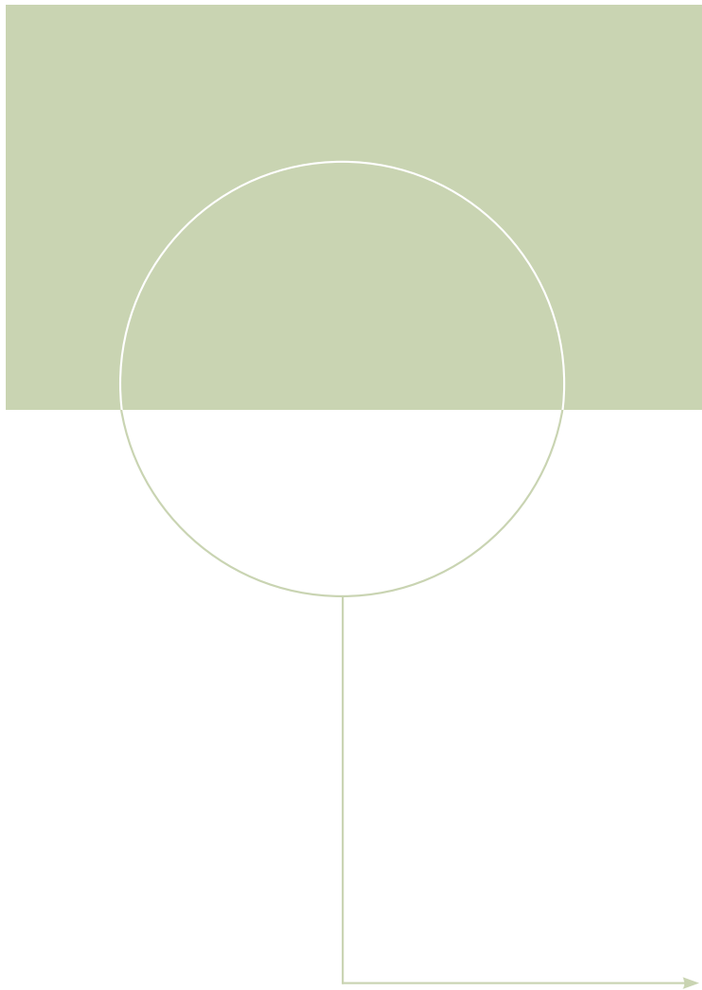

Master's thesis

2020

Quit Phuong Bui, Håkon Arnø Hoff

NTNU
Norwegian University of
Science and Technology
Faculty of Information Technology and Electrical
Engineering
Department of Computer Science

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Håkon Arnø Hoff

Master of Science in Computer Science
Submission date: June 2020
Supervisor: Alf Inge Wang, IDI

Norwegian University of Science and Technology
Department of Computer Science

Abstract

A sedentary lifestyle has become more common, leading to a higher percentage of people overweight and increasing the risk of cardiovascular disease. People have to become more physically active to overcome this problem, as some people find it hard to be motivated enough to be more physically active. Exergames can be a solution to this problem by encouraging people to exercise while having fun.

This thesis has reviewed existing exergames, literature, and technologies to explore the potential with exergames. As a result, a location-aware exergame played on the smartphone was designed. The game utilizes the smartphone's GPS to locate the players' physical position that is mapped directly into the game. Moving into the real world will make players move in the game as the GPS position changes. The game's objective is to try, within a time limit, to run away from dinosaurs in different levels.

Five participants from our social network with an interest in video games and exercise tested our game. The testing lasted approximately 45 minutes for each participant with observations. After observations, an interview of each participant was performed. Of the results, we found that our exergame has the potential to encourage people to exercise and gain physical benefits from playing that kind of game.

Acknowledgement

We wish to express our sincere appreciation to our supervisor, Professor *Alf Inge Wang* at the department Computer and Information Science (IDI), who has guided and encouraged us during our research. Without his help, the goal of this project would not have been realized. Being able to have flexible meetings during this COVID-19 epidemic has been a valuable resource to us. We also wish to acknowledge the participant that participated during the COVID-19, who helped us to gather valuable data during our research.

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Part I

Introduction

The first part of the report begins with a brief motivation for the project, including the project's and our motivation in regards to research of combining games and exercise. In the following chapter, we will present the research goal and the research questions that are defined to help us achieve the research goal. At the end of Part I, a report outline to provide a brief overview of the project is shown.

Chapter 1

Motivation

In recent years, studies have shown that more people are getting obese diseases because of an unhealthy diet combined with low physical activity. Many jobs do not require much physical activity, including jobs from our domain of computer science. Since many are not physically active during work, they struggle to find time to do it.

The reduction in physical activity has happened to us as well. For us, a combination of increased access to digital entertainment and a desire to do well in our studies has caused us to do fewer physical activities. What makes exergames interesting is that digital entertainment can not only be used for entertainment, but also to exercise. Digital entertainment is often thought of as making people less active, but exergames does the opposite. Many exergames have been used in research to find the physical benefits of playing exergames, and the results were promising.

With this project, we want to study how exergames can contribute to enhance the people's physical activity level, and how the enjoyment of games affect the physical health of players.

Our goal for the project is to create a game that is enjoyable while promoting exercise. Many teenagers and adults spend many hours on mobile games. Creating a mobile game can reach out to many users to increase their physical activity. Humans are made to be physically active, as it is a natural behavior. We hope that creating an enjoyable game that promotes exercise can be a solution to this social problem by examining various exergames and technologies.

Chapter 2

Project and Context

This project is a Master Thesis (*TDT4900*, Computer Science, Master Thesis), a continuation of the specialization project (*TDT4501*, Computer Science, Specialization Project) that was done in fall of 2019 [8]. The specialization project conducted a prestudy of literature, exergames, and technologies, resulting in generated game ideas. For this reason, the findings from the specialization project will be used to develop an exergame that should be tested on users. In this report, the chapters 5-10 and Chapter 16 are from the specialization project, with modified and added content.

This project is a part of research that the institute of data science and information technology (*IDI*) at the Norwegian University of Science and Technology has on exergames. The following task description of the project was:

[Exergames] Play to get fit

In this project, the goal is to come up with new game concepts and game technologies for exergames - games where the player carry out physical exercise at the same time. There are several approaches for exergames, and the challenge is to find the balance between something that is fun to play as well as you get a real physical exercise from playing the game.

The first phase of the project will consist of a theoretical study of exergames and mechanisms for how games can be used as a motivator. The second phase focus on implementing a prototype using various technologies. In third and final phase, the prototype will be evaluated and tested.

The first phase of the project corresponds to the specialization project, while the second and third phases correspond to the Master Thesis. In the first phase, the goal was to perform a theoretical study of exergames to learn about game development and exergames. A review of existing exergames and various technologies was conducted to gain insight into how different

game concepts and technologies can be used in exergames to provide exercise. Further, game engagement theory was investigated to understand how games can be a motivator to exercise. With these findings, game ideas of exergames were generated.

In the second phase, the game idea from phase one was implemented. The game was refined, and the game's implementation took approximately three months, including implementing features, testing technologies, and fixing bugs. Various technologies were used to develop a cross-platform mobile game.

When the prototype was implemented and tested for bugs, experiment execution was conducted. Research methodologies were applied to collect qualitative data of the exergame and the test participants. Qualitative data was collected by observing and interviewing the test participant. The experiment's execution lasted over two weeks, where the participants were either family members, friends, or acquaintances. Data collected from the interviews was divided into the aspects of background, gameplay, physical, enjoyment, engagement, motivation, technical, and future play.

The collected data from the experiment was further processed to make an evaluation of the exergame and achieve the goal of the project by answering research questions that are presented in the next chapter.

Chapter 3

Research Questions and Method

From the specialization project, we studied how we could create an exergame that promoted physical activity, while being motivating, enjoyable and engaging. We also examined technologies to determine how games could be developed and track body movements. This project is about implementing the proposed game that was designed in the specialization project, and also test if the game fulfills the criteria for motivation, enjoyment, and engagement discussed in the specialization project.

The primary research method in this project is *The Goal Question Metric* approach (GQM) [9]. The approach is divided into three levels: conceptual, operational, and quantitative. We will first define a *research goal*, which corresponds to the conceptual level, followed by *research questions* to characteristic the achievement of the research goal, and lastly, a set of *metrics* from data gathering will be collected to help us to answer the research questions.

Research goal: Investigate the physical effect and engagement of playing a location-aware exergame.

By decomposing the research goal, the following research questions were created:

RQ1 What is the physical effect of playing a location-aware exergame? *This research question studies if there are any physical effects of playing a session of location-aware exergame.*

RQ2 How is the player's motivation affected of playing a location-aware exergame? *This research question aims to find out if the player has any goals of playing location-aware exergame, and if some metrics affect this goal.*

RQ3 How is the player's enjoyment affected of playing a location-aware exergame? *This research question studies if the player has fun while playing exergame. An exergame must be fun if the user keeps playing the game.*

RQ4 How is the player's engagement affected of playing a location-aware exergame? *This research question studies the engagement of a player when playing a location-aware exergame. Engagement is essential to how much effort the player put into the game.*

RQ5 How does the gameplay affect the game experience of playing a location-aware exergame? *This research question studies if there are any game design decisions that affects the play or user experience of a player.*

RQ6 What are the challenges of playing a location-aware exergame? *This research question studies the genre location-aware exergame. Does it give any restrictions to the players when playing?*

To answer these research questions, we have developed an exergame promoting cardio/aerobic exercise. The game's foundation was designed in the specialization project where decisions of game design and gameplay were decided after having conducted a literature review of game engagement theory, technologies, and existing exergames (see Part II). After finishing implementing the exergame, the next step was to research to answer our research questions.

Different research methods were carried out to gather qualitative data from test participants. Including observations and interviews of test participants to evaluate our exergame. The test procedure lasted two weeks, when friends, family members, and colleagues were asked to play our game. Data collected was divided into the aspects of background, gameplay, motivation, enjoyment, engagement, physical, technological, and future play.

By processing the data, an evaluation of the exergame was conducted. The result from the evaluation was used to address our research questions, which is presented in Part V.

Chapter 4

Report Outline

This is the outline of the master thesis:

Part I introduces the motivation of the project, the project context, and the research goal and questions.

Part II contains necessary knowledge to be able to create an exergame. This part presents basic physical activity theories, existing exergames, relevant technologies to exergames, and game engagement theories.

Part III describes the implemented exergame. This part describes the game concepts, design, technology, and game development to give readers an understanding of our exergame, and how knowledge from Part II was applied.

Part IV outlines the research methodology that was applied during the research. This part presents the execution of the research methods, and the validity and reliability of the data.

Part V contains a discussion of the results and the working process, followed by a conclusion of the research questions from Chapter 3. Lastly, further work for further development of the project is presented.

Part II

Prestudy

The second part of the report provides the readers with an insight into the exergames. We will present existing exergames and various technologies to examine how players' movements can be monitored. Besides, investigating the theory about exercise and game engagement has been conducted to understand how games can promote enjoyment while exercising. These fundamental elements will be taken into our concern when developing our exergame.

Chapter 5

Types of Exercise

Exergames are games that promote players to exercise. Before looking into exergames, we will have a look at various types of exercise that exists.

Exercise is defined as "any bodily activity that enhances or maintains physical fitness and overall health and wellness" [10]. Harvard Health Publishing has divided physical activity into four basic categories [11]: cardio, strength, flexibility, and balance, as shown in Figure 5.1.

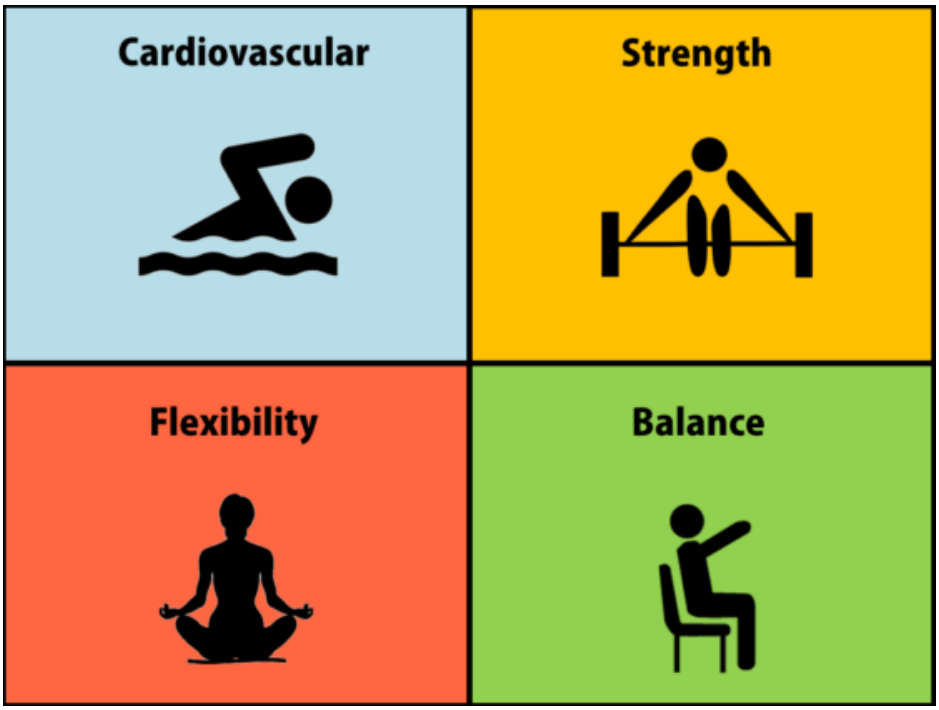

Figure 5.1: Four types of exercise [1]

Strength is an anaerobic exercise where the intensity and power of a workout is high. It enhances their size, strength, and endurance by increasing

muscle fibers. Strength exercise varies due to different tissues in a human body. To increase the power of a muscle, strength exercise on the muscle must be performed. Weight lifting with repeated sets and repetitions are the main workout to achieve strength exercise. Strength exercise can be dangerous and therefore lead to injury if not done correctly.

Exergames that provide strength exercise are usually very restricted and, therefore, do not put players in a dangerous situation that can lead to injuries. *EA Sport Active*, *Skyrim Exergaming Mode*, and *Exermon* that we will see in the sections 7.4, 7.8, and 7.9 are examples of exergames where only body weight is used [12, 13].

