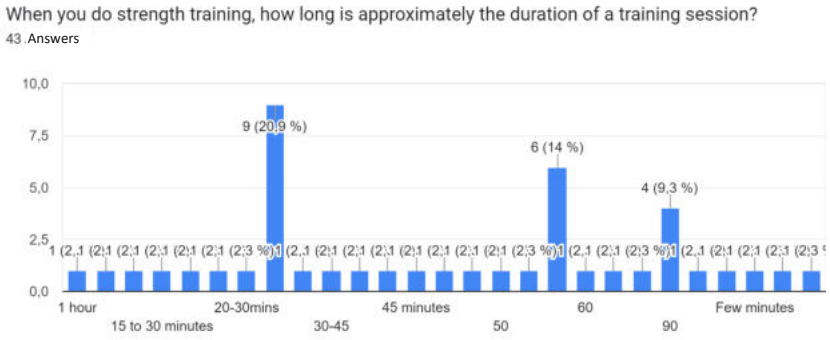


Figure 7.10: Fragebogen Antworten 9/22

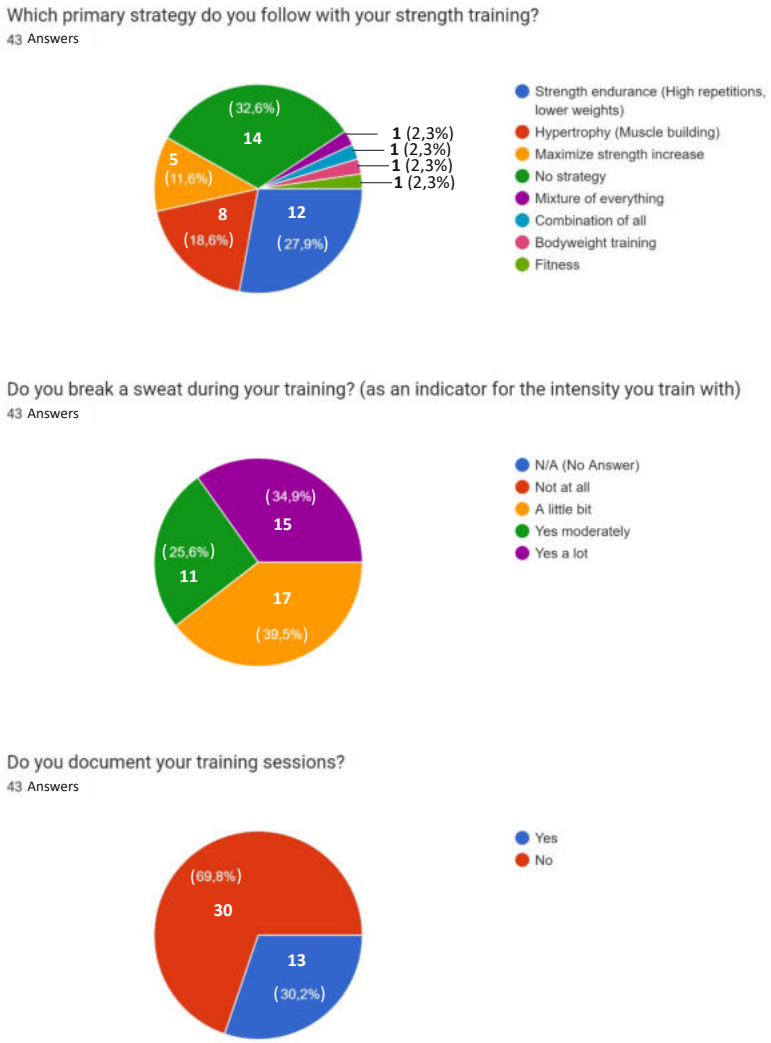


Figure 7.11: Fragebogen Antworten 10/22

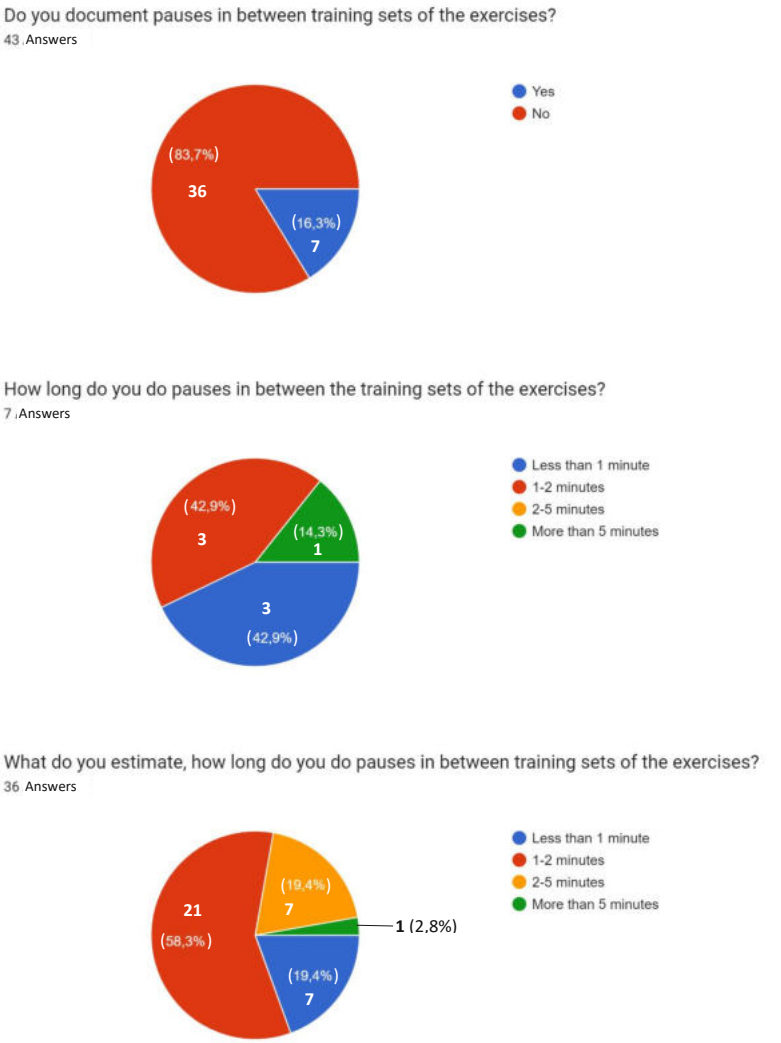


Figure 7.12: Fragebogen Antworten 11/22

Figure 7.13: Fragebogen Antworten 12/22

Figure 7.14: Fragebogen Antworten 13/22

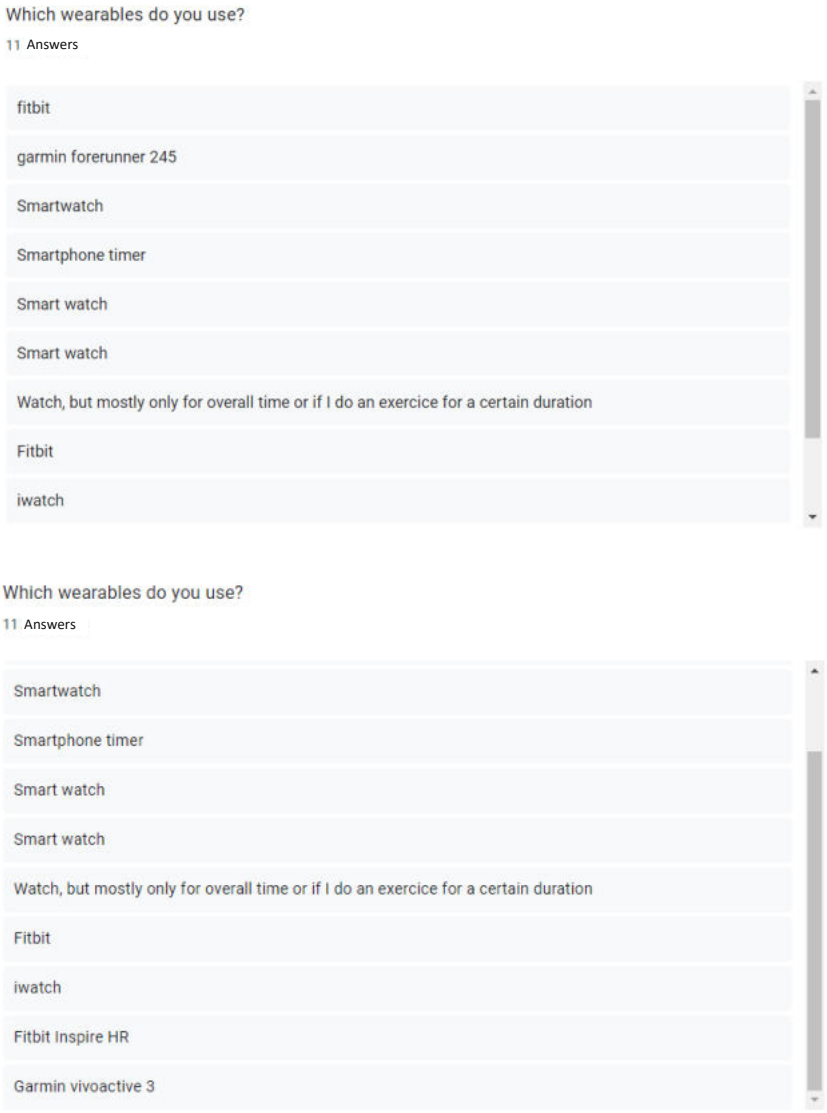


Figure 7.15: Fragebogen Antworten 14/22

What is the reason for you not to use wearables?

32 Answers

