



Informatics

Analysis, Design and Development of a Serious Game to Enhance Motivation for Strength and Endurance Workouts

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Wien, 21. August 2024

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Analysis, Design and Development of a Serious Game to Enhance Motivation for Strength and Endurance Workouts

DIPLOMA THESIS

submitted in partial fulfillment of the requirements for the degree of

Diplom-Ingenieur

in

Software Engineering and Internet Computing

by

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to the Faculty of Informatics

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Vienna, August 21, 2024

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Kurzfassung

Bewegungsmangel stellt in der heutigen Gesellschaft eine große Herausforderung dar und kann zu einer Reihe von Gesundheitsschäden führen, darunter Herz-Kreislauf-Erkrankungen, Typ-2-Diabetes und Fettleibigkeit. Um diesen Entwicklungen entgegenzuwirken, bedarf es neuer und kreativer Strategien, um die Menschen zu einem gesünderen Lebensstil zu motivieren und regelmäßige körperliche Aktivität in ihren Alltag zu integrieren.

In dieser Arbeit wurde eine umfassende Analyse der theoretischen Grundlagen des Kraft- und Ausdauertrainings, der Motivationstheorie und des Spieldesigns durchgeführt. Krafttraining fördert den Aufbau und den Erhalt von Muskelmasse und erhöht die Knochendichte, wodurch das Risiko von Verletzungen und chronischen Krankheiten verringert wird. Im Gegensatz dazu verbessert Ausdauertraining die Effizienz des Herz-Kreislauf-Systems und erhöht die Sauerstoffaufnahmekapazität, was zu einer verbesserten körperlichen Leistungsfähigkeit und einem geringeren Risiko für Herz-Kreislauf-Erkrankungen führt. Darüber hinaus tragen beide Arten von Training zu einer positiven psychischen Gesundheit und zum allgemeinen Wohlbefinden bei.

Im Rahmen dieser Arbeit wurde eine mobile Anwendung entwickelt, deren Ziel es ist, die Motivation für Kraft- und Ausdauertraining zu erhöhen, um durch Bewegungsmangel verursachte Gesundheitsprobleme zu verhindern. Diese Anwendung wird als Serious Game eingestuft, das neben der Unterhaltung auch einen ernsthaften Zweck verfolgt, wie z.B. die Förderung eines gesunden Lebensstils. Das entwickelte Serious Game ermöglicht den Import von absolvierten Trainingseinheiten und aufgezeichneten Schritten von Fitness-Trackern, wobei die Art und Dauer des Trainings die Höhe der Belohnungen im Spiel beeinflusst. Ziel des Spiels ist es, die Langzeitmotivation für Kraft- und Ausdauersportarten zu erhöhen, indem motivierende Elemente wie Herausforderungen, Erfolge, Statistiken und eine Bestenliste integriert werden, die den Wettbewerb zwischen den Nutzerinnen und Nutzern fördern.

Der Entwicklungsprozess begann mit qualitativen Interviews, um die Anforderungen an das Serious Game zu ermitteln. Anschließend wurde mit Hilfe von Wireframes ein Low-Fidelity-Prototyp erstellt, der dann in einer weiteren Befragungsrunde bewertet wurde. Auf der Grundlage des erhaltenen Feedbacks wurde ein High-Fidelity-Prototyp entwickelt, der das eigentliche Gameplay und die Funktionen des Spiels enthielt. Der

Prototyp wurde einer zweiwöchigen Testphase unterzogen, in der die Nutzer Feedback gaben, das anschließend ausgewertet wurde.

Keywords: *Serious Game, Gamification, Krafttraining, Ausdauertraining, Motivation, Fitness, Gesundheit, Bewegungsförderung, Mobile App, Requirements Engineering, User-centered Design*

Abstract

Physical inactivity represents a significant challenge in contemporary society, with the potential to result in a range of adverse health outcomes, including cardiovascular disease, type 2 diabetes, and obesity. In order to address these developments, novel and creative strategies are required to motivate individuals to adopt a healthier lifestyle and integrate regular physical activity into their daily routines.

In this thesis a comprehensive analysis of the theoretical foundations of strength and endurance training, motivation theory, and game design is presented. Strength training is beneficial for the development and maintenance of muscle mass and increases bone density, thereby reducing the risk of injuries and chronic diseases. In contrast, endurance training enhances the efficiency of the cardiovascular system and increases oxygen uptake capacity, resulting in enhanced physical performance and a reduced risk of cardiovascular disease. Furthermore, both types of training contribute to positive mental health and general well-being.

As part of this thesis, a mobile application was developed with the objective of increasing motivation for strength and endurance training in order to prevent health problems caused by a lack of exercise. This application is classified as a serious game, which, in addition to entertainment, also has a serious purpose, such as promoting a healthy lifestyle. The developed serious game enables the importation of completed training sessions and recorded steps from fitness trackers, with the type and duration of training influencing the amount of rewards in the game. The objective of the game is to enhance long-term motivation for strength and endurance sports through the incorporation of motivational elements, including challenges, achievements, statistics, and a leaderboard, which fosters competition among users.

The development process commenced with qualitative interviews to determine the requirements for the serious game. Subsequently, a low-fidelity prototype was constructed using wireframes, which was then subjected to a further round of interviews for evaluation. Based on the feedback received, a high-fidelity prototype was developed, which included the actual gameplay and functions of the game. The prototype was subjected to a two-week test phase, during which users provided feedback that was evaluated subsequently.

Keywords: *Serious game, gamification, strength training, endurance training, motivation, fitness, health, exercise promotion, mobile app, requirements engineering, user-centered design*

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Introduction

This thesis aims to analyze, design, and develop a prototype for a serious game that enhances and maintains motivation for strength and endurance workouts. A serious game is designed for a primary purpose other than pure entertainment, in this case, to encourage regular workout sessions and promote a healthier lifestyle. The focus is on offering the user a distinctive experience in which real-life fitness achievements are translated into in-game progress.

This chapter describes the problem, the motivation behind the thesis, and the specific aims of the thesis. Additionally, it presents the methodology used and provides a brief overview of the thesis structure.

1.1 Problem Statement

The rising prevalence of physical inactivity represents a substantial health challenge in contemporary society. Despite the well-documented benefits of regular physical exercise, a significant portion of the global population remains inactive. According to the World Health Organization (WHO), 23% of adults and 81% of adolescents do not engage in sufficient physical activity [1].

There is a strong correlation between physical inactivity and a multitude of adverse health outcomes. It is a significant risk factor for chronic conditions, including heart disease, stroke, and high blood pressure, which are among the leading causes of mortality worldwide [1] [2] [3] [4]. Furthermore, a lack of regular exercise can contribute to the development of psychological issues such as depression and anxiety, and has been associated with a reduction in the quality of life and an increase in healthcare costs [5] [6] [7].

One of the most significant obstacles to addressing physical inactivity is the challenge of sustaining long-term engagement in physical exercise. Many individuals encounter

difficulties in maintaining the motivation required for regular exercise. Frequently cited reasons for this include a lack of time, a lack of interest, and perceived barriers to physical activity [8]. The efficacy of current solutions to promote physical activity in terms of long-term motivation is often limited. Conventional approaches, including informational campaigns and structured exercise programs, typically focus on short-term engagement and do not adequately address the psychological and behavioral factors that influence long-term commitment to exercise [9]. Furthermore, there is a deficiency of personalized and engaging tools that can sustain user interest and provide ongoing motivation [10].

A growing body of research is exploring innovative approaches to enhance motivation for physical activity, including the use of technology and gamification. However, there remains a significant gap in the understanding of how these approaches can be effectively designed to support long-term behavioral change. Serious games, which integrate game design elements with health-related objectives, have demonstrated potential in motivating physical activity by enhancing the enjoyment and engagement associated with exercise. Nevertheless, further research is required to ascertain how these games can be adapted to meet the diverse needs of users and to ensure that they retain their appeal over time [11].

1.2 Motivation

The contemporary lifestyle has resulted in a notable reduction in physical activity, largely due to prolonged periods of sitting and minimal physical exertion [12]. The pervasive convenience of technology has inadvertently fostered a more sedentary society. This trend presents a significant public health concern, as physical inactivity has been identified as a well-established risk factor for a multitude of chronic diseases, including cardiovascular diseases, type 2 diabetes, and obesity [1].

To address this issue, a proactive health approach that emphasizes prevention over treatment is necessary. The promotion of healthier lifestyle habits prior to the onset of health problems can significantly reduce the prevalence and severity of chronic diseases. This preventive strategy is not only more effective than managing existing health conditions, but also more cost-efficient [13].

Regular physical activity confers numerous health benefits, including a reduction in the risk of cardiovascular disease, hypertension [14], osteoporosis, diabetes, and obesity. Additionally, it assists in maintaining joint flexibility, enhances mental well-being, and boosts energy and endurance levels. Furthermore, regular physical exercise has been shown to alleviate stress and anxiety, increase the production of endorphins, boost self-esteem, enhance cognitive function, and support the development of bones and muscles [15].

Concurrently, the past decade has witnessed a considerable increase in the prevalence of smartphone usage, indicating a pervasive integration of these devices into the daily lives of individuals across a diverse range of global regions [16]. In 2020, 45.12 % of the global

population owned a smartphone [17]. This surge in smartphone ownership presents a unique opportunity to leverage technology to promote physical activity [18].

The combination of smartphones and serious games represents an optimal platform for the delivery of health interventions, given their pervasiveness, accessibility, and intimate engagement with users. By integrating game design elements with fitness tracking technology, an engaging and immersive experience can be created that encourages individuals to engage in regular physical activity. The incorporation of gamification into exercise not only enhances enjoyment but also provides clear objectives and incentives, which are essential for the long-term maintenance of behavioral change.

1.3 Aim of the Thesis

The aim of this thesis is to create a mobile application prototype that motivates individuals to engage in regular strength and endurance training, promoting a healthier and more active lifestyle. The serious game integrates real-world fitness data into a mobile game environment by synchronizing recordings of strength and endurance workouts while distinguishing between these different types of workouts. This classification aims to provide a more balanced training experience to a wider audience. Game design is a key aspect of this complexity, prioritizing the development of mechanics and reward systems that capture users' attention from the start and maintain their interest over an extended period. The game should be playable without physical exertion to allow for training breaks and to remind the player to keep up with the game and the fitness challenges.

The following questions should be addressed in this diploma thesis:

1. What are the requirements for a serious game for strength and endurance training?
2. Which game mechanics can be used for a serious game to convert real-life strength and endurance workouts to in-game rewards and progress?
3. What are the perceptions and attitudes of users towards a serious game that incorporates real-life sports participation as a gameplay mechanism?

1.4 Methodology

This section describes the methodology used to analyze, design, and develop a serious game that enhances motivation for strength and endurance workouts. The methodology integrates theoretical, practical, and empirical analysis. A detailed overview of the individual steps of the methodology is presented in the diagram shown in figure 1.1.

The first phase consisted of an extensive literature review on fitness, gamification, and motivation. The review had two main objectives: first, to identify effective exercises and intervals that promote health; and second, to understand the game mechanics necessary

to encourage consistent physical activity. The literature review also helped to identify gaps in existing research, which shaped the subsequent stages of the methodology.

Prior to game development, qualitative interviews were conducted with users of varying exercise and gaming experience. The objective was to understand their habits, goals, frequency of workouts, expectations from a serious game and possible game mechanic ideas. This step was crucial in gathering user insights and preferences, which informed the game's conceptual design.

Based on insights from the literature review and pre-development interviews, the conceptual design phase involved outlining the game's requirements. This includes different mechanics as well as reward strategies for workouts. This phase was crucial in translating theoretical understanding into practical application. Based on these requirements, the low-fidelity prototype was built using wireframes.

Qualitative interviews were conducted after the creation of the low-fidelity prototype to collect empirical data on the prototype's usability, screens, mechanics, reward strategies and overall experience. These interviews were crucial in evaluating the game and identifying areas for improvement.

As the next step, the development phase involved creating a high-fidelity mobile game prototype using the libGDX [19] framework for the Android operating system. The game was refined based on feedback from post-development interviews. This iterative process ensured that the game not only met theoretical expectations but also resonated well with end-users. To ensure optimal functionality and user privacy, a critical aspect of the methodology was integrating the game with Health Connect. The prototype served as a tangible product for further empirical analysis.

Upon completion of the high-fidelity prototype, it was distributed to six participants for a two-week period during which they were asked to test the prototype in their everyday lives. This duration was selected to ensure that participants would have sufficient time to engage with the prototype in depth. During the testing phase, participants engaged extensively with the prototype, exploring and evaluating various components of the serious game to assess its functionality and user experience.

Following the testing phase, individual interviews were conducted with participants to evaluate the prototype's influence on their physical activity levels and to gather detailed feedback. The interviews were designed to elicit information regarding the influence of the prototype on participants' exercise routines, the extent to which the prototype met their expectations in terms of functionality and game mechanics, and their overall impressions of the prototype. Qualitative feedback was essential for assessing user satisfaction and identifying discrepancies between the intended design and the actual user experience.

The final phase involved a comprehensive assessment of the high-fidelity prototype, integrating insights from the preceding interviews. The objective of this evaluation was to analyze changes in activity levels, confirm the prototype's alignment with predefined requirements, and assess the effectiveness of the game mechanics. Moreover, the user

feedback was subjected to a rigorous examination with the objective of determining the overall user experience and identifying areas that require further refinement.

1.5 Structure of the Thesis

This chapter provides a comprehensive overview of the various sections that constitute this thesis.

The first chapter serves as an introduction, setting the stage for the subsequent in-depth research. Chapter 2 delves into the theoretical underpinnings crucial to the thesis. This chapter systematically explains the fundamental concepts relevant to the thesis. It covers various topics, including the dynamics of strength and endurance training, the motivational factors that influence training consistency, the significant role and impact of serious games in this context, the complexities of requirements engineering, and the principles underlying user-centered design.

A review and analysis of existing scientific literature and commercially available solutions relevant to the thesis topic is conducted in chapter 3. This chapter evaluates these solutions based on their features and outcomes, and compares them against the specific aims of this thesis. This comparison helps to identify the distinctive features and contributions of the prototype developed in this thesis, setting it apart from existing publications and solutions.

Chapter 4 systematically presents the research findings and is subdivided into several sections. Chapter 4.1 provides insights from the initial interviews, highlighting requirements that informed the development of the first prototype. Chapter 4.2 presents the first low-fidelity prototype using wireframes. Subsequent interviews, described in chapter 4.3, provided critical feedback on this low-fidelity prototype. This feedback was incorporated into the development of the coded high-fidelity prototype, which is detailed in chapter 4.4. Chapter 4.5 describes the testing phase, where the high-fidelity prototype was used by test users in real-world scenarios over several weeks. Each user's experience was documented through interviews, providing insights into the final user experience.

Then the insights are evaluated by applying analytical methods to assess the efficacy and impact of the prototype in chapter 5. Subsequently, chapter 6 discusses the findings in detail and interprets the results in the context of the thesis objectives.

Finally, the thesis concludes with chapter 7, which summarizes the key findings and contributions of the research. This chapter also identifies potential areas for improvement, laying the groundwork for future research endeavors in this domain.

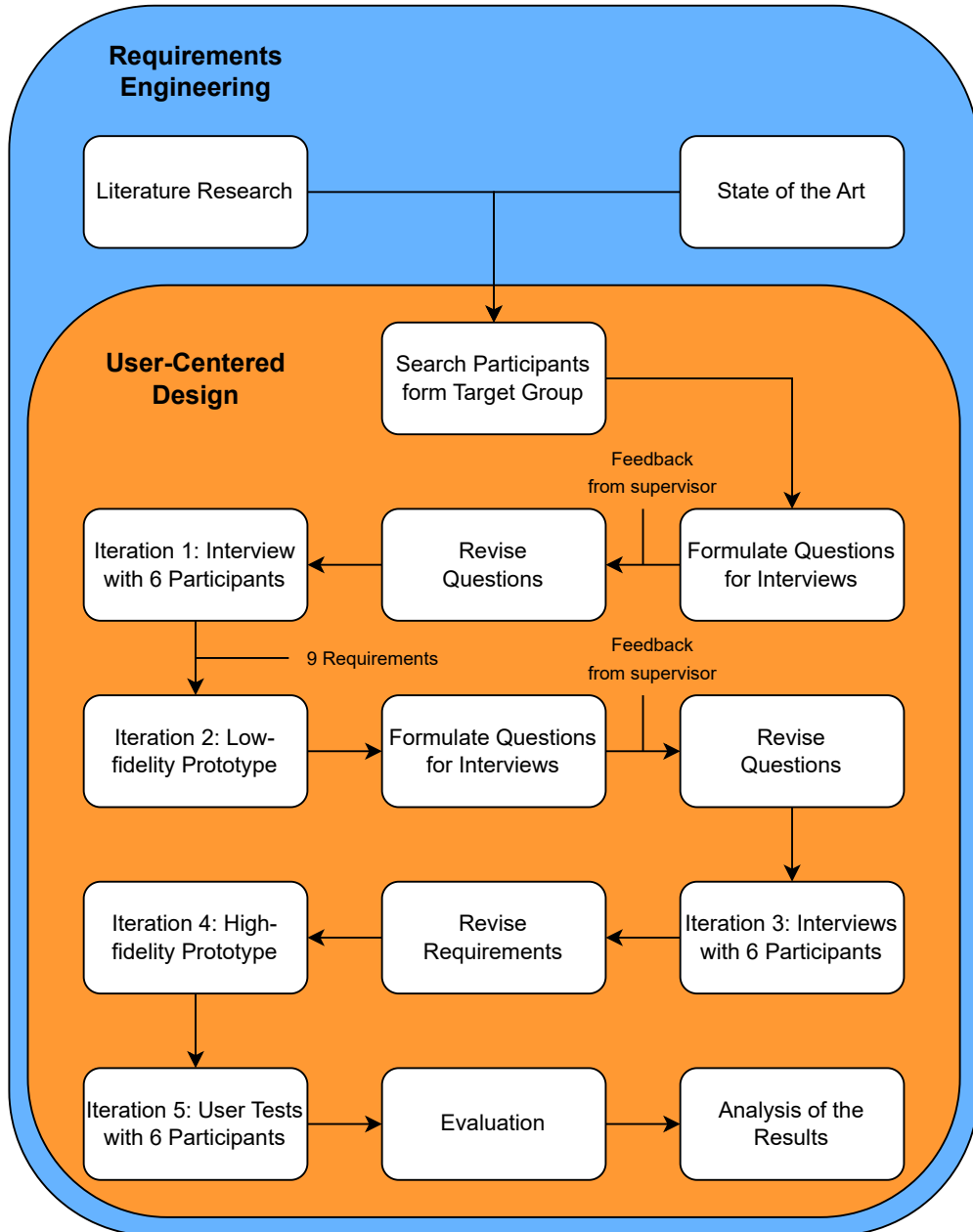


Figure 1.1: Methodology Diagram

Theoretical Basics

2.1 Strength Training

Strength training, also known as resistance training, involves a variety of exercises designed to improve muscular strength and endurance by applying resistance to muscular contraction. The primary objective of strength training is to enhance the functional capacity of muscles. This is accomplished through a systematic regimen that involves manipulating variables such as exercise selection, order, intensity, volume, and rest intervals [20].

At the cellular and molecular levels, strength training triggers a series of physiological responses that contribute to muscular hypertrophy, strength gains, and improvements in neuromuscular coordination. The mechanisms underlying muscle hypertrophy include mechanical tension, muscle damage, and metabolic stress, which collectively stimulate protein synthesis and inhibit protein degradation, resulting in an increase in muscle fiber cross-sectional area [20] [21].

Strength training can have a significant impact on the functioning of the immune system and inflammation in the body. When muscles undergo damage during strength training, the body sends immune cells, such as neutrophils and macrophages, to the affected muscle. These cells release specific proteins that aid in repairing and rebuilding the muscle. However, the process of inflammation is complex. Although muscle growth and healing require inflammation, excessive inflammation can prolong muscle soreness and impede recovery [20].

Resistance training encompasses three distinct training goals: hypertrophy, strength, and power. Hypertrophy involves an increase in muscle size and is typically achieved through resistance training with moderate to high volumes and moderate loads. Strength, on the other hand, refers to the ability to produce force against resistance and is maximized through training with heavier weights and lower repetitions. Power is defined as the

ability to exert force in a short amount of time, which is essentially the product of strength and speed. Power training is characterized by explosive movements and typically involves lighter loads than strength training [22] [21].

2.1.1 Training Considerations

This section presents the various training considerations and variables in detail. It covers morphological and neural factors, periodization, and different training methods.

Morphological and Neural Factors

Muscular strength development is influenced by both morphological and neural factors. Morphological adaptations refer to changes in the physical characteristics of muscles that contribute to increased muscle size and strength. Neural adaptations, on the other hand, refer to improvements in how the brain and nerves communicate with muscles, leading to more efficient and effective muscle contractions [22] [21].

Morphological factors pertain to the physical structure of muscles. Larger muscle size, or cross-sectional area, allows for more muscle fibers to engage during contractions, resulting in stronger force output. This is especially true for type II muscle fibers, which are more adept at producing rapid, forceful movements. Alterations in the arrangement of muscle fibers, such as an increased pennation angle, can also enhance a muscle's power by packing more fibers into the same space [22].

Neural factors play a crucial role in muscle control. Stiffer muscles and tendons can transfer force more effectively, leading to improved strength. Efficient activation of motor units, particularly those with fast-twitch fibers, is essential for higher force production. Training can enhance this activation, resulting in quicker and stronger muscle contractions. Faster firing of motor neurons increases muscle force in less time, which is important for both strength and speed [21]. Improved coordination of motor unit activation can enhance muscle force. Additionally, reducing neuromuscular inhibition through training can allow for stronger contractions [22].

Periodization

Periodization models are plans for organizing training to improve strength and power over time. They involve adjusting training elements like intensity and volume to achieve optimal results while avoiding overtraining and injuries [21]. There are two main types of periodization models: single-targeted block periodization and multi-targeted block periodization [22].

Single-targeted block periodization focuses on improving one main fitness aspect, such as strength or power, at a time while keeping others steady. This method uses concentrated training blocks, each aimed at a specific goal, allowing for focused training on one attribute. It is useful when a particular skill is crucial for performance. The employed training strategies include Concentrated Loads, Phase Potentiation, and Summated Microcycles

and Retaining Loads. Concentrated Loads divide training into blocks targeting specific outcomes such as muscle growth or strength. Phase Potentiation builds on previous training phases to enhance performance. Summated Microcycles and Retaining Loads manage fatigue and maintain fitness levels through short cycles and minimal training doses [22].

Multi-targeted block periodization aims to develop several fitness characteristics simultaneously, making it ideal for sports that require a range of physical skills. This approach emphasizes training compatibility, focusing on improving multiple related fitness aspects together and using concentrated loads to train compatible traits efficiently. By using this approach, athletes can develop a broad range of attributes at the same time [22].

Training Methods

There are several training methods available to enhance muscular hypertrophy, strength and power. Each method targets specific aspects of development through different mechanisms.

Bodyweight exercises are workouts that utilize an individual's body weight as resistance, such as push-ups, pull-ups, and squats. These exercises are accessible and can be effective for building foundational strength and muscular endurance. However, due to the fixed resistance (the individual's body weight), they have limited ability to increase maximal strength [22] [23] [24].

Machine-based exercises range from workouts that isolate specific muscles using machines to those that engage multiple muscle groups through free-weight movements. While machine-based exercises can target specific weaknesses and are useful for rehabilitation, free-weight exercises, such as deadlifts, offer greater functional benefits by mimicking real-life or sport-specific movements and improving overall strength and coordination [22] [25].

Weightlifting movements, such as the clean and jerk, and their derivatives, focus on developing explosive power and strength by requiring the body to move weights rapidly through space. These exercises enhance muscular power and coordination, and also contribute to improved athletic performance by simulating the dynamic and explosive actions found in many sports [22].

Plyometric exercises are a type of training that focuses on explosive movements, such as jump squats and box jumps, with the goal of improving power. These exercises utilize the stretch-shortening cycle of muscles to enhance muscular power, which can be beneficial for sports performance [22].

Eccentric training emphasizes the muscle lengthening phase of a movement. Accentuated eccentric loading involves increasing the load during the eccentric phase beyond what can be handled in the concentric phase. This method is particularly effective for increasing muscle strength and size, as eccentric actions cause more muscle damage, leading to greater hypertrophic adaptations [22].

Potential complexes involve performing a high-intensity, strength-based exercise followed by an explosive, power-focused movement to exploit the phenomenon of post-activation potentiation. This method aims to temporarily enhance muscular performance and power output, making it especially beneficial for athletes looking to improve explosive strength and speed in their specific sports [22].

Unilateral exercises involve training one side of the body at a time, such as with single-leg squats or one-arm shoulder presses. These exercises help to address and correct imbalances between the body's sides, improve stability, and increase unilateral strength and coordination [22] [26].

Bilateral exercises involve using both sides of the body at the same time, such as squats and bench presses. They enable the use of heavier weights compared to unilateral exercises, resulting in greater overall strength gains and training efficiency [22] [26].

Variable resistance training involves adjusting the resistance during the exercise's entire range of motion, often using equipment such as bands or chains. This approach guarantees that the muscle is sufficiently challenged throughout the entire movement, which may result in improved strength gains across the entire range of motion [22].

Kettlebell exercises combine cardiovascular, strength, and flexibility training. Kettlebell swings and snatches are effective for developing power and endurance. However, they may not be as effective for pure strength development as some other methods [22] [24].

Ballistic training is a method that emphasizes performing movements with maximal velocity. It includes exercises such as medicine ball throws and certain weightlifting derivatives. This approach is particularly effective for improving explosive strength and power [22].

These training methods are compared based on their theoretical potential, as shown in figure 2.1.

2.1.2 Training Recommendations

The American College of Sports Medicine recommends to perform 8 to 10 multijoint exercises that include major muscle groups. Furthermore, every major muscle groups should be trained on two or three nonconsecutive days per week with two to four sets for each major muscle group. 8 to 12 repetitions should be performed per set [27].

There is doubt regarding the necessity of training to muscular failure for optimizing strength gains. It is not required to push to the point of failure in every set to achieve maximal muscle strength. This approach may prevent potential overtraining and reduce the risk of injury. Therefore, submaximal training can be equally effective for strength development [22]. Nevertheless, training to muscle failure is of particular significance for the achievement of hypertrophic adaptations, as it ensures the recruitment and conditioning of muscle fibres, which is essential for the optimal growth of muscle tissue. [21].

Resistance training method	Hypertrophy	Strength	Power
Bodyweight exercise	+	+	++
Machine-based exercise	++	++	++
Weightlifting derivatives	+++	+++	+++++
Plyometrics	+	++	++++
Eccentric training	+++++	+++++	++++
Potential complexes	^a	+++	+++++
Unilateral exercise	+++	++	+++
Bilateral exercise	++++	++++	+++
Variable resistance	+++++	++++	++++
Kettlebell training	++	++	+++
Ballistic training	++	+++	+++++

Resistance training methods ranked on scale from +, meaning low potential and +++++, meaning high potential
Assigned exercises, volume-load prescription, and an athlete's relative strength may influence adaptations
^aLimited research available

Figure 2.1: Theoretical potential of resistance training methods to benefit hypertrophy, strength, and power [22]

A training regimen that incorporates both heavy and light loads is advocated to enhance both maximal strength and rate of force development, supporting improvements in muscular power. Heavy loading primarily increases maximal strength, while light loading performed at higher velocities targets improvements in muscular speed and power. This approach allows for a comprehensive development of the force-velocity profile. It is important to note that the loading strategy should be based on the athlete's training status. Novice lifters are encouraged to focus on building a foundation of strength with heavier loads before incorporating power-focused training. Conversely, advanced athletes with a strong foundation in strength may benefit from prioritizing power training while maintaining or slightly increasing their strength levels [22].

When comparing multiple sets to a single set of an exercise, it is recommended to use multiple sets to enhance muscular hypertrophy, strength, and power, especially for trained individuals. This is due to the greater volume of work and mechanical stress imposed by multiple sets, which are critical drivers of muscular adaptation. However, to determine the optimal number of sets, it is important to consider the individual's training status and current goals [22].

Rest intervals between sets can significantly impact the quality of training outcomes. To optimize strength and power development, it is recommended that practitioners implement rest intervals of 2 to 5 minutes. This allows for sufficient recovery, enabling the maintenance of high-intensity efforts across sets. It is important to note that the optimal rest interval length range can be influenced by factors such as the prescribed

training loads, the individual's training age, fiber type, and genetics [22].

2.1.3 Effects on Health

Research has demonstrated that consistent strength training yields numerous health benefits. In this section these health benefits are explained in greater detail and summarized in table 2.1.

Research has shown that resistance training consisting of 12 to 20 sets, two to three times per week, can significantly increase muscle mass in adults of all ages. Studies have reported an average increase in lean body mass of approximately 1.4 kg after approximately three months of training. A notable study involving over 1,600 participants aged 21 to 80 years found a similar average increase in lean mass after just 10 weeks of resistance training. The study found that there was no significant difference in muscle development between individuals who trained two or three days per week, regardless of age. This demonstrates the effectiveness of resistance training in promoting muscle growth, which is important for improving physical strength, metabolic health, and maintaining functional independence as we age [27].

Resistance training significantly increases muscle protein turnover and resting metabolic rate through two mechanisms. Firstly, it increases muscle mass, which inherently requires more energy for maintenance, thereby increasing the resting metabolic rate. This means that for every kilogram of muscle gained, the body burns approximately 20 more calories per day at rest. Secondly, resistance training causes minor muscle damage that requires energy for repair, leading to a temporary increase in metabolic rate for up to 72 hours after exercising. This effect can significantly enhance daily energy expenditure. Overall, regular resistance training not only helps to build and maintain muscle mass but also elevates the metabolic rate, contributing to better weight management and overall health by increasing the body's energy consumption even when at rest [27].

Strength training is emerging as a powerful tool in the fight against obesity and metabolic disorders, significantly reducing body fat and visceral fat, which are major risk factors for type 2 diabetes and cardiovascular disease. Studies have shown that regular resistance training sessions can help individuals gain lean muscle mass while losing fat. Resistance training has been demonstrated to reduce intra-abdominal fat in older men and women, as well as to restrict visceral fat accumulation in premenopausal women over a two-year period. These health benefits are due to an increase in resting metabolic rate and improved insulin sensitivity, which are facilitated by the energy expended during workouts and the muscle remodeling process afterward. Engaging in two 20-minute circuit resistance training sessions per week can lead to substantial energy expenditure, approximately 5000 calories per month. This underscores its effectiveness in enhancing metabolic health and aiding in weight management [27] [28].

Aging may lead to a decline in physical function, which can affect daily activities. However, studies have shown that resistance training can help mitigate these effects, even among the elderly [29]. For instance, a study conducted on nursing home residents averaging

89 years old demonstrated significant improvements in strength, lean muscle mass, and functional independence after just 14 weeks of resistance training. Research has shown that resistance training can significantly improve strength, lean weight, and daily task performance in older adults. Additionally, it has been found to enhance movement control, physical performance, and walking speed, making it a valuable tool for promoting healthier aging [27].

The prevalence of type 2 diabetes is increasing due to the rising obesity epidemic. Research has identified resistance training as a potent intervention for middle-aged and older adults to improve insulin sensitivity and combat the onset of type 2 diabetes. This is supported by evidence showing its benefits in enhancing insulin resistance and glycemic control. Resistance training effectively reduces abdominal fat, which is a significant factor in developing insulin resistance. High-volume and high-intensity resistance training protocols are recommended for better improvements in insulin resistance and glucose tolerance. Additionally, resistance training has been shown to significantly improve glucose and insulin homeostasis [27].

Resistance training is an effective method for reducing key risk factors associated with cardiovascular disease. It can improve body composition, reduce abdominal fat, lower resting blood pressure, and enhance lipid profiles. Although some studies have reported significant improvements in high and low density lipoprotein and triglyceride levels, others have shown minimal or no changes. Therefore, it appears that the effects of resistance training on blood lipids may vary among individuals. Comparisons with aerobic exercise indicate similar benefits on lipid profiles. However, combining resistance training with aerobic activity may offer superior improvements. Furthermore, genetic factors may influence how significantly resistance training affects an individual's lipid profile, highlighting the need for personalized exercise recommendations [27].