Aerobic/Stamina exercise is the same as aerobic exercise, static exercise to enhance endurance. Cardio is the typical activity to increase stamina with a moderate intensity. This kind of training improves the performance of an energy-demanding work on the body. For better oxygen intake, movement from muscle groups must perform moderate to intense exercise for some time, depending on the type of the activity. For instance, swimming for 20 minutes with a moderate intensity will give beneficial results [14]. Typical aerobic exercises are jogging, cycling, and swimming.

It is hard to define how long or how intense aerobic exercise must be performed to enhance stamina because of the physiology difference. Examples of exergames that promote aerobic exercise are *Pokémon Go*, *Dance Dance Revolution*, *Skyrim Exergaming Mode*, and *Wii Sports* that we will read more about in the sections 7.1, 7.2 , 7.7, and 7.8.

Flexibility exercise refers to the movement range of a joint or multiple joints in a body. When aging, the flexibility of joints and muscles of a person decreases [15]. The muscles become weaker, and the bones become stiffer. To prevent this, or mitigate, it is vital to expose muscles and joints to flexible movements. Typical exercise that can enhance mobility is yoga and other stretching exercises. One example of an exergame promoting this type of training is *EA Sport Active*.

Balance is about to keep an expected position while performing body movements. Performing balance exercises can help to prevent falls and injuries. In the aging process, the nervous system becomes weaker, and the sense of balance weakens [16]. Examples of exercises to enhance balance

are Yoga, Thai Chi, and Balance Class. An exergame that provides balance exercise is *Wii Fit* from Section 7.3.

Chapter 6

What is an Exergame?

Before looking into existing exergames, this chapter will describe the term exergame.

An *Exergame* is a video game that encourages physical body motions. The physical motion load in an exergame session increases to a threshold like an exercise session [17]. Tracking body motions can be performed by measuring physical activities such as movements and pulse with various technologies.

World Health Organization (WHO) has reported that physical inactivity is the leading cause of disease and disability. "*Sedentary lifestyles increase all causes of mortality, doubles the risk of cardiovascular diseases, diabetes, and obesity*" [18]. With exergames, it is possible to motivate people to be more physically active. Exergames have expanded widely in recent years, and today there exist a lot of different kinds of exergames.

Chapter 7

Exergames

This chapter describes existing exergames. Reviewing existing exergames is an excellent way to gain knowledge about how to combine games and exercise. The games presented in this chapter are most familiar and represent how the concepts of today's exergames look.

7.1 Dance Dance Revolution

In 1998, the first commercially successful exergame was released, Dance Dance Revolution (DDR) [19]. To play the game, a player must have a PC/game console, a monitor, and a dance mat. Arrows will show up on the monitor along with the song's rhythm. The players have to step on them as they appear. Many songs have multiple difficulty levels, where more arrows will show up on the higher levels. It started as arcades, and then it got released to console, so they are playable from home. In 2001, Stepmania was released, which is an open-source simulator for DDR that allows users to create their songs/steps for people to play [20].

According to our testing, DDR games gives a moderate amount of exercise for a beginner. Still, the effect will be significantly higher for intermediate that learn how to play the game and have the coordination to do more challenging courses.

Figure 7.1: Children playing Dance dance revolution with an instructor

A study conducted on children between the age of 9-11 years found that playing DDR had an impact on the children's physical activity level [21]. The study consisted of 101 children divided into two groups. Fourth-graders placed in the intervention group and fifth graders in the comparison group where the intervention group had 30x3 minutes DDR sessions each week from Aug 2008 to May 2009. The study results showed that the intervention group had increased physical activity, while the comparison had decreased. Moreover, it was a significantly positive effect on the children's self-efficacy and social support.

7.2 Wii Sports

Figure 7.2: Image of Wii sports case cover

Wii sports is a game that came bundled with the Nintendo Wii in 2006 [22]. It consists of five sports: bowling, tennis, boxing, baseball, and golf. The game is simple and easy to pick up for less experienced gamers. From playtesting Wii Sports, we found boxing and tennis were most intensive of these sports. Boxing because the player had to punch with both hands, and tennis because lots of small swing motions accumulates.

While the game is simple and not that physically demanding, requiring less exercise than other games [23], it also has a significantly lower threshold that can get even the elderly to play it. For the elderly that are not very active, this can be very positive, both for health and happiness [24].

In a study made in 2007, physiological response while playing Wii sports was examined. Twelve subjects participated. When playing the game, the peek of oxygen extraction (VO2) and heart rate (HR) was measured. The result of the study was that playing Wii Boxing and Tennis with high intensity, increased VO2 and HR to a threshold with cardiovascular benefits [25].

7.3 Wii Fit

Figure 7.3: Wii Fit

Wii Fit is an exergame released in 2007 [26]. The game includes a Wii Balance Board that utilizes sensors to track the balance of players. In 2012, the game was the third best selling console game.

The game features strength training, aerobics, yoga and balance games. People described the game as "a way to help get families exercising together" and was applied in various health clubs because of its success.

A study found that Wii fit could improve a person's balance [27]. An 86 year old woman was unable to walk without a supervisor, due to a fall after a stroke. She participated in four training sessions and took physical tests before the first session, and after the last meeting. Later, she was able to walk with minimal supervision, and the result of the previous test showed improvements in balance.

7.4 EA Sport Active

Figure 7.4: Playing EA Sport Active.

EA Sport Active is a video game made by EA Canada [13]. The game is played with motion controllers, and the set includes a Wii balance board that can be applied. A Wii Remote is used to track movements of the upper body, and a pouch to monitor the lower part. The gameplay consists of several numbers of exercise modes with a virtual personal trainer. Gameplay such as jogging on the same spot, or mirror the body motions of the personal trainer. The objective of the game is to burn as many calories as a regular workout. The game provides different kinds of features that can be played in the game, such as the 30-day challenge or tracking progress. Players are encouraged to complete these types of challenges by being awarded with trophies for completion.

University of Wisconsin conducted a study to verify if EA Sport Active could substitute a legitimate workout. Surprisingly, it did. Sixteen adults between the ages 25-45 played the game with a working heart at 64-94% maximum. A player could burn around 200-300 calories each session, which is approximately the equivalent as a moderate workout [28].

7.5 Nintendo 3DS StreetPass

StreetPass is a mode on Nintendo 3DS that encourages Nintendo owners to explore outdoors and pass by other Nintendo owners with StreetPass enabled. This is illustrated in Figure 7.5. The game's concept is to exchange Mii characters (customizable avatar) and game data from many games, most notably "StreetPass Mii Plaza". When Mii characters are exchanged, the next time players play StreetPass Mii Plaza, the Mii characters will appear in the game, and can be used to help the players. The game also has a step counter that rewards the player with in-game currency for walking [2].

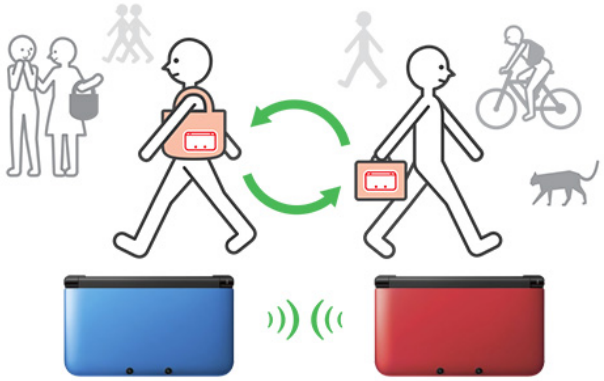

Figure 7.5: Illustration of 3DS StreetPass meeting other devices [2].

7.6 Just Dance

The Just Dance series was initially released for the Nintendo Wii in 2009 by Ubisoft [29]. Ubisoft has since then made yearly releases of the game and is releasing it for all major consoles (Nintendo, Xbox, Playstation) [30]. The exergame scores the player based on how well he or she can mirror the motions of the avatar on the screen. Depending on the console, the game uses either camera controls or motion controls for scoring. Compared to DDR, this dancing game is easier to get into and more comfortable to be social.

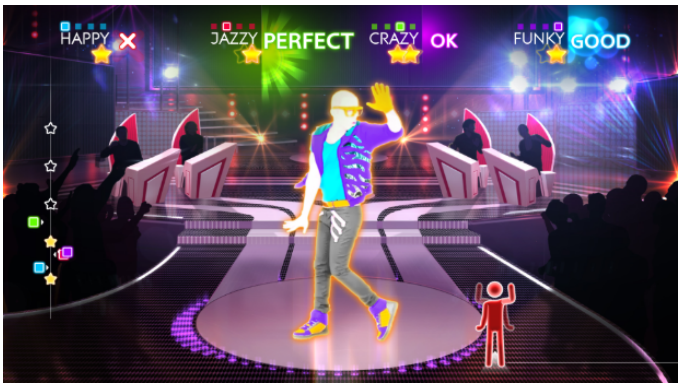

Figure 7.6: Visualisation of dance moves in Just Dance

7.7 Pokémon GO

Pokémon GO is an AR/Location-aware exergame based on the Pokémon series for Android and iOS [31]. The central concept of Pokémon is that the player controls a character called a Trainer, trying to capture and train monsters called Pokémon. The primary technology that is used in this exergame is GPS. When a player is walking in the real world, the game character moves synchronously with the player. The game rewards trainers for walking, as it allows for among other features such as hatching eggs based on steps walked and collected Pokémon supplies in real-world locations called Pokéstops. Another feature in the game is fighting other players asynchronously in real-world areas called Pokémon Gym. The game was a massive success with 752 million downloads, with 60 million active users in 2016 [32].

Figure 7.7: Pokémon Go trainer mapped to the physical world

Health experts are praising the game as it makes people get out of the couch and decrease the sedentary lifestyle [33–36], with significant short term (first 30 days of gameplay) effect on activity level [37]. However, after six weeks, the activity levels of the players fell to similar levels as before installing the game [38].

7.8 Skyrim Exergaming Mode

Figure 7.8: Exergame model for Skyrim Exergaming Mode [3]

Exergaming mode is a mod for the game The Elder Scrolls V: Skyrim made for research purposes. Skyrim is a role-playing action game where the player can level up the game-character by performing actions in the game. The mod removes this mechanic, replaces it with fetching logs from *exercise.com* to level up the player character instead. As the game becomes increasingly harder, the player needs to exercise more, or their game-character becomes too weak to play the game as [3]. Figure 7.8 illustrates this process.

7.9 Exermon

Exermon is a game made for research purposes where the player creates a virtual monster called an exermon [12]. The game is about fighting other exermons in an arena to progress in the game. The enemy exermons will be more durable while advancing the game, and the enemies become impossible to defeat without training the exermon.

To train the exermon, the player will have to perform strength exercises, like push-ups and sit-ups. Exermon utilizes the proximity sensor and accelerometer for counting repetitions. After a strength exercise session, the exermon gains stats, and the player can progress in the game. Figure 7.9

shows the overview of the exermon, stats to the left, money and achievements on the right, and modes at the bottom.

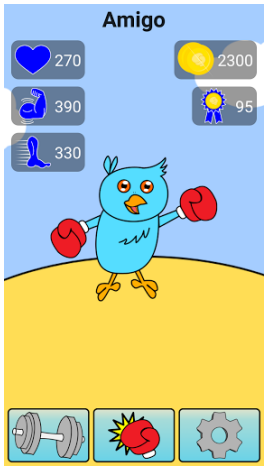

Figure 7.9: Exermon overview

In 2018, 24 test-subjects between the ages of 18-24 were participating in the evaluation of the game Exermon [39]. The goal was to evaluate the effect of using an exergame as a motivation for strength training. The result was that 40% of the test-subjects started to exercise more, 90% were motivated to workout, 90% felt better of playing the game, and 90% of the participant found the game engaging.

However, the game had some issues with tracking too many or too few repetitions, making the players not have full control of the game. This issue resulted in being vulnerable to cheating, resulting in different player experiences.

7.10 Exer Dungeon

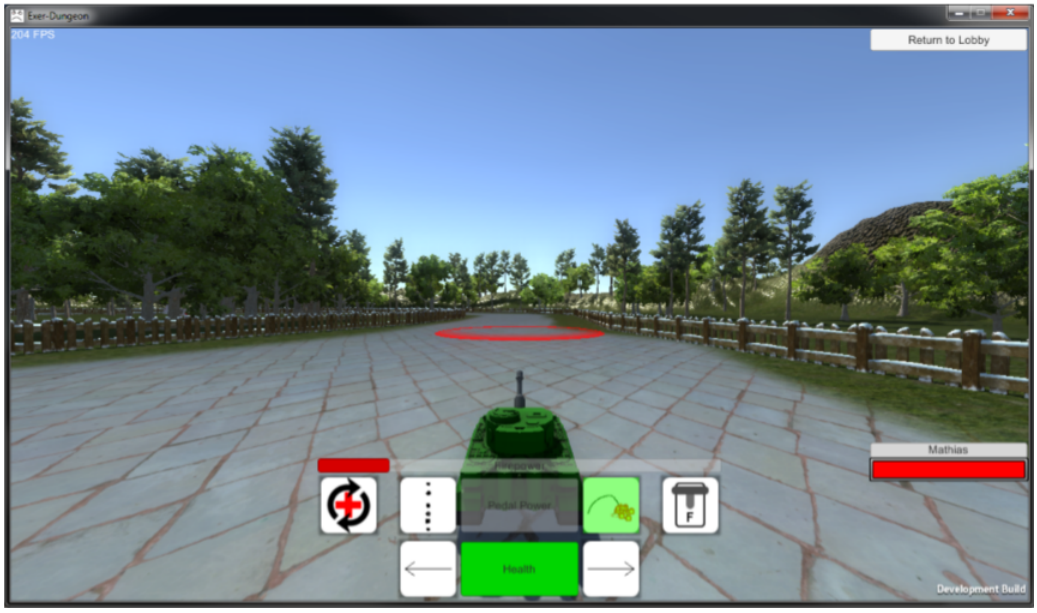

Figure 7.10: Exer Dungeon gameplay [4]

Exer Dungeon is an exergame made for research purposes that took in use an exercise bike. It is a cooperative dungeon crawler, where the players cooperate to defeat enemies while healing each other to stay alive. The game has multiple levels for the players to try and beat. The players win the game by destroying all enemies.

The game was tested and found to be engaging and enjoyable, the heart rate was higher during gameplay, and it was evaluating to be a fun and enjoyable game [4].