For strength training I don't see how it can help me. Also I don't own one.

Too expensive; I like to listen to my body. But ff I would be a pro athlete I would use wearables

i never felt like i need it, i want to keep the training simple

I don't see the value of wearing one for 1-2 times exercise per week.

I do not own wearables such as a smart watch

They annoy me

As I don't practice regularly

Don't like them

Not useful

What is the reason for you not to use wearables?

32 Answers

I don't feel I need it

I forget them

I bought no wearables, so I can't use them

Finde es unnötig. Mache Sport damit es Spaß macht, nicht um Zahlen festzuhalten.

I don't have any

No interest

I do not have wearables and I am not interested, I am using an app on the smartphone

Security of health data.

No interest

Figure 7.16: Fragebogen Antworten 15/22

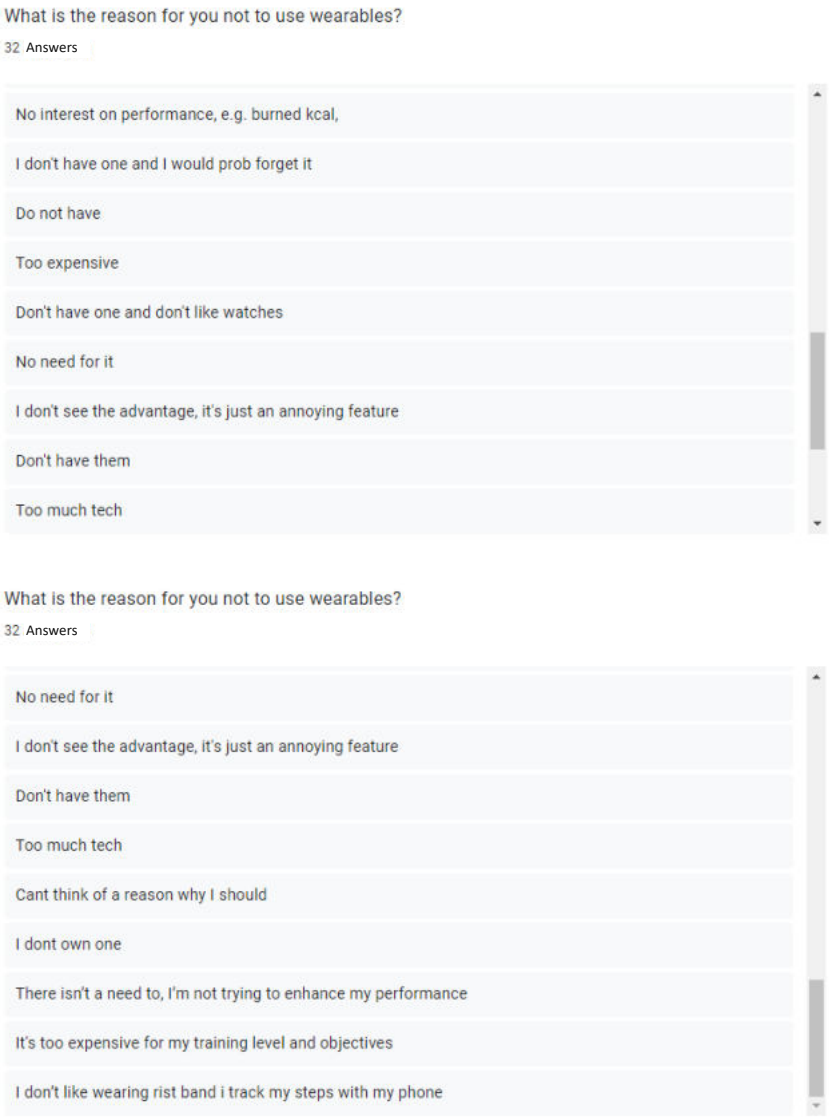
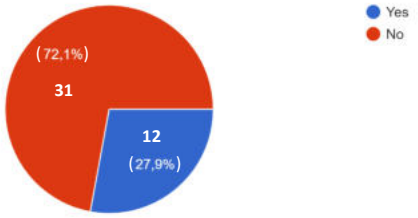