Both standard and circuit-style resistance training can significantly reduce resting systolic and diastolic blood pressure in adults, contributing to a lower risk of cardiovascular disease. Research has shown that engaging in resistance training combined with aerobic activity 2 to 3 times a week for 10 weeks leads to notable reductions in blood pressure, with improvements comparable to those seen with aerobic exercise alone. This evidence supports resistance training as an effective intervention for managing hypertension [27].

Osteoporosis increases the risk of bone fractures. Research suggests that resistance training can help prevent bone loss by increasing bone mineral density (BMD). However, results may vary, and some studies do not show significant improvements in BMD. Despite these inconsistencies, resistance training is generally considered beneficial for enhancing BMD in adults and may offer greater benefits for bone health than other forms of exercise [27].

Furthermore, resistance training provides substantial mental health benefits, such as reducing symptoms of fatigue, anxiety, depression, and pain associated with conditions like osteoarthritis and fibromyalgia [30]. It also enhances cognitive abilities and self-esteem across various age groups. Research has specifically highlighted its effectiveness in

improving cognitive function in older adults and boosting self-esteem in a diverse demographic, including cancer patients and those undergoing cardiac rehabilitation. Research has shown that resistance training can effectively alleviate symptoms of depression. Some studies suggest that regular resistance training sessions can lead to significant reductions in clinical depression, particularly in elderly individuals. These findings highlight the potential of resistance training as a valuable intervention for mental health, with the ability to improve psychological well-being and cognitive function [27].

2.2 Endurance Training

Endurance training is a physical activity regimen that aims to improve the body's ability to perform prolonged exercise by increasing the efficiency of oxygen utilization and metabolic adaptations. It involves activities such as cycling, running, and swimming that last from several minutes to several hours at varying intensities and rely mainly on aerobic energy-generating processes. The primary physiological adaptations to endurance training include an enhanced ability of the cardiovascular system to deliver oxygen to working muscles and an increased capacity of those muscles to utilize oxygen, thereby generating energy more efficiently for sustained activity without significant improvements in muscle strength [31].

2.2.1 Training Methods & Recommendations

This section compares several distinct training methodologies: high-volume training (HVT), threshold training (THR), high-intensity interval training (HIIT), and polarized training (POL).

HVT emphasizes a training approach with a large volume of training at low intensities. The focus is on accumulating a significant amount of training hours, primarily performed at a low intensity, typically below the lactate threshold (LT) or at an intensity where athletes can sustain aerobic metabolism without significant accumulation of lactate [32].

THR involves exercising at or near the LT. This type of training is considered moderately high intensity, falling between sprinting and a comfortable long-distance pace [32] [33].

HIIT involves short bursts of high-intensity exercise followed by periods of rest or low-intensity exercise for recovery. The high-intensity intervals are typically performed at or above VO_{2max} or maximum heart rate levels [32] [34].

POL involves a combination of low-intensity and high-intensity training, with minimal work done at moderate intensities or the LT. The distribution often follows a „polarized“ model, where a significant majority of training time is spent at low intensity (75-80%), and a smaller (15-20%), yet crucial portion is dedicated to high-intensity work, with very little time (0-10%) spent in the middle-intensity zones. The objective of polarized training is to optimize performance improvements by utilizing the advantages of both low-intensity training (for developing aerobic base and promoting recovery) and high-intensity training

Health Effect	Description
Increase in Muscle Mass	Resistance training increases muscle mass by an average of 1.4 kg in 3 months.
Improved Metabolic Rate	Increases muscle protein turnover and resting metabolic rate. Each kg of muscle gained burns about 20 more calories per day. Temporary metabolic rate increase up to 72 hours post-exercise.
Reduction in Body Fat and Visceral Fat	Significant reduction in body and visceral fat. Two 20-minute sessions per week can burn approximately 5000 calories per month.
Enhanced Functional Independence in Elderly	Improves strength, lean muscle mass, and daily task performance in older adults. Increases movement control, physical performance, and walking speed.
Improved Insulin Sensitivity and Glycemic Control	Effective in reducing abdominal fat, enhancing insulin resistance, and improving glycemic control.
Cardiovascular Health	Reduces abdominal fat, lowers resting blood pressure, and enhances lipid profiles. Benefits similar to aerobic exercise, with combined training offering superior improvements.
Blood Pressure Reduction	Reduces systolic and diastolic blood pressure. Combined training with aerobic activity yields significant improvements.
Bone Health	Helps prevent bone loss by increasing bone mineral density.
Mental Health Benefits	Reduces symptoms of fatigue, anxiety, depression, and pain. Enhances cognitive abilities and self-esteem. Effective in improving cognitive function in older adults and reducing clinical depression.

Table 2.1: Summary of the effects of strength training on health.

(for enhancing VO₂max and lactate handling) while avoiding the potential drawbacks of excessive moderate-intensity work, such as an increased risk of overtraining and less efficient recovery [35] [36].

Research shows that POL resulted in the most significant improvements. Experiments comparing the performance of athletes using different endurance training methods demonstrated that athletes in the POL group exhibited the greatest increases in peak oxygen uptake, time to exhaustion, and peak velocity/power among the groups [35]. Experiments involving POL, HIIT and THR with healthy young adults showed that a 4-week THR regimen significantly enhanced the first ventilatory threshold, while 8-week HIIT and POL protocols notably improved the second ventilatory threshold. Additionally, all three training modalities — POL, HIIT, and THR — substantially increased VO₂max and time to exhaustion after 8 weeks. Third, the POL approach was found to be more effective in improving cardiorespiratory fitness, as indicated by larger effect sizes, compared to HIIT and THR over the same period [36].

2.2.2 Effects on Health

This section presents the health effects of endurance exercise. The various effects are elucidated in greater detail and summarized in table 2.2.

Endurance training increases the efficiency of the heart and blood vessels. It increases VO₂max. By improving the heart's ability to pump blood and increasing the oxygen-carrying capacity of the blood, endurance exercises can reduce the risk of cardiovascular disease, including high blood pressure, coronary heart disease and stroke [31] [37].

Defined as the oxygen cost of exercise at a given intensity, exercise economy varies from person to person. Research shows that endurance training improves exercise economy, allowing a lower percentage of VO₂max to be used during exercise, thereby improving exercise performance [37].

The interaction between VO₂max and exercise economy is a critical determinant of endurance performance. The concept of velocity at VO₂max (V-VO₂max) integrates individual VO₂max and exercise economy characteristics and serves as a critical predictor of endurance performance. This relationship is exemplified by its ability to strongly predict performance in endurance events such as running. Research has shown that endurance training increases V-VO₂max, allowing athletes to run at higher speeds for a given percentage of VO₂max [37].

LT and ventilatory threshold are important indicators of endurance performance. They reflect the exercise intensity at which there is a significant increase in blood lactate levels and changes in gas exchange. These thresholds are highly responsive to endurance training, which usually results in a shift to higher power outputs or running speeds. This adaptation enables athletes to maintain higher exercise intensities without a corresponding increase in blood lactate accumulation, thereby enhancing endurance capacity. Endurance training results in several physiological adaptations that contribute to this improved

performance, including a reduction in lactate production for a given exercise intensity. Endurance training increases the capacity for lactate removal from the blood. This is facilitated by an increase in the proportion of slow-twitch (type I) muscle fibers [37].

Endurance training can significantly improve the body's response to exercise, particularly in the speed and efficiency of oxygen utilization. At moderate exercise levels, the body quickly increases its oxygen uptake to meet energy demands, stabilizing within a few minutes. However, at intensities just above the lactate threshold, this response is delayed, and blood lactate levels rise, indicating a shift to less efficient energy production. The concepts of maximal lactate steady state and critical power are crucial in determining the highest intensity at which an athlete can exercise while maintaining a stable blood lactate level. Training can enhance this capacity, enabling athletes to perform at higher intensities without significant lactate build-up, which is indicative of improved endurance [37].

Research has shown that endurance training can significantly improve the lipid profile. This is due to an increase in high-density lipoprotein (HDL) levels and a decrease in low-density lipoprotein (LDL) and very low-density lipoprotein (VLDL) levels. HDL is responsible for removing other forms of cholesterol from the bloodstream, and higher levels of HDL are associated with a lower risk of heart disease. The reduction in LDL and VLDL levels further suggests a decreased risk of cardiovascular diseases [38].

Furthermore, endurance training can lead to an increase in hemoglobin levels and red blood cell (RBC) counts. Hemoglobin is essential for transporting oxygen from the lungs to the body's tissues and returning carbon dioxide from the tissues back to the lungs. An increase in hemoglobin and RBC counts can enhance oxygen delivery to muscles, improving endurance and performance [38].

Additionally, endurance training can increase creatine levels, which is a compound essential for energy production in muscle cells. Elevated creatine levels after training may indicate improved muscle energy metabolism, which can be beneficial for high-intensity activities and overall athletic performance [38].

2.3 Combination of Strength and Endurance Training

This section explains how strength and endurance training work together, and which types are suitable for different goals. It also discusses whether it is beneficial to engage in both types of training simultaneously.

Concurrently training for both strength and endurance can lead to divergent adaptations in muscle, resulting in an interference effect that compromises the development of muscle strength. This interference may be due to changes in protein synthesis in response to endurance exercise, training sessions that occur too frequently, or other unidentified factors [31] [39].

A study involved 26 male basketball players who were divided into four groups: a strength training group (S), an endurance training group (E), a combined strength and endurance

Health Effect	Description
Improved Cardiovascular Efficiency	Increases the efficiency of the heart and blood vessels, improving VO ₂ max. It enhances the heart's ability to pump blood and increases the oxygen-carrying capacity, reducing the risk of cardiovascular diseases such as high blood pressure, coronary heart disease, and stroke.
Enhanced Exercise Economy	Improves exercise economy, allowing a lower percentage of VO ₂ max to be used during exercise, thus improving exercise performance.
Increased V-VO₂max	Increases velocity at VO ₂ max, enabling athletes to run at higher speeds for a given percentage of VO ₂ max. This is a critical predictor of endurance performance.
Higher Lactate and Ventilatory Thresholds	Shifts lactate threshold and ventilatory threshold to higher power outputs or running speeds. This adaptation allows for higher exercise intensities without a corresponding increase in blood lactate levels, enhancing endurance capacity.
Improved Oxygen Utilization	Improves the body's response to exercise, particularly in oxygen utilization efficiency. It enhances the ability to maintain higher exercise intensities without significant lactate build-up, indicating improved endurance.
Enhanced Lipid Profile	Improves the lipid profile by increasing high-density lipoprotein levels and decreasing low-density lipoprotein and very low-density lipoprotein levels, reducing the risk of cardiovascular diseases.
Increased Hemoglobin and RBC Counts	Increases hemoglobin levels and red blood cell counts, enhancing oxygen delivery to muscles and improving endurance and performance.
Elevated Creatine Levels	Increases creatine levels, which is essential for energy production in muscle cells, indicating improved muscle energy metabolism and benefiting high-intensity activities and overall athletic performance.

Table 2.2: Summary of the effects of endurance training on health.

training group (S+E), and a control group (C) that did not participate in any training. The 7-week training program consisted of 4 sessions per week. The results showed that the S+E group experienced greater improvements in VO₂max compared to the E group, while the S group experienced a decline in VO₂max. Both the S and S+E groups exhibited significant improvements in strength and vertical jump performance. Furthermore, the S+E group displayed superior post-training anaerobic power compared to the S group. The E and C groups did not exhibit any significant gains in strength, power, or anaerobic power. The study concludes that concurrent endurance and strength training is more effective in enhancing athletic performance than either endurance or strength training alone. Athletes can benefit from incorporating both types of training into their regimen to improve overall performance, including aspects of strength, power, and aerobic capacity [40].

A review of 26 studies indicates that strength training can enhance the performance of endurance athletes. The results suggest that strength training significantly improves muscle-force-velocity, time-trial performance, muscle power, economy (amount of oxygen consumed at a given speed or power level), VO₂max, and the peak velocity attained during a maximal anaerobic running test. The evidence suggests that strength training can enhance the overall muscle power and performance of endurance athletes. [41].

However it is important to note that the specific type, duration, and intensity of strength or endurance training should be tailored to the individual athlete's needs and current training program [41].

In summary, this section has demonstrated that combining strength and endurance training can present challenges, such as the interference effect. However, when properly structured, concurrent training can significantly benefit athletic performance. It is important to tailor the training to an athlete's specific needs in order to enhance VO₂max, muscle power, and anaerobic capacity. When deciding whether to focus on strength training, endurance training, or both simultaneously, it is important to consider the different goals of individuals.

2.4 Motivation

As the purpose of this thesis is to enhance motivation for strength and endurance sports to promote a healthier lifestyle, this section discusses various aspects of motivation.

2.4.1 Flow Theory

The Flow theory emphasizes the psychological state of being fully immersed and engaged in activities that match one's skills with the challenges presented by the environment. This state of flow is characterized by a profound sense of enjoyment and intrinsic motivation, where the activity itself is rewarding enough to encourage continued engagement. Furthermore, flow is characterized by deep involvement in the activity, a merging of action and awareness, a strong sense of control over the action, and a distorted perception of

time. To experience flow, there must be a balance between the challenges of the task and the individual's skills, clear goals, and immediate feedback. Factors that promote flow include appropriate focus, optimal arousal, positive thoughts and emotions, confidence, and supportive environmental conditions [42] [43].

2.4.2 Self Determination Theory

The Self-Determination Theory (SDT) compares two motivation constructs: intrinsic and extrinsic motivation. Intrinsic motivation involves engaging in an activity for its inherent satisfaction and enjoyment, rather than for some separable consequence. This type of motivation is characterized by a natural human propensity to learn, explore, and assimilate knowledge, which is crucial for high-quality learning and creativity. Intrinsic motivation is determined not only by the amount of motivation but also by its orientation. This emphasizes the importance of the underlying attitudes and goals that drive actions [44] [42] [45].

Extrinsic motivation is the act of performing an activity to achieve a separable outcome or reward. There are different types of extrinsic motivation, depending on its autonomy. The continuum of extrinsic motivation ranges from external regulation (least autonomous) to integrated regulation (most autonomous), with introjected regulation and identified regulation falling in between. This view suggests that extrinsic motivation can reflect external control or emanate from true self-regulation, depending on the degree of internalization and integration of the extrinsic motives [44] [45].

2.4.3 Self-Concordance Theory

The Self-Concordance Theory centers on the alignment between an individual's goals and their core interests and values, referred to as self-concordance. This theory suggests that goals can be either intrinsic or extrinsic. The theory posits that the degree to which a goal reflects an individual's genuine interests and values can have a significant impact on their motivation, effort towards achieving the goal, and ultimately, their psychological well-being. Research has shown that goals set at the beginning of a sports season that are autonomously motivated, meaning they align with personal values, are associated with greater effort, successful goal achievement, and improvements in psychological need satisfaction and emotional well-being by the end of the season [42] [46].

2.4.4 Self-Efficacy Theory

The self-efficacy theory pertains to an individual's belief in their ability to succeed in specific situations or accomplish a task. This belief influences their choices, effort, persistence in the face of adversity, and resilience to failure. Higher self-efficacy is linked to greater motivation, higher goals, and increased persistence, leading to better performance. Essentially, self-efficacy affects how much effort individuals will put into an activity and their perseverance when facing challenges [45] [47].

2.4.5 Locus of Control Theory

The locus of control theory distinguishes between two types of belief systems regarding the causes of events in one's life: an internal locus of control and an external locus of control. An internal locus of control suggests that individuals believe they are responsible for the outcomes of their actions, attributing success or failure to their own efforts and abilities. Individuals with a strong internal locus of control believe that their own hard work, skills, or actions determine the events in their life. On the other hand, external locus of control indicates that individuals perceive their successes or failures as being influenced by external factors beyond their control, such as luck, fate, or other people's actions. Individuals with a strong external locus of control may believe that external factors such as luck or the actions of others will ultimately dictate the outcomes of their endeavors, regardless of how hard they try. The concept of the locus of control theory is crucial in understanding motivation, as it affects how individuals perceive challenges and respond to success or failure [45] [48].

2.4.6 Attribution Theory

The attribution theory is closely related to the locus of control theory. It explains how individuals attribute the causes of their successes and failures, and how these attributions influence their motivation and behavior. The theory suggests that the types of attributions people make, such as attributing success to effort or ability, and failure to lack of effort or external factors, can affect their level of motivation. Specifically, attributing success to internal, controllable factors like effort is associated with higher motivation and persistence, while attributing failure to external, uncontrollable factors can lead to decreased motivation. The theory highlights the importance of how perceptions and beliefs about the causes of outcomes can shape an individual's motivation to engage in and persist with tasks [45].

2.5 Serious Games

This chapter explains the theory behind serious games and gamification. The different types and concepts are discussed in more detail.

Serious games are designed for purposes beyond entertainment, with specific and beneficial outcomes in mind. The main concept of serious games is to use the motivational and interactive features of gaming to tackle real-world issues, educate players on complex topics, or resolve problems in different fields. By combining entertaining game elements with serious content, these games aim to enhance learning and engagement. They encourage players to think critically, develop new skills, and gain insights into the presented topics [49] [50].

Serious Games can have a wide range of applications and purposes, including education, training, healthcare, and environmental topics. This chapter focuses primarily on health-related applications in relation to the goal of this thesis, which is to develop a serious

game prototype aimed at motivating individuals to participate in strength and endurance workouts [49] [50].

2.5.1 Gamification

It is important to distinguish between serious games and gamification. Gamification is the use of game-design elements and principles in non-game contexts. Unlike serious games, which are complete games designed with a purpose beyond entertainment, gamification involves incorporating elements such as points, badges, leaderboards, challenges, and progress tracking into non-gaming environments to engage and motivate people. The goal of gamification is to increase user engagement, participation, and motivation in activities that may be perceived as tedious or difficult by making them more enjoyable and game-like. For instance, in an academic context, gamification can enhance learning by making it more interactive and rewarding, which can lead to improved student motivation and engagement [49] [51].

2.5.2 Exergames

One category of serious games that focuses on improving health is exergames. Exergames are video games that combine exercise with gameplay. These games typically use tools such as cameras or controllers to track the user's movements. Research shows that exergames can combat obesity by encouraging movements that lead to caloric expenditure. Additionally, exergames can enhance social interactions, self-esteem, motivation, and support cognitive development. Research indicates that integrating exergames into physical education classes is a promising method for involving students in physical activity, especially for those who may not be interested in conventional sports [52] [53] [54].

2.5.3 Game Design

To successfully develop a serious game or an application with gamification elements, there are several steps that need to be taken. This chapter provides more details about the steps involved in designing such a game.

The design process begins with establishing clear goals for what the game is trying to accomplish. This includes understanding the purpose behind the game, such as whether it's designed to educate, train, raise awareness, or solve a problem. Identifying the target audience and desired outcomes for players is critical at this stage [49].

The content and themes of the game should be carefully considered. This includes deciding on the subject matter of the game, how it will present its themes (explicitly or abstractly), and the setting (realistic or fantastical). These decisions will greatly influence the game's appeal and effectiveness in conveying its message [49].

A core aspect of game design discussed is the development of game mechanics that embody the message of the game. The mechanics should be designed to support and

reinforce the educational or behavioral goals of the game. The rules and systems of the game should contribute directly to the learning or engagement objectives [49].

It is important to consider user-centered design, which focuses on creating an enjoyable and meaningful experience for the player. This includes providing clear feedback, making the game relatable, and ensuring that the game is fun. It is encouraged to consider the player's perspective throughout the design process to create games that are both engaging and effective. Iterative design through prototyping and playtesting is emphasized as a critical part of the game design process. It is recommended to create prototypes of their games, test them with real users, and refine the design based on feedback. This iterative process helps to identify and resolve problems, improve game mechanics and usability, and ensure that the game effectively achieves its goals [49].

2.6 Requirements Engineering

Requirements Engineering is a crucial process in software project development. Its purpose is to comprehend the problem scope of a project and focus on the specific goals of the software. Requirements have a direct impact on the system's feasibility in the early stages of development. The primary activities within the requirements engineering process are elicitation, modeling & analysis, assurance, and management & evolution. Elicitation is the process of discovering the actual needs of stakeholders and exploring alternative specifications for the system-to-be. This is achieved through various techniques, including brainstorming and interviews. Modeling and analysis are then used to describe the elicited information precisely, using techniques ranging from natural language to structural methods. Assurance involves validation and verification processes to ensure the adequacy and quality of specified requirements. Management and evolution focus on managing changing requirements while maintaining traceability between requirements and other software artifacts [55].

2.6.1 Requirements

To understand requirements engineering, it is important to first define what a requirement is. A requirement is a statement expressing desired properties of the environment that the software system should bring about. These statements are not about the properties of the machine itself, but rather about what stakeholders need or want from the system within its operational environment. It is emphasized that requirements should capture the goals, functions, and constraints on software systems and their relationship to precise specifications of software behavior, as well as their evolution over time and across software families [55]. Another definition for requirement is „what the stakeholders in a potential new system need from it and also what the system must do in order to satisfy that need“. They provide the „navigation chart“ and the means of steering towards the selected destination for the development project. This enables the management of risks from the earliest possible point in development and forms the foundation for assessing the impact of changes and managing project success factors [56].

Requirements can be categorized as functional and non-functional. Non-functional requirements cover aspects such as performance, usability, and security, specifying measurable criteria for system attributes. Functional requirements describe the system's operations, inputs, and outputs, often organized by system modes, user classes, or other schemes to clearly describe system behavior [57].

2.6.2 Methods

Several methods exist for eliciting requirements. This process is crucial for scoping the problem and identifying stakeholders' needs. Depending on the project, different methods may be used to determine requirements [55] [58].

Brainstorming

Brainstorming involves informal sessions with customers and stakeholders to generate broad goals for a system. While it can be structured with agendas and formal rules, higher creativity often results from more informal settings. The primary aim is to foster idea generation rather than to finalize requirements. Any significant findings should be recorded for later refinement. Effective brainstorming sessions require a facilitator, an ideas recorder, and well-prepared participants. The brainstorming process benefits from individual idea generation before group discussion, maintaining focus on the topic, encouraging unrestricted creativity, and taking breaks in longer sessions. All ideas should be visibly recorded for everyone. After brainstorming, the ideas are refined using other elicitation methods [57] [58].

Interviews

Interviews are a crucial method for eliciting system requirements from stakeholders, especially for comprehending usability aspects. They can be conducted one-on-one or with small groups and are classified into three main types: unstructured, structured, and semi-structured [57].

Unstructured interviews are informal and conversational, allowing for spontaneous discussions that can occur at any time, making them quite common. However, their effectiveness heavily depends on the interviewer's skill. On the other hand, structured interviews are formal, with pre-planned questions. While they provide a controlled environment for gathering information, they may lead to stakeholders withholding information due to the rigid format. Semi-structured interviews combine the structured approach with the flexibility of unstructured interviews. They begin with prepared questions but also allow for impromptu queries based on the conversation flow [57].

The selection of interview types depends on the situation, including the client's corporate culture and the specific goals of the elicitation process. For example, unstructured interviews may be more effective in informal settings, while structured or semi-structured interviews are better suited for formal or process-oriented environments [57].

Effective interviews should include well-thought-out questions to avoid missing critical information or asking irrelevant or offensive questions. Face-to-face interviews are preferred for capturing nuanced responses, but remote interviews are also options when necessary, albeit with some limitations in understanding subtle aspects of responses [57].

Multiple approaches exist for choosing interview participants, which can be divided into three categories: non-probability, probability, and multi-stage. Non-probability sampling methods, such as convenience or purposive sampling, do not utilize random selection. In contrast, probability sampling techniques, such as whole frame or systematic random sampling, involve randomness. Multi-stage sampling is a specialized technique that combines multiple strategies [59].

To obtain high-quality insights, this thesis conducts qualitative semi-structured interviews. Furthermore, a combination of convenience and purposive sampling methods for interviews is used. The target demographic is individuals in the immediate vicinity with varied experiences in sports and video games who are accessible, motivated, and willing to contribute meaningful insights to the research. The approach chosen is designed to ensure a focused and representative data collection process that aligns with the objectives of the thesis. It is important to note that this method may not be representative of the broader population and may be subject to researcher bias. Therefore, the findings should be interpreted with caution regarding generalizability [59].

Qualitative interviews aim to provide deep insights and understanding rather than statistically representative results. Therefore, the required sample size is generally smaller than in quantitative research. For this thesis, the sample size is determined using saturation since there is no clear answer as to how many people should be interviewed. Saturation means conducting interviews until no new information or themes emerge.

2.6.3 Requirement Documentation

To finish the requirements engineering process, the requirements need to be documented using the system requirements specification. Before finalization, it's crucial to analyze the raw requirements to identify and resolve any issues, such as confusion, redundancy, conflicts, or omissions [57].

The questions that need to be asked are [57]:

1. Is the requirement complete?
2. Is the requirement clear?
3. Is the requirement implementable?
4. Is the qualification plan clear and acceptable?

Requirements can be represented using various techniques, such as natural language and diagrams, or formal languages. The choice of representation depends on factors such

as the technique's maturity, complexity, project constraints, and the team's expertise. Representation styles include informal methods, such as natural language, semiformal methods, such as UML diagrams, and formal methods, such as mathematical formalisms. Formal specifications are preferred, occasionally supplemented by semi-formal or formal elements for clarity and precision [57].

Effective avoidance of imprecision and ambiguity can be achieved through the use of well-organized, clear, and concise documentation of requirements. It is important to employ a consistent writing style and structure, separating operational specifications from descriptive behavior and using a mix of informal, semiformal, and formal representations as appropriate [57].

2.7 User-Centered Design

User-Centered Design (UCD) is a methodology and philosophy in software development and design that places the needs, expectations, and limitations of the end-users at the forefront of the product design and development process. UCD focuses on creating products that are usable, useful, and desirable from the user's perspective [60] [61].

UCD involves several principles. For this thesis, we will focus on the most relevant ones. First, it is crucial to involve users early in the design process to ensure that the product meets their needs and expectations. Second, involving users frequently throughout the process is crucial. Continuous user feedback throughout the design and development process ensures that the project remains aligned with user expectations and needs. This principle advocates for the inclusion of users at every stage, from development through to post-launch, utilizing a variety of methods such as interviews, prototyping, and usability testing. Finally, it is important to prioritize essential features and avoid overwhelming users with too many options at once to prevent cognitive overload. This can be achieved by removing unnecessary features, relocating less frequently used ones to less prominent places, and hiding complex settings that are not needed by all users [62].

The process of USD is divided into different steps, as shown in figure 2.2. The process is called RABBIT, which stands for Research Users, Assess the Situation, Balance Needs, Build an Operative Image, and Test the Product. It is not necessary to follow these steps in order, as methods or techniques can be used interchangeably. The initial step involves gathering comprehensive information about the users, including their behaviors, needs, motivations, and the contexts in which they will use the product. This research is important for basing the design process on actual user requirements rather than assumptions. After researching users, the next step is to evaluate the specific situations in which the product will be used. This involves understanding the physical, social, and technical contexts that can affect how the product is used and the challenges users may encounter. Balancing needs involves finding a compromise between the requirements of various stakeholders, such as users, business objectives, and technological limitations. It entails prioritizing features and design choices based on their significance to user satisfaction and the overall success of the project. Creating an operational image involves

developing a prototype or operational image of the product that translates research findings and balanced needs into a tangible form. This image is a testable model of the product that reflects its intended design and functionality. The final step is to test the prototype with real users to gather feedback on its usability, effectiveness, and satisfaction. This testing is crucial for identifying areas of improvement and validating that the product meets user needs before moving forward with development [62].

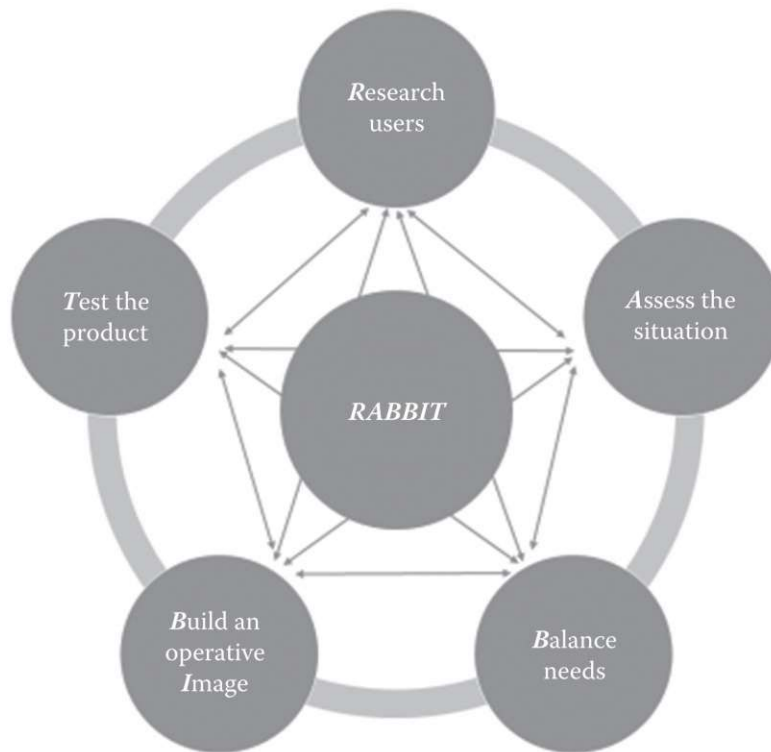


Figure 2.2: Key steps of the RABBIT process of UCD [62]

Prototypes

Building prototypes or operative images is a crucial step in the UCD process. It transforms the abstract vision of a product into tangible and interactive prototypes, shifting the focus from theoretical aspects to practical elements. Different prototypes with varying levels of fidelity exist in the product design process, including the Minimal Viable Product (MVP) and low-, mid-, and high-fidelity prototypes [62].

The MVP approach concentrates on creating a prototype with the least amount of features required to initiate the user testing phase. The MVP is intended to promptly collect feedback on essential functionalities and authenticate the product concept with real users. This prompt feedback is essential for making decisions on product development and avoiding the expenses and time associated with developing features that users do not require or desire [62].

Low-fidelity prototypes, such as paper prototypes, involve creating hand-drawn versions of the product. This technique is characterized by its simplicity and rapid development, making it particularly useful in the early stages of design. It allows for quick and cost-effective exploration of different design concepts, while also making it easy for users to provide feedback on the usability and intuitive nature of the design. This facilitates early identification and resolution of potential issues [62].

Medium-fidelity prototypes provide a more detailed representation of the product's layout and structure. They provide a more refined view of the product design, incorporating a higher level of detail and interactivity than low-fidelity prototypes, but without the full functionality or final visual design elements of high-fidelity prototypes. Medium-fidelity prototypes are particularly useful for testing specific design concepts, user flows, and interactions in a more structured and realistic context [62].

A high-fidelity prototype is a prototype that closely resembles the final product in terms of design, interactivity, and functionality. It offers a realistic experience that can elicit detailed feedback on both the usability and aesthetic aspects of the product. High-fidelity prototypes are typically used in the later stages of the design process to validate design decisions, conduct detailed user testing, and present a realistic version of the product to stakeholders [62].

CHAPTER 3

State of the Art

This chapter examines the state of the art in fitness, motivation, and technology. First, it provides an overview of scientific publications, detailing their objectives, methodologies, key features, and findings. This is followed by a review of a curated selection of commercially available solutions. A comparative analysis of these solutions is presented in the following chapter, highlighting the differences between the different approaches and evaluating their effectiveness in achieving the intended goals. Furthermore, the innovations introduced by this thesis beyond the current state of the art are discussed.

3.1 Scientific Publications

A comprehensive search for scientific publications with objectives analogous to those of this thesis was conducted. The search employed a number of criteria, including „serious game“ or „gamification“ in conjunction with „motivation“ and „physical activity“, along with their respective synonyms.