7.11 Geocaching

Geocaching is a social, mobile game where a player can go treasure hunting with friends, family or alone. The application displays a map of hidden treasures near the player's location and even further away. Information of treasures is provided by GPS that shows where a player has to move to

discover treasures. Treasures in geocaching are made and hidden by other players. When a player finds a treasure, the player logs the finding to notify others about the discovery. The player can then add a message to the person who placed the geocaching-treasure [40, 41].

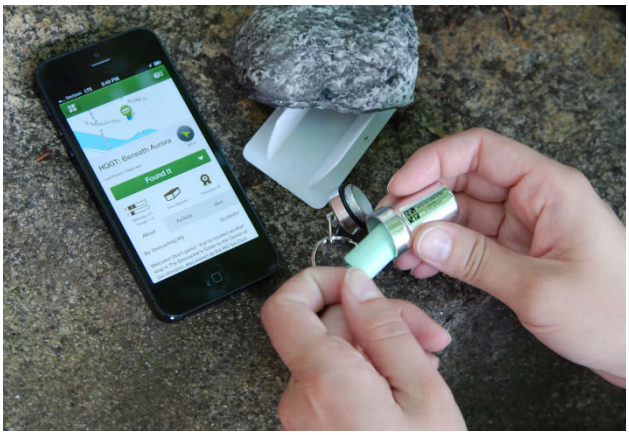

Figure 7.11: Geocaching displaying the location of the treasure

7.12 Zombies, run!

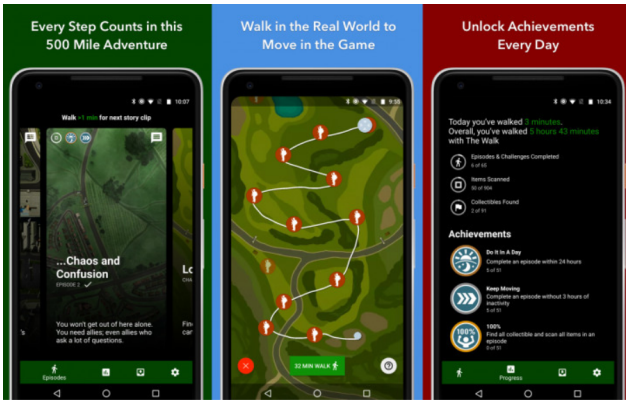

Figure 7.12: Treasure hunting with GeoCashing

Zombies, Run! is an exergame promoting cardio exercise. It is a mobile application with a moderate to high intensity of walking [42]. The gameplay

is to run away from zombies while listening to an engaging story or music through headphones. The goal of the game is to run away from being killed by zombies. Running away from the zombies are tracked with a GPS or a step counter on the smartphone. As the player is moving, the game continues. This kind of activity can resemble interval training as players have to run when zombies chase them, which happens in intervals. Promoting interval training improves the cardiovascular system of the body and is one of the most efficient exercises for beneficial health results [43].

7.13 Beat Saber

Figure 7.13: Beat Saber

Beat Saber is a VR rhythm game where the player has to use VR motion controllers to slash blocks coming towards them, as seen in Figure 7.13 [44]. In addition to smashing blocks, the players are forced by the game to move horizontally or vertically by obstacles. The exergame scores the player based on the length and the accuracy of the cut. Beat Saber has a leaderboard where the players can compare their scores against each other.

A study of the game showed that the participants' heart rate increased, and the participants moved a lot while playing. Participants were unsure

about if they would be motivated to exercise more from the game, but they would recommend it as an exercise to others [45].

7.14 Ring Fit Adventure

Figure 7.14: Ring Fit Adventure

An exergame that provides various types of exercise is Ring Fit Adventure game for the Nintendo Switch [46]. The exergame includes a Ring-Con and a leg-strap, as illustrated in Figure 7.14. There are two different modes in the game, a story mode and mini-games, with physical intensity adjusted towards the player's fitness. The objective of the game is to complete the story mode and achieve the best possible score from the various mini-games. One example of a mini-game is where the players compress and stretch the ring as fast as possible within a time limit. Playing the story mode, the player controls a character to defeat a monster boss. To be able to defeat the boss, the player must pass through many obstacles, such as performing running activities and fight mini-bosses before reaching the primary target.

The game is played by holding the Ring-Con and equipping the leg-strap on the hip. The Ring-Con is essential as it requires for almost all actions performed in the game. Navigating in the menu view is done by compressing or stretching the ring to either select or go back in the game. In gameplay, the

ring map actions from the physical world into the game by registering body movements such as running, sit-ups, squats, and other exercises, providing all types of training to players.

7.15 Summary and comparison

This chapter has gone through different kinds of exergames played on various platforms. A few games have been used in research studies and have proved that exergames can improve physical activity among people. Table 7.1 shows a comparison of the exergames discussed in this section. From the comparison, we can see that the activities are mostly aerobic activities where the player performs the same motion over a more extended period. The outdoor games are games that require a lot of space, including games with walking activities such as Pokémon GO. The intensity offered by the games differs, but most of them are low or moderate. The games are either synchronously or asynchronously, depending on whether the game is played while exercising. If exercise takes place while playing the game, it is synchronous gameplay. Social Interaction in the games is mainly types of competing or cooperating, among others.

Looking at the elements activity, environment, and genre, we see that the games with many of the same elements are similar. One example is *Dance Dance Revolution* and *Just Dance*. Both games promote indoor dance activities with music, and the objective of the game is much likely. Other examples are *Geocaching*, *Nintendo 3DStreetPass*, and *Pokémon GO*. These games have common game elements with a game goal to find "something".

Table 7.1: Comparison of exergames

Game	Activity	Environment	Intensity	Sync/Async	Social Interaction	Genre
Dance Dance Revolution	Dance	Indoors	Medium	Synchronous	Compete/ Cooperate	Music/ Rhythm
Just Dance	Dance	Indoors	Medium	Synchronous	Compete/ Cooperate	Music/ Rhythm
Wii Fit	Yoga, Strength, Aerobics, Balance	Indoors	Medium	Synchronous	Compete/ Cooperate	Fitness
Wii Sports	Golf, Tennis, Boxing, Baseball, Bowling	Indoors	Low-High	Synchronous	Compete/ Cooperate	Sport
EA Sport Active	Sport	Indoors	High	Syncronous	Not supported	Fitness
Pokémon GO	Walk	Outdoors	Low	Asynchronous	Compete/ Cooperate	AR/ Location-aware
Nintendo 3DS Street-Pass	Walk	Outdoors	Low	Asynchronous	Connect	Simulation
Exermon	Strength	Indoors & Outdoors	Medium	Synchronous	Compete	Role Playing Game
Geocaching	Walk	Outdoors	Low	Asynchronous	Connect	Location-aware
Zombies, Run!	Walk/Run	Outdoors	Low-High	Synchronous	Not Supported	Location-aware

Skyrim Exergaming Mode	All	Indoors & Outdoors	High	Asynchronous	Not supported	Role Playing Game
Beat saber	Hand movements	Indoors	Medium	Synchronous	Compete	VR Rhythm
Ring Fit Adventure	Yoga, Strength, Aerobics, Balance	Indoors	High	Synchronous	Compete	Role Playing Game

Chapter 8

Motion Detection Technologies

To understand how exergames can register physical movements, we need to investigate some motion-detection technologies. This chapter presents motion-detection technologies used in the existing exergames from the previous chapter.

8.1 Dance mats

Dance mats can be found in Dance Dance Revolution and Stepmania (see Section 7.1). There are soft and hard pads. Soft pads are cheaper, while hard pads are more expensive, and used in arcades [47]. The dance mats have buttons on the left, right, up, and down, with some additional buttons for menu navigation on the dance mat. When pressing a button, the game registers the action.

Figure 8.1: Dance mat

Typically, the dance mats are typical on game modes where players dance

by following the stepping pace. Players dance to various songs with various speed and sequence of steps. As the game modes become more complicated, more stamping events occurs in a time interval. The player must, therefore, increase their speed of stamping to keep going. Thus, playing more difficult levels results in higher intensity as the player has to be more accurate as the speed increases. Dance mats are therefore suitable for music exergames where a fitting stamping sequence can be chosen based on song and difficulty.

8.2 Wii Balance Board

In 2007, Nintendo introduced the Wii Balance board. It is an accessory to the Wii and Wii U console, and can track the center of balance from a user. The balance board was mainly developed to the Wii Fit Game (see Section 7.3), but has become an extension for the Wii remote, later in the development process. Several studies have been looking at the balance board's effects of enhancing balance control to older adults. From meta-analysis, the conclusion was that the balance could be improved. Still, due to the high variability of results and measures, the study concluded that the effects could not be decided [48].

Figure 8.2: The Wii Balance Board

8.3 Motion controllers

Motion controllers became popular in 2006 with the Wii, and have been used in many games, see sections 7.2, 7.4, and 7.6 for further information. The idea of a motion controller can be traced back as far as 1976 to Sega's arcade boxing game [49]. The accessory is actively used in the modern gaming platform Nintendo Switch where motion controllers play a big part in many of their games to track movements of the hands.

Figure 8.3: Motion controllers from Wii. The Joy-Con on the left side, the Wii Remote on the right side.

The Wii Remote is one of the motion controllers developed by WII. It can register motions by operating an accelerometer (see Section 9.2) to measure acceleration in three axes [50]. The pointing direction of the controllers is tracked by a sensor bar, which consists of IR LEDs that emits light to measure pointing coordination of the remote.

Another motion controller created by Wii is the Joy-Con, as illustrated in Figure 8.3. This motion controller is an upgrade from the Wii Remote with the same features of tracking motions. But instead of using a Sensor bar to measure pointing direction, the controller has a Gyroscope (see Section 9.5) that computes the player's leading path.

8.4 Ring-Con and Leg Strap

In October 2019, the game Ring Fit Adventure was released along with the equipment Leg-Strap and Ring-Con. Ring-Con is a bendable, electronic product that gives players resistance when playing. The ring consists of sensors detecting compression and stretching of the ring.

Figure 8.4: Leg strap and Ring-Con

On Figure 8.4, the Joy-Con from the previous subsection is connected with the ring via electronic contact, thus adding additional inputs. With the Joy-Con, the motion controllers are used to track motions, while the sensors in the ring detect stretching or compression actions on the ring. Combining another Joy-Con on the leg-strap makes it possible to measure the distance between the Joy-cons by registering body movements of stretching or compressing. Connecting the ring, leg-strap, and Joy-Cons makes it possible to identify most of the body movements performed by a player in the game *Ring Fit Adventure*.

8.5 Kinect

In 2009, Xbox introduced the Kinect as a new gaming technology [51]. One of the most popular games for the Kinect is *"Just Dance"* (see Section 7.6), where players perform body movements regarding to the current played song.

Other games that are possible to play on the Kinect are *"Kinect Adventure"*, played with different body motions, and *"Shape Fitness"*, which is a similar exergame such as *EA Sport Active* (see Section 7.4).

Figure 8.5: Xbox Kinect

With Kinect, the players become the controller, making them feel be inside of the game. The Kinect comes with a webcam that uses RGB camera, depth sensor and microphone array to provide full-body 3D motion capture [52]. The camera detects red, green, and blue colors, body-type, and facial features. The depth sensor creates a 3D imaginary throughout the room by measuring the time of flight that light has emitted. Lastly, the microphone records voice from the players, while isolating the background noise. From the sensors, 48 points on a player's body are monitored. However, to fully work, the Kinect is installed with software and data of real-life scenarios to create the Kinect's "brain".

In 2013, Xbox One introduced a newer version of Kinect [51]. The release was similar to Xbox Kinect 360, but had more advanced hardware, which provided better quality of motion tracking. But in 2017, the lifetime of Kinect 360 and Kinect One ended due to the hardware cost.

8.6 Virtual Reality (VR)

In 1968, the first VR was created. However, the first major commercial release of sensor-based tracking, allowing for users' free movement within a defined space, came in 2016 [53]. VR headsets provide users a 360 degree 3D

virtual environment. The actions of the head are tracked with the VR and maps body movements with changes in the virtual environment [54].

Figure 8.6: Samsung Gear VR

The purpose of VR is to give users a real feeling of the virtual environment. One example is the game *Beat Saber* (see Section 7.13). The game is played with a VR headset and motion controllers. The effect from the VR is to make players immersed being inside the virtual environment.

Like the Kinect, whole-body movements can be tracked and measured. The main difference is that VR gives the feeling of being inside the game. Combining VR with other technology accessories, the exercise effect can be high, with most of the exercises available.

8.7 Activity trackers

Many companies produce activity trackers with various functionalities. Some of the most popular activity trackers are from Fitbit, Polar, Samsung, and Apple. Activity trackers have features such as pulse measurement, GPS monitoring, and step counting, and are often paired with smartphones to display data.

Figure 8.7: Different types of activity trackers

One example of an activity tracker is the Fitbit. The Fitbit has the sensors: accelerometer, barometer, orientation, gyroscope and heart rate in most of their sport clocks to provide a lot of user data [55]. The provided data can be used as input to an exergame or integrated with applications. For instance, Strava is an exercise application that is compatible with many activity trackers. The application process data from the activity tracker to make summarizes of the user's exercise session [56].

Another type of activity tracker is Pokémon GO plus. The Pokémon Go Plus can be connected to the phone for additional features in the Pokémon GO (see Section 7.7). Playing Pokémon Go with Pokémon Go Plus simplifies the functionalities in the game. Players can play Pokémon without having the phone's screen open by having a Pokémon Go Plus. The wristband notify players of Pokémons nearby, egg hatching, and catching Pokémon with feedback of sound and vibration [57].

8.8 Summary

The technology area in exergames is extensive. Devices that can track big and accurate motions require a lot of space when played. In this section,

we described the activity tracker and the indoor technologies dance mats, motion controllers, Kinect, Wii Balance Board, and VR. Table 8.1 gives an overview of the promoted exercise, the physical intensity, and the cost of the presented motion-detection technologies. The sensors in the technologies are advanced to provide an accurate measure of body movements. However, the price of some of these accessories might be too high for our budget. Testing on several people will be challenging without the necessary equipment.

Table 8.1: Motion-detection technologies - overview

Accessory	Type of exercise	Intensity	Estimated cost
Dance mat	Aerobic Balance	Moderate	27$
Wii Balance Board	Balance	Moderate	39$
Motion controllers	Aerobic Balance	Moderate	77$ - 87.6$
Ring Con	Strength Aerobic Balance Flexibility	Moderate/High	79$
Kinect	Strength Aerobic Balance Flexibility	Moderate/High	300$
VR	Strength Aerobic Balance Flexibility	Moderate/High	20$ - 2079$
Activity tracker	Mostly Aerobic	Moderate/High	14$ - 32$

Chapter 9

Smartphone

Another technology that is also able to detect motion is the smartphone. This chapter describes the smartphone as its technology as it consists of several sensors and runs as its platform. Figure 9.1 presents different sensors in the smartphone.