Figure 7.17: Fragebogen Antworten 16/22

Use of Technology in Strength Training

Do you use any apps for your strength training?

43 Answers



Which apps do you use for your strength training?

12 Answers

AthleanX

Intervall Timer, GoWod, Excel

YouTube
Apple Notes

Runtastic, Samsung Training, Freeletics

Time interval tracker

Kernwerk

Apps that prepare me a workout (with numbers of reps)

Fitness

Freelethics

Figure 7.18: Fragebogen Antworten 17/22

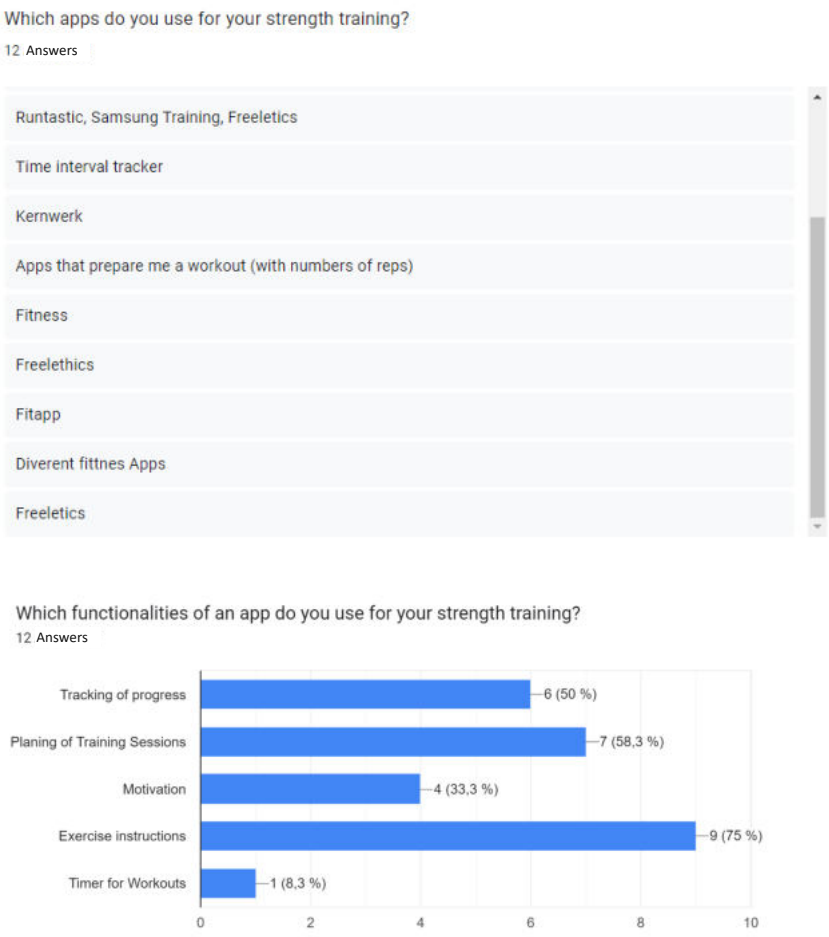


Figure 7.19: Fragebogen Antworten 18/22

What would you want from an app which supports you with your training?