In order to ensure the relevance of the selected publications, two criteria were applied. Firstly, the studies had to present a digital product. Secondly, the goal of the studies must be to motivate users to engage in physical activity. The type of sport was not constrained, as motivational techniques applicable to various sports can also be adapted to strength and endurance training, which is pertinent to the aims of this thesis.

The subsequent sections provide an in-depth examination of various selected publications. The selected publications were chosen due to their close alignment with the objectives of this thesis and their demonstration of diverse concepts and methodologies for achieving those objectives in the context of gamification, motivation, and physical activity.

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

The paper titled „Mobile gaming in gyms - can fitness and games join together“ [63] investigates the integration of a gym-themed mobile game with real gym exercises. The objective is to comprehend how a mobile game focused on gym activities can be linked to the actual gym environment and how gym-goers perceive this connection. The research aims to merge the trends of mobile gaming and fitness. The study is carried out as a project involving a mobile gaming startup and a gym company [63].

To promote physical activity, the game uses gamification and exergaming elements. The game’s main activities are gym-themed, including boxing, weightlifting, and treadmill use. Players engage in these activities to earn rewards and progress in the game. Additionally, a location-based subgame allows players to explore the real world using GPS coordinates, similar to Pokémon Go, for the opportunity to earn in-game rewards. Competition is available as an option, allowing players to participate in minigames and daily challenges, and compete against each other while striving to climb the daily rankings and earn in-game currency. Figure 3.1 shows the selection of a minigame and figure 3.2 the treadmill minigame. The game integrates with fitness equipment, such as cardio devices and fitness trackers like Google Fit, Apple Health, Polar Flow, and Fitbit, to import real-world exercise data and convert it into in-game currency. Players can also purchase in-game currency to advance faster [63].

The study involved a field test in which gym-goers played a game and provided feedback through questionnaires. The game did not significantly enhance exercise motivation or alter the participants’ workout regimens. However, it did increase their gaming duration. Integrating substantial exercise data into the game provided an additional stimulus for players to interact with it. The paper proposes that the game-first approach was effective in engaging gym-goers who already had an intrinsic motivation to exercise. However, it is necessary to conduct further research to explore how such games could motivate those who need more encouragement to start exercising [63].

The publication and this thesis aim to combine workouts and mobile gaming. However, the publication includes certain implementations that do not align with the objectives of this thesis. The main aim of this thesis is to differentiate between workout categories, specifically strength and endurance, and provide specific incentives to achieve a more customized outcome. Furthermore, the goal of this thesis is to inspire engagement in any form of sport or physical activity, not just those typically found in a gym setting. Additionally, the mobile game discussed in the paper incorporates a monetization system, allowing for in-game purchases with real money to enhance the game’s progress. The aim of this thesis is to promote strength and endurance training by providing in-game rewards to users without the option to progress further with real money. Moreover, the mobile game was utilized as a marketing tool for the collaborative fitness studio. The aim of this thesis is not to endorse any products or ideas, but rather to emphasize that participating in games and deriving pleasure from them should motivate individuals to engage in exercise, regardless of other factors.

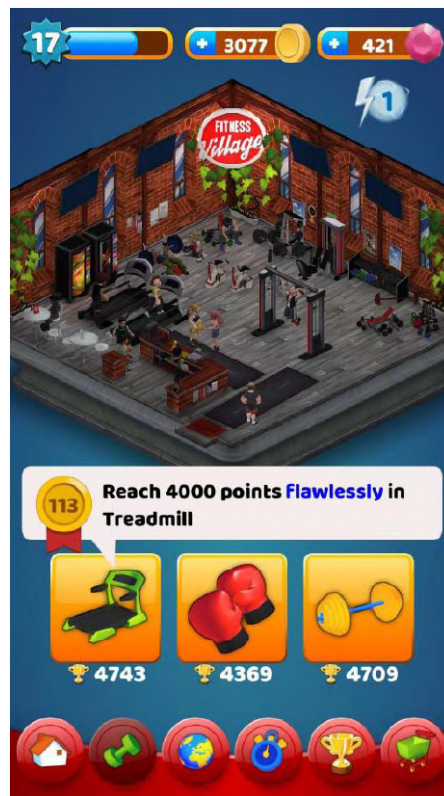


Figure 3.1: Selection of a minigame in the app [63]

3.1.2 Lazarus

This scientific publication centers on the objective of enhancing individuals' motivation for regular physical exercise through the utilization of a serious game dubbed „Lazarus“ [64]. The authors aspire to confront the issue of sedentary conduct and encourage physical activity by administering virtual incentives and gains within the game. The principal constituents of the game consist of fusing real-world athletic endeavors with gameplay to attain in-game benefits. A study with participants who gave feedback on their preferences and motivations for exercise-related games was conducted. The study utilized literature analysis, online surveys, and user-centered design methodology to collect requirements, create the prototype, and assess user preferences. The study participants desired achievements, game advantages, and tangible benefits such as money or coupons for online shops to increase motivation. The game utilizes a rock-paper-scissors principle for gameplay wherein players execute attacks and defenses compared to their opponents. The overview and fight screen can be see in figure 3.3 The game's design aims to promote physical activities lasting at least 30 minutes and provide in-game benefits called „items“. The map displays physical activities, as depicted in figure 3.4, and allows users to check in for completing their sports [64].



Figure 3.2: Treadmill minigame in the app [63]

The findings of the research suggest that the notion of relating physical activity to in-game incentives shows promise for stimulating individuals to engage in exercise. However, additional examination and experimentation are required to verify the efficacy of this approach and examine supplementary characteristics like ranking boards [64].

Lazarus and this thesis both aim to promote physical activity through serious games, but they differ in their approach. This work aims to distinguish between various sports, while Lazarus provides equal rewards for workouts regardless of the sport practiced. Furthermore, the goal of this work is to facilitate synchronization with health services, such as Health Connect, to ensure that real-life workouts have a direct impact on the game.

3.1.3 An IoT Sensing Platform and Serious Game for Remote Martial Arts Training

The paper „An IoT Sensing Platform and Serious Game for Remote Martial Arts Training“ presents an approach to motivate users to participate in sports by integrating Internet of Things (IoT) technology and gamification [65]. The system combines an IoT-enabled sensing platform with a serious game designed for martial arts training,

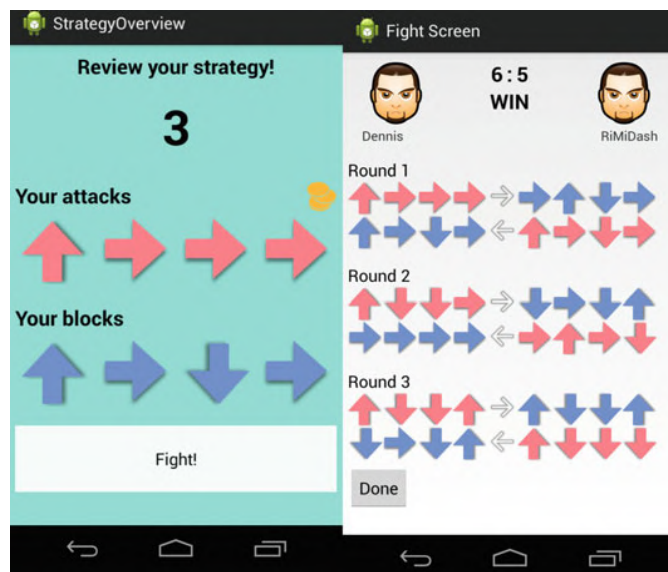


Figure 3.3: Lazarus game procedure [64]

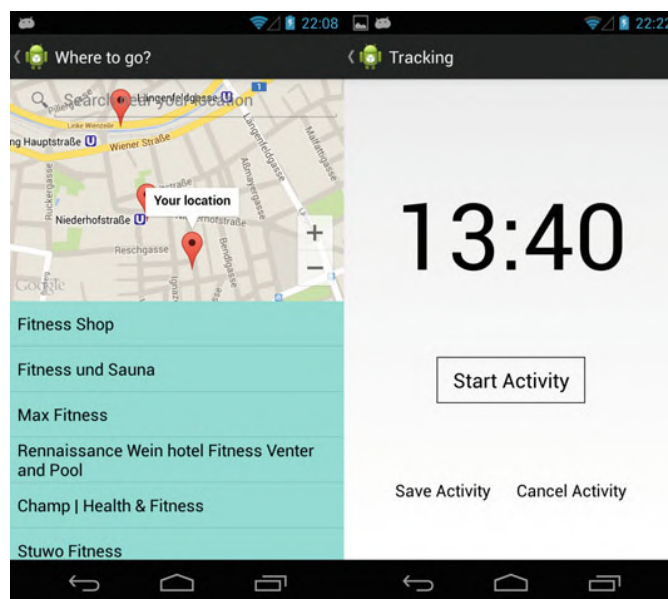


Figure 3.4: Tracking of sports in Lazarus [64]

specifically the Mabu stance in Shaolin Kung Fu. Real-time feedback is provided through pressure-sensitive mats. Figure 3.5 provides an overview of the system [65].

The paper discusses the use of gamification in martial arts training through the „Kung Future“ game. The game provides real-time feedback to enhance the training experience and uses an interface inspired by a Zen garden to create a relaxed focus state. The

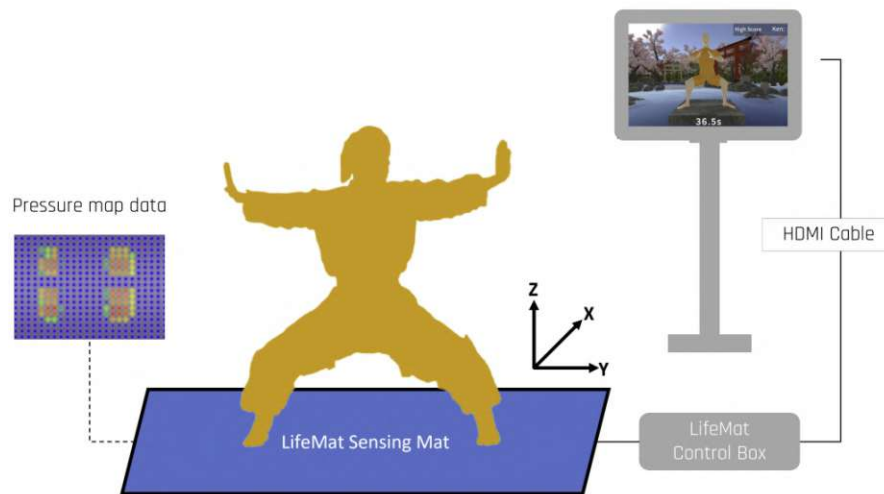


Figure 3.5: System overview of Kung Future [65]

game starts by verifying the user's stance and then uses the LifeMat system's data to provide corrective feedback if the user's posture or balance is off. The game feedback, with the different states, is shown in figure 3.6. This approach turns the training into an interactive game experience, engaging users in the process [65].

Fourteen participants with experience in martial arts were tested under three conditions: no feedback, stopwatch feedback, and game feedback. The results demonstrated that the game feedback condition led to the highest performance in terms of duration and correct technique. Participants were more engaged and motivated when focusing on the game, which was evident in their improved performance compared to the other conditions. The study concludes that gamification improves the training experience by increasing motivation and engagement [65].

The paper discusses the potential benefits of integrating modern technology with sports training to create more engaging, effective, and motivating environments. This integration involves using IoT for real-time feedback and data analysis, combined with gamification elements to make training more interactive and enjoyable. By turning exercises into games, participants are more likely to be motivated and engaged, leading to better performance and adherence to training programs. This approach can be applied to different sports, providing a new perspective on conventional training methods [65].

The focus of this paper is mainly on Mabu stance, rather than strength and endurance training. Additionally, the prototype presented in this thesis is designed to be playable only with a smartphone, while additional hardware, like the pressure-sensitive mat, is required for Kung Future.

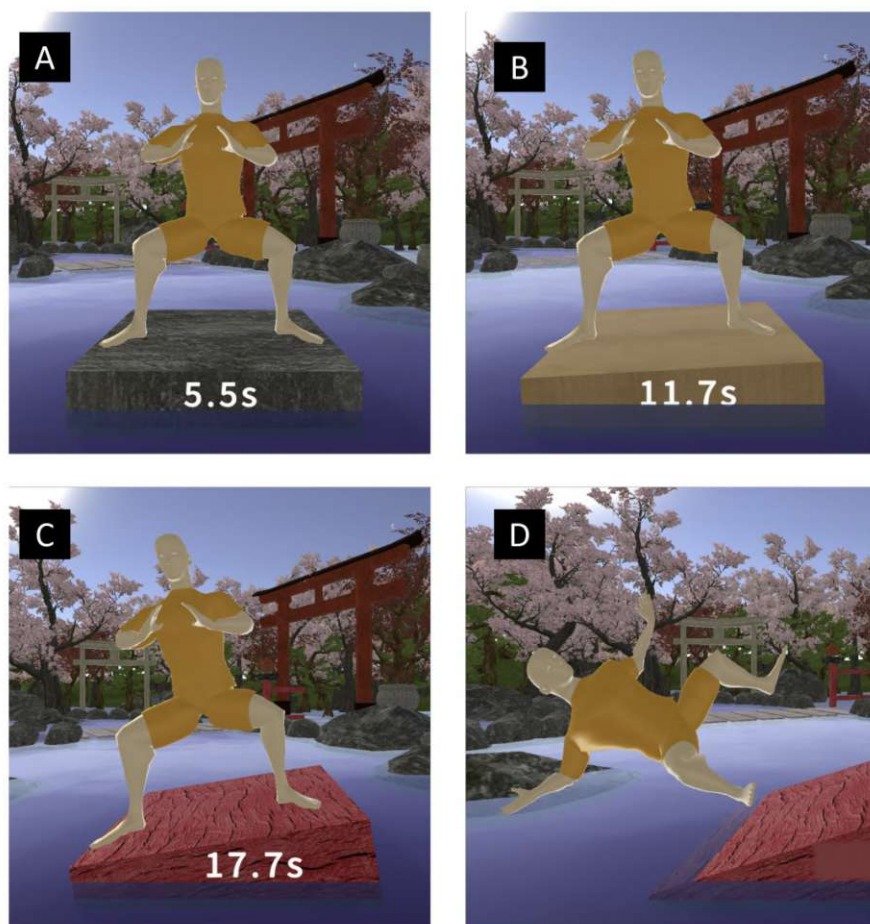


Figure 3.6: Kung Future game feedback system. (A) balanced Mabu condition, (B) slightly leaning Mabu stance, (C) significantly leaning Mabu stance, (D) extremely imbalanced stance breaking Mabu [65]

3.1.4 FitPet

The paper „Examining the Efficiency of Gamification Incentives for Encouraging Physical Activity – Social Collaborations or Interactive Mobile Games?“ examines the effectiveness of a game-based mobile application in promoting physical activity [66]. It acknowledges the prevalent issue of sedentary lifestyles leading to chronic diseases and the difficulties in motivating adults to engage in regular physical activity. The study focuses on FitPet, a mobile game designed to motivate users to walk more [66].

The game uses gamification techniques to increase physical activity through social interactions, virtual avatar visualization, and game-based approaches. The application motivates users to interact with a virtual pet whose health is linked to the user’s physical activity. Steps are converted to game coins, which can be used to interact with and

care for the virtual pet. The health and growth of a pet, shown in figure 3.7, are directly linked to the user's daily physical activity, promoting a sense of responsibility and attachment. Additionally, the growth levels are established by meeting specific step count thresholds and maintaining regular activity, providing long-term goals. Meeting daily goals is rewarded with visual cues such as particle fireworks animations [66].

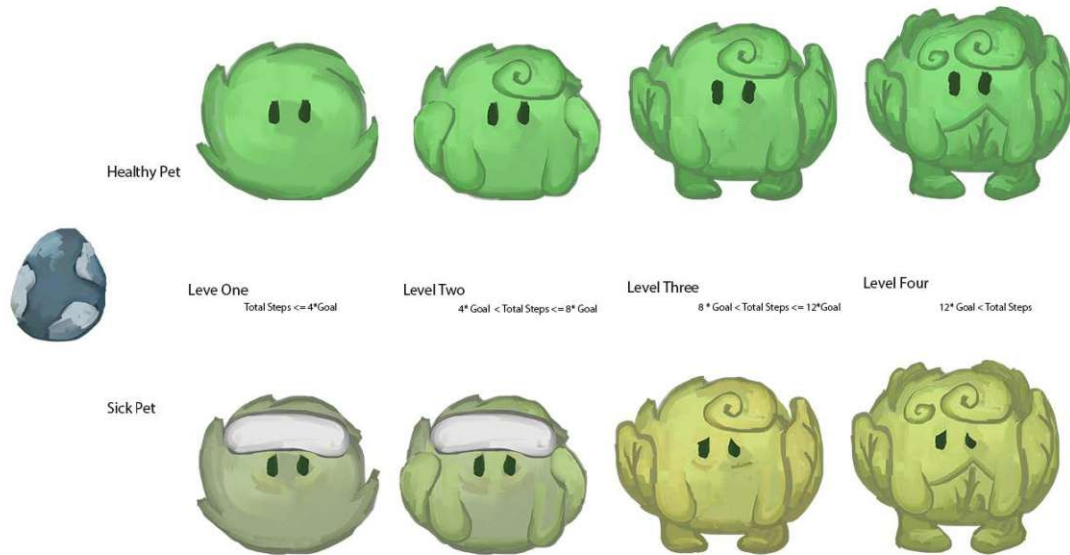


Figure 3.7: The growth levels and health conditions in FitPet [66]

The study prototype examines the efficacy of gamification in promoting physical activity over a six-week field study. The results indicate that social interaction, particularly in mobile challenge groups with active participation and real-time feedback, was the most effective strategy. In contrast, goal-setting was less effective, as participants had difficulty setting appropriate personal goals. FitPet did not motivate as expected due to its lack of continuous feedback and emotional engagement compared to a wearable device. The study concludes that active social elements and continuous engagement are crucial in gamification strategies for promoting physical activity [66].

FitPet focuses solely on walking, whereas this thesis aims to promote both strength and endurance training.

3.1.5 Related Works in Adjacent Fields

This chapter presents additional research on serious games that, while not directly aligned with the specific focus of this thesis, offers valuable insights into related areas of healthcare and rehabilitation. These publications are included because they illustrate the broader potential of serious games to enhance motivation, engagement, and adherence in various

therapeutic contexts, thereby providing a useful perspective on the diverse applications of gamification in health.

A noteworthy trend is the incorporation of serious games into the management of chronic diseases, as evidenced by the development of gamified self-tracking portals for diabetes management. The results demonstrate how gamification can transform the often tedious task of monitoring blood glucose levels into a more engaging and motivating activity. By linking routine health management tasks with game rewards, this approach has shown promise in improving the daily lives of individuals with diabetes, thereby highlighting the broader applicability of serious games in chronic disease management [67].

Another pertinent application of serious games is observed in the training of professionals who are required to make decisions rapidly and with precision. The integration of video training with gamification has been demonstrated to enhance referees' capacity to process information and make rapid decisions in high-pressure situations [68].

In the field of rehabilitation, serious games have been employed to address the monotony often associated with repetitive exercises, which are essential for recovery but can result in patient non-compliance. For example, research on knee rehabilitation has demonstrated that the incorporation of serious games into standard rehabilitation protocols can markedly enhance patient motivation and adherence. Studies employing the use of standard mobile phones attached to balance boards have demonstrated that even simple, cost-effective technologies can be effectively utilized to create engaging rehabilitation experiences. These findings highlight the potential of serious games to enhance the accessibility and enjoyment of rehabilitation, which may ultimately lead to improved patient outcomes [69] [70].

Nutritional education is of paramount importance in maintaining overall health. However, many individuals persist in making poor dietary choices, which can result in serious health conditions such as metabolic syndrome, diabetes mellitus, and cardiovascular diseases. In recognition of the shortcomings of conventional health promotion strategies in Austria, which tend to concentrate on particular demographic groups through the dissemination of informational materials and the organisation of workshops, a novel approach has been introduced in the form of a serious game. The objective of this game is to enhance nutritional knowledge by integrating educational content into an engaging narrative that incorporates mini-games. The game has been designed for a broad audience and can function as both a standalone tool for improving dietary habits or as part of a larger health promotion strategy. It offers a novel approach to combating malnutrition and promoting healthier lifestyles [71].

Furthermore, the potential of serious games in cognitive rehabilitation has been investigated, particularly in the context of stroke recovery. Games that integrate cognitive and physical exercises, such as those utilizing the Leap Motion Controller for wrist and hand rehabilitation, have been developed to assist stroke patients in regaining motor abilities while also engaging their cognitive processes. The iterative development process, informed by feedback from therapists and patients, has resulted in highly adaptable

and user-centered games that offer a personalized rehabilitation experience. These developments underscore the significance of personalization in therapeutic game design, guaranteeing that the particular requirements of patients are met [72] [73].

Furthermore, the utilisation of virtual reality (VR) in rehabilitation signifies a pioneering application of serious games, as evidenced by the creation of VR-powered therapy games for wrist injuries. These games provide a highly immersive environment that can enhance therapeutic adherence and demonstrate the technical feasibility of integrating VR into routine rehabilitation practices. The favorable feedback on usability and acceptance from preliminary evaluations indicates that VR-based serious games have the potential to become a valuable tool in modern rehabilitation strategies [74].

3.2 Commercially Available Solutions

Since not all games or apps were created for scientific purposes, other freely available products are searched. The focus was on finding products that motivate users to engage in physical activity or integrate sports into the gaming experience.

Not only games are presented, but also regular apps. The reason for this is that regular apps also have built-in mini-games or additional motivation mechanisms to encourage users to engage in physical activity.

3.2.1 Games

Ring Fit Adventure

Ring Fit Adventure is an exercise action-RPG game released in 2019 [75]. It uniquely combines physical exercise with the engaging format of a video game. The game uses two key pieces of hardware, shown in figure 3.8: the Ring-Con, a flexible resistance ring, and a leg strap, both of which house the Switch's Joy-Con controllers. Players navigate an in-game character (see figure 3.9) through various levels, and challenges by performing real-world physical exercises, such as jogging in place, performing squats, and squeezing the Ring-Con.

The primary focus of Ring Fit Adventure is to motivate individuals to be physically active through the gameplay itself. While it provides a fun and immersive gaming experience, complete with story, characters, and a fantasy world, the core design and purpose is focused on physical fitness and encouraging a more active lifestyle. The physical activities in Ring Fit Adventure are varied and focus on both aerobic exercises (such as jogging in place, high knees) and muscle-strengthening exercises (such as squats, presses, and yoga poses). The game is designed to provide a full-body workout that targets different muscle groups and promotes overall fitness.

Ring Fit Adventure uses the following mechanisms to encourage physical activity:



Figure 3.8: Ring-Con and leg strap for Ring Fit Adventure [75]



Figure 3.9: Virtual player running the world of Ring Fit Adventure [75]

- **Exercise-Based Gameplay:** The game requires players to perform physical exercises in order to control the in-game character, navigate levels, and fight enemies. This direct integration of exercise into the gameplay mechanics is a fundamental motivator.
- **Customizable Workout Routines:** Players can customize their workout routines by adjusting the intensity and type of exercises, making the game adaptable to different fitness levels and preferences.
- **In-Game Progress and Rewards:** Progress in the game is tied to the player's physical effort. Successfully completing exercises leads to defeating enemies, leveling up, and

unlocking new in-game abilities and areas, providing a sense of accomplishment.

- **Fitness Goals and Tracking:** The game allows players to set fitness goals and track their progress over time, including estimates of calories burned and exercise duration, providing motivation and a sense of accomplishment.
- **Engaging Story and Characters:** The adventure aspect of the game, with its storyline and characters, provides an additional layer of engagement that encourages players to continue training to see the next part of the story.

While this thesis shares the same goal of motivating individuals for strength and endurance workouts, the approaches differ. The goal of this thesis is to provide a low-cost gaming experience that does not require additional hardware beyond the smartphone. In addition, the workouts should be synchronized after the workout to allow full focus on the workout during execution without distractions. Furthermore, Ring Fit Adventure only offers gameplay that requires physical movement, making it impossible to play during a break or rest day.

Pokémon Go

Pokémon Go is a mobile game that uses augmented reality technology [76]. Launched in 2016, the game allows players to locate, capture, battle, and train virtual creatures called Pokémon. These creatures appear as if they are in the player's real-world location, thanks to the game's use of a smartphone's GPS. Figure 3.10 illustrates the process of catching a Pokémon. To navigate the in-game map, players must move around in the physical world, as shown in figure 3.11. The game includes PokéStops and Pokémon Gyms, usually found at notable real-world landmarks, which are essential to the gameplay.

Although Pokémon Go is a game, a significant part of its design and appeal is its ability to motivate players to engage in physical activity, primarily walking. The game's design encourages players to walk to hatch eggs, discover new Pokémon, and interact with in-game locations. Other forms of movement, such as running or cycling, can also contribute to in-game progress.

The game incorporates the following features to promote physical activity:

- **Walking to Hatch Eggs:** Players can find Pokémon eggs at PokéStops, which hatch into Pokémon only after the player has walked a specific distance (ranging from 2 to 10 kilometers), promoting walking or running.
- **Exploration for Pokémon:** The game encourages exploration, as Pokémon appear in various locations, and some types are specific to certain environments. This aspect motivates players to walk or travel to different areas.
- **PokéStops and Gyms:** These are often spaced out within a community, requiring players to walk to reach and interact with them. Engaging in battles at Gyms and collecting resources at PokéStops promotes further movement.



Figure 3.10: Catching a Pokémon in Pokémon Go [77]

- **Adventure Sync:** This feature tracks the walking distance of a player even when the app is closed, counting towards hatching eggs and earning rewards, thus incentivizing daily walking or running.
- **Community Events:** Regular events like Community Days and Raid Hours encourage players to go out, often in groups, to specific locations to catch rare Pokémon or engage in battles, leading to increased physical activity.

The approach of Pokémon Go to motivate people to engage in physical activity differs from the focus of this work. This thesis focuses on strength and endurance training while Pokémon Go solely encourages walking or running.

Zombies, Run!

„Zombies, Run!“ is a mobile app that combines storytelling and exercise [78]. It was launched in 2012 and allows players to listen to various story missions while jogging, walking, or running. The narrative is delivered through audio recordings and voice instructions, and is interspersed with music from the player’s own playlist. Players take on the role of „Runner 5“ in a post-apocalyptic world infested with zombies. They



Figure 3.11: In-game map of Pokémon Go [77]

complete missions that involve gathering supplies, rescuing survivors, and uncovering the story behind the zombie outbreak. Screenshots of the gameplay are shown in figure 3.12.

The game primarily focuses on physical activity through running, but it is also suitable for walking. The app aims to make running more engaging and less intimidating, appealing to a wide range of users, from casual walkers to serious runners. By integrating exercise into a game and story format, it provides a unique and entertaining way to motivate regular physical activity.

„Zombies, Run!“ uses the following methods to motivate physical activity:

- Immersive Storytelling: The app employs immersive storytelling to captivate users, enticing them to eagerly anticipate their next run to hear more of the narrative.
- Zombie Chases Feature: The app includes a feature where players must speed up to escape from zombies, promoting interval training.
- Audio Cues and Feedback: Players are provided with audio cues to track their progress and receive instructions for their next actions, which helps to keep them engaged and motivated.

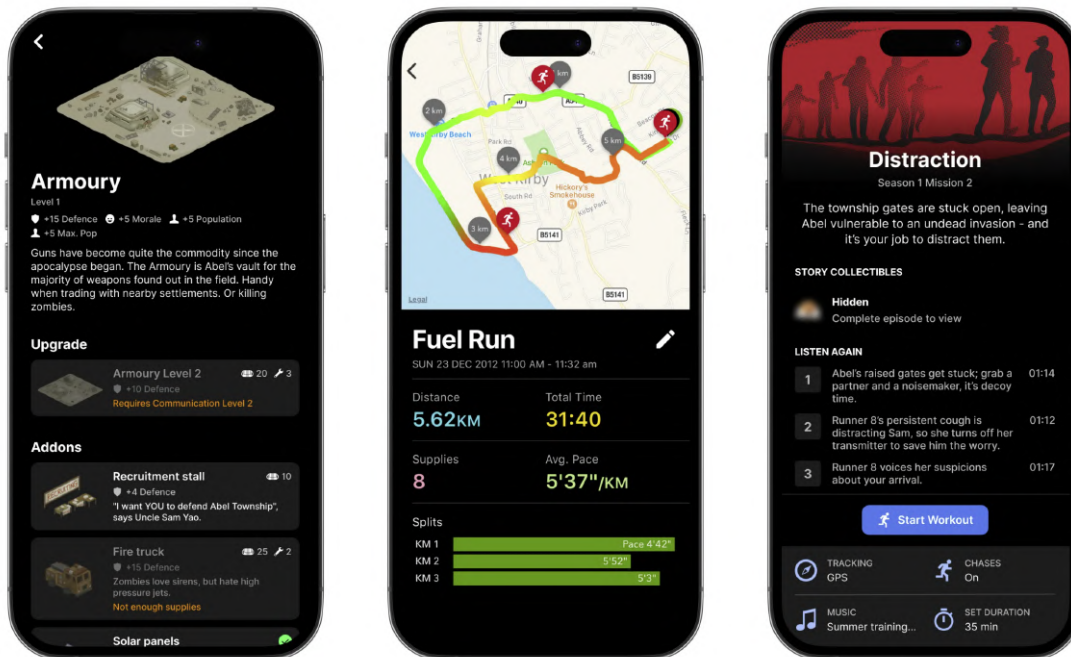


Figure 3.12: Screenshots of Zombies, Run! [78]

- **Mission Structure:** The game is structured into missions, providing users with a sense of purpose and achievement with each run. This can be motivating for users.
- **Customizable Workouts:** Users can customize their running experience based on their fitness level and goals, making it suitable for beginners and challenging for advanced runners.

„Zombies, Run!“ solely focuses on walking or running. In contrast, this thesis concentrates on strength as well as endurance training.

Walkr: Fitness Space Adventure

Walkr: Fitness Space Adventure is a mobile game that combines a fitness tracker with a space exploration adventure [79]. In Walkr, players embark on a cosmic journey where their steps in the real world fuel space exploration in the game. The game features a galaxy with numerous planets to discover, each with its unique environment and characters. Players can build their spacecraft, form galaxies, and embark on missions. The player's movements are translated into „energy“ that propels their spaceship, enabling them to discover new planets and overcome various in-game obstacles. The game design and step counter feature are shown in figure 3.13.

While Walkr is designed as an engaging mobile game, its primary focus is to motivate individuals to engage in physical activity, specifically walking. The game uses the allure



Figure 3.13: Screenshots of Walkr: Fitness Space Adventure [79]

of space exploration and the progression of a storyline to encourage players to be more active in their daily lives. The integration of a step counter with the game mechanics makes physical activity a central element of the gameplay.

Walkr employs the following mechanisms to encourage physical activity:

- **Step Counter Integration:** The main mechanic links the number of steps taken by the player to in-game energy, connecting physical activity to game progress.
- **Exploration and Discovery:** As players walk, they can discover new planets and unlock additional content. This provides a sense of achievement and encourages players to continue walking.
- **Missions and Challenges:** The game features missions and challenges that necessitate a specific amount of energy (measured in steps) to accomplish, motivating players to remain active.

- **Social Features:** Walkr enables players to connect with friends, create or join fleets, and participate in cooperative missions, providing a social incentive to be more active.
- **Rewards and Progress Tracking:** The game provides incentives for reaching specific goals and monitors the player's advancement, providing extra motivation through a feeling of achievement.

While this thesis aims to increase motivation for strength and endurance training, Walkr solely includes mechanisms that encourage taking more steps.