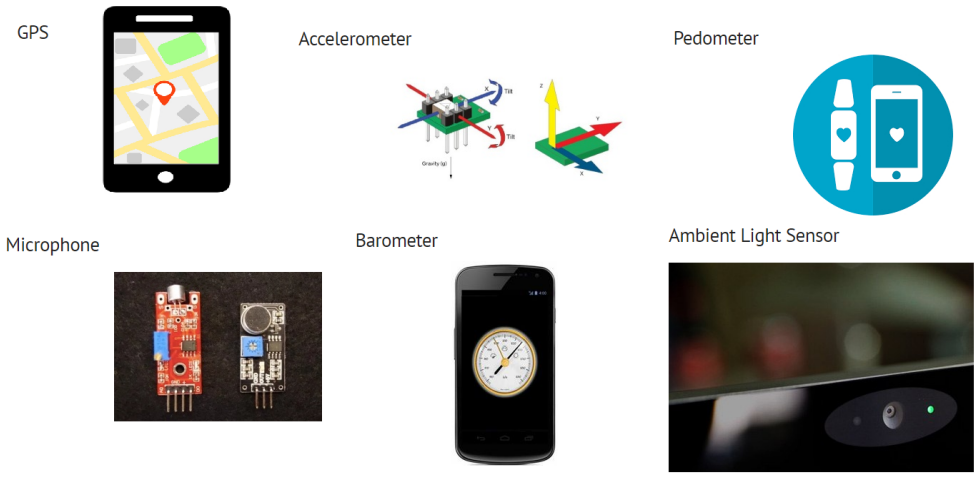

Figure 9.1: Overview of different sensors in a smartphone

In the last years, mobile gaming has been dominating the gaming market [58]. Playing exergames on smartphones has some limitations, but the opportunities for game design are extensive. Most smartphones have many sensors for different purposes. Applying some of these sensors in an exergame makes it possible to collect input data from the physical world.

As over 80% of Norwegians own a smartphone [59], it can be easier to get a bigger audience for an exergame when people already have the equipment that is needed to play the game. In the following sections, we will review the most common sensors found in a smartphone, and examine how they can be utilized to create an exergame.

9.1 GPS

GPS is an abbreviation for Global Position System. The technology has a GSM-network [60] that can approximately locate devices, making it suitable for transportable devices like smartphones, clocks, and other devices. GPS is widely used in exergames like "*Zombies, run!*", "*Pokémon Go*", and *"Geocaching"*. GPS signals can calculate speed by measuring distance traveled over time. Pokémon GO is an example of using this method. However, the speed measure will only be accurate if the player runs in a straight line. Running in curves or backward results measured speed will be lower than actual speed [61].

9.2 Motion sensors

Most smartphones have a proximity sensor to measure distance and accelerometer to measure acceleration. In the game *Exermon*, the proximity and accelerometer sensors measure the strength exercise [12]. By applying a motion equation from the physics, it is possible to calculate speed and distance with the measurements from the accelerometer if the initial velocity is known [62].

9.3 Pedometer (Step counter)

A pedometer is a portable electromechanical device that counts steps by detecting motions of the user's hips or hands [63]. The pedometer includes a mechanical sensor and software to count steps. Today's step counters rely on a MEMS sensor, which has one to three-axis detection of acceleration. The software technology interprets the output of the internal sensor and estimate "accurate steps".

The accuracy of steps varies between devices. Walking a constant pace on a flat surface with the device in the pocket can measure steps accurately. Still, traditional step counters find it difficult to have accurate measurements when the device's location or angle is affected drastically [64].

9.4 Camera

Cameras can be used for both AR functionality or be used as a Kinect for a game (see Section 8.5). It is also possible to use the camera to measure heart rate by using the LED sensor [65]. Data received from the LED sensor can transfer data to the application for interpretation. The Camera API from Android developer, supports camera features for building applications. It allows applications to use the camera of a device to take photos or record videos [66].

9.5 More sensors

In many smartphones, there are around 14 sensors for measuring different units [67]. This section will look at potential sensors that can be utilized in an exergame:

Magnetometer can be used as a compass. It is used by measuring the magnetic force and direction. Applying the magnetometer in an exergame can be used for directions.

Barometer can be used to measure the elevation, or forecast the weather by monitoring the air pressure [68]. This sensor can be useful to a game if the game design depends on the weather or needs data of the altitude of the device.

Hearth rate sensor can be applied by using the camera of a smartphone. The camera consists of a LED and an optical sensor that emits the light onto the skin while receiving rhythm of color change as feedback.

Gyroscope is used to add an extra dimension for the accelerometer. The device helps the accelerometer to find out the phone's orientation in a room. For instance, when a player tips on to steer in a racing game on the phone, the gyroscope registers movements, and not the accelerometer.

Proximity sensor is a sensor that can detect other objects in the same room without any physical contact. The transducer emits an electromagnetic

beam to search for changes in the returning signal. It can be useful if creating an augmented reality game.

Ambient light sensor is used to detect the amount of ambient light in the present. It is often used to adapt the phone's screen light to avoid a bright screen when it is dark [69].

Microphone is a sensor that measures the loudness of a sound within a range. It can distinguish different types of sounds, such as voice, noise, and wind [70].

9.6 Bluetooth

There are two different types of Bluetooth technology on the smartphone, Bluetooth and Bluetooth Low Energy (Bluetooth LE) [71]. With Bluetooth, it is possible to wireless exchange data between devices, like the activity trackers connected to a smartphone (see Section 8.7). To transfer data with Bluetooth LE, a device that behaves as a GATT server and another device as a GATT client must exist. The server has several protocols that the client must follow to access the desired functionalities. A smartphone can both be a GATT server and a GATT client.

9.7 Summary

The technologies from a smartphone can provide various input data from a user. Table 9.1 displays what types of data the Android API offers. With the availability of the provided data, exergames have many possibilities. If the sensors are not sufficient to collect input data, expanding it with Bluetooth is an opportunity. The reviewed sensors have demonstrated that measuring motion and environment, locate devices, and searching for nearby devices are some features that are possible with a smartphone.

Table 9.1: Overview of the sensors from Android API [72]

Mobile technology	**Type**	**Description**	**Unit**	**Common use**
GPS	Location	Allows app to publish updates to the device's physical location	N/A	Monitor device's location
Camera	Media	Build a camera or vision based apps, or take photos.	N/A	Taking photos
Accelerometer	Sensor - Motion	Acceleration force along the x axis (including gravity).	m/s^2	Motion detection (shake, tilt, etc.).
Magnetometer	Sensor - Position	Geomagnetic field strength along the x,y,z axis.	μT	Creating a compass.
Barometer	Sensor - Environment	Ambient air pressure.	hPa	Monitoring air pressure changes.
Gyroscope	Sensor - Motion	Rate of rotation around the x axis.	rad/s	Rotation detection (spin, turn, etc.).
Proximity sensor	Sensor - Position	Distance from object	cm	Phone position during a call.
Step counter	Sensor - Motions	Number of steps taken by the user since the last reboot while the sensor was activated.	Steps	Count steps
Ambient light sensor	Sensor - Environment	Illuminance	lx	Adjust screen brightness

Microphone	Audio	Implementing special pre processing effects like noise suppression of beam forming	N/A	Receive information about mic
Bluetooth LE	Bluetooth	Wirelessly exchange data with other Bluetooth devices	N/A	Data transfer

Chapter 10

Game Engagement Theory

To explain how a game can be enjoyable, and why people prefer certain games over others, we will look at some theory of game engagement to gain a better understanding. This chapter goes through a game design framework on intrinsic motivation [5] and the GameFlow framework [73].

10.1 What makes games fun?

One of the biggest challenges for a game developer is to create a fun game. Creating a fun and enjoyable game can be challenging as the interest of people differ. Based on the paper *"What makes things fun to learn"* [5], we will look at how games can be fun.

There exist a driving force for people desires and actions, and that is motivation. Two types of motivations exist, an external motivation to achieve external rewards, and an internal motivation to achieve physiologic rewards. Since external motivation varies, we will only be looking at the internal motivation.

Thomas W.Malone claimed that three essential elements are the mechanisms for making something fun and motivational.

The first element is **challenge**. A game should be challenging to play. Table 10.1 displays how games can provide challenges. A game without any challenges has no goals, which makes the game boring. The goal must be uncertain to attain. What makes a game challenging is subjective. For instance, in the Dance Dance Revolution, different difficulty levels exist, so players can choose a suitable level of difficulty depending on their experience (see Section 7.1).

The second element is **curiosity**. Curiosity helps a game to be enjoyable or fun, where the information complexity is in an appropriate amount to make a player curious. There are two categories in curiosity, sensory and cognitive curiosity. Sensory curiosity utilizes audio, visualization, or ani-

mation to create curiosity, while cognitive curiosity forms one's knowledge structure. With sufficient information, a player will understand the game without knowing everything. Most exergames use sensory curiosity rather than cognitive curiosity, as visualization and sound have a greater impact on the player's curiosity than knowledge building.

Pokémon Go is an excellent example of a game using sensory cognitive. Sounds and vibration is utilized to notify a player when a Pokémon is nearby, or when a Pokémon egg is hatching. When battling or catching Pokémons, the game comes with colorful animation and light effects.

Lastly, the third element is **fantasy**. Fantasy makes a game more interesting, making it possible for a player to do the impossible. A game can use an illusion to appeal to a player's emotion. As seen in Figure 10.1, there are two types of fantasy, fantasy in the game depending on the player's skill (extrinsic fantasy), and skill depending on the imagination and vice versa (intrinsic fantasy).

In the game Wii sports (see Section 7.2), both extrinsic and intrinsic fantasy are applied. The boxing mode in the game has extrinsic fantasy, where the game's fantasy is based on the skills of a player. On the other hand, in the bowling mode, the player's imagination and skills depend on each other. When playing the bowling mode, players receive feedback about aim and position from the game, which affects the performance.

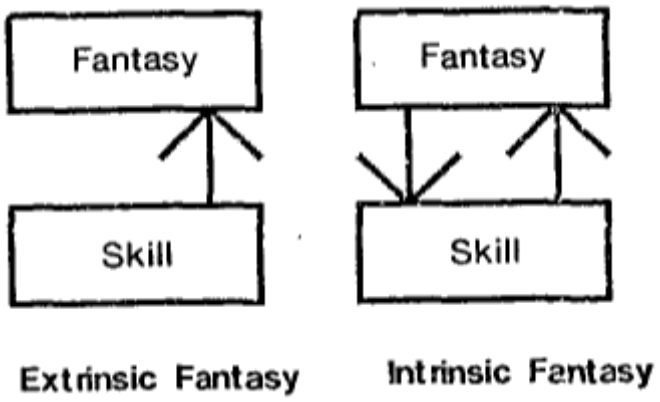

Figure 10.1: Types of fantasy in a game [5]

Table 10.1: Elements to make a game challenging

Elements	Why	How
Obvious goals	Have an idea what to do	Visual effects, fantasy
Appropriate complexity	Easy to generate goals	Goals based on the players
Fantasy goals	Increase interest	Add impossible things to the game
Performance feedback	Tell if player is getting closer to a goal	Sound or visualization
Uncertain outcome	Prevent the game to be booring	variable difficulty level, in game goal and meta-goal
Self-esteem	Appeal feelings	Add fantasy, interaction with player

10.2 Social interaction in exergames

Games should allow players to cooperate, compete, or connect with other players to provide social interaction. Interacting with other players is an essential factor in being able to spend time with friends while playing. This social interaction can be chatting, watching other play, or play together.

The exergames discussed in this article have a varying degree of social interaction, as seen in Table 7.1. There are different ways of having social interaction in a game. Playing synchronous together in a multiplayer mode to compete or cooperate, connect with others by player interaction when they meet each other, or even real-world interactions, like Geocaching (see Section 7.11) are some examples.

10.3 GameFlow

GameFlow is a framework used for designing and evaluating video games [73]. The model was made by Sweetsen and Wyeth to measure the flow of playing a game. In a state of flow, the player will play the game for its own sake

and become so immersed in the game that they may become less aware of their surroundings. Sweetsen and Wyeth compared two real-time strategy games, one high rated game, and the other low rated. The result was that they were able to distinguish the high- and low rated game, and identify why one succeeded, and the other not.

GameFlow has the following criteria [73]:

Concentration The player must be able to concentrate on the game while playing. The player should be completely absorbed in the game.

Challenge Challenges in the game must match the player's skill level, and become more difficult as the player's skill increases. It should be challenging, but not discouragingly hard to prevent the player from getting frustrated and giving up.

Player Skill Players need to develop the skills in order to enjoy playing. Developing skills should be rewarded.

Control The player needs to feel control of the game, and their intent should be translated to in-game behavior. The controls should be easy to use, and errors in play should be avoided.

Clear Goals The end goal, and the intermediate goals should be clear.

Feedback Players should receive immediate feedback on how close they are to reaching their goals.

Immersion Immersion describes as deep but effortless enjoyment in the game. The player should be able to escape the worries from real life.

Social Interaction While social interaction is not an element of flow, it is part of the GameFlow criteria, as it is a strong element of enjoyment in games. Games should allow players to compete, cooperate, and connect.

GameFlow is not the solution of how games can be enjoyable, but more like a guidance of designing and evaluating enjoyable games. The more elements

and scores a game has, the more likely is it to achieve the flow, resulting in enjoyment.

10.4 Dual Flow

Dual Flow is a model used to measure enjoyment in exergames. For Dual Flow, the player needs to feel challenge both in terms of both their skill level, like regular GameFlow. And also, being challenging in terms of their physical shape, as illustrated in Figure 10.2. To achieve the flow state, the amount of fitness and intensity have to match. In Figure 10.2, we can see that low physical-intensity will either result in no benefit or deterioration, and high physical-intensity with bad fitness will cause the exercise to fail. Exerting physical effects from exergames must have enough intensity with the right amount of the player's fitness to achieve the exercise flow. The intensity must rise as the shape of a player increases to have any effect on the exercise.