43 Answers

Motivation
Exercise Instructions, Training Plan
All-In-One Solution: Tracking, Programming, Timer etc.
i dont want to spend too much time looking on the phone
To be able to plan the workout and modify it if needed. Keep track of the progress. Tracking of weight / Water consumption Potentially pair it with digital health apps and /or services.
monitoring heart rate, duration, burned calories
I prefer youtube tutorials
Simple, easy to use, easy to personalize

What would you want from an app which supports you with your training?

43 Answers

Type of trainings and supportive messages to keep going on
A calender where you can plan your workouts
Easy handling and interaction with equipment
photos/video of the exercise, and of the wrong way to it so (something that prevents you from doing it wrong)
No
keep track of weight and motivate
not to judge if I skip a training session or not to tell me when I used the app the last time
no ads, no notifications, let me give the choice of forgetting about excercising.
Good overview of exercises for the Training days

Figure 7.20: Fragebogen Antworten 19/22

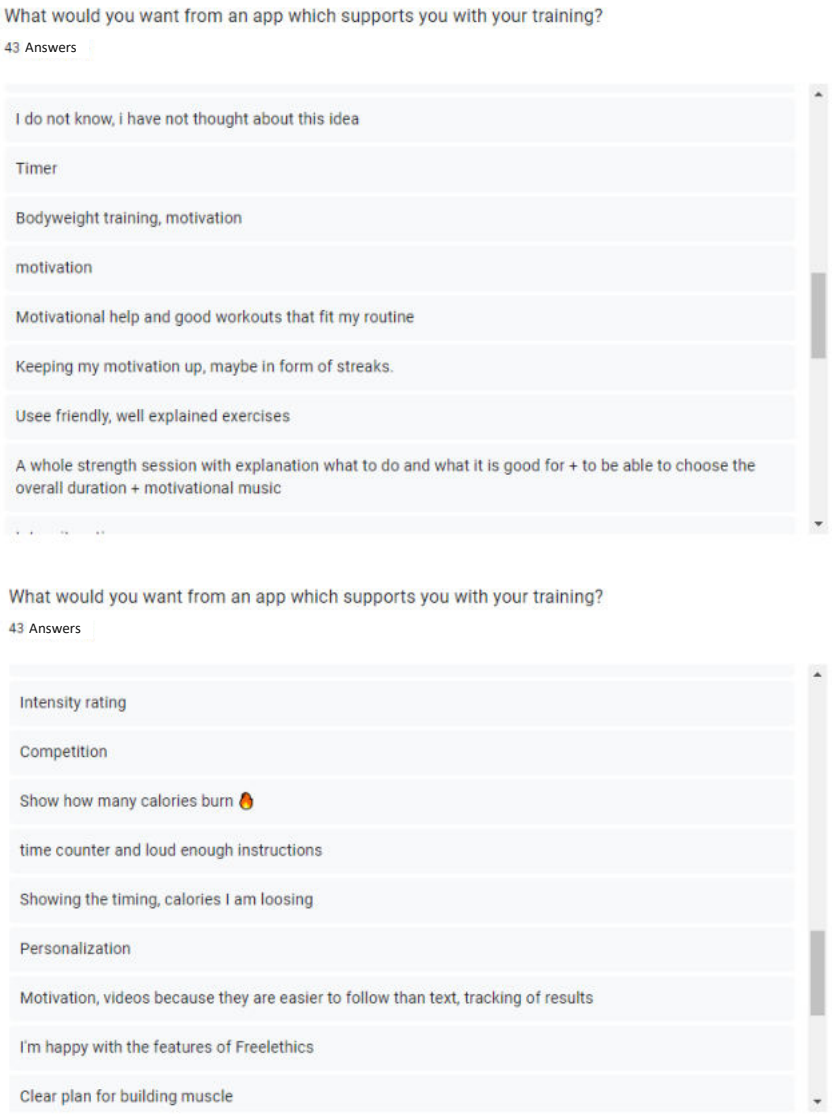


Figure 7.21: Fragebogen Antworten 20/22

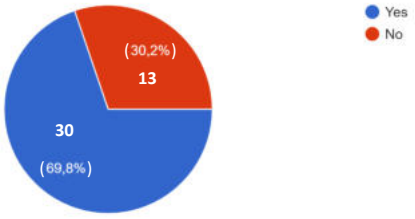
What would you want from an app which supports you with your training?

43 Answers

- Clear plan for building muscle
- To be free and show how to do the exercises
- Meal plan
- Intervall timer
- Different training styles
- To measure the intervals between repetition
- Guidance
- To set goals and give awards
- Free, fitness plan, nutrition plan

Are you interested in games?

43 Answers



Do you like to play mobile games on your Smartphone?

43 Answers

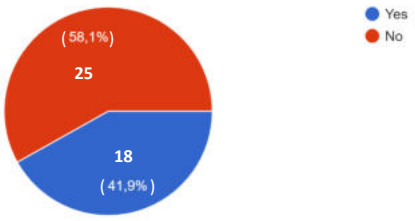


Figure 7.22: Fragebogen Antworten 21/22

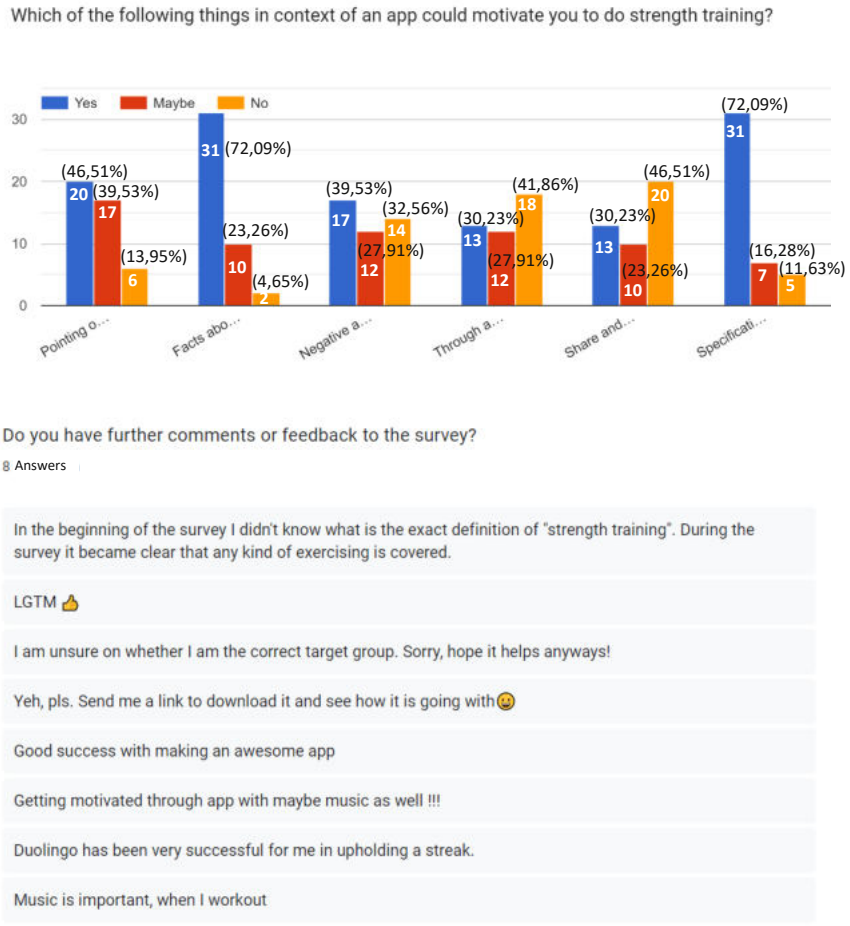


Figure 7.23: Fragebogen Antworten 22/22

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