Other games

During the research, other games were found that try to motivate players to move more. Examples for mobile games are:

- **Marvel Move and Venture:** From the same company as „Zombies, Run!“ (see section 3.2.1), these games also provide an audio adventure with various themes, where the user has to walk or run to proceed in the game [80] [81].
- **Wokamon:** A simulation game for virtual pets that synchronizes with fitness tracking apps to track daily steps. The counted steps aid in the growth and development of the player's virtual monster pet [82].
- **Fitness RPG:** A fitness-themed role-playing game where daily steps are converted into in-game energy. The in-game energy is essential for advancing characters, engaging in battles, and uncovering treasures [83].
- **Ingress:** A precursor to Pokémon Go, where players physically move to capture „portals“ located at real-world significant landmarks [84].

These games share a common approach of encouraging player movement, but none of them focuses on strength and endurance training like this thesis.

Exergames, such as Ring Fit Adventure (see section 3.2.1), incorporate physical activity and movement as an integral part of gameplay. These games are intended to promote physical activity and provide entertainment and engagement similar to that of video games.

Various exergames are available on different platforms. Here are some examples:

- **Nintendo Switch Sports:** The game is an engaging sports simulation that offers a variety of sports, including soccer, bowling, or tennis. Players control the game using the console's motion-sensing Joy-Con controllers. It is designed for players of all ages and emphasizes physical activity and multiplayer, allowing for both in-room family play and online competition [85].

- **Fitness Boxing 2 (Nintendo Switch):** This game combines rhythm-based gameplay with boxing exercises. Players punch and dodge to the rhythm of the music, providing a cardio workout [86].
- **Beat Saber (VR Platforms):** This virtual reality rhythm game is not designed as a fitness game, but it requires players to engage in physical movement. Players use VR controllers to slash blocks representing musical beats [87].
- **Just Dance (Various Platforms):** Just Dance is primarily a dance game that encourages physical activity through dancing. Players imitate on-screen dancers to popular songs, and the game tracks their movements and awards points for accuracy [88].

Although the exergames presented have active movement as their core gameplay, they require additional hardware to play. Furthermore, these games primarily promote endurance training, with essential exercises for strength training being absent.

3.2.2 Apps

Fitbod

Fitbod is a fitness app designed to provide personalized workout plans tailored to an individual's fitness goals, equipment availability, and physical condition [89]. The app is known for its algorithm that adapts to the user's workout history, strength training ability, and recovery state (see figure 3.14). It offers a wide range of exercises covering various forms of strength training, bodybuilding and cardiovascular workouts. Fitbod displays detailed instructions, sets, reps and weight recommendations for each exercise as demonstrated in figure 3.15. It also includes features such as exercise demonstrations, progress tracking and workout logging.

Fitbod's main focus is to help individuals to engage in physical activity, particularly strength training and general fitness workouts. The app covers a wide range of exercises, including free weights, machines, bodyweight exercises, and cardio, making it versatile for different training preferences and goals. It uses a data-driven approach to keep users engaged and motivated, without incorporating gaming elements. The application is intended for individuals seeking to enhance their physical fitness, regardless of their experience level, whether they are beginners or experienced athletes.

Fitbod uses various methods to promote physical activity:

- **Personalized Workout Plans:** The app creates customized workouts based on the user's fitness level, goals, and available equipment to keep the exercise routine varied and challenging.
- **Adaptive Training Algorithm:** The application adjusts to the user's previous workouts, recommending various exercises to promote well-rounded and thorough muscle training. This approach facilitates ongoing progress and motivation.

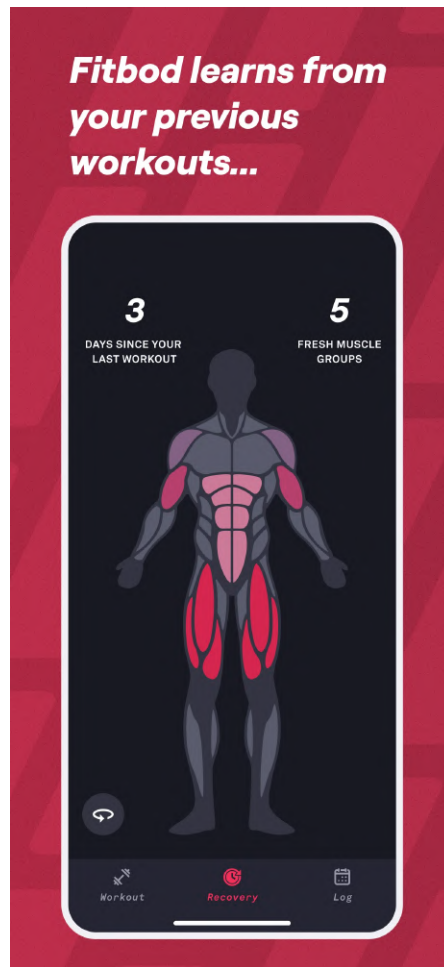


Figure 3.14: Learnings from previous workouts in Fitbod [90]

- **Progress Tracking:** Users are able to monitor their progress over time, including personal records, workout frequency, and volume, which can be highly motivating.
- **Exercise Instructions and Demonstrations:** Detailed instructions and video demonstrations assist users in performing exercises correctly, making the app accessible to beginners and ensuring safety.
- **Integration with Wearables and Health Apps:** Fitbod can synchronize with other fitness devices and applications, providing a more comprehensive perspective of the user's fitness and health data.

Although the app offers assistance for carrying out workouts, it lacks essential motivational mechanisms in form of gamification to encourage users to engage in strength and endurance training for extended periods of time.

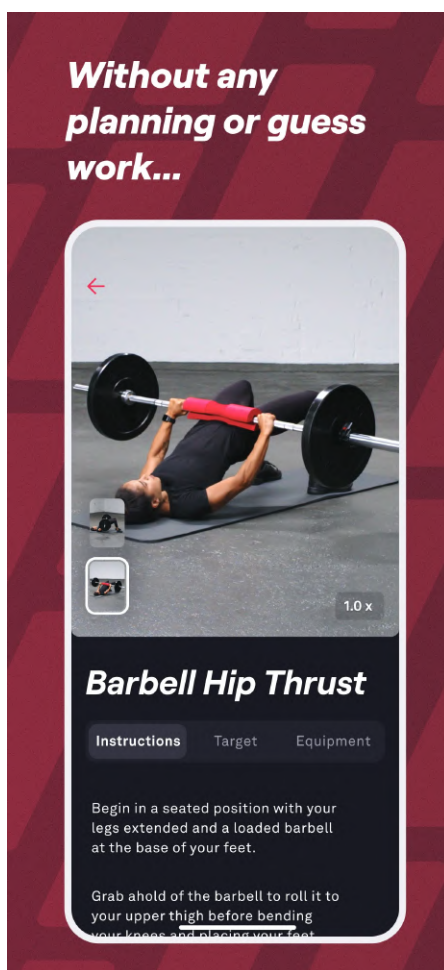


Figure 3.15: Exercise instructions in Fitbod [90]

JEFIT

JEFIT is a fitness app designed for strength training and bodybuilding. It serves as a workout planner, tracker, and instructional resource for fitness enthusiasts [91]. The app features an exercise database with detailed descriptions and animations demonstrating proper form. Users can create personalized workout routines or choose from pre-designed plans tailored to various fitness goals as seen in figure 3.16. JEFIT enables detailed tracking of workouts, including sets, reps, and weights, and provides progress reports, analytics, and body measurement tracking. The app also includes a workout analyzer (see figure 3.17).

JEFIT's main focus is to assist individuals in engaging in strength training and bodybuilding. The app's robust set of features is designed to make workout planning and tracking as efficient and effective as possible, without incorporating gaming elements. It aims to help users achieve their fitness goals, whether they want to gain muscle, improve

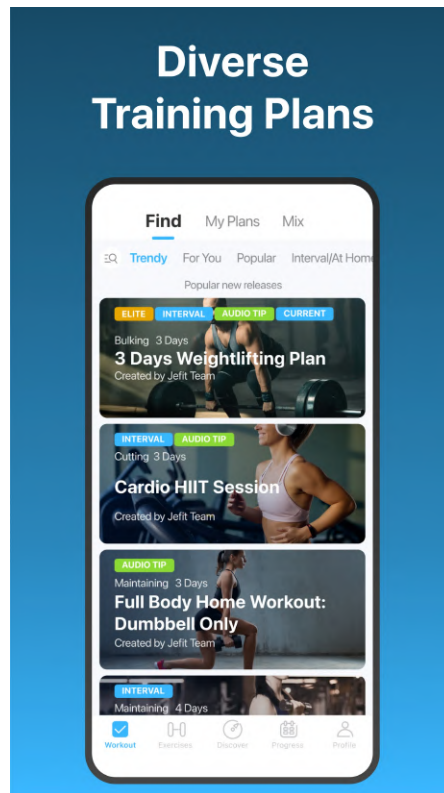


Figure 3.16: Training plans in JEFIT [92]

strength, or enhance overall fitness.

JEFIT includes several mechanisms to encourage physical activity:

- **Customizable Workout Plans:** Users are able to create and personalize their workout routines, which assists in maintaining a consistent exercise regimen.
- **Detailed Tracking:** The capability to record every detail of a workout, such as the number of sets, repetitions, and weights, assists individuals in tracking their advancement and maintaining their drive.
- **Progress Reports and Analytics:** The application offers visual progress reports and analytics, providing insights into performance and improvements over time.
- **Exercise Database with Instructions:** A library of exercises with detailed instructions and animations is available to help users learn new exercises and maintain proper form.
- **Social Community Features:** JEFIT includes a community feature that allows users to connect with others, share workout routines, and participate in challenges, providing a social motivation factor.

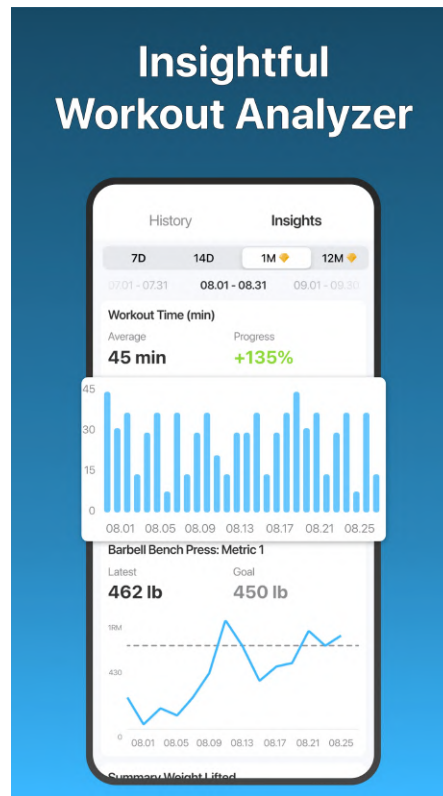


Figure 3.17: Workout analyzer of JEFIT [92]

The app supports executing exercise routines, but lacks crucial motivational features, such as gamification elements to inspire users to consistently participate in strength and endurance training over long durations.

3.2.3 Other apps

During the research, other apps that attempt to motivate players to be more active were found. Some examples include:

- adidas Running (Runtastic): Runtastic is primarily a running tracking app, but it can also access data from other forms of exercise through its integration with health platforms. This integration allows users to have a comprehensive view of their fitness journey, keeping them motivated through extensive data insights. The app's vast integration capabilities make it a valuable tool for tracking fitness progress [93].
- MyFitnessPal: The app is primarily a nutrition tracker, but it also allows users to log their exercise routines, including weight training. Although not a traditional

game, users can track their progress and visualize improvements. Individuals may experience a sense of reward, which can encourage motivation and consistency [94].

- **Iron Path:** A specialized tool that has been developed for weightlifters specifically focused on Olympic lifts. The application records and displays the barbell's motion during a lift, providing in-depth feedback and analysis. Despite not containing conventional gamification aspects, the app's tracking and feedback features enhance the training experience by making it more informative and engaging [95].
- **StrongLifts 5x5:** Focused on the 5x5 weight training program, this application enables weightlifters to track their progress. Serving mostly as a log, it offers the ability to synchronize data with Google Fit and Apple Health. The structure of the 5x5 regimen, coupled with progress tracking, presents users with a clear path to advance, promoting perseverance and devotion [96].

3.3 Summary and Comparison of State of the Art

This analysis examines a variety of state-of-the-art solutions, with a specific focus on their application to fitness and exercise motivation. The selection includes both scientific publications and commercially available products, categorized into games and applications.

The evaluation emphasizes the range of physical activities targeted by these solutions. While some focus solely on walking, others include strength and endurance training.

The use of technology is also a significant area of interest, with solutions utilizing a variety of devices such as smartphones, controllers, and IoT sensors. The analysis examines how these devices are used, particularly how additional hardware can enhance training motivation through innovative approaches.

User engagement strategies employed by these solutions form a core part of the evaluation. This includes methods like tracking personal fitness progress, providing structured training instructions, and creatively incorporating physical activity progress into game mechanics. These strategies are pivotal in understanding how digital tools can effectively motivate and sustain user engagement in physical activities.

Furthermore, the analysis assesses each solution for potential shortcomings or gaps, particularly in relation to the aim of this thesis. The identified areas where existing solutions may fall short in motivating regular strength and endurance workouts provide valuable insights for future development.

In the subsequent section 3.4, a detailed summary of the innovative prototype developed as part of this thesis is provided. This summary highlights the unique features and design approaches of the prototype and positions it within the context of the analyzed state-of-the-art solutions, emphasizing its potential contribution to the field of serious games, motivation, and physical activity.

3.4 Innovation of Prototype Developed in Thesis

This section compares the innovation of the prototype developed in this thesis to the state-of-the-art solutions in the fields of serious games, motivation, and physical activity.

It offers a unique approach by integrating both strength and endurance training in any setting, unlike many existing applications that concentrate solely on activities like walking or running or exclusively on endurance training. This focus addresses a notable gap in the current market, offering users a more versatile approach to fitness.

This prototype has the ability to synchronize with health services like Health Connect. This feature allows users to focus solely on their exercise without the distraction of interacting with the app during their workout. Additionally, synchronization helps tracking progress.

The objective of this thesis is to introduce an feature to distinguish between different types of workouts, enabling the creation of more customized training routines. This approach is expected to improve the effectiveness of workouts and enhance user engagement and motivation.

Recognizing the significance of rest and recovery in any fitness regimen, the game is designed to be playable without physical exertion. This characteristic guarantees that users can take necessary breaks while still engaging with the game. This continuous interaction with the game keeps the user's upcoming workouts and fitness goals top of mind, fostering a consistent and sustainable fitness habit.

The prototype is designed to function with just a smartphone, making it more accessible, cost-effective, and simple for a broader user base. This design choice sets it apart from state-of-the-art solutions that require additional equipment.

In summary, these features culminate in a new and innovative prototype. It distinguishes itself from other fitness apps and games by providing a more all-encompassing method of motivating individuals for both strength and endurance workouts.

CHAPTER 4

Results

This chapter presents the results of the thesis and the conducted iteration steps and requirement elicitation. The development process was iterative, incorporating multiple stages of user feedback and prototype development in order to ensure that the final product met user needs and preferences. This chapter is organized to present each iteration step, the methodologies employed, and the findings that contributed to the creation of the serious game.

The initial iteration was primarily concerned with the collection of qualitative data through semi-structured interviews. Six participants with varying levels of experience in both sports and video games were selected to provide a broad perspective. The objective was to gain insight into their current exercise habits, experiences with sports and fitness apps, and their perceptions of how a serious game could enhance their motivation for physical activity. Based on the findings of the interviews, a comprehensive set of requirements for the serious game was developed. The key features identified included the provision of rewards for gameplay and physical activity, the incorporation of competitive mechanics, and the necessity for an intuitive user interface.

The second iteration involved the creation of a low-fidelity prototype based on the requirements identified from the initial interviews. The prototype included wireframes to illustrate the various screens, their layout, and functionality. It focused on game mechanics designed to motivate users to engage in regular physical activity. The objective was to create a visual representation of the game's structure and features without delving into the intricate details of its design.

In the third iteration, the low-fidelity prototype was subjected to a new round of interviews with the original participants. They provided feedback on the prototype, sharing their general impressions, preferences, and suggestions for improvement.

The fourth iteration entailed the development of a high-fidelity prototype that incorporated the feedback and requirements gathered from the previous iterations. The prototype

included a fully operational game with enhanced graphics, detailed gameplay mechanics, and a comprehensive synchronization system for integrating real-world physical activity data. The game was designed to provide a more engaging and immersive experience.

The final iteration involved user testing with a new set of participants, including some from the previous iterations. The high-fidelity prototype was installed on the participants' smartphones and they were asked to engage with the game over a two-week period. The objective of the testing was to assess the efficacy of the serious game in stimulating physical activity and to obtain feedback on the user experience and any remaining areas for improvement. The feedback from these tests provided valuable insights into the game's impact on physical activity motivation.

4.1 Iteration 1: Interviews

In the first iteration, qualitative and semi-structured interviews were conducted with the aim of gathering experiences and suggestions to serve as a basis for defining the requirements for the serious game. The participants were asked whether and in what form they do sport regularly, including the type and frequency of activities. In addition, the extent to which a serious game could serve as a motivational aid for regular sporting activity and what specific ideas and wishes they have regarding the game will be discussed.

The following questions served as the basis for the interviews:

- Socio-demographic data
 - Age
 - Gender
 - Highest level of education completed
- Do you exercise regularly?
 - If yes, which sports?
 - * How often do you exercise?
 - * Do you combine strength and endurance training or do you only focus on one category?
 - * What is your goal?
 - * What is your personal motivation for doing sport?
 - If not, what are the reasons for this?
 - * Would you like to do more sport? If yes, what prevents you from doing so?
- Do you often play video games?
 - If yes, which ones?

- What was your previous experience with sports and fitness apps or games?
 - What did you like and dislike about these apps?
- To what extent can you imagine the use of serious games in your work or personal environment?
 - For what specific purposes or projects would you use serious games? Can you give specific examples of where you see the added value?
 - If you are not currently considering serious games: What are the main reasons for this? Are there specific challenges or concerns that are holding you back? How could these be overcome?
- Do you think that a serious game could (additionally) motivate you to exercise?
 - If yes, why?
 - If not, why not?
- What features or game mechanics would a serious game need to have to motivate you to exercise regularly?
 - What kind of rewards or incentives would motivate you the most?
 - How important would social features such as leaderboards or group challenges be to you?
 - How would you like to be informed about progress and achievements?
- How important is it for you that the game predetermines the type of physical activity that should be done?
 - Would it be important for you to focus on one discipline (strength or endurance) or would you prefer to promote both at the same time?
- If you could create a serious game about fitness, what would it look like (Style/Theme)?

In order to cover a broad field, six different people with varying amounts of video game and sports experience were interviewed. Table A provides an overview of the various participants with their age, gender, highest completed education, their experienced training types as well as game genres.

All participants have already tried out various apps or games that require physical movement. Pokémon Go was mentioned most frequently, with participants particularly emphasizing that they had walked significantly more as a result of playing the game. However, the game was criticized for the fact that the game concept became boring relatively quickly and was only played by the participants for a few months. This has led to a subsequent decline in their movement activity. In addition to this game, examples such as Eyetoy, Wii Fit, Wii Sports, Fitness Hike and Apple Fitness were also mentioned.

4. RESULTS

Participant	Age	Gender	Education	Training types	Game genres
Participant A	27	Male	Compulsory school	Karate, handball and gym	Mixed with mostly first-person shooters and card games
Participant B	26	Male	Bachelor's degree	Strength training, soccer and tennis	Mixed
Participant C	27	Male	Bachelor's degree	Soccer, yoga, pilates and HIIT	Mixed
Participant D	30	Female	Bachelor's degree	Kick boxing and gym	Mixed
Participant E	27	Male	Bachelor's degree	Soccer and strength training	Mixed
Participant F	26	Male	Technical high school	Gym	Mixed with mostly multi-player games

Table 4.1: Summary of participant information

The participants exhibited a generally positive attitude towards serious games. Many recognized the potential of these games to integrate seamlessly with real-life activities and considered them beneficial for enhancing motivation and engagement. Several participants appreciated the concept of serious games not just as a form of entertainment but as a tool for personal development, including physical fitness and skill acquisition. For instance, one participant highlighted the usefulness of serious games in initiating beginners into new fields such as programming, suggesting that the engagement level might vary with the complexity of the topic. All participants can imagine using such a serious game to increase their motivation for sport. Furthermore, all participants who are not currently actively involved in physical activity said that they could imagine being more active again with the help of a serious game.

The participants mentioned several game mechanics that they could imagine would increase their motivation for strength and endurance training. These include:

- Progress: All Participants highlighted the importance of progress within the game. It is important to them that you can progress through the gameplay and unlock new rewards. Examples mentioned were leveling up characters and unlocking new abilities or equipment.

- **Integration of Physical Activity:** Many participants said that it is important that physical activity should have a direct impact on the game. Similar to game progression, there could also be mechanics to unlock new or unique rewards through sport.
- **Competitive:** All respondents emphasized the value of competitive features. It is important to the participants that they can compare their own game and sports performance with other people, as this could provide additional motivation to take part in sport. Leaderboards are a frequently cited example of this.
- **Statistics:** One participant commented that it would be important for him to have a statistics page where he could see the current progress of their game and sport performance, as this would motivate him to continue playing and training. An important aspect of this is statistics that show that you exercise regularly, as this would provide additional motivation not to break this regularity.
- **Notification and Reminders:** The irregular schedule of one participant led to the suggestion of in-game notifications and reminders. It would be helpful if the game sent notifications if no workout was done for a few days.

Besides the game mechanics, during the interviews these three rough game ideas were evolved:

- A fighting game in which the character gets better when the player is physically active in real life. In particular, a mechanic which directly links the amount, intensity and type of physical activity to the progression and capabilities of the character in the game, was met with a positive response from all participants.
- A game where the player receives some sort of currency like energy when doing workouts in real life. This currency could then be used to continue playing the game, unlock new content or enhance the character's abilities.
- A storytelling game where the story continues as soon as you start exercising in real life.

When it comes to whether the game should predetermine the type of physical activity, all participants said that it would be good if each person could pursue their own sporting goals independently of the game. However, it was said that it would be an additional motivation if the game gave different rewards depending on the type of physical activity, as this would make the game more dynamic. On that regard, one participant had the idea that there should be different levels of difficulty and depending on the selected difficulty, the rewards should be linked to the type of sport or not. Furthermore, this participant suggested that at the highest level of difficulty, you should lose the rewards you have won over time if you do not complete any training sessions in order to increase your motivation to train regularly.

Id	Requirement
R1	Rewards through gameplay
R2	Rewards through physical activity
R3	Competitive mechanic in form of leaderboard
R4	Statistics about the progress in game and physical activity
R5	Notification for regular physical activity
R6	Long-term motivation for playing and physical activity
R7	Different difficulties to match sporting goals of players
R8	Matching game theme
R9	Intuitive UI and easy-to-use operation

Table 4.2: Requirements extracted from the analysis of the conducted interviews

No participant named a preferred game style, but some factors were named which would be important to the participants. These include that the all graphics should follow the same style and that style should match the game type. Furthermore, the theme should be appealing and, if possible, contain matching animations. One participant explicitly emphasized that the game should have an intuitive UI and easy-to-use operation.

4.1.1 Requirements

Based on the results of the interviews, the requirements for the serious game were created. Particular attention was paid to which aspects and game mechanics were most important to the interviewees in order to design an appealing game for all participants. These game mechanics are shown in table 4.2.

4.2 Iteration 2: Low-fidelity Prototype

A game idea for the serious game was designed based on the requirements obtained in section 4.1.1. This section provides a detailed description of this idea using wireframes. The wireframes are used solely to provide an overview of the different screens, their layout, and functionality, rather than the design of the elements.

4.2.1 Game Idea

The game puts the player in the role of a gladiator competing in an ancient colosseum against waves of enemies. The character has three core attributes: health, strength, and stamina. These attributes determine the gladiator's ability to withstand damage, the effectiveness of their attacks, and their agility and speed in combat. The game is titled „Colosseum Champions“. The gladiator theme is chosen in order to match the fighting game style, meeting the requirements of R8.

In contrast to the conventional approach of creating a series of short-lived levels, the focus of this game is on a single, dynamically designed level that continually fills with new

waves of enemies. Players are challenged to consistently surpass their peak performances to achieve new high scores, which is reminiscent of the popular rogue-like genre. This game mechanic fulfills a significant portion of the R6 game design criteria without the need to design numerous levels.

Upon completion of each run, the gladiator is awarded experience points based on their performance to meet R1. Once a sufficient number of experience points has been accumulated to reach a new level, the player is presented with the option to enhance one of the character's attributes, either strength or stamina. Health is automatically increased with every level-up. The game is played from a bird's-eye view. The player controls movement via a touch control pad and executes attacks with a touch button.

Gameplay Variety: Weapons and Temporary Upgrades

To provide long-term engagement and enjoyment and further fulfill R6, it is critical to offer a dynamic and varied gameplay experience. This is accomplished by offering players a range of permanent weapons and temporary upgrades that can be unlocked and utilized throughout the game. At the beginning, players only have their fists as a basic weapon. However, by successfully completing challenges, which are explained in more detail in section 4.2.1, they can unlock additional, uniquely functioning weapons. The following list presents all available weapons:

- Fists: Allow attacking a single opponent, slightly pushing them back upon impact.
- Sword: Enables striking multiple opponents in one swing.
- Spear: Offers increased range but is limited to targeting only one opponent at a time.
- Bow and Arrow: Allows attacking targets from a distance.

The introduction of temporary upgrades, which are randomly generated during gameplay, expands the strategic options available to players. The availability of these upgrades is contingent upon the number of enemies defeated. The following upgrades are available:

- Bleeding: Causes temporary bleeding damage to opponents upon impact.
- Heart: Restores a portion of maximum health if it is not already full.
- Clock: Temporarily slows down all enemies in the level while the player operates at normal speed.
- Lightning: Deals damage to nearby enemies through a quick burst of lightning.

This strategy permits players to experiment with various combinations of tactics, weapons, and upgrades during each run, thereby encouraging curiosity and sustained engagement.

Progress Through Physical Activity

The primary objective of this serious game is to encourage players to engage in regular strength and/or endurance training. Consequently, the greatest rewards are accrued through physical activities in the real world. To achieve this objective, players must utilize a fitness tracker to monitor their physical activity and synchronize this data with Health Connect. In the game, points are allocated based on the duration and intensity of the physical activity, as determined by the data provided by the API. Subsequently, the aforementioned data can be imported in order to enhance the character accordingly. Training sessions that last longer than 20 minutes guarantee a level increase. Additionally, the character's level is incrementally increased with each improvement point earned, thereby reflecting the character's evolving abilities. This mechanic is implemented with the objective of achieving R2.

In order to accommodate each player's balance between gaming tactics and fitness goals and fulfill R7, three difficulty levels are offered:

- **Easy:** After training, players have the option to enhance either their character's strength or stamina, with their health automatically increasing with each improvement.
- **Normal:** In this mode, improvements are directly tied to the type of physical activity performed. For example, strength training increases strength, while endurance activities like running boost stamina. Health also improves automatically without any additional effort.
- **Hardcore:** Similar to Normal mode, but with the addition that the character's attributes decrease weekly if no physical activity is recorded.

Players have the ability to change difficulty levels at any point, with the exception of Hardcore mode, which is locked for three weeks upon exiting to prevent abuse.

Steps tracked by a fitness tracker or smartphone do not count as dedicated workout, but still provide additional experience points to encourage regular movement.

To increase the motivation to train regularly, the first workout of the day will be rewarded with 50% extra experience points.

Home Screen

Figure 4.1 shows the main menu, which is the first screen the player sees when starting the game. From here, the player can navigate to the following screens:

- Start
- Challenges

- Synchronization
- Statistics & Achievements
- Settings
- Help

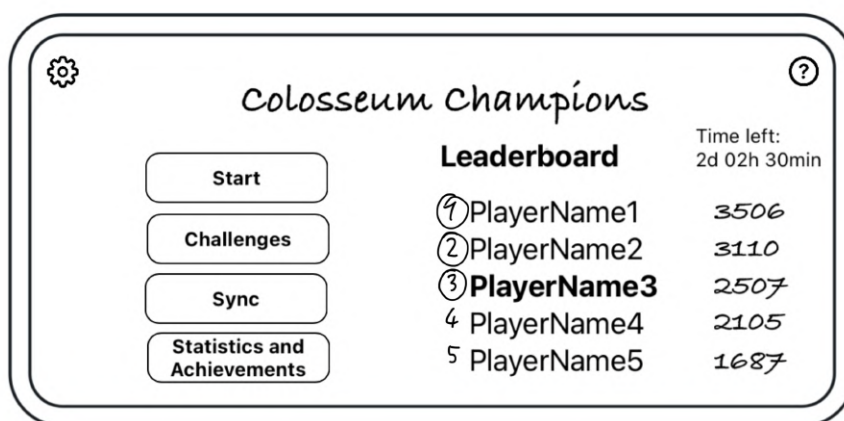


Figure 4.1: Home screen

To satisfy R9, the navigation is very simple: All game menus can be accessed from the main menu. Within these menus, the player has the option to return to the main menu at any time.

In addition, the player is presented with the current leaderboard, which is explained in section 4.2.1. A timer indicates when the leaderboard will be reset.

Game Screen

Figure 4.2 depicts the game screen, which displays the character, enemies, and the current values of the character's attributes: health, strength, and stamina. Additionally, the control pad, attack button, and current score are visible.

In the event that the character's health is depleted, the game will end and the player will be directed to the game over screen, as illustrated in figure 4.3. This screen displays the score achieved and the current high score, as well as the experience gained. At this point, the player may elect to return to the main menu, resume gameplay, or access statistical data to enhance attributes following a level-up.

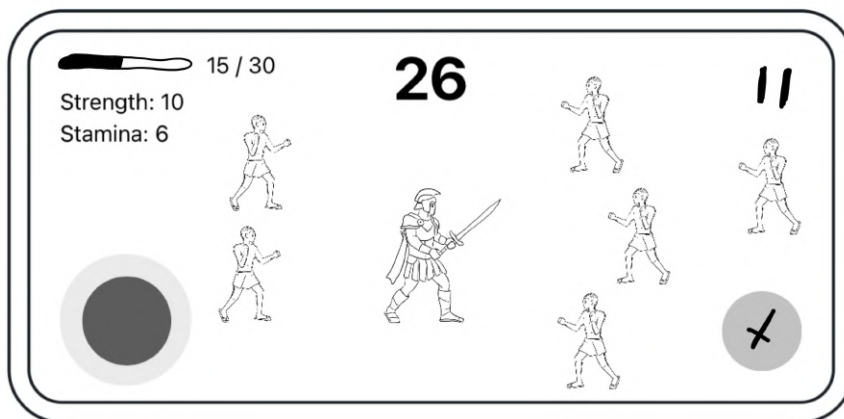


Figure 4.2: Game screen



Figure 4.3: Game Over screen

Challenges

In order to promote regular physical activity and further fulfill R2, the game features weekly challenges that players can choose based on their fitness goals. The player is permitted to select one challenge per week. The challenges are as follows:

- Weekly Workout: Complete a workout session at least three times per week on

different days for a minimum of 20 minutes.

- Step Counter: This week, aim to walk at least 40000 steps.
- Calorie Burn: Burn at least 1500 calories this week through physical activities.

Figure 4.4 illustrates the manner in which completed training sessions update the challenge progress bar and unlock new weapons. The weapons that have been unlocked are displayed alongside those that remain locked, which are symbolized by a question mark. Upon selecting a weapon, it is designated as the current weapon, if it is unlocked. Moreover, the player is presented with a display of completed challenges and their respective rewards. Those players who have already unlocked all weapons will receive additional experience points when they complete a challenge.