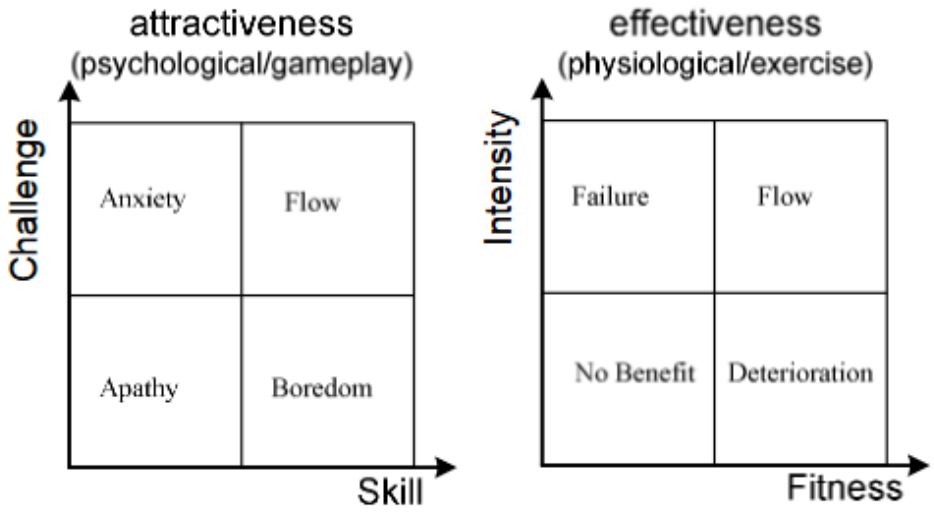

Figure 10.2: Dual Flow where the left corresponds to the GameFlow and the other one corresponds to the Exercise flow [6]

10.5 Summary

Having a fun and engaging exergame is important to sustain the motivation for physical movements. We will, therefore, utilize both frameworks discussed in this chapter for designing and evaluating our exergame. All elements from *Tom Malone's theory on intrinsic motivation* and most of the elements from *GameFlow* will be applied in our game. We will apply obvious and clear goals like achievements and unlocking levels in our game. The game will promote fantasy and immersion through the game mechanics, and feedback will be implemented to help the players tell if the players are close to their goal. To achieve Dual Flow, testing our exergame will be conducted to find a suitable physical intensity.

Part III

Our Exergame Design - Dino Radar

During the specialization project, we made many suggestions of game concepts for creating an exergame. The final result was to carry out the exergame **Dino Radar** to inspire people to exercise. This part presents an overview of the game ideas from the specialization project, followed by the game concept, the gameplay, the promoted physical activity, and the development of the chosen exergame, **Dino Radar**.

Chapter 11

Game ideas - Overview

From the specialization project, we made many suggestions for game ideas that could be a potential exergame. The designs were generated during a brainstorm session, and later built upon the earlier concepts with game engagement theories from Chapter 10. Table 11.1 displays all the presented game ideas from the specialization project.

Table 11.1: Game ideas from the specialization project

Game	Activity	Environment	Intensity	Sync/Async	Social Interaction	Genre
Dino Radar	Running	Outdoors	Low-High	Synchronous	Cooperate	Location aware/ Action
The Ultimate Swolemon	All	Indoors/Outdoors	Low-High	Asynchronous	Compete	RPG
Hunter x Hunter	Walking	Outdoors	Low	Asynchronous	Compete	Location aware/ RPG
Village Builder	Walking	Outdoors	Low	Asynchronous	Cooperate	Location aware/ RPG

Dino Radar is a game idea inspired by the exergame Zombies, run! from Section 7.12. The idea with this game is that humans have to run away from dinosaurs that are chasing them. Dinosaurs will have various attributes like size, speed, stamina, and vision to make many various dinosaurs with different behaviors. GPS will be utilized to track the location of a player and map it into the game. The exercise that the game provides is running and walking activities.

The Ultimate Swolemon is a game idea based on the game Exermon from Section 7.9. Players have to perform strength exercises to make their

monster more powerful. The battles in the game will be more like an RPG battle style with different types of attacks that can be leveled up by different exercises. In Exermon, the smartphone is the only monitoring device that is used, but adding more external devices to monitor the player's motions. We can get broader options of strength activities that players can perform in the game.

Hunter x Hunter is an RPG game idea where players fight against each other. Players have their avatar with several skills such as attack, defense, strength, fishing and woodcutting. These abilities are leveled up by performing exercises at a specific location. The GPS will locate the player and decide geographically where the player is exercising. If the player is training near an area with water on the geographic-map, fishing levels will increase. The idea with different skills is to give players a variation in the game, fishing and woodcutting to collect resources, and combat skills to fight other players.

Village Builder is an exergame idea inspired by the Facebook game Farmville [74]. The goal of the game is to build a secure village to defend and attack other villages. The village's strength depends on the amount of the resources the village has. By staying in an area for some time, the player gets funds. The exercise in the game is to travel to different terrains like forests, mountains, and lakes. Terrains are differentiated by using a GPS in the same way as how Hunter x Hunter uses the GPS.

All presented game ideas provide aerobic exercise and mainly played outdoors. One exergame that can has the possibility to play indoors is The Ultimate Swolemon. The physical intensity of the games varies. Hunter x Hunter and Village Builder are two exergames with the option to play with low physical activity. The players in the gameplay the game by walking and are therefore marked as low-intensity games.

On the other hand, Dino Radar and The Ultimate Swolemon can be played in different intensity as the game depends on the players choice of intensity. The games are either synchronously or asynchronously gameplay, meaning if the exercise and the playing are done simultaneously. The only game that provides synchronous playing is Dino Radar. All games except for The Ultimate Swolmon, are location-aware games, and the social interaction in the game is either by competing or cooperating. Further details of the

games are described in Chapter 14 from the specialization project [75].

In the next chapters, we will talk more about our chosen game idea, **Dino Radar**.

Chapter 12

Game Concept

The game Dino Radar is a location-aware exergame [76], making the world as a game map and the player as the character of the game. The player is spawned in a game world together with various dinosaurs with various attributes. The game's objective is to avoid being eaten by the dinosaurs as they hunt prey. The player has to move in a direction to avoid collision with a dinosaur. How fast the player moves depends on the needed speed that is required to outrun the chasing dinosaurs. In the game, there are various levels with various difficulties, and in the game, it is possible to unlock achievements. When a game session has finished, the player receives Dino Coins, which can be used in the shop to buy handy items for more difficult levels.

The exergame Dino Radar is inspired by the exergame *Zombies, Run!* that was presented in Section 7.12. The objective of the game is similar to Dino Radar. The player has to run away from zombies to survive, and as the player is running, he or she will be able to collect useful survival items for a zombie apocalypse. Figure 12.1 displays the exergame *Zombies, Run!*.

Figure 12.1: Zombies, Run!

Chapter 13

Game Description - Dino Radar

This chapter will attempt to provide readers with a clear understanding of the exergame Dino Radar by using screenshots and descriptions of how the game works. The game is mainly played with the phone in the pocket, and the game view has a radar to help players with directions.

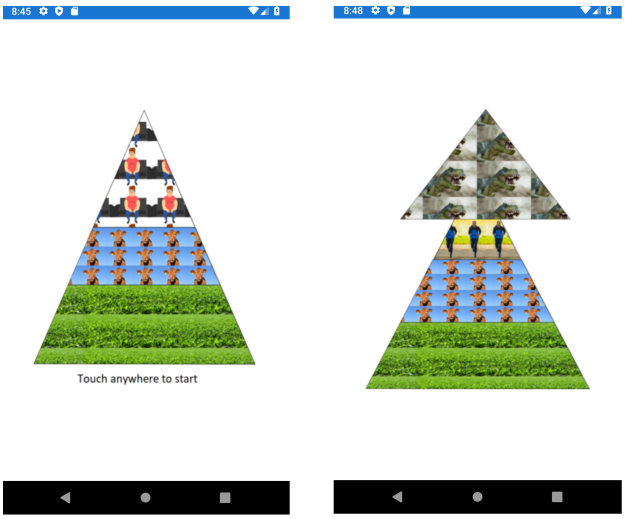

Figure 13.1: The splash screen of the game consisting of two pictures.

When opening the game, the player is welcomed with a humorist splash screen, as illustrated in Figure 13.1. The splash screen demonstrates that people think that they are at the top of the food chain, but when the dinosaurs have returned, they are no longer at the top food chain. The result of this return drives players to start walking or running away from dinosaurs to survive. Players passing through the splash screen are navigated to the menu view of the game, as shown Figure 13.2. The menu has a forest as background to try to give players the feeling of being in the woods where the dinosaurs are. In this view, the players have the options: Play, Shop, Achievement, Dino Dex, and How to play.

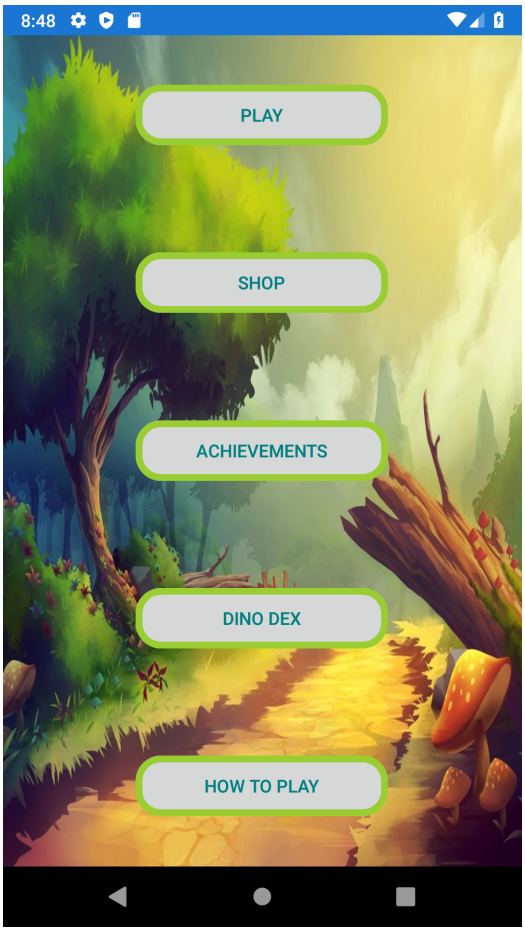

Figure 13.2: Dino Radar - Menu View

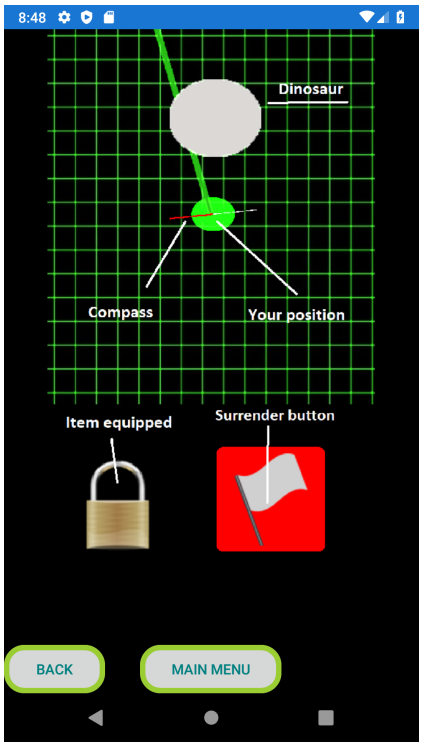

Figure 13.3: Dino Radar - Help View.

Figure 13.3 shows the "How to Play" page to players. This page operates as a guide, explaining to players how the game works. Reading the page is optional for players. The option "How to Play" is to give players *control* by not forcing them to do something that they do not wish. Instead of learning the game by reading, they have the opportunity to learn the game through the trial and error method. Reading the "How to Play" page makes it easier for players to play the game by improving the *player skill*.

In the play mode, five levels can be played, but only one level is unlocked in the beginning. The locked levels have a lock icon, as seen in Figure 13.4, and cannot be played before unlocking the level. To unlock levels, players have to complete the previous level. Each level consists of several dinosaurs and a fixed time limit, which shows how long the player has to survive to win the level. Table 13.1 displays the dinosaurs and the time limit for the different levels.

Table 13.1: Elements to make a game challenging

Difficulty	Time limit	Dinosaurs
Level 1	120 second	Stegosaurus
Level 2 - sprint	15 seconds	Spinosaurus
Level 3	120 seconds	Pterodactylus
Level 4	120 seconds	Pterodactylus, TRex
Level 5	300 seconds	Velociraptor, Stegosaurus, Pterodactylus, TRex

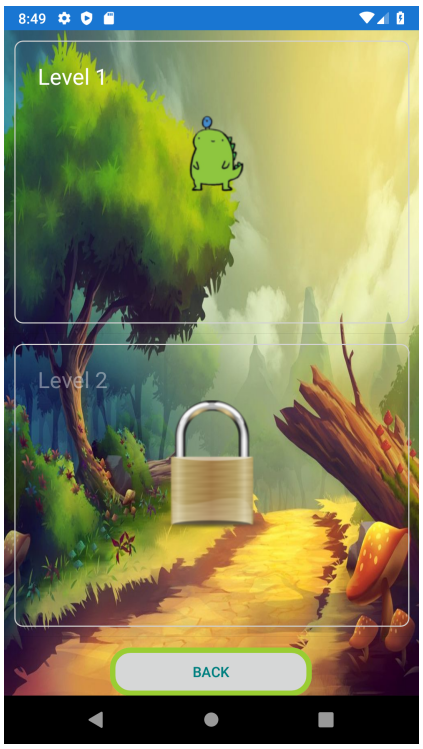

Figure 13.4: Dino Radar - Level menu

Dinosaurs spawned have different attributes and behavior based on their color. The dinosaurs renders as circles in the game with different colors. This game mechanic makes the player become *curious* about these circles,

and might start studying after some patterns of the circles. The Dino Dex on Figure 13.6 displays the dinosaurs that the player has already encountered, so the player can look up after winning or losing a game to learn more about them.

Table 13.2 displays their corresponding attributes. The walking and running speed in the game indicates units that dinosaurs move for each iteration of the game loop (d). Stamina of dinosaurs decreases when they are in chasing state as they are using their running speed instead of walking speed. If the stamina of the dinosaur is 0, the dinosaur will change state, having walking speed while recharging stamina. When stamina is fully recharge, and the dinosaur spots the player again, it starts chasing. The size of the dinosaurs shows the radius of their circles in the game. Dinosaurs are spawned at a fixed distance away from the player.

Table 13.2: Attributes of dinosaurs in Dino Radar

Dinosaur	**Walking speed**	**Running speed**	**Stamina**	**Size**
Stegosaurus	10 units/d	10 units/d	0 d	150 radius
Spinosaurus	125 units/d	125 units/d	0 d	100 radius
Pterodactylus	7 units/d	28 units/d	3 d	85 radius
TRex	8 units/d	18 units/d	10 d	85 radius
Velociraptor	10 units/d	10 units/d	0 d	100 radius

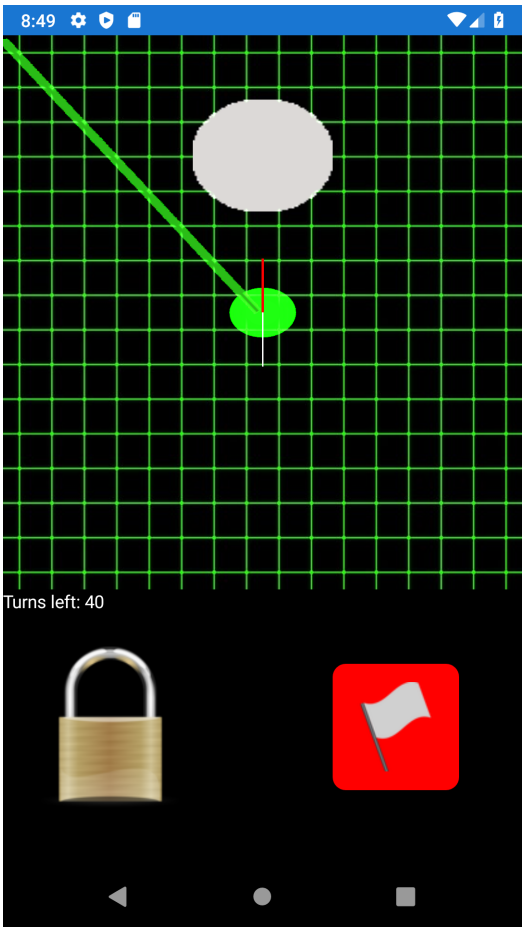

Figure 13.5: The view of the first level of the game

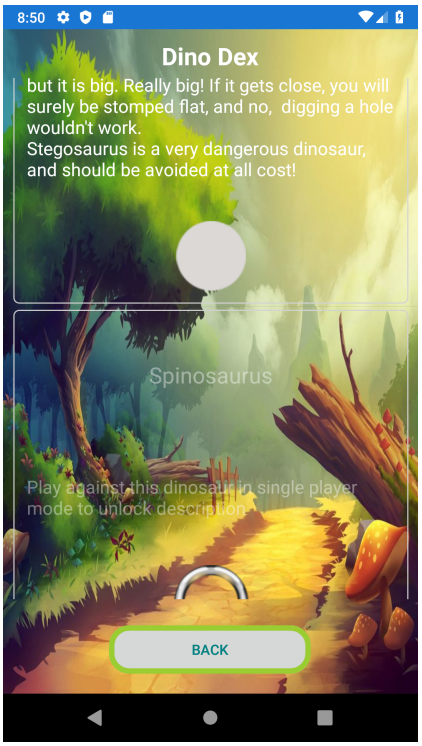

Figure 13.6: The Dino Dex

Figure 13.5 illustrates the game view of a chosen level. The game view consists of two parts. The top part displays the game view, and the lower part shows action buttons in the game. The button with the flag is the option to surrender. When tapping on the surrender-button, a popup dialog asks the player if he or she wants to quit. If so, the player will be navigated back to the level menu in Figure 13.4. The other button shows the item that is available and ready to be used in the play session. Tapping on the item button activates the item. The circle at the center of the game view is the player and is static.

The background of the game view is a radar background, which gives the player feeling that he or she is looking at a radar as it behaves like one with animation of searching for dinosaurs. There is a line at the center which goes 360 degrees around the player's circle to "search" for dinosaurs. When a nearby dinosaur is spotted, a "radar sound" is played to give players feedback about dinosaurs in the vicinity. When dinosaurs are coming closer, they start to roar with different loudness, depending on their location. Additionally,

the phone will vibrate if the dinosaurs are very close. The graphic view of the game uses a simple design, because as the intention is for players not be focusing too much the screen. The screen should assist players by indicating where the dinosaurs are and which direction they are currently moving. Running away from the dinosaurs after identifying their location, and hearing roars from them, players require *concentration* to be able to run away successfully.

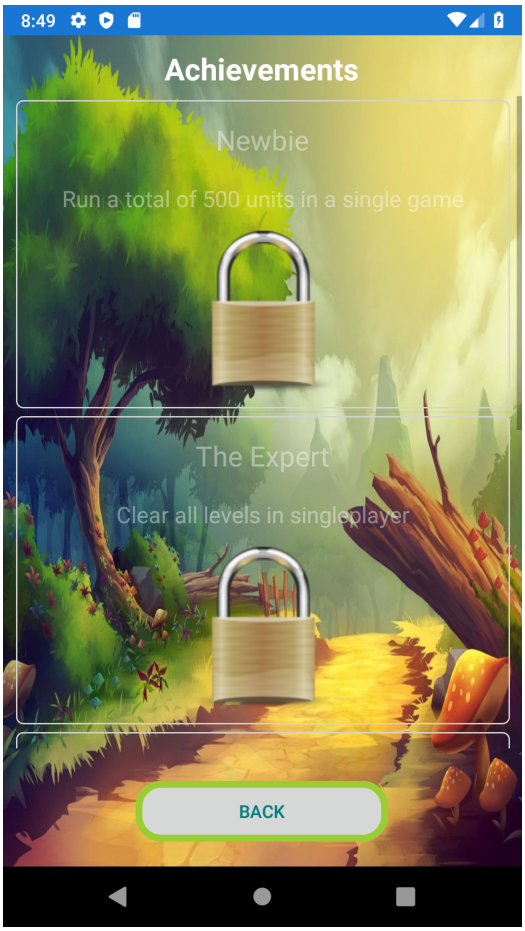

Figure 13.7: Achievement in Dino Radar

Figure 13.7 displays all the achievements in the game. Each achievement has a title and a description. The achievements that are not unlocked yet have a lock icon and opacity labels. The intention with achievements is to

give player sub-goals of clearing a level since players can unlock achievements during play sessions. When an achievement is unlocked, players are alerted with a popup and a sound. In the Shop page (see Figure 13.8), various power-ups can be bought that can be useful to a player. The player can equip one power-up per game that can be used once per game. Each power-up in the shop has a name, usage description, and a price tag in Dino Coins.

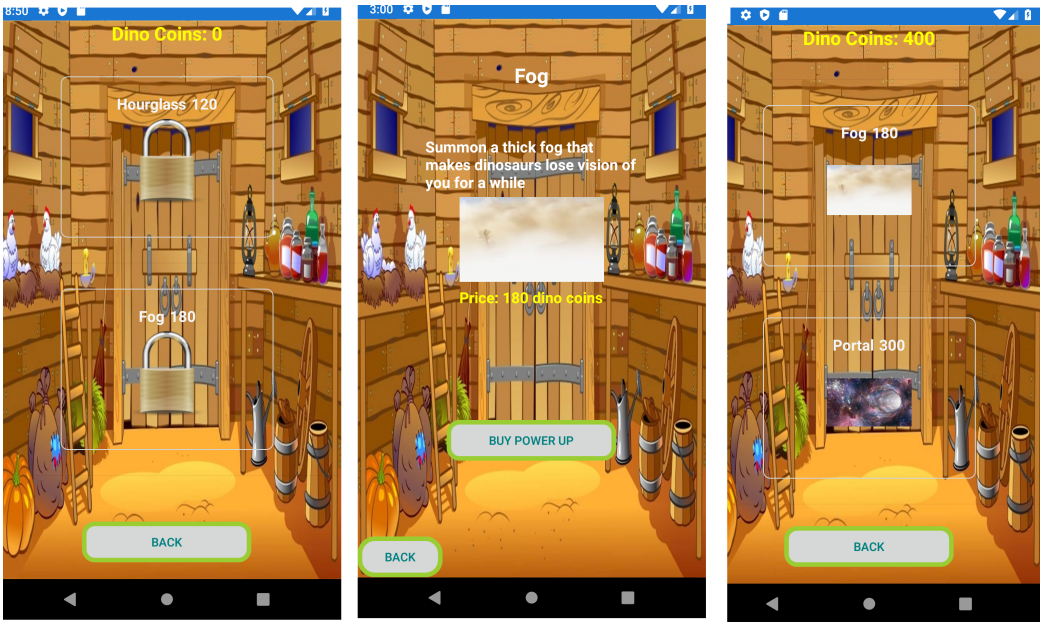

Figure 13.8: Dino Radar - Shop Page

Once a power-up is unlocked, it is unlocked forever. However, it can only be used once per game, and only one power-up is equipped when playing. The different power-ups are robust against certain dinosaurs and weak against others.

- **Hourglass**: An item that stops all dinosaurs' movements for one turn.
- **Portal**: A portal will instantly jump the player a set amount of in-game distance.
- **Fog**: The fog will make the dinosaurs unable to see the player, so they will walk in to a random direction.

Chapter 14

Game Design

In Chapter 10, we looked at how games can be fun and enjoyable, which is crucial to make players keep playing a game. To make a game fun and enjoyable, the three essential factors, *challenge*, *curiosity* and *fantasy* is needed besides the state of *flow*. This chapter will look at how the game Dino Radar has applied game engagement theories to provide enjoyment to players.

14.0.1 Challenges

For each level in the game, the goal is to survive from being eaten by dinosaurs. This goal gives players a clear objective of how to achieve this. However, to achieve their goal, they have to go through various challenges. The levels in the game vary in difficulty level, and to clear one of the challenging levels they have to progress. For instance, level 5 is way more complicated than level 1 in the game, and requires some experience before completing one of the challenging levels. In the game, there are also sub-goals, such as achievements and Dino Coins.

14.0.2 Curiosity

In Dino Radar, there are two types of curiosity, *sensory* and *cognitive* (see Chapter 10). Cognitive curiosity in Dino Radar is the missing information about dinosaurs, the outcome of the game, and how the items work. During gameplay, dinosaurs are spawned to chase the player. The dinosaurs come with various attributes and therefore behave differently. To be able to understand how they work, players need to gain knowledge from their playing. Items in the game provide curiosity. The description of the items is not sufficient enough to give players a clear understanding of optimal usage, and are therefore encouraged to obtain the items to figure out how they work.

The sensory cognitive in the game depends on the sound and the graphical design of the game. When a play session has started, the game view displays different circles on the radar. As the dinosaurs are approaching, the game plays different roaring sounds with different frequencies and loudness

depending on the situation. From those events, the player will start to question why the circles and the movements are different, besides being aware of the different sounds in the game.

14.0.3 Fantasy

Extrinsic fantasy in the game plays a big part in Dino Radar. The Dino Radar helps the player to locate dinosaurs, which are updated while the player is moving. It makes the game more exciting and can affect the emotion of a player. As a location-aware game, with the world as a game map, players will try to visualize dinosaurs in the real world. The radar helps players to imagine the location of the dinosaurs. The dinosaurs' sound helps the player's fantasy of being hunted of dinosaurs to be more realistic. Running or walking in the game becomes then an action with a purpose.

14.1 Flow

The player is required to *concentrate* on where the dinosaurs are moving and plan accordingly. When the player is just running, he or she might lose concentration on the gameplay due to awareness of the player's surroundings. Apart from that, the intensity increases along with the difficulty levels.

The game intends to be *challenging*, as the levels will be progressively more difficult as they complete levels, and their *skills* and physical abilities hopefully increase. Difficulty will be expanded with more dinosaurs, different dinosaurs, and longer survival time.

Starting a game gives the player full *control*. The player is the character of the game, and the game registers player's movements in the real world into the game. The *goal* is clear. Complete levels by avoiding being eaten by dinosaurs. The game provides real-time *feedback* as the gameplay is synchronous. During the gameplay, sound and graphic provide the moving direction of the player and an overview of dinosaurs nearby.

Chapter 15

Exercise Design

Dino Radar is an exergame that promotes motivation for physical activity in the form of aerobic activity. The game requires a lot of space when playing as the game focus on cardio exercise by running or walking during the game. It is, therefore, natural to play the game outdoors.

The game encourages players to walk and run as there are goals and sub-goals in the game. Players can choose how fast they want to run to complete the levels. But as the levels become more complicated, higher speed than walking speed is needed to complete some levels. Completion of a level rewards players with Dino Coins, and a new level opens. Besides, achievements can be unlocked while playing the game. Achievement view displays all the achievements, locked and unlocked ones. Fantasy in the game is applied to motivate people to put a lot of effort into Dino Radar. As the willingness of survival from the dinosaurs increases, players' movement might increase from this motivation.

In some levels, players are free to choose if they would rather walk or run to complete a level, but the harder ones require more physical intensity than walking. The aerobic exercise varies by varying walking and running in the game, which affects the heart rate of the players. Making players run more, results in more efficient training. The levels have various time limits. Levels with a high time limit can vary from walking to running speed, while levels with short time limits require sprinting or running speed to complete the game. The most difficult levels require players to run and use items from the shop.

Chapter 16

Technologies

This chapter goes through the chosen technologies for the game Dino Radar. In Chapter 8, we found that many techniques were possible to use in exergames. After the investigation of technologies, we decided to make the game Dino Radar as a mobile game with Xamarin as the mobile game development framework.

16.1 Platform

Dino Radar is a game where players require much space when playing. The game suits, therefore, to be played outdoors. To be able to play games outdoors, many types of equipment are required, or something portable with great battery life. The result was to develop an exergame on a smartphone. A dominating game industry market, which is very common to develop games. Examples of existing exergames which is played on smartphones are *Pokémon Go*, *Zombies Run!* and *Geocaching* (see sections 7.7, 7.12, 7.11). Utilizing technologies from the smartphone is a great way to track body movements. The smartphone technologies used in Dino Radar are the GPS and magnetometer, presented in Chapter 9.

One of the great things of developing games for smartphones is the range of target audience and agile development for adding new features and updates. As 80% Norwegians have a smartphone [59], it is easier to reach a broad target audience. The most common operative systems on the market for smartphone users are iOS and Android, with 74.3% and 24.76% respectively [77].