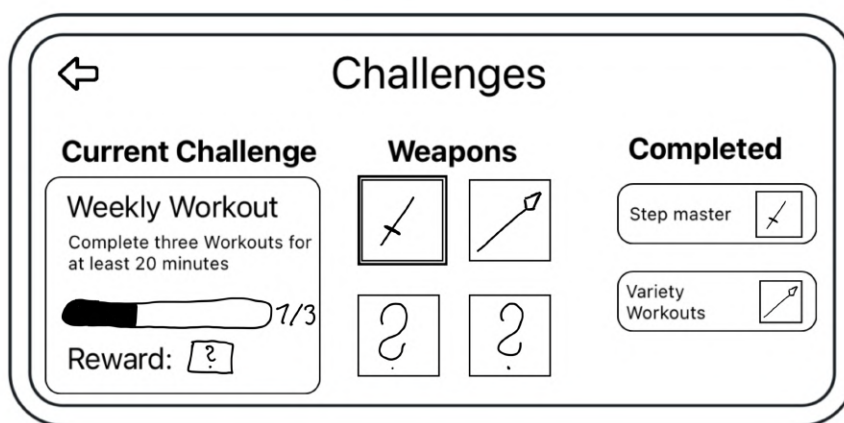


Figure 4.4: Challenges screen

Leaderboard

In order to achieve R3 and to further motivate players by incorporating competition into the game, a leaderboard is added. As the prototype will be played by a limited number of players, all participants will be included on the leaderboard. The three highest-ranking players at the conclusion of the week will receive additional experience points based on their respective positions. Also, the leaderboard will be reset, thereby affording each player a fresh opportunity to compete. The overall score for the leaderboard is comprised of two primary components:

- Highscore: The player's high score for that week.

- **Workout Score:** Calculated based on the player's workout performance that week. This score is based on the same metrics used to calculate rewards for individual training sessions.

It is crucial to acknowledge that the workout score is given greater weight than the high score, which serves to enhance motivation for physical activity. In the leaderboard, each player is highlighted in a color corresponding to the selected difficulty level, thereby encouraging players to select a higher difficulty level:

- Easy: blue.
- Normal: yellow.
- Hardcore: red.

Statistics and Achievements

In order to comply with R4, a page displaying the player's statistics and achievements is included. The design of this page is illustrated in figure 4.5. The statistics are designed to provide the user with an overview of their achievements and serve as further motivation to continue engaging with the game and physical activities. Furthermore, the option to allocate surplus points for improvement will be available. The statistics include the following:

- Current character level and experience
- Current health, strength, and stamina
- Experience through playing
- Experience through sport
- Highscore
- Completed workouts in this week
- Completed workouts overall
- Weekly workout streak: A chain of weeks in which the player has conducted at least one training session each week for at least 20 minutes
- Steps in this week
- Steps overall

In order to further fulfill R2, achievements are implemented. The objective of these achievements is to sustain motivation to continue playing the game and participating in regular physical activity. They can be unlocked at any time and include:

- Walk 5.000/10.000/15.000/20.000/25.000/30.000 steps in one day.
- Accumulate a total of 10.000/25.000/50.000/100.000/150.000/200.000/300.000 steps.
- Complete your first workout session.
- Complete two/three/five/seven workout sessions in one week.
- Burn 500/750/1000/1250/1500/2000/2500 calories in one week through training.
- Complete at least one workout every week for two/four/six/eight/ten/twelve weeks.

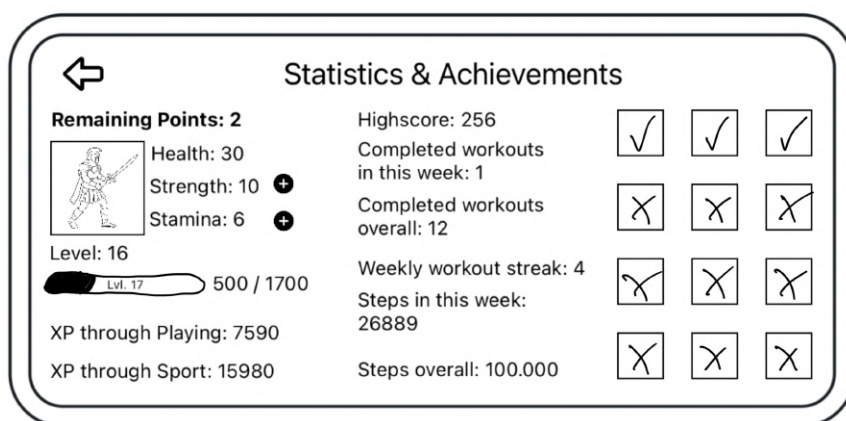


Figure 4.5: Statistics and Achievements screen

Help

A help page will be provided within the game, offering useful information about the game itself and the physical activity involved. The design of this page is illustrated in figure 4.6, which includes the following elements:

- An explanation of the game principle.
- Details about challenges, leaderboard, achievements, and additional bonuses.

- Information for players to take breaks to prevent overexertion.
- Further tips about physical activity:
 - Set goals, such as losing weight or building muscle
 - Document your progress
 - Pay attention to your diet
 - Give your muscles time to recover
 - Sleep enough

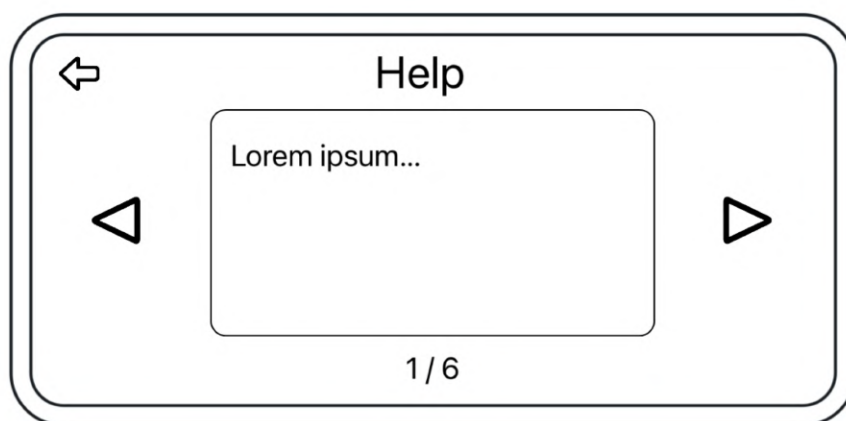


Figure 4.6: Help screen

Synchronization

The synchronization screen provides players with the option to synchronize their tracked workouts with the game. Moreover, players are presented with more detailed information regarding the previously synchronized workouts, including the date, time, and duration, as well as the game rewards received as a consequence. The layout is depicted in figure 4.7.

Notifications

To meet R5, players will be duly informed via notifications if they have not engaged with the game for an extended period of time. This approach ensures continued engagement with the game and the sport. It is of the utmost importance to refrain from sending notifications with excessive frequency, as this may lead to player frustration and a decline

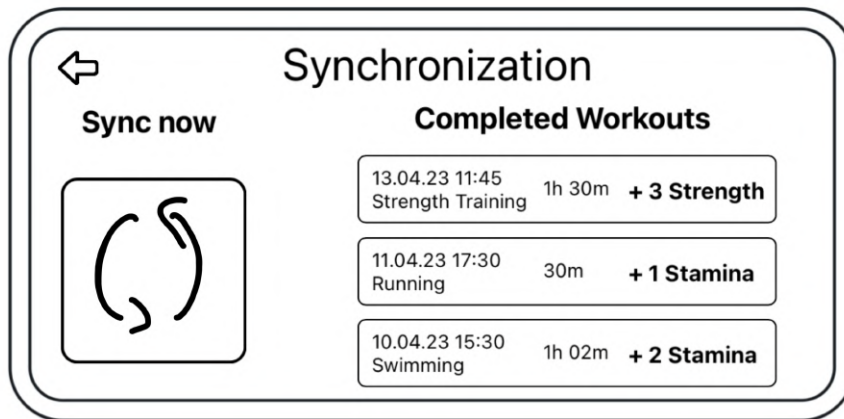


Figure 4.7: Synchronization screen

in motivation. Moreover, the aforementioned settings can be deactivated within the settings menu.

Settings

The settings permit the user to activate or deactivate notifications and adjust the difficulty level. Furthermore, the player is afforded the option of selecting their desired player name. The layout is illustrated in figure 4.8.

4.3 Iteration 3: Interviews

The subsequent phase involved conducting interviews regarding the low-fidelity prototype described in section 4.2. The participants were given one week to reflect on the game concept. Subsequently, each participant was interviewed, during which they first provided their initial impressions and were then queried with the following questions:

1. What is your general impression of the prototype?
2. Which features of the prototype do you particularly like?
3. Which features of the prototype do you dislike?
 - a) How would you improve that aspect?
4. Do you think the number of points in the leaderboard should be limited to prevent demotivation?

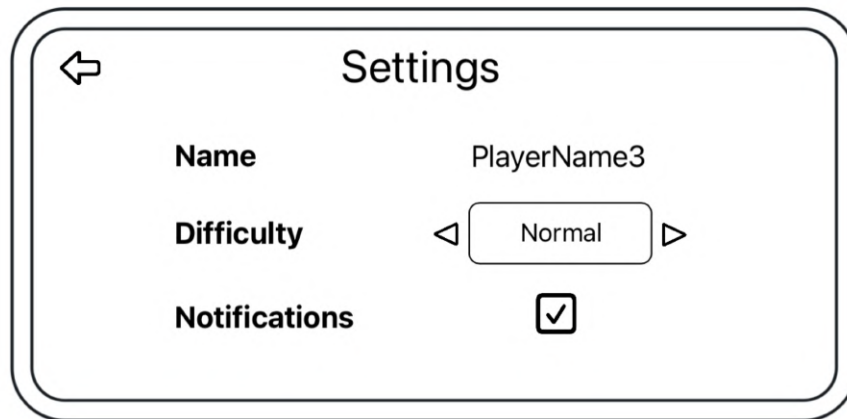


Figure 4.8: Settings screen

- a) If yes, how? Would you prefer a soft cap or a hard cap?
 - b) If not, what is the reason for this?
5. Do you think that the duration and difficulty of the challenges are appropriate or would you change them?
 6. Can you imagine that the serious game could motivate you to exercise?
 - a) Which aspects would motivate you the most?
 7. Are there any aspects that would demotivate you? If yes, which ones and why?
 8. What do you think of the notifications? Would you change anything about them?

All participants of the initial interview iteration (as detailed in section 4.1) were included in this subsequent interview iteration. In order to provide a comprehensive overview of the participants, the list of participants is presented again in table 4.3.

4.3.1 Interview Results

The participants' general impression of the prototype was overwhelmingly positive. It was observed on several occasions that the participants considered the game concept to be well thought out and expressed enthusiasm for the final result. When queried as to which features the participants found most appealing, their responses were diverse. Some participants expressed a preference for the diverse array of weapons, the dynamic level of difficulty, and the opportunity to complete challenges and attain achievements.

Participant	Age	Gender	Education	Training types	Game genres
Participant A	27	Male	Compulsory school	Karate, handball and gym	Mixed with mostly first-person shooters and card games
Participant B	26	Male	Bachelor's degree	Strength training, soccer and tennis	Mixed
Participant C	27	Male	Bachelor's degree	Soccer, yoga, pilates and HIIT	Mixed
Participant D	30	Female	Bachelor's degree	Kick boxing and gym	Mixed
Participant E	27	Male	Bachelor's degree	Soccer and strength training	Mixed
Participant F	26	Male	Technical high school	Gym	Mixed with mostly multi-player games

Table 4.3: Summary of participant information in second iteration of interviews

Nevertheless, some participants cited the leaderboard or the straightforward game structure as their preferred aspect of the prototype.

When queried as to which aspects could be enhanced, the participants' responses diverged. Two participants proposed that the leaderboard could be enhanced in the following manner: Rather than displaying a leaderboard populated by numerous individuals, it would be more effective to group people with similar activity levels into leagues. Within these leagues, individuals could then compete with one another to achieve the highest levels of performance. Should an individual's activity level exceed or fall below the average, they would be promoted or relegated to the subsequent league. The advantage of this league system is that individuals with a less active lifestyle would not be demotivated by the presence of more active competitors, who consistently occupy the top positions on the leaderboard.

None of the participants expressed a preference regarding the potential limitation of the points accumulated through physical activity on the leaderboard. Although they acknowledge the potential disadvantage of demotivating players with a lower activity level, they believe that this factor would be too negative for players with a high activity level. Such a scenario could potentially result in a loss of motivation among players to maintain or enhance their performance, as their achievements would no longer be

reflected in the leaderboard.

With regard to the level design, one participant observed that it would be beneficial to introduce a variety of bosses or temporary weapon upgrades with enhanced damage to enhance the excitement of the game. Regarding the temporary upgrades, one participant proposed replacing the heart with a shield, which would also confer an advantage when the health is full. The shield would serve to temporarily block incoming damage. Furthermore, the individual in question would appreciate a different weapon approach, whereby each weapon is capable of inflicting damage upon multiple enemies, in accordance with the hack and slay genre. Another participant posited that the game should have a narrative, as is the case with other rogue games, for example. Such an addition would undoubtedly enhance the game's appeal and potentially encourage a greater number of individuals to engage with it. Moreover, one participant observed that the waves of enemies should possess a uniform character, akin to numerical values (e.g., Wave 1 or Wave 2). Such a system would permit players to more effectively assess their own performance relative to that of other players, thereby enhancing their motivation to engage with the game.

One participant observed that the first training of the day bonus could be more effectively utilized if the player were to receive additional experience points following regular training on different days, rather than a single bonus for each workout session. Such an approach would enhance the motivation for regular physical activity.

One participant commented that the hardcore mode should not be locked when exiting the game, as this could potentially diminish the motivation to play the game, as there are fewer opportunities to experience different difficulty levels.

With regard to the challenges, one participant posited that it would be advantageous to be able to complete multiple challenges simultaneously, as this would allow for the establishment of a greater number of fitness goals and an enhanced motivation for further physical activities. Two participants observed that it would be advantageous to modify the difficulty of the challenges in accordance with the selected difficulty level, thereby affording players the opportunity to tailor the game to their personal fitness objectives. In light of the current difficulties associated with the challenges, two participants proposed increasing the required steps for the „Step Counter“ challenge to 50,000 or 60,000. The remaining difficulty levels would be appropriate.

One participant observed that the statistics and achievements screen is cluttered and could be divided into two distinct screens. To circumvent the proliferation of large buttons in the main menu, it was proposed that these two menus could be accessed through a small button located at the top of the main menu, analogous to the settings or help button.

With regard to the visual aspects, one participant proposed that it would be beneficial to alter the appearance of the character in accordance with their current attributes, thus demonstrating their strength. Furthermore, another participant expressed a desire to be able to select a male and female character.

Five participants indicated that they believed the game would encourage them to engage in more physical exercise. Another participant stated that he already engages in regular exercise and is therefore already highly motivated. He further indicated that the game would not be a significant motivator for him. Nevertheless, this individual posits that the game could potentially serve as an effective motivator for other individuals. When queried as to which aspects would be most motivating, a variety of responses were provided. The most frequently cited motivators were the leaderboard and the challenges. Two participants indicated that all aspects that provide rewards for physical activity would motivate them. Additionally, one individual noted that the gladiator arena theme is particularly appealing to him, suggesting that it could serve as a significant motivator for gameplay and subsequent engagement in physical activity.

When queried about the aspects that would be most demotivating, the leaderboard was mentioned on two occasions. This was in response to the perception that players are frequently beaten by opponents who have a much higher activity level. Another participant indicated that they would find the gameplay demotivating if it were too difficult.

In regard to notifications, all participants expressed satisfaction with the current concept. They emphasized the importance of limiting the number of notifications and the ability to disable them. One participant suggested that it would be beneficial to receive a reminder before the conclusion of a challenge to encourage completion.

4.3.2 Prototype Changes

This section presents the findings of the interviews and elucidates the manner in which the concept of the prototype is being refined. In determining which comments from the interviews are incorporated into the prototype, the extent to which these would enhance motivation for physical activity and do not extend beyond the scope of this master's thesis is assessed.

The proposal to replace the leaderboard with a league system is a promising one, as it would effectively address the potential issues of demotivation. However, as only a few individuals test the prototype in this work, a league system would only have disadvantages, as there are too few players to fill different leagues. Nevertheless, this feature should be considered in future work.

It has been determined that the inclusion of level bosses, temporary upgrades, and a narrative storyline will not be incorporated into the game. This decision is based on the assessment that such additions would substantially increase the development effort required without providing evidence that they would significantly enhance players' motivation to engage in physical activity. However, the heart upgrade will be replaced with a shield, thereby conferring benefits on players who have demonstrated proficiency at the current level and have not lost any health.

The following modifications will be made to the weapons: All weapons will be changed to have a larger attack range, thereby enabling them to strike multiple opponents

simultaneously. In order to provide the sword with an additional advantage, it will be modified to have a larger attack radius than all other weapons. This modification does not necessitate any significant additional investment of time or resources and is designed to enhance the gaming experience, thereby increasing the overall enjoyment of the game.

It is important to note that a new wave of enemies is initiated at a specific interval, rather than solely upon the defeat of all previous enemies. If the player were to be displayed each time a new wave commenced, this could potentially induce stress and diminish the overall enjoyment of the game. Consequently, this feature will be subjected to testing during the development process and implemented in accordance with the results.

In order to enhance the motivation to engage in regular exercise, the first training of the day bonus will be modified as follows: Beginning with the third workout of the week, users will receive 50% more experience points for the first workout of the day.

Additionally, the game will include the feature to reselect the hardcore mode upon exiting, providing players with increased flexibility and the ability to experiment with different difficulty levels. This is particularly advantageous for the prototype, as it is only tested for a limited period of time in the user tests.

A modification to the challenges would be necessary to enable multiple challenges to be completed within a week. This would necessitate either an increase in the number of rewards or the introduction of more complex mechanics. This would necessitate an additional, significant investment of time and resources, and thus represents a potential area for future development. However, in order to enhance the significance of the difficulty levels, it would be beneficial to incorporate them into the challenges. This will also afford players a more effective means of adjusting their fitness goals through the game.

The challenges are modified as follows:

1. Easy:
 - a) Weekly Workout: Three times per week on different days for a minimum of 15 minutes each.
 - b) Step Counter: 40.000 steps.
 - c) Calorie Burn: Burn at least 1000 calories.
2. Normal:
 - a) Weekly Workout: Three times per week on different days for a minimum of 30 minutes.
 - b) Step Counter: 50.000 steps.
 - c) Calorie Burn: Burn at least 1500 calories.
3. Hardcore:

- a) Weekly Workout: Three times per week on different days for a minimum of 45 minutes.
- b) Step Counter: 60.000 steps.
- c) Calorie Burn: Burn at least 2000 calories.

The statistics and achievements screens will be divided into two distinct sections. These will be accessible via two matching icons in the main menu. Figures 4.9 and 4.10 illustrate the revised layout.

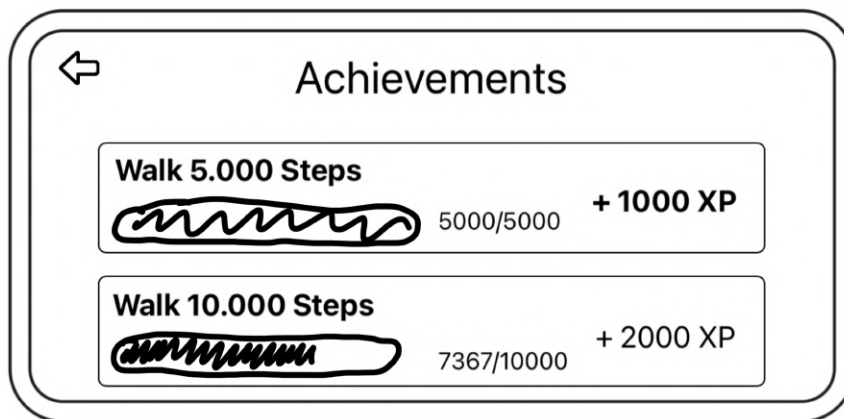


Figure 4.9: Achievements screen

A notification will be added two days prior to the end of the week, in order to remind participants of the need to complete an uncompleted challenge.

A summary of this section is provided in table 4.4. It illustrates the various features and their respective planned deployment state. The features in the „Prototype“-state will be incorporated into the prototype. The „Maybe“-state symbolizes features that will be tested during the development phase, while „Future Work“ reflects features that should be considered in future work.

4.4 Iteration 4: High-fidelity Prototype

This section presents a detailed description of the technical architecture and the implementation of the high-fidelity prototype. The various screens are illustrated with screenshots, accompanied by a description of the changes that have occurred during the development process. A comprehensive overview of the screens is provided in the screen flow diagram located in the appendix, as shown in figure 8.1.

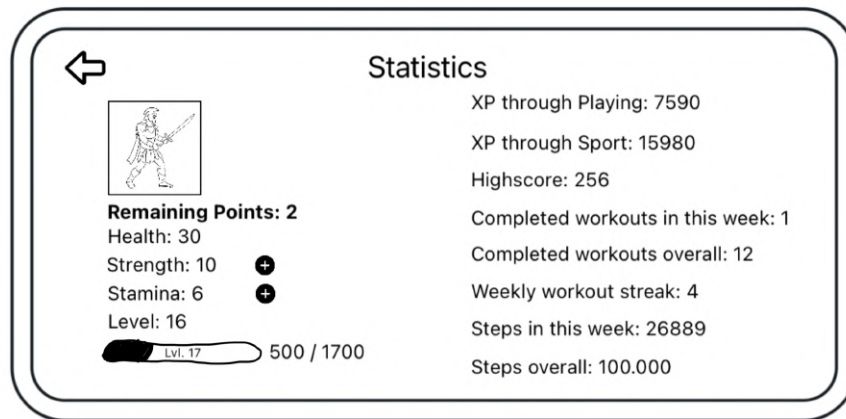


Figure 4.10: Statistics screen

4.4.1 Technical Architecture

The LibGDX framework (version 1.12.1) [19] was used as the foundation for the serious game. This can be justified as follows: It is open source, has a substantial community, is cross-platform, and offers an accessible entry point for individuals who possess considerable experience with Java. Additionally, libGDX provides a highly modular architecture, allowing developers to select only the components they need, thereby reducing the overall footprint of the application. The framework also offers extensive support for both 2D and 3D graphics, which can be beneficial for creating visually engaging game environments. Although the prototype was primarily developed for the Android operating system, further development for the iOS operating system would be possible, as only a few aspects would need to be modified or expanded. These include, for example, the connection to Apple Healthkit [97] and the adaptation of the notifications to the iOS operating system.

The final prototype utilises Google's Health Connect API [98] to obtain the requisite training data. This service was provided by Google to replace the previous Google Fit service [99]. This has several advantages. The service aggregates data from various apps and is seamlessly embedded into the operating system, starting with Android version 14. This approach obviates the necessity for users to log in with a separate account, as it uses the existing Google account that is linked to the device. Instead, users are merely required to grant authorization for the system to read their health data. In the high-fidelity prototype, the training data is only saved locally and is not transmitted to any other servers. This local storage is utilized exclusively for the purpose of displaying the history and rewards received for completed training sessions within the app.

Google Firebase [100] is utilized for the storage of data pertaining to the leaderboard.

Prototype Change	Planned Deployment
Replacing the heart upgrade with shield	Prototype
Weapons have larger attack range and hit multiple opponents; the sword will have a larger attack radius than other weapons	Prototype
From the 3rd workout in a week, the user will receive 50% more experience points for the first workout of the day	Prototype
Remove Hardcore mode lock upon exciting	Prototype
Adapting challenge difficulty based on chosen difficulty	Prototype
Splitting Statistics and Achievements Screen & Redesign	Prototype
Reminder for uncompleted challenge	Prototype
Displaying and identifying enemy waves	Maybe
Leaderboard with league system	Future Work
Adding level bosses, temporary upgrades, and a story to the game	Future Work
Make multiple challenges completable within a week with potentially more rewards or complex mechanics	Future Work

Table 4.4: Prototype changes with respective planned deployment state

This decision is based on a number of considerations. Firebase is available at no cost up to a specified limit and offers seamless integration with the LibGDX framework. Firebase offers a cloud-hosted, NoSQL database that synchronizes data in real time, making it an optimal choice for applications that require dynamic updates and low latency, such as a competitive leaderboard.

The structure of the Firebase database is designed with the objective of efficiently managing and storing key player data. Within the leaderboard node, each player's data is indexed by a unique player ID, which serves as the primary key for that player's record. The following data is stored for each user:

- playerName: The name chosen by the player.
- difficulty: The selected level of difficulty.
- playerScore: The total number of points accumulated by the player over the course of the current week.

In addition to the aforementioned individual records, a node designated as „weekly_top_players“ is utilized to track the top performers on a weekly basis. The list includes the three most highly ranked players from the previous week, along with the number of experience points (XP) they earned to attain their respective positions on the leaderboard at the conclusion of the week. Upon subsequent login, the player is rewarded with the requisite experience points. Subsequent to the awarding of experience points, the player's experience points

total within the database is reset to zero, thus preventing the player from earning the same experience points again within the same week.

The local data storage in the provided architecture employs libGDX's Preferences API and JSON serialization to facilitate the efficient management of save data. The use of preferences allows for the simple and effective storage of key-value pairs on the device. The conversion of complex data structures into string format through JSON serialization enables the storage and retrieval of these structures in an easily accessible format. This approach ensures the persistence of data across sessions, thereby conferring upon it a degree of robustness and reliability. The advantages of this approach include ease of implementation, cross-platform compatibility, and the ability to handle complex data structures in a human-readable format, enhancing both development efficiency and user experience.

4.4.2 Implementation

This section delineates the distinctions between the low-fidelity prototype and the high-fidelity prototype, which is presented in its entirety, divided into the various screens.

Changes compared to the Low-fidelity Prototype

All of the changes described in section 4.3.2 and marked as „Prototype“ have been implemented into the high-fidelity prototype. Moreover, the recommendations to display and identify enemy waves has been incorporated into the final prototype. This allows for more effective comparison of progress across different game rounds, in addition to the high score, providing a new sense of achievement when reaching previously unattained waves.

The policy regarding guaranteed level-ups for workouts has been revised. Previously, a single level-up was offered for any workout lasting at least 20 minutes. The revised policy provides an additional level-up for each full 20-minute increment of exercise. This change is implemented to address the inherent disadvantage faced by users who engage in longer, continuous workout sessions, such as a 40-minute workout, compared to those who split their exercise time into shorter, separate intervals of 20 minutes each. The revised policy ensures that rewards are commensurate with the total time spent exercising, thereby encouraging users to engage in longer sessions without the need to split their workouts to maximize level-ups. This adjustment serves to promote fairness by aligning rewards with effort, while also motivating users to extend their workout duration.

Moreover, the challenges have been revised to permit the immediate unlocking of all weapons for players upon the completion of the initial challenge. This modification broadens the scope of gameplay possibilities and enhances the user experience by providing immediate access to the full arsenal. The decision was made to accommodate the limited two-week duration of the user test period, which would otherwise not allow sufficient time for players to unlock all weapons progressively.

Furthermore, the statistics screen has been renamed the character screen, thereby affording players a more transparent understanding that they can utilize this screen to enhance and develop their character.

Initial Start

Upon launching the game for the first time, the player is required to grant permissions for Health Connect (see figure 4.11) and for notifications (see figure 4.12). The player has the option to decline these permissions. However, without granting them, the player will not be able to synchronize workouts or receive notifications.

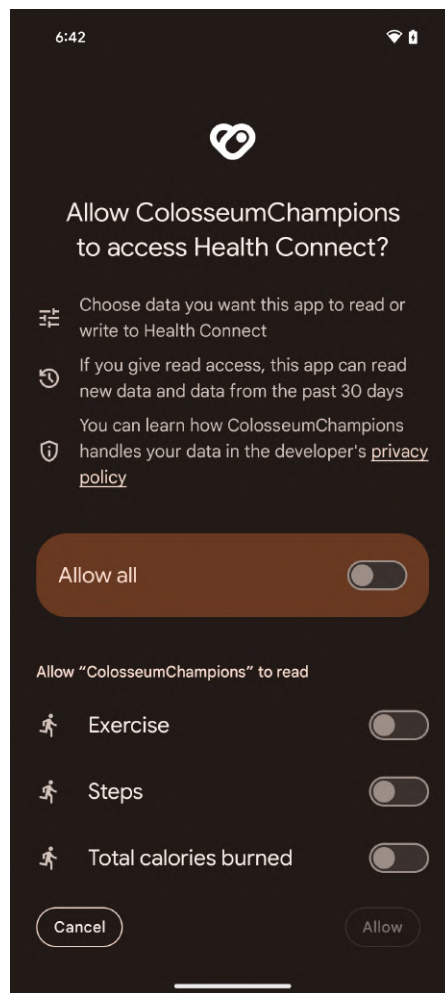


Figure 4.11: Health Connect permissions

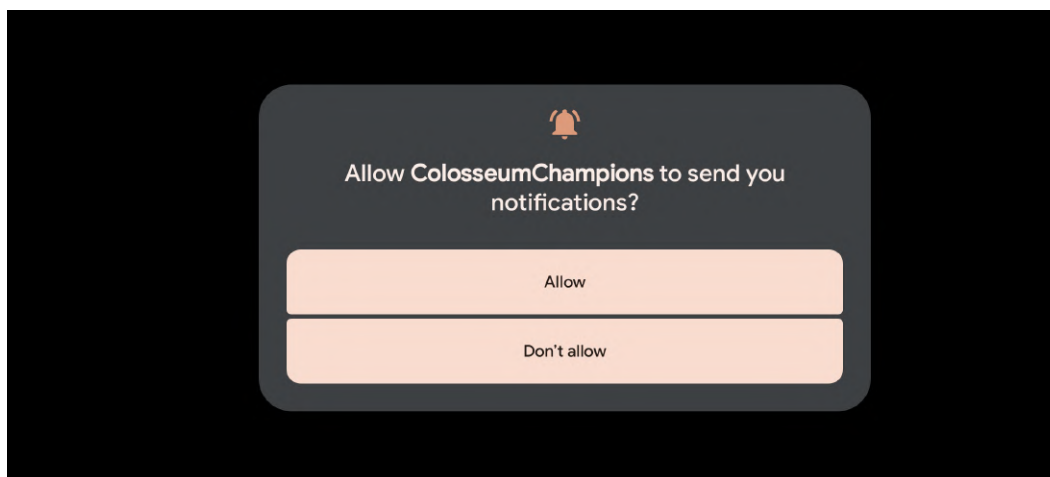


Figure 4.12: Notifications permissions

Main Menu

Once the player has granted the requisite permissions, the main menu is the initial screen encountered upon launching the application. The design and layout of the main menu are illustrated in figure 4.13. From the main menu, the player can navigate to various relevant screens by using the corresponding buttons. The available menu options include: character, challenges, synchronization, achievements, settings, help, and game start. The following sections will provide a detailed overview of these screens.



Figure 4.13: Main menu

The right-hand side of the screen displays the leaderboard, showing players' names, their scores, and a timer indicating when the leaderboard will reset. The color of each player's name indicates the selected difficulty level: blue for easy, yellow for normal, and red

for hardcore. A „(You)“ is displayed after the player’s name to help the player easily recognize their own position. The score is calculated by combining the player’s high score with the training activity completed during the current week. Training minutes are included in the score calculation because they are a consistent component of every training session. This is not the case for other metrics, such as heart rate, which is not consistently recorded by all wearable devices. Additionally, one point is awarded for every 10 steps taken.

A training week is defined as a period beginning at 00:00 on Monday and ending at 23:59 on Sunday. At the end of a training week, the first player to start the game in the following week triggers a background process that saves the top three players in the online database. These players receive additional experience points for their character upon starting the game. The leaderboard is then reset, allowing players to compete for the top positions again.

Character

The character screen allows the player to view the current progress of their character, including various statistics such as the high score and completed workouts for the current week. Additionally, players can enhance their character’s strength and stamina upon leveling up. The layout and a comprehensive list of statistics are illustrated in figure 4.14.