However, the drawback with smartphones is inaccurate measurements, which leads to the exploitation of this vulnerability. A smartphone takes input from the user, but cannot differ if the input source comes from a human or something else. As seen in *Pokémon GO*, players can cheat by driving a car with a low speed to gather steps to speed up the process of hatching eggs to get

rewards. In *Exermon* (see Section 7.9) players were able to register executed exercise by flipping the phone. Another drawback of playing games on the smartphone is the hardware difference. With different operating systems, and different hardware, the measurement from sensors will give different results, and the newest and most expensive phones will give a more accurate measurement, rather than old phones. These concerns must be taken into account when developing mobile games with technologies from the smartphone.

Figure 16.1: Smartphones that can be found among consumers

16.2 Mobile Game Development

Decisions must carefully be taken when developing games on smartphones. Mobile games can either run natively or cross-platform. Natively means only on a specific operating system, and cross-platform is more than one operating system. The best choice is to choose something that can run on iOS and Android, so 99% of the smartphone users can have the game available.

Before choosing a mobile game development tool, we conducted tests in the specialization project. The game engines/technologies Unity, Godot,

Xamarin, and Android Native were all potential usage for developing our exergame. The tests included checking criteria such as ease of use and if it was free and open source. The decision was to create the exergame on Xamarin with C#. Xamarin is a framework to develop mobile applications on cross-platform. It is a framework that is easy to learn in a short time, and functionalities it offers cover mostly our exergame's need. Native development was an option, but due to the restriction of the target audience and the same or less dividend as Xamarin, we discarded the option. Unity and Godot are popular game engines that offer many functionalities and great animations and graphic designs. However, the learning curve was high and time-consuming. Making great games with Unity or Godot requires a lot of experience to give a good trade-off. Thus, the test concluded that Xamarin would be the chosen framework to develop our exergame.

Figure 16.2: Architectural view of Xamarin

16.3 External libraries

This subsection gives an overview of external tools that have been used in mobile game development. The external tools are free and open-source that can be found on Github.

CocosSharp is an open-source game engine that mainly provides 2D graphics, rendering images, sprites, and animation. It also offers other features such as reading touch input, and playing audio.

Plugin.Permissions a plugin that is used to ask user's permission to hardware settings such as using the GPS, Bluetooth, and local storage.

Acr.UserDialogs is a cross-platform library for user dialog. The library simplifies the interactions of game events and the player.

FreshMvvm is a framework to make the application flexible and straightforward. Structuring the files, modules, classes following the MVVM pattern (see Section 18.3).

PCLStorage provides applications to save data on the local storage.

NUnit is a unit testing framework for all .NET languages. Unit tests are useful to test if the expected behavior of the units matches their actual behavior.

Chapter 17

Requirements

When we designed the game Dino Radar, functional and quality requirements were documented to clarify game functionalities in the game. Each functional and non-functional requirement has an id, description, and priority. Table 17.1 and Table 17.2 display all the requirements of Dino Radar. The requirements are prioritized in three different categories. Requirements marked as **High** are functionalities that the game must have, **Medium** indicates functionalities that the game should have, and **Low** indicates that the functionality is not necessary, but is nice to have.

As multiplayer mode was not play-tested, due to time constraints and uncertainties regarding the Covid-19 epidemic (see Appendix B), the multiplayer mode was not deployed to the released version of the game. Thus FR (11-15) was not fulfilled.

Table 17.1: Functional requirements of Dino Radar

Number	**Functional Requirement**	Priority
FR1	The player should be able to start a game from the unlocked levels	High
FR2	The player should be able to control his or her in-game character by moving in real life	High
FR3	The dinosaurs should move around	High
FR4	The dinosaurs should be able to spot the player	Medium
FR5	If the dinosaurs spots the player, they should be able to move at a higher pace, chasing the player	Medium
FR6	The dinosaurs should get tired if they chase the player for too long, and will then slow down to a regular pace	Medium

FR7	The dinosaurs should have differing behavior and stats	medium
FR8	The player should lose if his or her character gets in contact with a dinosaur	High
FR9	The player should win a single player level if a defined timer reaches zero	High
FR10	The player should unlock the next level after winning the previous level	High
FR11	Two players should be able to meet each other and start a multiplayer game	Medium
FR12	The players should win if the human is eaten	Medium
FR13	The players should lose if the timer runs out	Medium
FR14	The players should unlock the next level when completing a multiplayer level	Medium
FR15	The player can play a game if at least one player has unlocked the level	Low
FR16	The game should support achievements	Low
FR17	The player should be informed of the criteria to unlock the achievement	Low
FR18	Playing the game should reward in-game currency based on time played	Low
FR19	In-game currency can be used to buy items	Low
FR20	Items can be used as an aid in single player and coop mode	Low

Table 17.2: Quality requirements of Dino Radar

Number	Category	Quality requirement
QFR1	Accurancy	The game should track the player's position with an accuracy of 150m
QFR2	Modifiability	Adding a new dinosaur, should not take more than 4 hours
QFR3	Reliability	The game should not crash in 99,9% of launches
QFR4	Reliability	The online services should work 90% of the time

Chapter 18

Architecture

This chapter presents design decisions that were made to achieve our functional and quality requirements of the game.

18.1 Architectural drivers

Architectural drivers are a set of requirements that have a significant influence on the system's architecture [78]. This section briefly describes the requirements and their impact on the software.

Technical Constraints

- **Operating system**: The necessity to have the application available on both iOS and Android for further development has led to the decision to use a cross-platform system.
- **Sensors**: The requirement of tracking the physical movement of a player led to the decision to use the GPS and magnetometer. Other sensors might be more inaccurate and differ from devices.

Business Constraints

- **Time** The short project time was an important decision to use a technology that we were familiar with.

Quality Attributes

- **Usability** User interfaces should be simple and easy to use. The user interface should follow a universal graphical design.
- **Modifiability** To not restrict the features of the game. The game should be able to be modified and updated for further development.

- **Performance** As the game is battery driven and relies on the internet. The game should not drain batteries so quickly, and the response time of the game should not be more than 3 seconds.

18.2 Architectural tactics

Architectural tactics are tactics used in software to enhance quality. Design patterns have been used to achieve tactics.

> *Design patterns are descriptions of communicating objects and classes customized to solve a general design problem in a particular context. One person's pattern can be another person's building block* [79].

This section describes the architectural tactics that have been used to meet the quality requirements: usability, modifiability, and performance.

18.2.1 Usability tactics

Usability aims to make intuitive applications. A desired task that a user wants to perform should not be complicated, and the program will help the user to achieve their desired task.

Separate the user interface from the application

During and after the development, the user interface will change frequently. Maintaining the user interface separately from the code makes it possible to change the system without changing the user interface. To achieve this, we will use the *MVVM* pattern, presented later in this section.

Support User Initiative

Support user initiative is to give the user feedback on what the application is doing once an event is executed. One tactic used is Cancel. The app listens for tasks to be canceled to free up resources and notify the collaborating components.

18.2.2 Modifiability tactics

Modifiability aims to reduce the complexity and cost of making system changes. This quality requirement is achieved by increasing cohesion, reduce coupling, and maintain interfaces regulating communication between sub-systems.

Maintain semantic coherence

Maintaining semantic coherence is aimed at getting sub-systems with different responsibilities working together in the system without being too dependent on each other. We can achieve this by increasing cohesion and reduce coupling. Modular architecture can increase cohesion. Each module has a specific responsibility, and all functionality belongs there. If the module grows large, splitting into two modules is a solution. Increasing cohesion reduces coupling, as functionalities are sorted and less disorder.

Abstract common services

Many functionalities are used in the software in several ways, and are therefore suitable as an abstract module. A separate module that serves as a shared utility to the system avoids duplication of code, supports re-use, and can improve cohesion.

Prevention of ripple effects

A ripple effect occurs when a change in one part of the system necessitates altering other parts of the system. Defining the relationship between parts of the system can reduce the probability of having a ripple effect. Two tactics were used to achieve this.

The first technique is *maintaining interfaces*. We wrote interfaces for modules in the system to define what functionalities are available to the system. By maintaining interfaces continuously, we avoid the necessity of changing the rest of the system.

The second technique is *use and intermediary*. When changes are difficult to anticipate, the interfaces are less likely to stay stable. In those situations,

we can use intermediaries between dependencies to prevent rippling.

18.2.3 Performance tactics

Performance tactics aim to generate a response within a time-limit to an event. In the application, a user triggers an event which generates a response. The time from an occurred event to a generated response is called latency.

Control Resource Demand

Controlling resources demand is a tactic used to increase performance [80]. By limiting the sampling rate of the GPS to once every 3 seconds, the game will have predictable latency, and the battery will not be as drained as if we had chosen a higher sampling rate.

18.3 Patterns

This section presents the architectural and design patterns that have been utilized in the application.

18.3.1 Model-View-Viewmodel

Model-View-Viewmodel (MVVM) is an architectural pattern made to separate the views, which is how data presents, to the models, which is the app's data model [7]. With the MVVM pattern, each view has one ViewModel. The view uses commands and bindings to the ViewModel, that the ViewModel implements. The ViewModel then executes the commands, using one or more models, then notifies the view of property changes as seen in Figure 18.1.

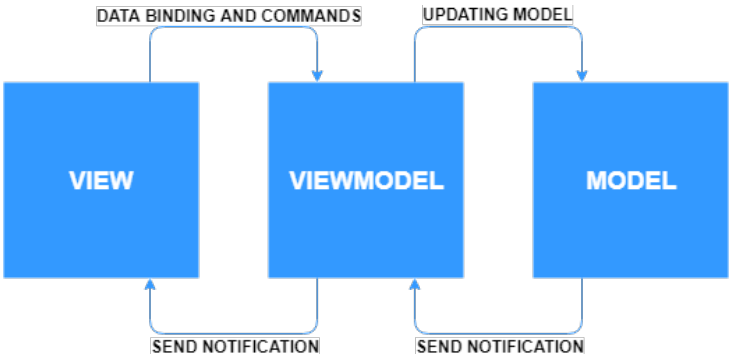

Figure 18.1: Model View Viewmodel illustration [7]

MVVM solves the problem of separating the view from the model so designers and developers can work independently, and models and views can be changed separately. This makes the code easier to maintain, test, and evolve.

18.3.2 State pattern

The State pattern defines states an object can be in a behavior for each state, as well as how to change states [79]. In the application, the State pattern is used to control the non-player characters' behavior in different contexts, like searching for the player and spotting the player. The *Template pattern* is used alongside with the State pattern to reduce coupling and increase cohesion.

18.3.3 Singleton pattern

The Singleton pattern is used to make one instance of a class while providing global access. This makes it possible for classes to access the singleton without having to initiate the singleton. The application combines the Singleton pattern with *dependency injection* to provide global access.

18.4 Views

Views are representations of the application's architecture, and describes the system from different perspectives to various stakeholders, such as developers

and end-users. This section presents the logical view, the process view, the physical view, and the development view [81].

18.4.1 Logical view

The logical view presents the given functionalities to the end-users. Figure 18.2 displays the overall view of the structure of the application. There are four components where all classes belong to one component with reference to other classes, depending on the component dependency. The component *ViewModel* binds the *Model* component with the *View* component, and are responsible for controlling the state of the application. The View component represents the application's view, and the Model component contains the model of the data in the application.

The GameMenuPageModel class in ViewModel is the start of the game. The class loads the main menu screen, and the end-users can freely start to navigate in the game. When starting a game session, the class GameViewPageModel loads the game.

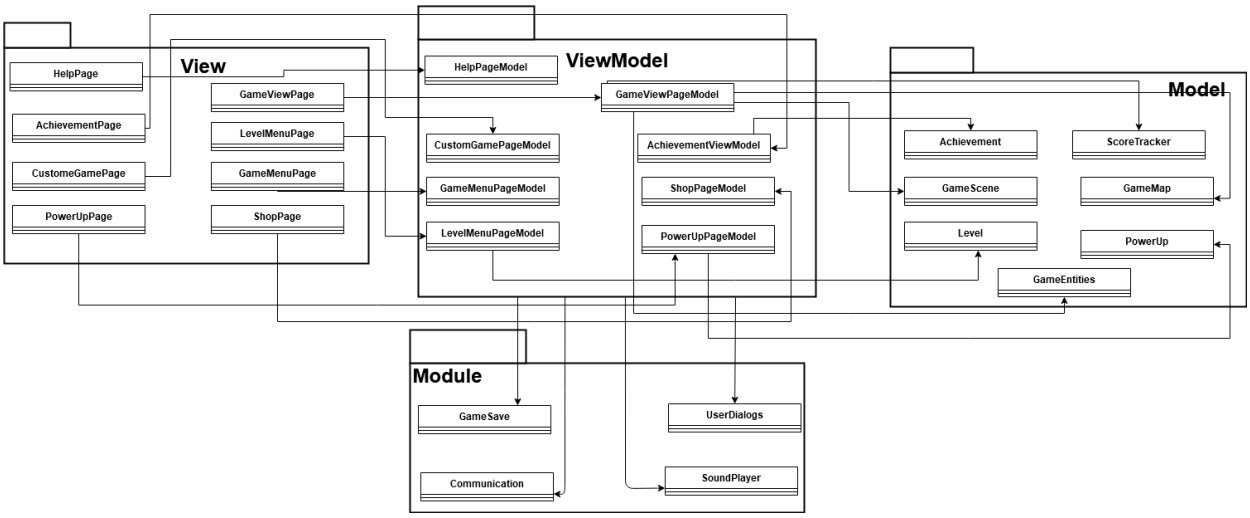

Figure 18.2: Logical view of the game

18.4.2 Development view

The development view shows how we planned to implement the system, and is useful when dividing work between developers. Figure 18.3 displays the

relationship between the subparts of the system and where the classes belong. The game consists of four main parts: Model, ViewModel, View, and Module. Changes in the ViewModel results change in the view, while changes in the models results changes in the ViewModel.