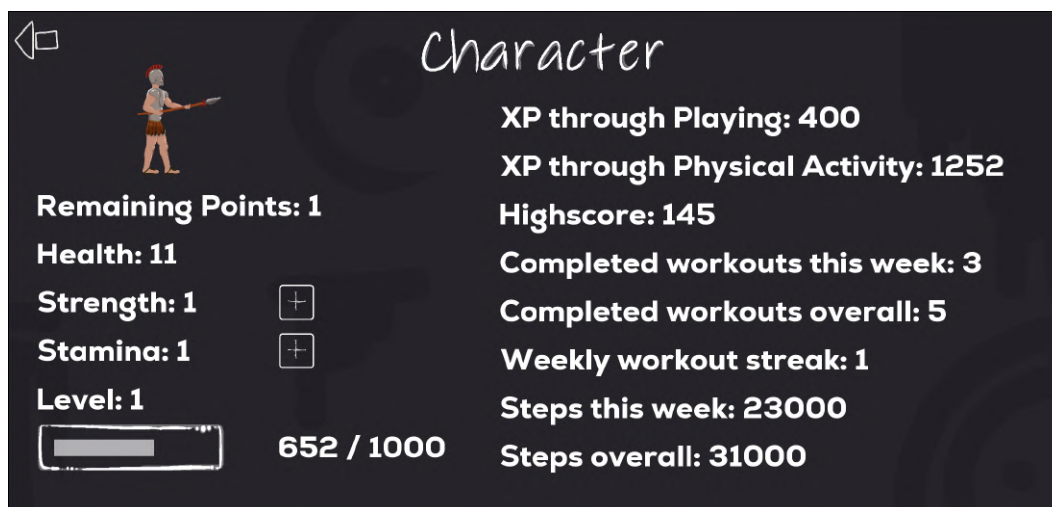


Figure 4.14: Character screen

Challenges

In the challenges screen, players can select a challenge or view the progress of their current challenge. Challenges are always valid for the current week. The difficulty of a challenge is determined by the difficulty selected in the settings (see section 4.4.2).

4. RESULTS

Additionally, players can choose their currently equipped weapon. By default, only fists are available. Players can unlock additional weapons by completing challenges. As the user tests are time-restricted, all weapons are unlocked upon completing a challenge to give players the opportunity to try out all available weapons. These weapons include the sword, spear, and bow & arrow. Each weapon has unique characteristics that add dynamic elements to the gameplay, which are explained in more detail in section 4.4.2.

The final third of the screen displays the completed challenges and the corresponding weapon rewards. Figure 4.15 shows the selection of a challenge with only fists available as a weapon and no completed challenges. In contrast, figure 4.16 depicts the screen with an active challenge, all weapons unlocked, and completed challenges.

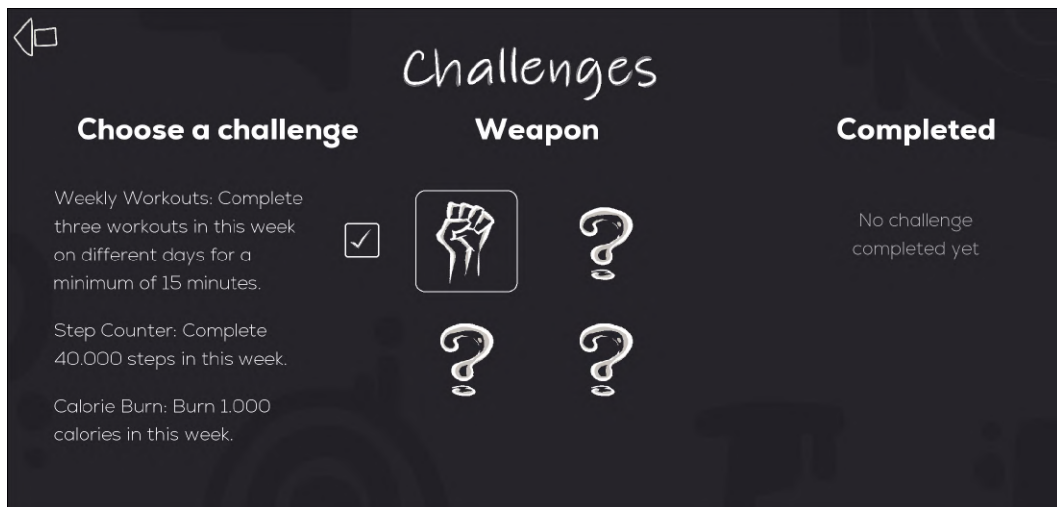


Figure 4.15: Challenges screen without any progress

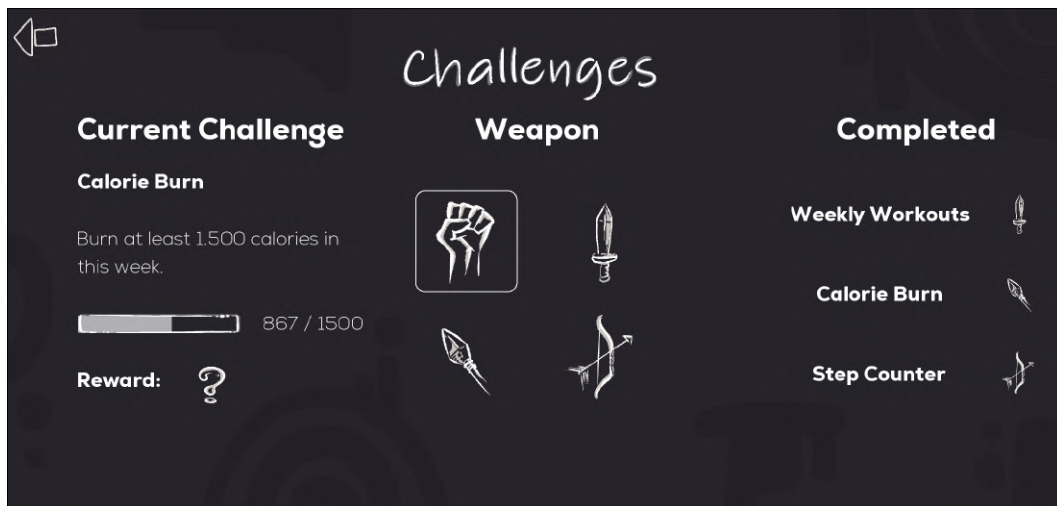


Figure 4.16: Challenges screen with every weapon unlocked

Synchronization

The synchronization screen is a key component of the synchronization process, linking completed training sessions with the game. To streamline the process, the left half of the screen features a synchronization button, which automatically queries completed workouts, calories burned, and steps in the background. The synchronized data is then displayed on the right-hand side of the screen. Once the synchronization process is completed, the values, statistics, challenges, achievements, and the leaderboard are updated accordingly.

Players receive rewards based on the selected difficulty and the duration of their workouts. They earn XP for each minute of training and for the number of steps taken. Figure 4.17 shows a list of completed workouts for a player at normal difficulty, with the character receiving attribute enhancements based on the type of activity upon leveling up. Additionally, the character is awarded a level-up for every 20 minutes of workout time, irrespective of the remaining experience points needed to reach the next level.

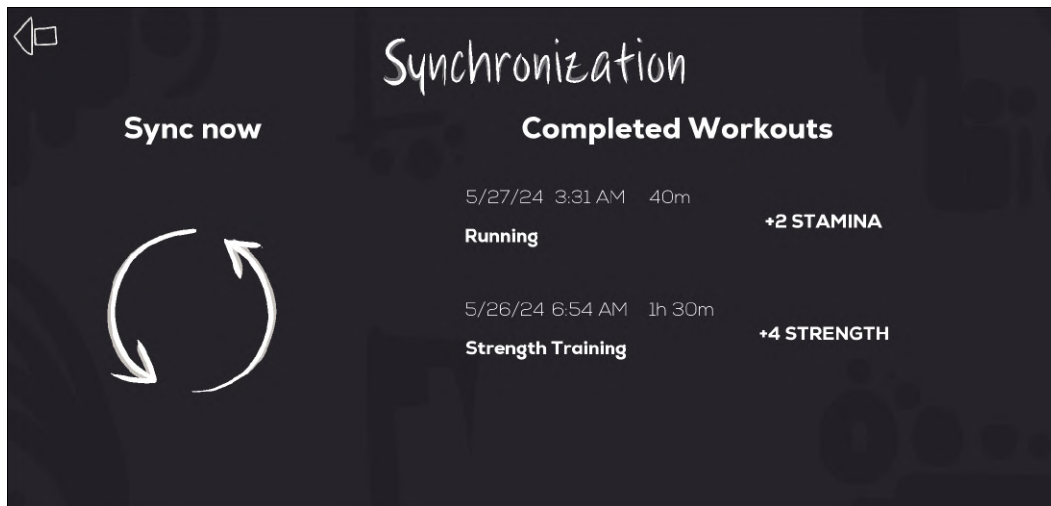


Figure 4.17: Synchronization screen

To minimize the amount of data queried, the most recent synchronization time is stored, and only new data since that time is retrieved. If the player initiates synchronization for the first time and no previous synchronization time is recorded, all data from the current day is requested.

Achievements

The achievements screen presents a scrollable table displaying all achievements. Each achievement is linked to training activities, such as steps taken, workouts completed, and calories burned. As illustrated in figure 4.18, each achievement is represented by a description, a progress bar indicating the percentage of completion, a text indicating the goal, and the reward. Upon successful completion of an achievement, the progress is

set to the target value, the progress bar is updated, and the reward text is displayed in white instead of gray.



Figure 4.18: Achievements screen

Settings

In the settings screen, as illustrated in figure 4.19, the player has the option to modify their name, adjust the difficulty level, and enable or disable notifications. The player's name, which is visible to others on the leaderboard, may only consist of letters and numbers.

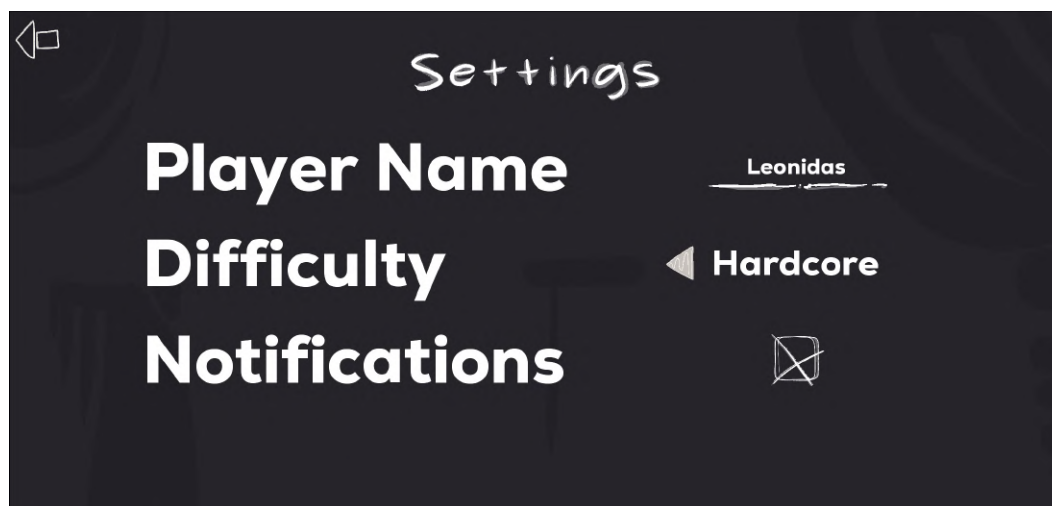


Figure 4.19: Settings screen

In the Easy mode, players receive experience points for their training efforts, allowing

them to enhance their character's attributes as they see fit upon leveling up. In Normal and Hardcore modes, the character's strength and stamina are improved based on the type of sport completed. Furthermore, in Hardcore mode, the character's attributes decrease if the player fails to complete any workouts during a given week.

Help

The help screen provides detailed explanations of various aspects of the game, including how to synchronize workouts and challenges. It also offers advice on physical activity. The player can switch between different sections of the game using two buttons. Figures 4.20 and 4.21 illustrate examples of game descriptions.

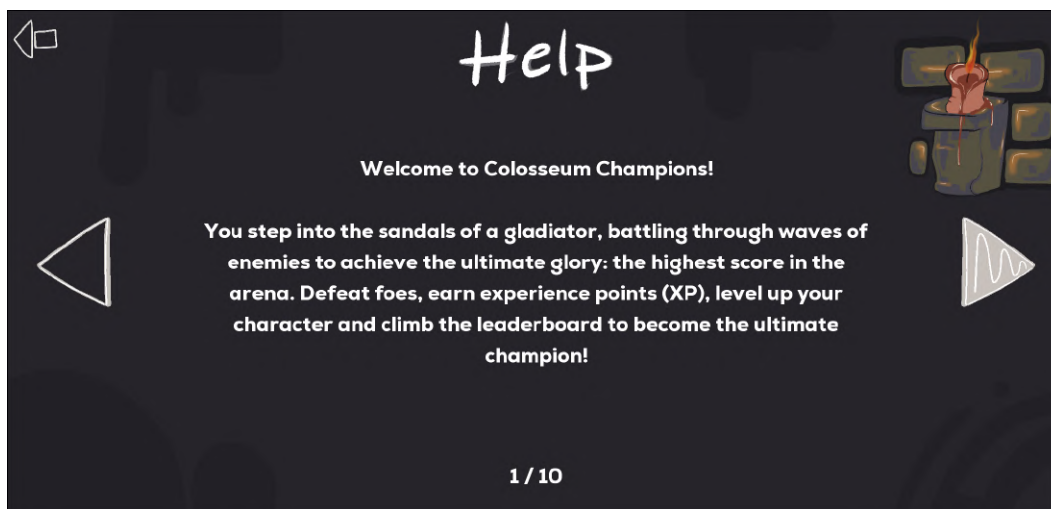


Figure 4.20: Help screen with welcome message

Game

The game centers around a gladiator who must engage in combat with a series of opponents within a colosseum. The objectives are to defeat enemies, achieve a new high score, and enhance the character's abilities by accumulating experience points. As illustrated in figure 4.22, the statuses for health, strength, and stamina are displayed at the top left of the screen. It should be noted that only the health status changes during a game round. The current score is shown at the top center of the screen and increases as the player defeats opponents. The game can be paused using a button located at the top right.

The player can navigate through the game environment using an on-screen joystick, which allows movement in any direction. Attacks can be initiated by pressing the attack button located in the bottom right corner of the screen. For simplicity, the direction of the attack is always aligned with the direction of movement.

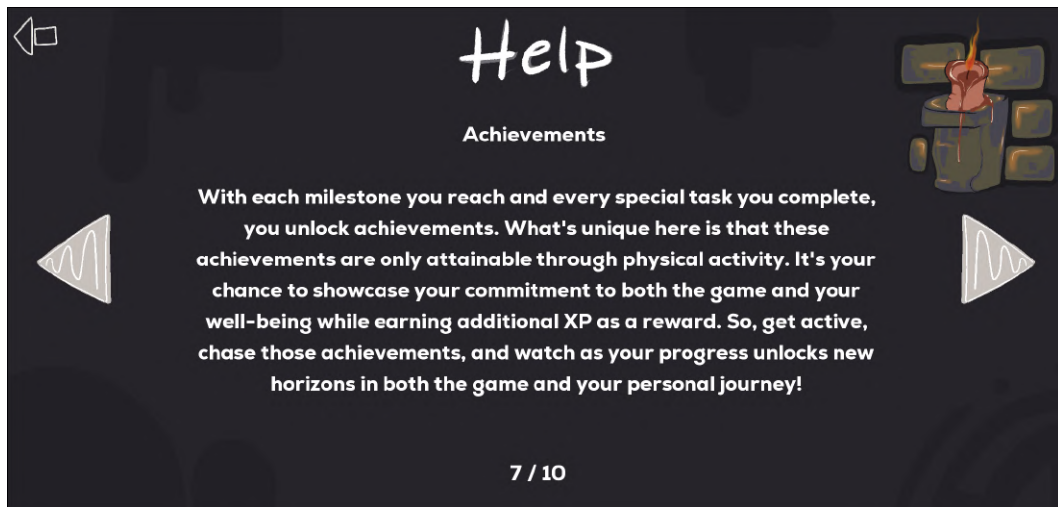


Figure 4.21: Help screen with achievements description



Figure 4.22: Game screen

The player can move freely within the colosseum, but new enemies spawn randomly at the edges, continuously attacking from all sides. The higher the character's strength, the more damage the gladiator inflicts on opponents. Increased stamina allows the character to move and attack faster. When an opponent touches the character, the character takes damage. To prevent the character from dying too quickly, enemies have an attack cooldown. If the character's health drops to zero or below, the game ends, and the corresponding screen (see section 4.4.2) is displayed.

The character model changes depending on the selected weapon. These different character models are shown in figure 4.23. Each weapon has a unique attack ability and can attack multiple enemies simultaneously. Fists push enemies slightly back upon impact, the

sword has a wider attack radius, the spear offers an increased attack range, and the bow allows shooting arrows.

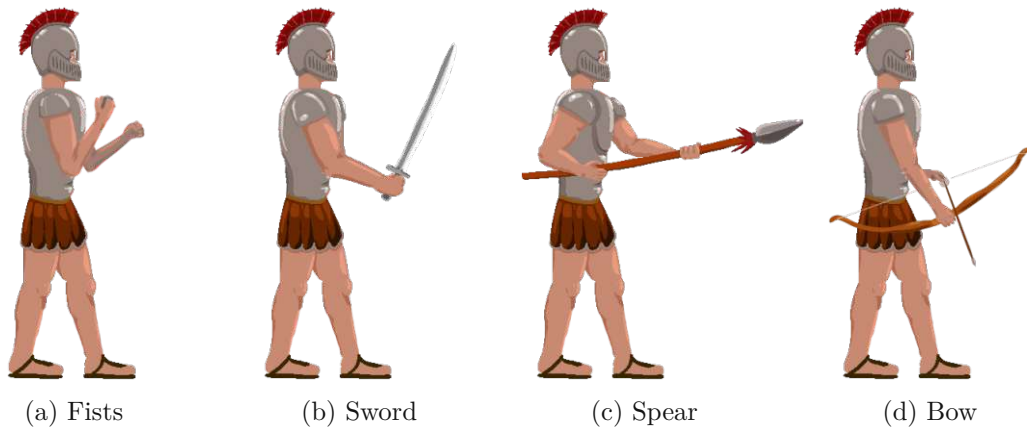
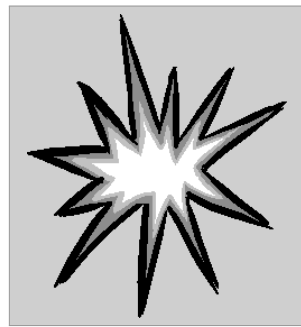


Figure 4.23: Character model with different weapons

For the fists, sword, and spear, weapon animations are displayed during an attack, allowing the player to estimate the attack radius and range. These animations appear briefly and then fade out. The bow, on the other hand, has no attack animation but features an arrow that flies across the screen and disappears upon reaching its destination. The respective weapon attack animations, as well as the arrow graphic, are shown in figure 4.24. An example of attacking with the sword is provided in figure 4.25. When an enemy is hit, the damage value appears in red above the enemy for a short time. An example of attacking with the bow and arrow, including damage animations, is shown in figure 4.26.

Figure 4.27 illustrates the three different enemy types encountered in the game. During the first wave, only enemies of the initial type, referred to as „Basic“, are spawned. These enemies are characterized by lower health, damage, and score metrics compared to other types, but they have a faster movement speed. In the second wave, a new enemy type, designated as „Strong“, is introduced. This type is depicted as a gladiator equipped with armor, a sword, and a shield, and it features higher health, damage, and score values than the „Basic“ enemies, although it moves at a slower pace. The third wave introduces the „Tank“ enemy type, represented by a larger model wielding an axe. This type boasts the highest health, damage, and score values among the enemies, but it has the slowest movement speed. Figure 4.28 shows gameplay during the third wave, including all enemy types.

To enhance the gaming experience, various temporary items are generated based on the number of enemies defeated. The following items may be obtained: shield, clock, bleeding, and lightning. The shield provides protection against incoming damage for a brief period. The clock slows down opponents by reducing their movement speed. The bleeding item causes enemies to lose health over time after being attacked. Lightning deals damage to all nearby enemies. The character’s strength affects the amount of



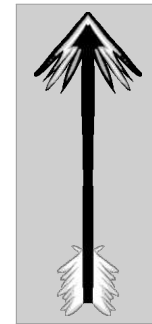
(a) Fists attack animation



(b) Sword attack animation



(c) Spear attack animation



(d) Arrow

Figure 4.24: Weapon attack animations

bleeding damage inflicted. The different icons for these items are shown in figure 4.29. Active items are displayed at the top of the screen, between the status values and the high score. Figure 4.30 shows a screenshot with an active clock item.

Game Over

The game over screen is displayed as soon as the game ends, as shown in figure 4.31. The player is presented with the score achieved in the current round and the current high score. Additionally, the screen provides information on the number of experience points accumulated and the points still required to advance to the next level. If the player has achieved a new high score or advanced to a new level, this is highlighted with animated text. The player can choose to return to the main menu, start a new game, or access the character screen.

Notifications

The system performs a daily background check to determine if the player has not completed any training for two days or has not yet completed the current challenge by the end of the week. If either condition is met, the player receives a notification as a reminder. Figures 4.32 and 4.33 show screenshots of the different notifications sent.

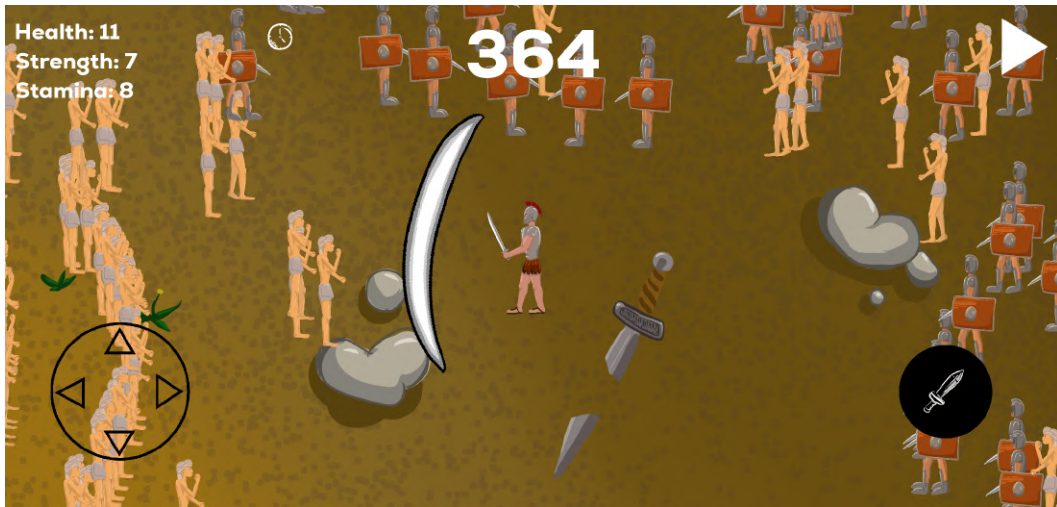


Figure 4.25: Game screen while attacking with sword

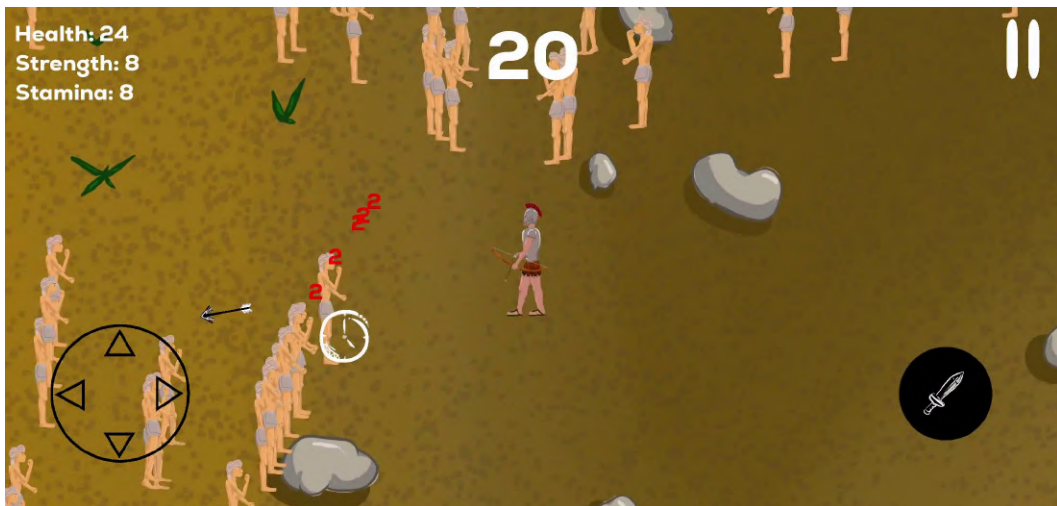


Figure 4.26: Game screen while attacking with bow & arrow

Assets

All graphics, including background images, user interface elements, and character & enemy animations, were hand-drawn by a colleague. The fonts used in the design were carefully selected to match the established theme.

The musical compositions for the game, including the game over screen, were created with the assistance of an artificial intelligence (AI) tool called Suno[101]. The music was meticulously crafted to align with the overarching theme of the gladiator. The remaining background noises and sound effects were sourced from freely available audio libraries.

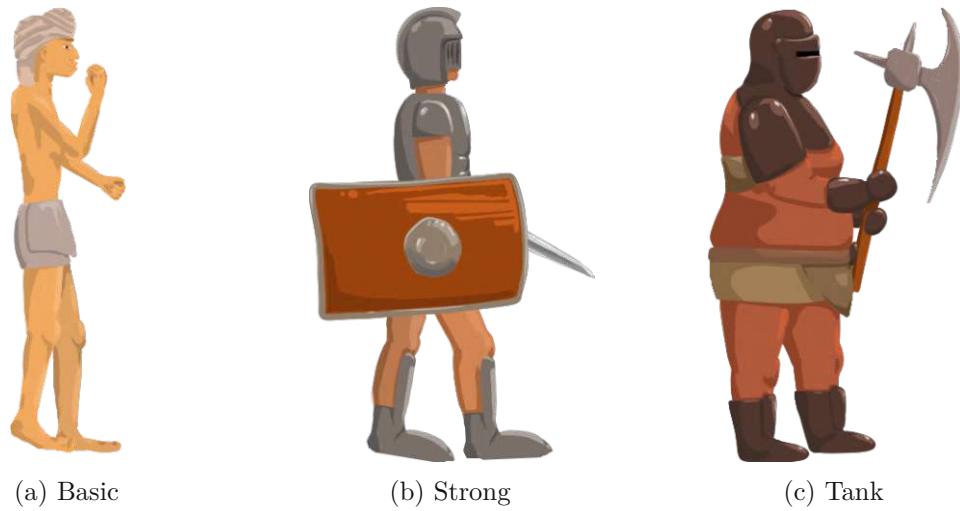


Figure 4.27: Enemy types



Figure 4.28: Game screen during the third wave with all enemy types

4.5 Iteration 5: User tests

In a subsequent iteration, the high-fidelity prototype was tested by six individuals from the target group. The serious game was installed on their personal smartphones, and each participant tested it within the same two-week period. This simultaneous testing period was essential to properly assess the competitive aspect of the game.

The participants in the user tests are detailed in table 4.5, which includes their age, gender, previous training experience, and whether they participated in the previous interview iteration. The participants were selected to include individuals who had been involved in earlier iterations, allowing them to evaluate improvements made to the high-fidelity

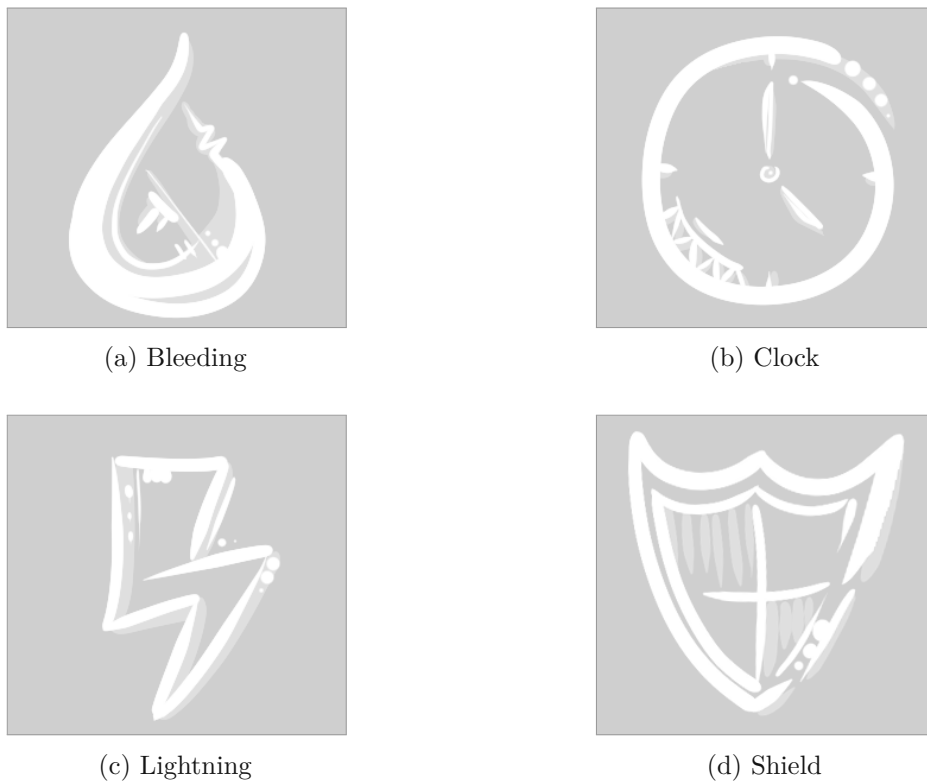


Figure 4.29: Items available in the game

prototype as a result of previous iterations. Given that the serious game features a leaderboard with social and competitive components, it should be noted that some of the participants know each other.

The participants were required to engage with the entirety of the application in a comprehensive manner. The participants were instructed to explore the various components of the game in detail, with particular emphasis on the synchronization mechanics of the steps and workouts and the resulting rewards. Additionally, the participants were requested to assess whether the serious game encouraged them to increase their physical activity or engage in more sports, and to identify which components of the game were most motivating. Furthermore, participants were requested to propose any enhancements and identify any additional features they believed should be incorporated into the game.



Figure 4.30: Game screen with active clock item

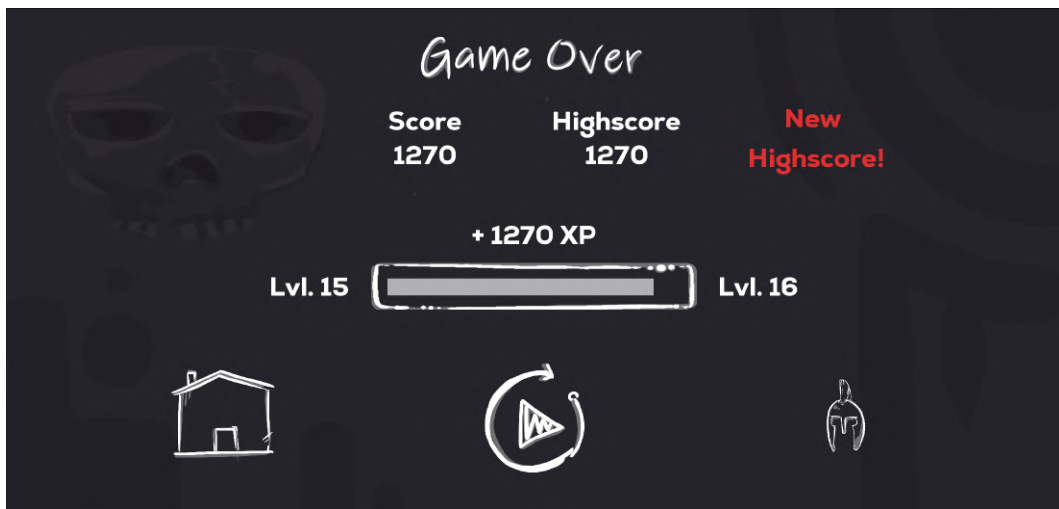


Figure 4.31: Game over screen

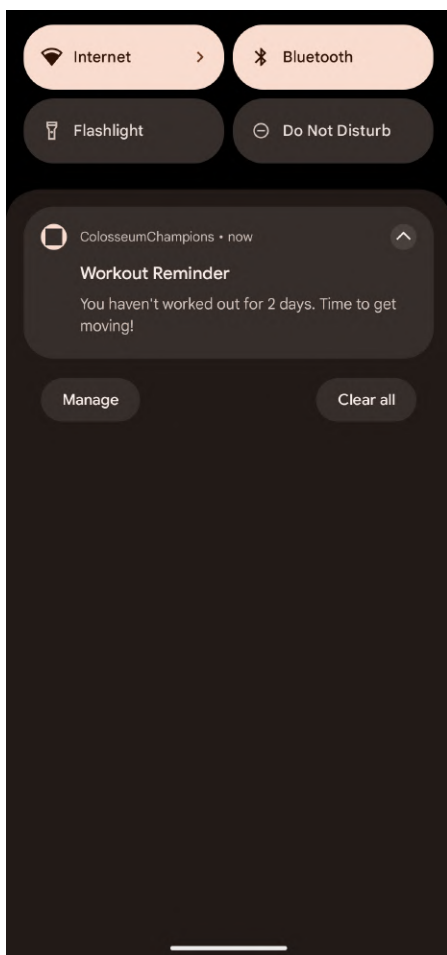


Figure 4.32: Workout reminder notification

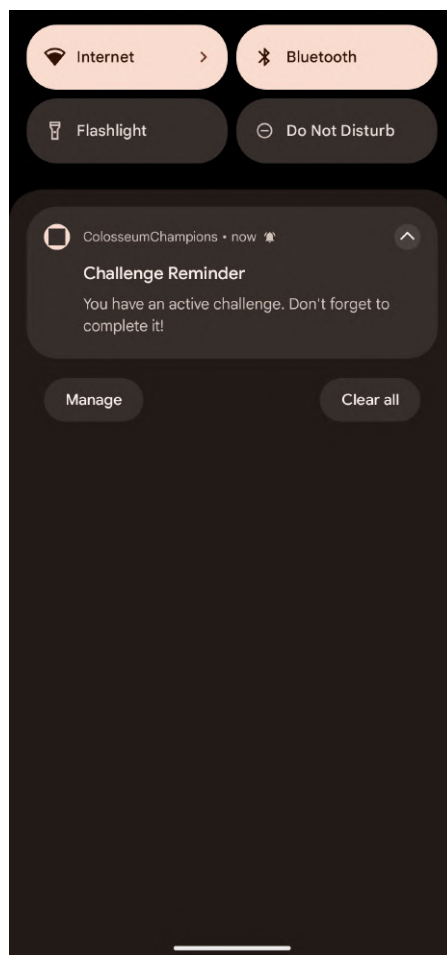


Figure 4.33: Challenge reminder notification

4. RESULTS

Participant	Age	Gender	Training types	Game genres	Involved in previous Iterations
Participant A	27	Male	Soccer and strength training	Mixed	Yes
Participant B	26	Male	Gym	Mixed with mostly multi-player games	Yes
Participant C	28	Male	Gym	Mixed	No
Participant D	29	Male	Hiking and gym	Mixed	No
Participant E	29	Female	Hiking, Running, Gym and Skiing	Rarely Nintendo Switch games	No
Participant F	32	Male	Cycling and bouldering	Mixed	No

Table 4.5: Summary of participant information in user tests

Evaluation

Following the completion of the testing phase, each user was interviewed individually in a semi-structured format to assess the high-fidelity prototype. The primary objective was to address the research questions posed in this work. Furthermore, participants were requested to provide feedback on the various components of the serious game. The following list enumerates all the questions posed during the interviews:

- Socio-demographic data
 - Age
 - Gender
 - Highest level of education completed
- Do you exercise regularly?
 - If yes, what type of sport and how often per week?
- Do you often play video games?
 - If yes, what type of games and how often per week?
- What is your overall impression of the prototype?
 - Which components did you like the most and why?
 - Are there specific aspects or features you would improve? Which ones and why?
 - How much time did you spend with the prototype? How much did you actually play the game?
- Has the frequency of your physical activities changed due to the serious game?

- If yes, how has your activity specifically changed (e.g., more training sessions, longer duration)?
 - If no, what are the reasons for no change in your physical activity?
 - Do you believe the game could change your attitude towards sports in the long term? Why or why not?
- Does the prototype meet the requirements to motivate people to engage in more sports?
 - If yes, which aspects are particularly motivating?
 - If no, what aspects are missing?
 - Does the game meet your expectations regarding motivation, interactivity, and usability?
- What do you think of the game's mechanics to reward sports?
 - What additional game mechanics can you imagine, and which would you prefer?
 - Are there specific rewards or mechanics you would find particularly motivating?
- What do you think of the individual components of the prototype?
 - Difficulty levels. Which did you choose and why?
 - Character/Statistics
 - Leaderboard
 - Challenges. Which challenge and why?
 - Achievements
 - Synchronization
 - Help
 - Gameplay
 - How easy or difficult did you find it to use the individual components?
- What do you generally think of serious games that incorporate sports as a game mechanism?
- Do you have any other questions or comments?

In order to maintain a clear and systematic approach, the evaluation chapter is divided into several sections. Each section presents the key takeaways.

5.0.1 General Impressions, Highlights, and Time Investment

This section presents an overview of the participants' overall impressions of the prototype, as well as an examination of the aspects they found most appealing and the amount of time they spent engaging with the serious game.

Participant A

Participant A found the app to be highly successful in terms of both its concept and implementation. The competitive angle, especially the leaderboard feature, exceeded his expectations and proved to be a stronger motivator than he had anticipated. He appreciated the fundamental idea of integrating serious games as an engaging activity that can be played independently of actual sports, yet offering the option to engage in physical exercise. This combination was perceived as a well-conceived concept that effectively boosts motivation. However, he raised the question of whether this initial motivation could translate into long-term intrinsic motivation over time. Among all features, the leaderboard was his favorite, as he frequently checked it. He particularly enjoyed receiving feedback in the form of toast notifications after synchronizing his activity, which led to changes in his leaderboard ranking. Additionally, he found the game itself to be quite enjoyable, which kept him engaged with the app even after the two-week test period. Regarding his usage patterns, Participant A opened the app 5-10 times a day on average and spent approximately 30 minutes daily using it.

Participant B

Participant B found the game itself very cool and appreciated the concept of motivating users to engage in sports activities. He particularly liked the challenges, as they were the most motivating aspect for him. Additionally, he enjoyed the leaderboard because it included his friends, which added a competitive and social element to the experience. Participant B spent an average of 22 minutes daily with the prototype during the first week. However, his engagement significantly decreased in the second week, dropping to an average of 3 minutes per day.

Participant C

Participant C was pleasantly surprised by the idea and found it good overall. However, over time, he noticed an imbalance in the leaderboard due to players achieving very high scores. He enjoyed the gameplay but found it slightly frustrating to start over repeatedly, as it took time to reach new and exciting points. He considered the leaderboard a core component of the game, appreciating the comparison with friends and envisioning it working well with other groups, like a workgroup. He didn't favor playing with random people as much. He also liked the game principle where real-life sports activities impact both the leaderboard and the in-game character, finding this a nice component. Over time, he enjoyed the game itself more, considering it a good match for its purpose. He felt the rogue-like style was very suitable for this type of game. Additionally, he appreciated

the idea of challenges unlocking over time with effort. During the first week, his peak usage was 1 hour and 27 minutes, with an average of 45 minutes. In the second week, his peak usage dropped to 52 minutes, with an average of 24 minutes, due to the perceived imbalance.

Participant D

Participant D found the prototype cool and surprisingly fun, even addictive. He likened the gameplay to Vampire Survivors and enjoyed defeating enemies. The prototype worked very well and provided a strong sense of progress. He particularly liked the game principle where the character becomes stronger through sports activities. The presence of friends on the leaderboard was a highly motivating factor; competing with strangers would likely be less motivating. He also found the weapon challenges very motivating, pushing him to do more sports to complete the challenges and unlock weapons. He suggested that the challenges could be expanded to include unlocking skins. Additionally, he appreciated the seamless connection between the app and his fitness service, Google Fit. Participant D spent an average of 32 minutes per day on the prototype, with more intensive engagement during the first week. After completing much of the content, his engagement decreased. His peak usage was two hours per day on Tuesday and Sunday.

Participant E

Participant E had a divided impression of the prototype. Initially, she did not enjoy it as much because she found using fists as weapons less fun. However, as she progressed and gained access to more weapons, the game became significantly more enjoyable for her. She appreciated that there was always something to do in the game, with no waiting periods, making it convenient to play even in short intervals. She also liked that the game allowed for breaks without losing progress. The combination of independently playing the game and incorporating sports was very cool, and she found the gameplay itself to be enjoyable. She found the leaderboard motivating, even when others were ahead of her. She also appreciated the flexibility of the sports activities, particularly that steps counted towards progress. In the first week, Participant E engaged very little with the prototype, mostly just synchronizing her data. In the second week, she played the game for about 15 to 20 minutes each day.

Participant F

Participant F found the idea of the prototype to be excellent, noting that it has a lot of potential. He felt that the prototype itself was quite okay and successfully motivated him to engage in more sports activities. The leaderboard was particularly motivating for him, as it allowed him to compare his performance with others and gauge how well he was doing. This comparison encouraged him to strive to rank higher. He also found the challenges and achievements very motivating, which were the aspects that drove him the most. During the first week, he engaged very little with the prototype due to time

constraints and setup difficulties with Google Fit and Health Connect. In the second week, he spent an average of 20 minutes per day using the prototype.

Summary

The general consensus among participants was that the prototype has significant potential to motivate sports activities through its engaging concept and implementation. The leaderboard was frequently highlighted as a highly motivating feature, driving users to compare their performance with others and strive for higher rankings. The combination of game-based progress and physical activity was well-received, with the game itself being described as enjoyable and addictive. However, some noted imbalances in the leaderboard and the need for more varied content to maintain long-term engagement. Challenges and achievements were also significant motivators, although setup difficulties with synchronization and an initial lack of understanding of certain game mechanics were mentioned as minor drawbacks.

5.0.2 Changes in Sport Frequency

This section examines whether there was a change in the frequency of involvement in sporting activities among individual participants as a result of engaging with the serious game. Additionally, it explores whether participants became generally more active and whether they engaged in different types of sports.

Participant A

Participant A reported that the frequency of his gym sessions did not change because he was already attending three times a week, which he considers substantial. He has been maintaining this routine for the past five months and aims to continue it. The app never had the potential to motivate him to increase his workout frequency because he fundamentally does not have the time for more sessions, and increasing the frequency is not an option for him. However, what did change was his awareness of his daily activities, such as the number of steps he takes and the distance he cycles. He became more conscious of his physical activity and started to do more to improve his performance in the app. For example, when he was close to reaching the top position on the leaderboard, he chose to walk home after an evening out to accumulate more steps. Upon reaching home and finding himself just shy of the first place, he decided to unpack his walking pad and walked an additional 8000 steps to secure the top spot. As a result of the game, he has increased his daily steps and cycling. He now opts to walk or cycle more frequently instead of using public transportation or a scooter.

Participant B

The frequency of Participant B's physical activities improved. He felt more motivated to walk instead of using public transportation and began incorporating workouts into his

routine. He had been planning to start working out for a long time but never followed through until the game provided the impetus to do so.

Participant C

Participant C reported an increase in his physical activities due to the serious game. He walked more to collect steps and realized that walking is enjoyable, a habit he continues even without the game. One week before starting the game, he began going to the gym, and the game motivated him to continue his gym visits. Additionally, he completed several home workouts specifically to achieve the game's challenges and achievements, which he otherwise would not have done.

Participant D

The frequency of Participant D's physical activities increased due to the serious game. The step challenge motivated him to walk more because he wanted to unlock and discover what the other weapons did. He focused on walking a lot initially to climb higher on the leaderboard, and he found the reward system effective for this purpose. However, he did not do any workouts because he lost his fitness tracker. He mentioned that if he had the appropriate equipment, he would be motivated to do workouts as well.

Participant E

Participant E found herself more motivated to walk more frequently. She chose to walk instead of using public transportation more often. However, the game did not increase her motivation for workouts due to her irregular daily schedule, which involved staying at friends' places and not having her sports gear available. She noted that with a more regular routine, she could see herself being better motivated for workouts as well.

Participant F

Participant F's physical activity frequency did not change significantly due to setup difficulties and an irregular daily routine. However, he believes that extending the test period would likely increase his physical activity levels.

Summary

In summary, the serious game led to an overall increase in participants' physical activities, primarily through heightened awareness and motivation to walk more frequently. While the frequency of gym sessions remained unchanged for some, participants reported opting to walk or cycle instead of using public transportation, driven by the desire to improve their leaderboard rankings and achieve in-game rewards. Besides incorporating more steps into their daily routines, several participants also began new workout regimens. However, irregular schedules, missing equipment and setup difficulties limited the impact

for a few, though they believed that a longer test period would likely enhance their physical activity levels further.

5.0.3 Long-term Impact on Attitude Towards Sports

This section addresses the question of whether the participants believe that the game has the potential to motivate long-term engagement in sports. Furthermore, it discusses the key aspects that are required to achieve sustained motivation.

Participant A

When asked whether he believes the game could change his attitude towards sports in the long term, Participant A responded affirmatively, but noted that some improvements are necessary, such as additional content and rewards. He highlighted that the game effectively provides extrinsic motivation through direct competitive battles with people he knows. This familiarity is crucial because it fosters trust and a willingness to engage in competition. Competing against unknown individuals would make him skeptical about potential cheating. He finds motivation in being behind a known person on the leaderboard, as it encourages him to improve. Conversely, if he competes against someone less athletic, he expects to outperform them and see this reflected in the app. Regarding intrinsic motivation, he believes it is a challenging area. To enhance intrinsic motivation, the game should emphasize mechanisms that allow for self-comparison, such as tracking personal progress and gains compared to the previous day. He suggests that the game should incorporate additional mechanisms to promote the habit of exercising, aligning with psychological principles. Participant A also noted that individuals who download the app already possess a certain level of motivation to improve themselves, which is essential since the app alone cannot create this drive. Once someone has downloaded the app, it is the app's responsibility to nurture this initial spark through rewards and engaging mechanisms to increase and sustain motivation. He compared this to Duolingo, which maintains user engagement through interactive notifications. He acknowledged that the app's success also depends on the target audience. Some friend groups might not be interested in downloading the app together, which is necessary for the leaderboard feature. For such users, he suggests community-building features, such as creating local lobbies where people can track each other, similar to how online communities like Discord operate. If users meet others through the app, whether via global or national leaderboards, seeing different players around them could motivate them to improve. This could also lead to forming connections through features like friends lists and chat options, enhancing the overall user experience and motivation.

Participant B

Participant B believes that the game could change his attitude towards sports in the long term. The competitive aspects of the game provide strong motivation and give him an

additional reason to train. Notifications serve as helpful reminders, and the fun nature of the game itself makes it enjoyable to engage with regularly.

Participant C

Participant C believes that the game could change attitudes towards sports in the long term. For people who do not engage in any physical activity, the game could serve as a motivation to overcome the initial barrier to starting exercise. Similarly, for those who already exercise regularly but occasionally feel lazy or unmotivated, the game could provide the extra push needed to complete their workouts.

Participant D

Participant D believes that the serious game can help overcome the initial barrier to starting a fitness routine. Once a user establishes a routine, the app may not be as necessary. However, the long-term impact depends on the amount of content available. To maintain long-term engagement, the game would need more rewards to unlock, providing continuous motivation.

Participant E

Participant E does not believe that the game alone would be sufficient to motivate her in the long term. However, she thinks that for someone who already has some personal motivation, the game could be helpful in overcoming laziness and the initial barrier to starting physical activity. While it provides an extra motivational boost, she doubts it would sustain long-term motivation on its own.

Participant F

Participant F believes that, in the long term, the game could change his attitude towards sports, leading him to take more steps and engage in more physical activities. This is because he would spend more time focusing on his fitness as he interacts with the game. However, he noted that this would require dedicating time to set up the synchronization process properly and having sufficient time to engage with the game regularly. He suggested that the game would benefit from more content, including more enemies, weapons, skins, and a storyline, to enhance long-term motivation. This would make the game more engaging and provide sustained motivation.

Summary

Participants generally believe the game could positively influence long-term attitudes towards sports, particularly through its competitive features and extrinsic motivation. Competing against known individuals fosters trust and engagement, while self-comparison mechanisms and tracking personal progress could enhance intrinsic motivation. The serious game is seen as effective in overcoming initial barriers to starting exercise, providing

an extra push for regular exercisers, and boosting existing motivation. However, it cannot create motivation independently. Participants emphasized the need for additional content, such as more enemies, weapons, skins, and a storyline, to maintain long-term engagement. Community-building features, like local lobbies and friends lists, were also recommended to enhance user experience and motivation.

5.0.4 Compliance with Requirements

This section assesses the extent to which the prototype fulfills the criteria for effectively motivating engagement in strength and endurance workouts. It also analyzes the elements that are particularly motivating and identifies areas for potential enhancement or additional features.

Participant A

Participant A affirmed that the prototype does meet the requirements to motivate individuals to engage in more physical activity, as he himself participated in more sports activities due to the serious game. When asked which aspects are particularly motivating, he identified the leaderboard as the most compelling feature. Additionally, he found the game concept itself motivating, especially the idea that the in-game character becomes stronger when the player engages in physical exercise in real life. Regarding whether the game meets his expectations for interactivity, and user-friendliness, Participant A had several insights. In terms of interactivity, he stated that the prototype meets his expectations but expressed a desire for more features and activities within the app. He believes that increasing the content available in the app would enhance engagement and encourage users to spend more time on it. Currently, the limited content, such as viewing the leaderboard, challenges, and achievements, causes him to exit the app sooner than he would prefer. He praised the user-friendliness of the app, noting that it is very good, although he did experience performance issues on his older device. He also suggested that the statistics page could be improved to be more organized.

Participant B

Participant B believes that the prototype does meet the requirements to motivate people to engage in more sports, but he noted that some improvements are necessary. He suggested that the game's balancing needs adjustment to ensure that it is not possible to achieve excessively high scores through gameplay alone, which currently diminishes the value of physical training. He emphasized that the challenges and the leaderboard were key factors that motivated him. While he generally felt the game met the requirements, he suggested that adding more challenges, weapons, and rewards would significantly enhance the experience. For interactivity, he mentioned that the challenge selection process was confusing, as it was not clear that one needed to explicitly select a challenge. He suggested that a popup should be displayed if no challenge is selected. Additionally, he felt that the pause menu could offer more options, such as the ability to return to

the main menu. Regarding user-friendliness, he suggested that it would be better if the home screen indicated when a skill point is available, perhaps with a notification point over the character button.

Participant C

Participant C believes that the prototype can motivate people to engage in more sports, especially within friend groups, as it adds a fun competitive element. However, he mentioned that the leaderboard balancing needs to be fixed for it to be effective. For widespread and long-term engagement, the game would need more content. Overall, Participant C felt that the game met his expectations for motivation, interactivity, and user-friendliness. However, he pointed out that it was not clear that one needed to select a challenge, which caused some confusion. Besides this issue, he found the rest of the game to be good. He was particularly impressed with the quick synchronization feature.

Participant D

Participant D believes the prototype meets the requirements to motivate people to engage in more sports. He found the leaderboard, progress in the game, and challenges particularly motivating. However, he noted that the visual aspect is lacking; the character's development, such as armor and more animations, could enhance motivation. He also suggested adding titles for the leaderboard, such as a special title for those who walk a lot, as these could serve as status symbols within the game. Additionally, he proposed collaborations with fitness studios, where completing challenges could earn users free drinks. The game exceeded his expectations for motivation, as he walked more steps than usual. Initially, he found the installation a bit challenging due to the setup with Health Connect, but it functioned smoothly afterwards. He found the menus well-described, intuitive, and easy to use. He suggested that workouts should count retroactively for challenges. He also recommended implementing an auto-attack feature because manual clicking becomes tedious at high attack speeds. He appreciated that the game did not annoy him with notifications, unlike other apps, but thought it would be beneficial to receive notifications when someone surpasses him on the leaderboard. Additionally, he mentioned that the XP bonus from regular workouts was not very noticeable and could be made more visible.

Participant E

Participant E believes the prototype meets the requirements to motivate people to engage in more sports. The most motivating aspects for her were the leaderboard, achievements, and the combination of low-effort sports (such as walking and making steps) with the enjoyable gameplay. This combination integrates well into daily life without requiring significant effort. While she found the prototype motivating, she suggested that push notifications for the leaderboard, such as notifications when someone surpasses her, would enhance motivation. Additionally, if the game aims to motivate users towards specific

sports, it should include explicit achievements for those sports to provide extra incentives. The game mostly met her expectations, but she felt it should be made clearer that users need to select a challenge. Aside from this, the game fulfilled her expectations for motivation, interactivity, and user-friendliness.

Participant F

Participant F believes the prototype meets the requirements to motivate people to engage in more sports. He found the leaderboard and the general principle of leveling up the character particularly motivating. He compared the character leveling aspect to World of Warcraft, where improving the character is a major motivational factor. Overall, the game met his expectations. However, he noted a few areas for improvement. The pause menu should include an option to exit the game. Adding more character attributes, such as dexterity, would make the gameplay more dynamic. Aside from these points, he found everything else to be sufficient.

Summary

The participants agreed that the prototype effectively motivates physical activity through features like the leaderboard, challenges, and achievements. The concept of character progression through exercise was particularly motivating. Improvements suggested include adding more content (challenges, weapons, rewards), balancing gameplay to prevent excessively high scores, and enhancing interactivity and user-friendliness. Clearer instructions for selecting challenges, additional pause menu options, and better indication of available skill points were recommended. Push notifications for leaderboard updates, retroactive workout counting for challenges, and an auto-attack feature were also suggested. Despite initial setup issues, the synchronization feature was well-received. Participants noted the need for better visual aspects, such as character animations.

5.0.5 Game Mechanics for Rewarding Sports

This section details the participants' opinions regarding the game mechanics utilized to reward sports activities. Additionally, it considers their suggestions for improvements and other potential game mechanics they could envision.

Participant A

Participant A found the game mechanics of the prototype to be quite ingenious. He particularly appreciated the concept of improving the in-game character through real-life sports activities. He found the rogue-like genre very fitting for the app's objectives. He suggested that the serious game could be expanded from its current rogue-like format into an Olympic-themed game, incorporating various sports and mini-games that involve the same character, to provide more content. When asked about additional game mechanics he could envision and prefer, he emphasized the importance of having a transactional element in the game: engaging in physical activity should yield rewards in the serious

game. He was flexible about the specific rewards, as long as the game itself was enjoyable. He could not think of a better concept than the current one. Regarding specific rewards or mechanics that would be particularly motivating, he reiterated his preference for the leaderboard. He finds the competitive aspect of ranking particularly motivating and effective in encouraging him to engage in more physical activity.

Participant B

Participant B thinks that the game mechanics of the serious game are good. He can imagine unlocking various skins through physical activities, such as earning a jogger skin for completing a marathon, would be a nice addition. He finds skins and in-game content, as well as competitive features, to be particularly motivating.

Participant C

Participant C finds the game mechanics of the prototype to be good. He suggested additional game genres, such as a mini-shooter or tower-defense games, although he was unsure if these would be better. Another idea he proposed was adjusting the game's enemies based on how far other players are on the leaderboard. He also envisioned a Clash of Clans-style game where players could build and upgrade a base that faces attack waves. Physical activity and achievements would earn gold or building materials to enhance the base, providing a visual representation of progress, such as building a watchtower after walking 20,000 steps in a day. Participant C emphasized the need for more diverse rewards and mechanisms. He suggested including daily challenges and a variety of achievements that could be completed at any time, such as climbing 1,000 steps in a day. Exclusive rewards for specific achievements would also be highly motivating for him.

Participant D

Participant D appreciated the leaderboard and the progression system in the game. He suggested that specific rewards should be tied to physical activities, not just XP. For example, leaderboard titles, unique weapons, and other exclusive rewards that can only be obtained through physical activities would be more motivating.

Participant E

Participant E is not someone who intensely grinds in the game itself. She suggested that points for physical activities could be weighted more heavily on the leaderboard, as this could increase motivation for engaging in sports. She also recommended including exclusive rewards for physical activities that cannot be obtained through other means.

Participant F

Participant F finds the current game mechanics very cool and effective in motivating physical activity. He couldn't think of any additional mechanics that would be more motivating.

Summary

The participants found the game mechanics effective and motivating, especially the concept of improving the in-game character through real-life exercise and the competitive leaderboard. Suggestions for enhancements included expanding to an Olympic-themed format with various sports and mini-games, ensuring physical activities yield in-game rewards, and unlocking skins and unique items through specific activities. Other proposed mechanics included adding genres like mini-shooters or tower-defense games, adjusting enemy difficulty based on leaderboard positions, and integrating a system where physical activity earns resources to build and upgrade a base. Participants emphasized the need for diverse rewards, daily challenges, and exclusive achievements to maintain engagement and motivation.

5.0.6 Individual Components and Usability Assessment

This section presents the individual participants' opinions on the various components of the serious game. Additionally, it discusses their suggestions for improvement and offers an assessment of the game's usability.

Participant A

Participant A provided detailed feedback on the individual components of the prototype. Regarding difficulty levels, he chose the hardcore level because he already trains regularly and assumed he would perform well. He saw it as a challenge and wanted to showcase his abilities on the leaderboard. For the character and statistics, he frequently checked the stats to see his improvements. He suggested enhancing this by listing previous values to clearly show progress. He recommended providing examples of how to reach the next level, such as „10 minutes of strength training“, rather than just showing XP. Additionally, he felt it would be helpful to display how existing XP was earned (e.g., through strength training) to avoid having to convert XP to sports activities mentally. He also preferred more icons over text. Quantifying improvements is crucial for him, as seeing concrete data is highly motivating. The leaderboard was his favorite feature, as previously mentioned. He added that any additional information on the leaderboard, like the training plan of other players, would motivate him further as he often looks at what others are doing. Regarding challenges, he initially chose „Weekly Workout“ but encountered a bug that prevented it from working. He then focused on „Step Counter“, believing he could meet the challenge. However, imbalances on the leaderboard demotivated him. Overall, he thought the challenge concept was very good. For achievements, he rarely checked them due to their visual presentation. He suggested that better design, such as improved

layout and more attractive colors, would make them more motivating. He liked the synchronization feature, finding it very straightforward and intuitive. He appreciated the quick understanding of what actions to take and the history with rewards. The help section had ten sections, which he found good. However, for a fully developed app, he believes it needs to be better organized with less text, more images, and improved navigation. Overall gameplay was described as „pretty cool“. He found all components intuitive and easy to use.

Participant B

Participant B chose the easy difficulty level because he was not doing any sports at that time and did not want to be at a disadvantage compared to others. Regarding the character and statistics screen, he found the interface somewhat cramped but still appreciated that it contained all the necessary information. He suggested that overall playtime should be included and that statistics should be placed on a separate screen. He believed the leaderboard should be divided between friends and other participants. Additionally, he thought it would be beneficial if players could unlock titles that would appear next to their names on the leaderboard. Participant B primarily used the „Step Counter“ challenge since he spent a lot of time at home and could utilize his walking pad. He found the challenges well-balanced, motivating him to walk more. Achievements were only used once or twice by Participant B, and he did not find them personally motivating. He suggested that achievements would be more appealing if they allowed for comparison with others and offered rewards like titles for the leaderboard, visible to others, or other in-game content. He also thought larger rewards, such as significantly more XP, increased strength, or stamina, would be better. He recommended automatic synchronization of workouts and suggested that synchronized workouts should count retroactively for a challenge if it was not already selected. Consequently, he proposed removing the sync button but retaining the history feature. Participant B did not read the help section because it was too lengthy. He suggested keeping the information but adding a navigation menu to improve usability. Overall, he found the gameplay very enjoyable, with a simple design that was fun. He found all components intuitive except for the challenge selection, which was not clearly indicated as necessary.

Participant C

Participant C chose the easy level because the other levels did not make sense for him. He found the idea that sports affect attributes to be good, but was frustrated that it only counted after 20 minutes of activity. He also found the decrease in attributes for not exercising for a week in hardcore mode unnecessary, since everyone usually takes steps within a week. Given the two-week test period, easy was the only practical option. He suggested offering the game in just one normal mode. He thought the leaderboard was good as it was but suggested adding information on how points are calculated. It might be beneficial to separate high scores from gameplay and points earned through physical activity. He chose the „Weekly Workout“ challenge because he was too late for

the steps challenge. He found the workouts (15 minutes on three different days) much easier compared to 40.000 steps, indicating an imbalance. He didn't choose „Calorie Burn“ challenges because he was unsure how the data was calculated. He liked unlocking weapons through challenges and suggested tying specific rewards to certain challenges for better engagement. He found the achievements not very clear due to limited information visible at once. While he appreciated their simplicity, he suggested more variety in both the types of activities and rewards, not just XP. Despite these issues, achievements did motivate him. He found the synchronization quick and effective. However, he suggested that the history could be better organized for scrolling and displaying more past workouts in one place. He liked seeing the rewards in the history and proposed adding a sync button in the main menu with a popup showing the rewards. He also recommended implementing anti-cheating mechanisms, such as cross-checking steps in walking workouts or comparing recorded heart rates during and outside of workouts. He thought the help section was good but could be better divided for easier navigation and include screenshots. Tooltips within the menus, indicated by question marks, would also be helpful. Participant C found the gameplay fun and somewhat addictive, as it made him want to keep playing. However, he found the control pad too small and the attack direction linked to movement direction problematic, as it prevented standing still and attacking in one direction. He suggested adding a separate joystick for attacks. He also desired physical controller input. He felt that stamina had too much influence on movement speed, causing him to run into enemies. He suggested adding more enemies, a hit cooldown for the character, and improving performance. He found the bleeding effect too weak, the lightning item good but in need of scaling with character attributes, and the shield very strong. The clock item was okay. He appreciated the different effects of weapons but wanted more variation, such as faster attack speeds. He found everything easy to use except for the challenge selection, which was not clearly indicated as necessary.

Participant D

Participant D chose the easy difficulty level because he did not want to hinder his game progress and was unsure about the differences between the difficulty levels at first. He did not choose normal or hardcore because he had no time for strength training, which would prevent him from gaining strength through sports. He noticed that most people on the leaderboard were also at the easy level, and if this were not the case, he might have switched difficulty levels. Although he didn't have time for them, he appreciated the concept behind the normal and hardcore difficulty levels. He found statistics to be valuable, particularly in-game statistics like the high score. Having total XP displayed in the game would be beneficial. He chose the step challenge because it suited his plan to walk a lot. He was unsure what to expect from the „Calorie Burn“ challenge, so he did not select it. While he found achievements cool, they would be more motivating if they offered exclusive rewards instead of just XP. By the end of the game, the XP rewards became less meaningful because his character was already at a high level. He suggested that automatic synchronization in the background would be better, so users wouldn't have to remember to sync manually. It would also be helpful if synchronization

for challenges could be retroactive, counting past activities even if the challenge was not selected in time. He recommended that the help section be shown at the beginning and include screenshots to make it easier to understand. It should also be designed to be visually more appealing. He found the gameplay very enjoyable and addictive but noted that it needs more content in the long term, such as more enemies. He appreciated the variation in gameplay, where different items were better depending on the wave and character level, which significantly increased the fun and replay value. The sounds were satisfying, especially when defeating multiple enemies. He suggested making the control pad larger because his thumb often slipped off. Alternatively, allowing the control pad to be used anywhere on the screen would help with accuracy. Otherwise, he found everything else straightforward to use.

Participant E

Participant E chose the easy difficulty level because she does not play much and engages in minimal sports. She feared that a higher difficulty level would hinder her progress. While she found the concept of personalized rewards in the Normal and Hardcore modes cool, she would not engage in strength training just to level up her strength attribute. She found that all necessary statistics were present and motivating. Knowing how much XP she needed to reach the next level encouraged her to play more rounds. She suggested that with more players, there should be different categories, such as separate leaderboards for players in hardcore mode, as some individuals were significantly higher on the leaderboard. She chose the „Step Counter“ challenge because it was the most realistic for her to complete and easiest to integrate into her daily routine. She appreciated having different challenges to choose from and found the one-week timeframe appropriate. For longer periods, she suggested unlocking one weapon per week instead of all at once. She also recommended providing a hint in the first week about the good rewards from challenges. She found achievements motivating and very cool. Although she viewed them as secondary, she checked them regularly and felt incentivized to do more. She liked the diversity brought by having both challenges and achievements. Synchronization worked well for her. The game prompted her to install Google Fit/Health Connect, which might lead to her engaging more with fitness apps and thus doing more sports. She only briefly looked at the help section and did not use it much, preferring to ask a participant who had played more for advice. Initially, she found the gameplay somewhat frustrating, but it became very cool and enjoyable once she had additional weapons. She appreciated the increasing difficulty, the cool items (especially „Lightning“), and the balanced feel of the enemies. She liked the gameplay variation and thought it would be cool if players could hide behind objects like the stones depicted in the background. Although she wouldn't have downloaded the game based on its premise alone, she found it appealing once she started playing. She enjoyed trying to beat her high score and found the items easy to understand. The challenge selection process was somewhat unclear, but everything else was straightforward and understandable.

Participant F

Participant F chose the easy difficulty because he did not spend much time considering the difficulty levels and simply went with the default option. He found the character statistics to be cluttered and difficult to navigate because everything is written in the same style with no highlights. He suggested that better design could improve readability. He thought the leaderboard was generally good but suggested it should be clearer how the points are calculated. He did not realize during the test phase that the colors of the player names indicated different difficulty levels. He chose the „Step Counter“ challenge initially because he thought it would be the easiest, then switched to „Calorie Burn“ to try something different and because he thought it might be quicker. He suggested it would be helpful to see the rewards for completing challenges. He liked the achievements because they provided additional XP. He suggested that more achievements would be beneficial. He recommended making the scroll bar more noticeable and displaying more workouts in one place. He did not use the help section frequently. Participant F enjoyed the game concept but suggested several improvements. He recommended showing the actual damage dealt rather than just the amount reduced from the enemy’s health, as it is not immediately clear that increasing strength results in more damage. He also suggested displaying enemy health bars to better gauge their strength. Additionally, he proposed implementing a hit cooldown so that players do not take continuous damage after being hit once. He found all components easy to use and self-explanatory.

Summary

In summary, most participants chose the easy difficulty level due to varying levels of physical activity and to avoid hindering game progress. However, Participant A chose the hardcore level as a personal challenge and to showcase his abilities on the leaderboard. Regarding character statistics, participants found them useful but suggested improvements for clarity and motivation. Better design, highlighted information, and displaying total XP and detailed progress could enhance the experience. The leaderboard was a favorite feature for its motivational aspect, though there were suggestions for more transparency in point calculation and separating scores from physical activity and gameplay. Challenges were well-received, with participants choosing those that fit their routines, such as step counters. However, there were concerns about imbalances and the need for clearer rewards. Achievements were seen as motivating, but participants suggested more variety, better design, and more significant rewards. Synchronization was generally effective, but some recommended automatic syncing and improved history features. The help section was seldom used due to its length, with suggestions for better organization, navigation, and visual aids. Gameplay was widely enjoyed, with participants appreciating the fun and addictive nature. However, they suggested improvements like larger control pads, additional enemies, hit cooldowns, and better visual indicators for damage and enemy health. Overall, the prototype was found to be intuitive and easy to use, though the challenge selection process needed clearer indication.

5.0.7 Additional Recommendations for Improvement

This section presents supplementary recommendations for enhancement proposed by the participants. They discuss which components are absent, which elements should be augmented, and the rationale behind these suggestions.

Participant A

Participant A identified several additional aspects and features of the prototype that he would improve. Firstly, he would enable a feature that allows users to see how points on the leaderboard are accumulated. By clicking on a player's name, one could view detailed information such as the game high score, number of steps, workouts, and duration, providing transparency in how scores are calculated. He also suggested more balanced rewards. Currently, rewards are based solely on the duration of workouts, which can be demotivating. For example, harder workouts like strength training should yield better rewards compared to activities like walking. Participant A experienced performance problems due to his older device. While he accepted this issue, it affected his ability to use certain items, such as the „Lightning“, which he ignored due to performance issues. He suggested that the game should adapt by reducing the spawn rate of items he consistently ignores and increasing the spawn rate of more useful items, which would enhance his motivation. He proposed adding mechanics to regain health within the game. There was also an issue where a workout completed late on a Sunday did not count towards a challenge. He recommended allowing workouts to count retroactively and implementing auto-sync for workouts, which could occur once a day, especially on rest days. Participant A would like to see more players choosing higher difficulty levels, as he believes hardcore mode is superior and more rewarding. He suggested promoting diligent easy mode players to harder levels to prevent abuse of the easier setting. He noted an issue where two top players had achieved such high scores that normal training could not catch up. Understanding how these scores were achieved became a motivation for him to set personal goals, like overcoming challenges with his weaker device. He expressed a desire for increased engagement through more notifications, such as alerts when someone overtakes him on the leaderboard or starts a workout. He also suggested a feature to start and join a battle mode for simultaneous workouts with other players. Improving graphics and using more icons instead of text would enhance the visual appeal. He also saw potential for the app to expand by incorporating nutrition, rewarding positive eating behaviors and not rewarding negative ones. This would promote healthy eating alongside physical activity, though he acknowledged it might be challenging to monitor. Finally, he found the weight icon on the challenge screen misleading because it also serves to select the character's weapon. He suggested reconsidering this icon to avoid confusion.

Participant B

Participant B would prefer if weapons were unlocked one by one as challenges are completed, rather than all at once, to create a greater sense of progression. He noted that the hitbox for the character and enemies needs adjustment, as the character sometimes

takes damage without being touched by an enemy. He also suggested that the attack direction should be independent of the movement direction to enhance gameplay fluidity. There was a bug that allowed players to attack while the game was paused, which needs fixing. Additionally, he recommended that the damage dealt by the Lightning item should scale with the character's attributes rather than being a fixed amount. Participant B found the Bleeding and Clock items to be too weak and the Shield item to be overpowered. He highlighted that the leaderboard balancing needs adjustment because players who played excessively achieved very high scores that were difficult to surpass. He mentioned that running faster than attacking is frustrating, especially when leveling up stamina, as the running speed scales too quickly compared to movement speed. Lastly, he pointed out a bug where temporary items would spawn in inaccessible areas.

Participant C

Participant C suggested that the game should include a tutorial at the start to explain everything. He initially assumed that all challenges would run simultaneously, rather than needing to select one. He also thought the pause menu could be improved, such as by adding an option to end the current game and return to the main menu. He noted that it was not explained what strength and stamina do, and suggested that these should be explained on the character screen where they are upgraded. Similarly, he recommended explaining the available weapons and their effects. He found the initial workouts unbalanced, as two 10-minute workouts did not count the same as one 20-minute workout. He suggested adjusting this so that shorter workouts add up to the same total. To better measure effort, he proposed using heart rate data rather than just workout duration, as this would prevent people from cheating by starting a workout without actually exercising. This could be done by using the difference from the resting heart rate over a certain period to validate the workout. This would also provide better feedback and motivation. He also suggested that walking workouts should count steps as evidence. Different difficulty levels should have separate leaderboards for fairness. He also recommended more weapon variety and the ability to skill them differently, with different requirements for weapon level-ups. Adding more achievements with diverse tasks and rewards, such as those based on heart rate fluctuations during HIIT workouts, would encourage users to try new activities. Participant C felt the game should have more content, such as additional levels or stages, and potentially battlefield scenarios that require walking to advance, with attributes affecting performance in these scenarios. Daily challenges would also be motivating, providing something new to unlock each day. Finally, he suggested improving the performance and hitbox of the character and enemies. To motivate people who engage in different types of sports, he proposed that those who run and those who go to the gym could receive different weapons, balanced to ensure fair competition.

Participant D

Participant D would prefer a more transparent leaderboard that shows how points are accumulated. Specifically, he wants to see the breakdown of points earned through gameplay versus those earned through physical activities. He found that the overwhelming majority of leaderboard points came from gameplay, which made workouts less relevant. He suggested adjusting the scaling to ensure that both gameplay and physical activities contribute meaningfully to the overall score. He recommended enhancing the endgame experience by adding more enemies and adjusting the scaling to make the game progressively more challenging as players advance. This would keep the game engaging and provide a continuous sense of achievement.

Participant E

Participant E suggested that the challenges should better indicate the specific rewards that can be earned. Additionally, she found the life indicator not very visible and recommended that it should stand out more on the gameplay screen to improve visibility during play.

Participant F

Participant F suggested several improvements to the prototype. He found the user interface to be rudimentary and simple, lacking quality-of-life functions that would enhance the user experience. Regarding achievements, he noted that it was not clear that the section could be scrolled, making it difficult to see all available achievements. He found the hitbox to be frustrating because sometimes the game would suddenly end due to unexpected loss of health, making it hard to understand why he had lost all his health. He also mentioned that it was not immediately apparent what stamina did, as it was not explained in the help section. He suggested adding a tooltip in the character menu to explain the function of the attributes. Participant F also noted that it was unclear how to regain health in the game. He encountered an issue during the setup process where he installed the game and granted access to Google Fit, but the game was accessing Health Connect instead, which was not connected to Google Fit. This caused the game to miss some data. He recommended redesigning the setup process or providing a detailed guide. He suggested that temporary items should have descriptions explaining their effects. It would also be better if temporary items could stack. Regarding controls, he found the control pad too small, making it difficult to move accurately. He suggested adaptive placement for the control pad to improve usability. Finally, he mentioned that the impact of stamina on attack speed was not very noticeable and could be improved for better gameplay dynamics.

Summary

In summary, the participants suggested multiple additional improvements. It was recommended to add a feature that shows a detailed breakdown of points on the leaderboard,

including scores, steps and training sessions. They suggested balancing rewards so that harder workouts yield better results than lighter activities. Enhancing the user interface with more icons and better design for readability was also mentioned. Performance issues on older devices and the need to adjust hitboxes to prevent unexpected damage were noted. Temporary items should have clear descriptions and the ability to stack. Introducing mechanics to regain health and explaining strength and stamina attributes on the character screen were also suggested. Participants recommended having separate leaderboards for different difficulty levels and adding more endgame content, such as new enemies, levels, and daily challenges. Clearly indicating rewards for challenges and allowing retroactive counting of workouts were also advised. They wanted a greater variety and significance of achievements, offering exclusive items or titles, and recommended implementing automatic synchronization. Gameplay and control improvements included making the control pad larger and allowing adaptive placement. Participants suggested separating attack direction from movement for smoother gameplay, scaling damage with character attributes, adding hit cooldowns, and improving life indicators. They expressed a desire for notifications about leaderboard changes and workout starts. Additionally, incorporating nutrition tracking to reward healthy eating behaviors was suggested.

5.0.8 General Perception of Serious Games Incorporating Sports

This section presents a summary of participants' general views on serious games that integrate sports as a core mechanic, as well as an assessment of their likelihood of using these games over an extended period.

Participant A

Participant A provided positive feedback on the concept of serious games that incorporate sports as a game mechanism. He described the idea as „pretty cool“ and expressed strong approval of the approach. He noted that, in his experience, most serious games are excellent at achieving their intended educational or motivational goals but often fall short in terms of entertainment value. This lack of fun typically results in decreased user engagement over time. However, he found this prototype to be an exception. He praised it for being enjoyable to play even without the sports component, which in turn increased his overall engagement and motivation to participate in physical activities to earn rewards. This combination of intrinsic game enjoyment and the additional motivation provided by the sports component creates a more compelling and effective experience, according to Participant A.

Participant B

Participant B had never used serious games that incorporate sports as a game mechanism before but found the concept appealing. As a gamer and someone who considers himself a couch potato who would like to do more sports, he appreciated the potential for motivation that such games offer.

Participant C

This was Participant C's first experience with serious games, and he found it quite cool. He thought it was a nice idea and mentioned that he would continue playing it. He also knows about Fantasy Hike and considers it a good idea as well.

Participant D

Participant D thinks the concept is cool and can definitely be motivating if well-executed. He emphasized the importance of good balance and ensuring that the game itself is fun, which he felt the prototype achieved. He noted that many other games and apps do not meet these criteria.

Participant E

Participant E found the concept of serious games that incorporate sports as a game mechanism to be quite cool.

Participant F

Participant F thinks serious games that incorporate sports as a game mechanism are cool and a great idea because they provide additional motivation to engage in physical activities.

Summary

Overall, the participants had a positive perception of serious games that incorporate sports as a game mechanism, finding the concept appealing and motivating. They appreciated that the prototype successfully combined intrinsic game enjoyment with sports motivation, enhancing engagement and participation in physical activities. Some noted that, while many serious games achieve their educational or motivational goals, they often lack entertainment value, leading to decreased user engagement. However, this prototype was seen as an exception, being enjoyable even without the sports component. The combination of fun gameplay and additional motivation from the sports aspect was viewed as a compelling and effective approach. Participants also emphasized the importance of good balance and execution to ensure the game remains fun and motivating.

5.0.9 Additional Questions or Comments

This section presents the supplementary inquiries and remarks proffered by the participants, offering insights into any residual concerns, observations, or recommendations they may have had.

Participant A

Participant A mentioned that he will continue to play the game even after the test period ends in order to complete the challenges.

Participant D

Participant D expressed satisfaction with the prototype, stating that it was enjoyable and well-designed.

Participant E

Participant E commented that it is a very nice game. She noted that the synchronization works very well, and it is enjoyable and convenient for short play sessions.

Other participants

None of the other participants had any additional questions or comments.



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Discussion

This chapter discusses the most significant findings resulting from the research questions addressed in this thesis. Additionally, it assesses whether the objectives of this thesis were met through the conducted requirement engineering and the resulting prototype.

Research Question 1: What are the requirements for a serious game for strength and endurance training?

One of the primary requirements to motivate for strength- and endurance workouts is to ensure that in-game rewards through gameplay are engaging. It is essential that the game itself is enjoyable even without the necessity of performing physical exercise. This intrinsic enjoyment can lead users to regularly engage with the app and remain consistent in their usage. Once users find the game entertaining, they can be further motivated to undertake physical activities by recognizing the additional advantages they gain within the game through exercise. Many users during the test phase reported that the core gameplay was highly enjoyable, prompting them to open the app more frequently and engage with the game. Inspiration for this aspect can be drawn from already successful conventional games. For instance, the prototype developed in this thesis took inspiration from the rogue-like genre, which is known for its engaging and addictive gameplay mechanics.

Another critical requirement is the implementation of rewards through physical activity. Users are more motivated to engage in physical exercise when they see that it leads to further or exclusive in-game rewards. It is crucial to clearly delineate what rewards users will receive for specific types of exercise. Additionally, it is important not to restrict users to one type of physical activity but rather to offer them the choice of which sport or exercise to perform. It is beneficial to ensure that the game accommodates a variety of physical activities, as this helps to cater to a broader audience and enhance overall engagement. To encourage engagement in specific types of exercise, offering exclusive in-game rewards for particular sports can be highly effective.

Social aspects also play a significant role in user motivation within a serious game. During the test phase, it was found that the leaderboard component was the most favored and motivating feature for users. This competitive setting, particularly when it allows friends to compare their progress, greatly enhances motivation. The comparison with friends rather than strangers provides the strongest incentive, as users are driven to outperform their peers and rank higher on the leaderboard.

Furthermore, providing detailed statistics enables users to see their progress and accomplishments, which is crucial for motivating continued engagement and improvement. It is important to display the user's progress in the game and to visualize what actions are needed to advance. This clarity prevents users from having to spend time figuring out their next steps, making the process more seamless and motivating.

Notifications serve as an important tool to remind users if they have forgotten to complete a training session or to perform a task within the game, such as completing a challenge. Additionally, notifications can enhance interactivity; users reported that they would find it motivating to receive alerts if, for example, they are overtaken on the leaderboard. These notifications can help maintain user engagement and encourage continuous participation.

To motivate users not only in the short term but also in the long term, it is essential that the serious game remains interesting over an extended period. This could involve incorporating additional gameplay features, an engaging story and providing a sufficient variety of rewards. The goal is for users to develop and maintain a consistent exercise routine, ultimately recognizing the benefits of physical activity and continuing it independently of the serious game.

To cater to users with different levels of physical activity, the game should include various difficulty levels for exercises. This allows less active users to start with lower barriers and gradually increase their activity, while more active users can engage with higher difficulty levels that present a challenging and stimulating experience. This approach ensures that beginners do not feel overwhelmed and that more advanced users remain engaged, thereby accommodating a wide spectrum of fitness levels and preventing demotivation among users.

As with other games and software products, it is crucial that the serious game features an intuitive UI that is easy to navigate. Users should be able to clearly understand the functions of different menus and how to access them. This prevents users from feeling overwhelmed and encourages them to use the game. Additionally, the game should employ a consistent graphical style that enhances the user experience, providing appropriate feedback for user actions to ensure a cohesive and engaging interaction throughout the game.

Research Question 2: Which game mechanics can be used for a serious game to convert real-life strength and endurance workouts to in-game rewards and progress?

The prototype utilizes the rogue-like game principle, a genre distinguished by procedurally generated levels, permanent character progression, and high replayability. The game incorporates dynamically generated levels, ensuring that each session presents a unique experience. This design strategy maintains long-term engagement by continually introducing new challenges, thereby preventing monotony.

The serious game seamlessly integrates real-life physical activities into its core mechanics to enhance character abilities. Real-life strength and endurance workouts contribute directly to the progression of the in-game character. Each physical activity is converted into experience points (XP), which players can use to level up their character or directly enhance specific attributes such as strength or stamina, depending on the type of exercise performed. This leveling system allows users to see a tangible reflection of their real-world efforts within the game, thereby promoting sustained engagement and motivation.

A competitive leaderboard tracks users' progress and ranks them based on their physical activity and in-game high score. This feature harnesses the power of social motivation, as players strive to outperform their friends and climb the rankings. The competitive aspect is a significant motivator for maintaining regular physical activity.

The prototype includes a system of weekly challenges to motivate users to engage in regular physical activities. Players can select from a variety of challenges, such as completing a certain number of workouts, walking a specified number of steps, or burning a set amount of calories each week. Successfully completing these challenges rewards players with in-game weapons, which vary in characteristics and add dynamic elements to the gameplay. These weapons are exclusive rewards that can only be unlocked through completing the challenges, and they offer superior performance compared to the standard weapons available in the game. These rewards are designed to keep users engaged and provide a tangible goal for their physical efforts.

In addition to challenges, the game features a comprehensive achievements system. Achievements are linked to various training activities, including steps taken, workouts completed, and calories burned. Each achievement provides additional XP, enhancing the player's character and encouraging continuous engagement with both the game and physical activities. The achievements screen displays a progress bar for each goal, making it easy for players to track their progress and stay motivated.

During the interviews conducted for this thesis, several additional game mechanics were identified to convert real-life strength and endurance workouts into in-game rewards and progress. One such mechanic involves earning currency, such as energy, from real-life workouts. This currency can be used to continue playing or unlock new content within the game. Another idea is a narrative-driven game where the story progresses as users complete physical activities in real life. Additional suggestions included mini-shooters, tower defense games, and Clash of Clans-style games where users earn gold or building materials from workouts to enhance their base.

While these mechanics were mentioned, the interviews revealed that the rogue-like game principle, combined with character improvement through real-life workouts, received

particularly positive feedback. As users enhance their in-game character through physical activities, it adds a sense of personalization and motivation, making the gaming experience more compelling.

Research Question 3: What are the perceptions and attitudes of users towards a serious game that incorporates real-life sports participation as a gameplay mechanism?

The initial interviews revealed a generally positive attitude towards serious games that integrate real-life activities. Many participants recognized the potential of these games to enhance motivation and engagement by seamlessly integrating with daily activities. They viewed serious games not only as a form of entertainment but also as a tool for personal development, including physical fitness and skill acquisition.

Several participants highlighted the usefulness of serious games in initiating beginners into new fields, suggesting that the engagement level might vary with the complexity of the topic. The majority of participants could imagine using such a serious game to increase their motivation for sport. Additionally, those not currently active in physical activities expressed that they could envision becoming more active again with the help of a serious game.

After testing the prototype, participants provided overwhelmingly positive feedback. They found the concept of integrating physical activities with gameplay both appealing and motivating. Users appreciated the innovative approach, noting that while many serious games achieve their educational goals, they often lack entertainment value, which can result in decreased engagement. However, the prototype presented in this thesis was praised for its enjoyable gameplay, which remained engaging even without the sports component. The intrinsic enjoyment, coupled with the motivation to engage in physical activities for earning in-game rewards and advancing on the leaderboard to surpass friends, was identified as a compelling and effective feature.

Overall, participants regarded the prototype as an outstanding demonstration of how serious games can boost engagement and motivation by merging enjoyable gameplay with real-life benefits. The integration of fun gameplay with the motivational aspect of sports was seen as particularly effective. Additionally, participants highlighted the significance of achieving a good balance and execution to maintain the game's enjoyment and motivational impact.

Conclusion and Future Work

This thesis explored the development of a serious game designed to enhance motivation for strength and endurance workouts. The primary objective was to design and develop a mobile game that integrates real-world fitness data, thus promoting regular physical activity through engaging gameplay. The findings of this research indicate that such a serious game can be a powerful tool in encouraging sustained exercise habits.

The serious game prototype had a diverse impact on participants' physical activity levels. Although individuals with regular gym routines did not increase their session frequency, they became more conscious of their daily activities. This heightened awareness led to an increase in daily steps and cycling, as participants chose to walk or cycle instead of using public transportation to enhance their in-game performance. Several participants reported a notable improvement in physical activity levels, particularly through more frequent walking and incorporating new workouts into their routines. The game served as a catalyst for those who had been contemplating starting a workout regimen but had not yet done so. The game mechanics motivated participants to engage in additional physical activities, such as home workouts and longer walks. However, some participants faced barriers such as irregular schedules and lack of equipment, which limited their ability to fully engage in workouts. Despite these challenges, the overall trend indicated that the game successfully motivated increased physical activity, particularly through walking and other accessible forms of exercise. Participants with setup difficulties or irregular routines suggested that a longer test period might further enhance their activity levels, indicating that extended engagement with the game could yield more significant results.

The user feedback collected during the iterative design process was overwhelmingly positive, underscoring the game's potential to motivate regular physical activity. One key requirement for motivating strength and endurance workouts is ensuring that the game is enjoyable on its own, even without physical exercise. This intrinsic enjoyment can lead users to engage with the app regularly. Once users find the game entertaining, they are more likely to appreciate the additional benefits gained through exercise. During testing,

7. CONCLUSION AND FUTURE WORK

many users reported that the core gameplay of the prototype was highly enjoyable, encouraging frequent app usage.

Participants consistently highlighted the enjoyment derived from the game, with specific appreciation for the reward system and competitive elements. The leaderboard feature, in particular, emerged as a significant motivator. Users reported that seeing their progress relative to others fostered a sense of competition and achievement, driving them to engage more frequently in workouts to climb the ranks. Participants suggested several key improvements for the leaderboard to enhance its effectiveness as a motivational tool. Balancing the gameplay to ensure fair competition was highlighted as essential, as excessively high scores can undermine the credibility of the leaderboard. Making the point calculations more transparent would help users understand how their efforts translate into scores. Another recommendation was to separate the scores earned through physical activity from those gained through in-game actions, providing a clearer picture of a user's overall progress and effort. Additionally, the introduction of community-building features, such as local lobbies and friends lists, was suggested to foster a sense of community and enhance competition among known individuals, further increasing user motivation.

The core game principle, which allows players to improve their in-game character through both real-life exercise and gameplay, added a unique personalization aspect. This dual progression system made the game more engaging, as users felt a direct connection between their physical efforts and their virtual accomplishments. This personalization aspect, where the character evolves based on the player's real-world activities and in-game decisions, further enhanced user investment and motivation.

Challenges were identified as a key motivational element within the game. Participants appreciated the variety of challenges, which allowed them to select those that aligned with their routines, such as step counters or workout goals. A particularly motivating aspect was the exclusive rewards, like new and better weapons, which provided significant incentives by enhancing in-game performance and enabling players to achieve higher scores. Participants emphasized the need for more exclusive rewards for completing challenges to sustain engagement. Furthermore, integrating more personalized and dynamic challenges that adjust based on the user's progress and activity patterns could keep the gameplay fresh and continuously engaging. Additionally, the introduction of daily challenges was suggested to offer users fresh goals each day, encouraging consistent physical activity and maintaining long-term interest in the game.

Achievements, such as earning rewards for consecutive workout days or reaching specific step counts, created objectives that kept users engaged and encouraged them to increase their physical activity. Participants suggested the inclusion of more varied and meaningful achievements to cater to a broader range of user goals and fitness levels. Tailoring achievements to specific sports with unique rewards could further motivate users to engage in those activities. Improving the design and visibility of achievements was also emphasized. Achievements would be more effective if they could be compared with those of friends. In addition to XP, they could offer exclusive rewards, such as titles for the leaderboard, to further incentivize users.

Participants believe the game can positively influence long-term attitudes towards sports, primarily through its competitive features and extrinsic motivation. Competing against known individuals motivates users to improve their leaderboard rankings. Intrinsic motivation can be enhanced by incorporating self-comparison mechanisms to track and improve personal progress. While the game provides an initial push for physical activity, it cannot create motivation independently. Users need some intrinsic motivation to begin with, which the game can nurture through engaging content and reward systems. Further content implementations, such as more enemies, weapons, skins, and a storyline, are essential for maintaining long-term engagement.

Notifications for regular training and reminders of ongoing challenges served as prompts to engage in physical activity consistently. Participants appreciated that these notifications were not sent too frequently, which contributed to their positive reception. Furthermore, it was recommended to create push notifications for leaderboard updates to keep users informed and engaged with their rankings, thereby encouraging ongoing participation. Additionally, it was suggested to send notifications when a friend starts a workout, providing constant reminders to stay on the same activity level as friends.

Difficulty levels that changed the challenges and rewards for physical activity, as well as the leaderboard rankings for each player, were well-received. Most participants chose the easiest difficulty level to avoid any disadvantages. However, the participant who selected a higher difficulty level found the challenging tasks motivating and appreciated that other players could see he had chosen the most difficult setting. Future research could focus on offering better rewards for users who select higher difficulty levels, thereby increasing motivation for more challenging tasks and promoting greater physical effort.

Participants for the requirement engineering process and user testing were selected from the immediate vicinity, offering a convenient and accessible pool of interested users. This approach facilitated the gathering of initial insights and feedback, but it also introduced limitations related to the generalizability of the results. The restricted diversity and potential biases inherent in a homogenous group can impede the ability to accurately reflect the broader user base and their diverse needs and preferences. For future research, it is recommended that a larger and more diverse sample of participants be involved. In order to ensure the representation of a cross-section of potential users, it is recommended that random sampling methods be employed. This approach would facilitate the collection of more comprehensive and varied data, thereby enabling a more robust understanding of user requirements and interactions with the system. Furthermore, the engagement of a more diverse demographic spectrum can facilitate the identification of distinctive user needs and usability issues that might otherwise remain concealed within a more constrained participant pool.

In the current prototype, the primary basis for rewards for workouts is the duration of the exercise. While this approach can effectively motivate users to engage in longer periods of physical activity, it may not necessarily incentivize them to increase their intensity or improve their performance, such as running faster or lifting heavier weights. This limitation underscores the necessity for the development of more sophisticated reward

7. CONCLUSION AND FUTURE WORK

mechanisms that not only encourage longer workouts but also promote greater effort and advancement in users' physical performance. To address this, future work should explore and implement mechanisms that make it beneficial for users to exert more effort. One potential strategy is to integrate heart rate monitoring into the reward system. As an indicator of exercise intensity, heart rate could be used to correlate higher heart rates with increased effort and performance. For example, rewards could be scaled based on heart rate zones achieved during the workout. Moreover, integrating heart rate-based rewards could address the varying fitness levels and capabilities of different users. This feature enables the reward system to be tailored to the individual, offering more substantial incentives for users to achieve their personal best, regardless of their starting point. This can assist users in setting and achieving progressively challenging fitness goals, thereby fostering a sense of accomplishment and sustained motivation.

During the requirement engineering phase of this thesis, a multitude of innovative ideas were generated through interviews with potential users. The interviews yielded a substantial amount of information regarding user preferences and expectations for the serious game. However, due to the resource constraints inherent in the scope of this thesis, it was not feasible to implement all of these ideas. The constraints on resources necessitated a focus on core functionalities and essential gameplay mechanics, ensuring the development of a functional and engaging base game. Although this approach has resulted in a viable product, there is significant potential for enhancing the game's enjoyment and effectiveness in promoting physical activity through the incorporation of additional features and mechanics. In addition to the ideas generated during the initial interviews, further suggestions emerged from the post-interview analysis. Participants recommended several improvements to the game's existing features and proposed new functionalities to enhance user engagement. For instance, a comprehensive tutorial at the beginning of the game should be implemented to explain the various game mechanics. This would help users understand the gameplay more easily. This tutorial could be integrated with a setup process that guides users through configuring Health Connect, ensuring a smooth onboarding experience. Furthermore, the game should be visually enhanced with improved graphics and animations to increase enjoyment and engagement. Visual upgrades can significantly contribute to a more immersive and enjoyable gaming experience, thereby boosting user motivation. Additionally, the game's performance should be optimized to ensure it runs smoothly on older devices.

Currently, the workout synchronization mechanism in the serious game is designed to fetch all workouts recorded in Health Connect since the last synchronization timestamp. While this approach ensures that the game is updated with the most recent activity, it also introduces a significant limitation. If a workout is not saved in Health Connect before the next sync attempt, it may be permanently missed because the sync process does not recognize activities that started before the last sync timestamp but were saved afterward. This results in the loss of workout data and can negatively impact the user experience by omitting legitimate physical activity that contributes to the user's progress and rewards. Future research should consider a more robust synchronization

strategy to address this issue and improve the user experience. Rather than relying solely on the last synchronization timestamp, the system could compare workouts already stored in the game with newly recorded workouts in Health Connect. This approach would ensure that all relevant workouts are accounted for, regardless of when they were recorded or saved in Health Connect. Implementing this method would greatly improve the reliability and completeness of workout data within the game. It would also improve usability by reducing the risk of data loss and ensuring that all user efforts are accurately reflected and rewarded. Furthermore, an additional improvement for future work could be the implementation of an automatic synchronization process. Automating the synchronization of workouts at game launch or in the background would eliminate the need for users to manually initiate the process, thereby simplifying the user experience and ensuring that workout data is consistently up-to-date. Users would benefit from a seamless synchronization process, which is critical to maintaining their motivation and engagement in the game.

Integrating real-world workouts into the serious game via Health Connect offers a novel approach to incentivizing physical activity by providing in-game rewards based on users' fitness efforts. However, this system is susceptible to exploitation through the manual creation of fictitious workouts, potentially undermining the competitive integrity of the game's leaderboard. In a single-player context, the impact of cheating is confined to the individual's experience, primarily diminishing the game's effectiveness as a motivational tool. Conversely, in a multiplayer setting with a shared leaderboard, fraudulent activities pose a significant threat to fair competition, potentially demotivating players who adhere to the game's intended rules. The presence of dishonest players who artificially inflate their scores could dishearten legitimate participants, reducing their engagement and ultimately detracting from the game's goal of promoting physical activity. Future work should focus on developing robust mechanisms to mitigate cheating and ensure the validity of workout data. One promising approach involves incorporating heart rate monitoring into the game's data verification process, thereby authenticating reported activities by comparing physiological responses recorded during workouts with expected patterns based on the type and intensity of the activity. Additionally, the development of machine learning algorithms capable of detecting anomalies in heart rate data could further enhance the identification of fraudulent activities. Further research is necessary to explore alternative methods for authenticating workout data, such as utilizing GPS data to validate outdoor activities and implementing algorithms to analyze performance patterns.



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CHAPTER 8

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