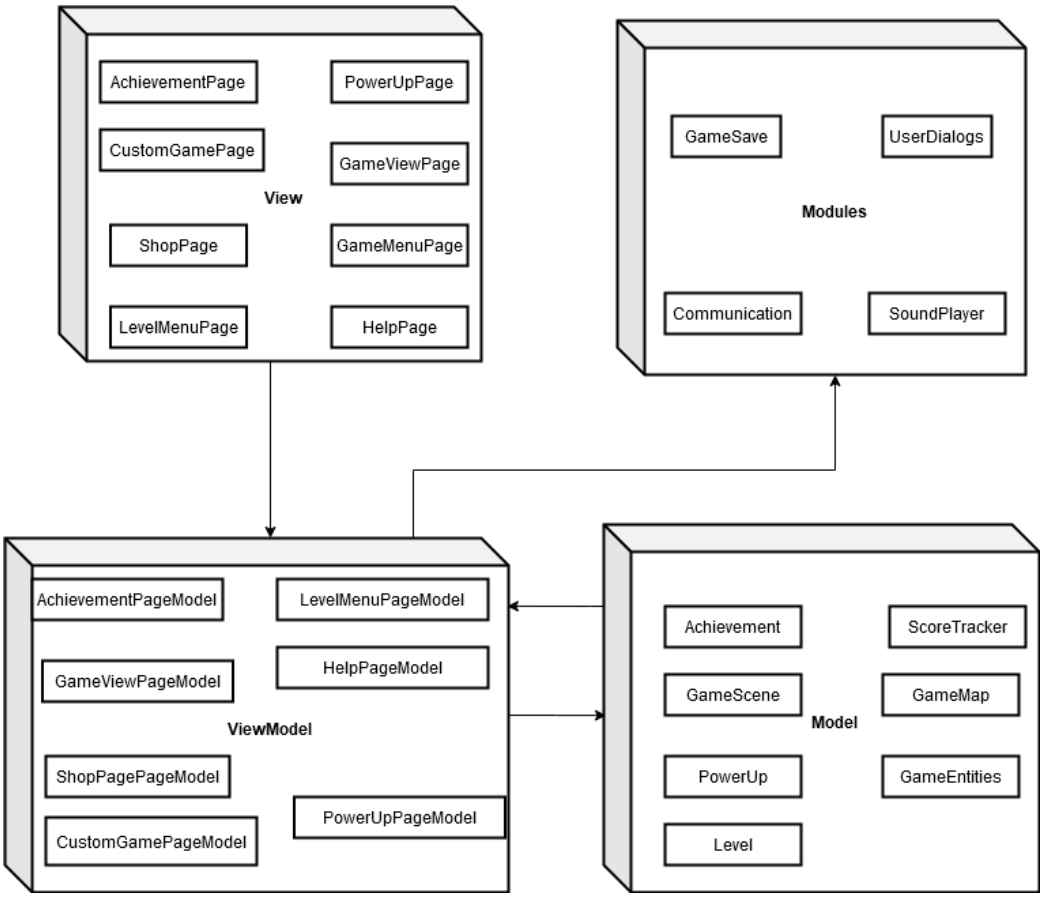

Figure 18.3: Development view of the game

18.4.3 Process view

The process view describes the process of a system and how they communicate. Figure 18.4 shows the process of interaction of an end-user and the game. As we can see in the figure, the entry point in the game is the GameMenuView. From this view, the player can choose different options: Play, Shop, Achievement, or Help.

In the SinglePlayerLevelView, several levels can be chosen to play. Once a level has been selected, a game session is started, and the player enters the GameView. From the GameView, the players can only be navigated to the GameMenuView when losing or winning the game.

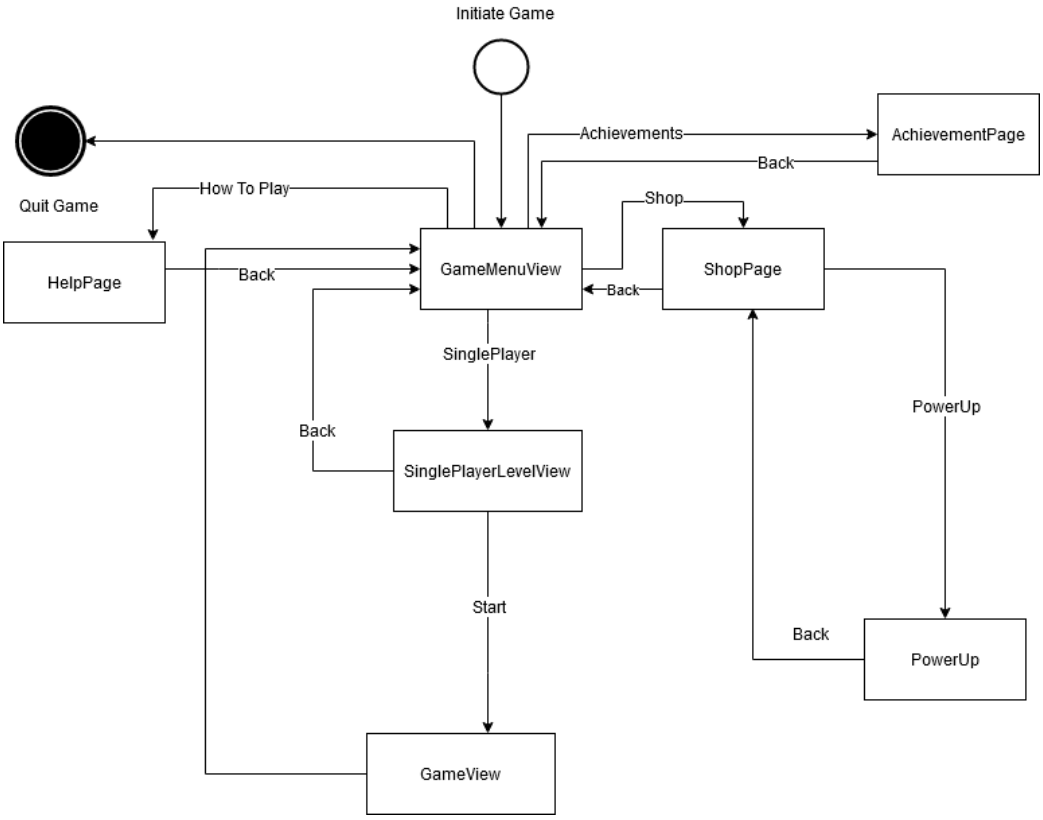

Figure 18.4: Process view of the game

18.4.4 Physical view

The physical view describes the game's topology. Figure 18.5 displays how the components interact with each other. The game is played on a smartphone with the required operating system iOS or Android. The state of the game is saved on a local storage to keep track of the state of achievements, items, and unlocked levels. When a game session is played, the smartphone sends out GPS signals to fetch the device's location to map the player's position in the game.

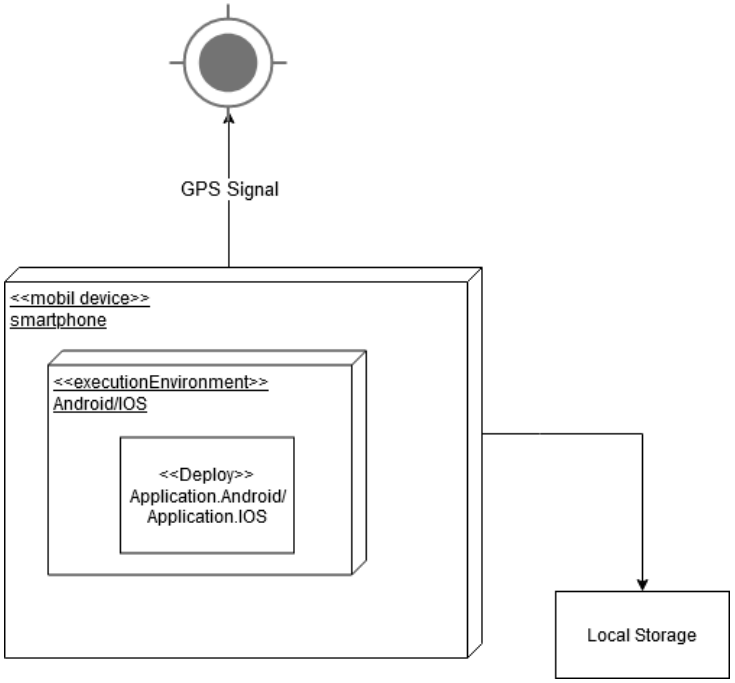

Figure 18.5: Physical view of the game

Chapter 19

Implementation Details

This chapter describes additional details of the implementation. The implementations described are essential classes in the game with great significance.

19.1 GameMap

The GameMap class is responsible for converting the player's real location (latitude and longitude) to Cartesian coordinates with the player's initial coordinates as the origin. The game model is a flat world with x and y coordinates, as this simplifies the implementation.

The approximation we are using is called equirectangular projection [82] and can be seen in Equation (19.2). The two constants C_lon and C_lat depend on what sort of measurement system will be used in the coordinate system. In the game, we map one unit of X to 1 meters east, 1 unit of Y to 1 meters north. Each degree of longitude is 111 km, which gives the constants in Equation (19.3) and eq. (19.4).

$$x = C_{lon} * (\Delta lon) * \cos lat_0 \tag{19.1}$$

$$y = C_{lat} * (\Delta lat) \tag{19.2}$$

$$C_{lat} \approx 6359830 \tag{19.3}$$

$$C_{lon} \approx C_{lat} * \cos lat_0 \tag{19.4}$$

19.2 GameScene

The GameScene class implements the view of the game, and a game loop where each turn corresponds to the timer goes down. This class is responsible for rendering background, animation, radar, and the compass of the game. In

addition to the graphical, GameScene is also responsible for the countdown of the survival time. For each iteration, the game fetches the player's location and updates the dinosaur's position. The game loop is limited to iterate once every third second to save the phone's battery.

19.3 GlobalGameState

GlobalGameState is a class saving the game state of the data in the game. This class allows users to load the last state of the game where they left. It is implemented as a Singleton to save game data during the session. The game data stored on the smartphone are: the Dino Dex, unlocked levels, the number of Dino Coins, unlocked achievements, and unlocked power-ups. All the data of the object is converted to JSON when saving the state.

Part IV

Research Methodology

Chapter 3 introduced the research goal and research questions regarding to exergames. To address the research questions, we conducted an experimental execution to collect data regarding the research questions. This part describes the experimental approach, the test procedure, the findings, and the validity and reliability of the results.

Chapter 20

Experimental Approach

This chapter describes our experimental design during our research. Due to the Covid-19 epidemic, our empirical study had to be adjusted to experiment as safe as possible. More about the Covid-19 epidemic and our original experiment can be read in the Appendix B and Appendix C.

20.1 Triangulation - Data Collection

The idea of the Triangulation method is to gather data from research by utilizing multiple methods [83]. The technique draws out data from different sources, at a different time, in different places from different people to approach data with various perspectives to maximize the validity of the data.

As mentioned earlier, we had to discard the quantitative method due to the Covid-19 epidemic. The data we have gathered is qualitative and was collected by conducting observations and interviews. Qualitative data will give us more in-depth answers to our research, which is to explore the potential of an exergame that we have implemented.

20.2 Qualitative Research

Qualitative research is to gain an understanding of underlying reasons, opinions, and motivation. In our study, we used semi-structured qualitative research.

Observation is one of the methods we used to gather qualitative data. This method includes watching what people do. There are several types of observation methods, but in our experiment, we carried out Naturalistic Observation [84]. As the name says, this technique involves studying participants in natural surroundings. All relevant behaviors are recorded, which gives ecological validity.

Interview is the second method we conducted to gather qualitative data. We held a semi-structured interview [85], which is more like a guided conversation. The advantage of this type of interview is that the discussions are more flexible, which makes it possible to adapt the questions to the given answers. The interviewers do not have to follow a question schedule. It also helps the interviewers to develop a sense of understanding of the interviewees. This method gives increased validity due to the possibility to probe and steer the interview's direction to get a deeper understanding of a situation.

Chapter 21

Participant Recruitment

All people who can use a smartphone and able to jog with a moderate pace is a potential user of our exergame. However, the target group in the experiment is teenagers and adults, as the game is a bit too complex for kids and elders for now. The chosen test-subjects are acquaintances, friends, and family members that have experience with video games and can run.

The sampling method we have carried out is the opportunity sampling method [86] because of a few reasons. First of all, due to time restriction, this method is quick, convenient, and economical. Secondly, it is fast and easy to get the participants' consent. And lastly, the sampling is strategically picked as the chosen participants have experience with video games and exercise. It is important to note that no general conclusion can be drawn from the study findings. The chosen participants may not provide a representative sample and could be biased. However, the results that are acquired are still meaningful and useful for further studies as the purpose of the study is to explore the physical effect and engagement of this type of exergame.

In our study, we had a total number of five participants to provide input about our exergame. The participants were between the ages of 20 and 28-years and technically competent.

Chapter 22

Experimental Execution

The experiment carried out lasted for two weeks. Before conducting the test, we did a quality assurance review on our exergame to ensure that there were no fatal errors or bugs. All participants were given an invite (see Appendix D) with time and place for a meetup to make sure that the weather or the physical environment would not affect the game experience.

Figure 22.1: A participant playing Dino Radar

The test consisted of five participants, and each participant was asked to download the exergame from Google Play. The following smartphones that were used during playtesting were *Huawei P20 Pro*, *Samsung Galaxy S9+*, *Samsung Galaxy S8* and *Samsung Galaxy A3*. All participants were asked to read the test participant agreement (see Appendix E) and the user manual (see Appendix A).

On the day of playtesting, we asked each participant if he or she had read the manual and wondered if there were something that was not clear to ensure that the player understood the game mechanics. The playtesting was carried out on a big area with few obstacles to give the participant freedom to choose the running direction. The weather was mostly cloudy, and the temperature was around 2 Celsius. The playtesting lasted approximately 45 minutes for each participant.

Before starting the game, we described the testing process and asked them to behave as naturally as possible even though we were observing and taking notes. After the observation, we had an interview with the participants that lasted from 45 minutes to 60 minutes.

Chapter 23

Results

This chapter presents the results from the observations and interviews conducted in the experiment.

23.1 Observations

The observation of the players was done by observing their behaviors and chosen paths during the playtesting. All of the participants were able to play the game on their smartphone without any complications.

Figure 23.1: Observation of some participants

All of the players started to try out level 1. They started jogging at a pace that was more than enough to complete the level when the level began, but none of them were able to complete on the first attempt. The reason was because the participants made several attempts to figure out which directions to go and how the compass operated. After figuring out the game mechanics, they managed to complete the first level and started straight on the second level. When they were able to complete a level, they started straight on the next level. If they did not manage to complete the level after several attempts, they paused the game and tried to plan how to win. None of the players explored the shop or achievements in the game until they came

to level 3. Once the players reached level 3, some of them began exploring the shop as items became affordable. One of the participants did not buy any item until the participants had enough Dino Coins for the most expensive item in the game, the Portal (see Chapter 13). At level 4, most of the participants had an item as the game became more difficult, and they had attempted to clear the level several times. The participants that had the Portal were close to clearing it, but were caught off guard by the Pterodactylus outside the screen before using the Portal.

The players expressed engagement, enjoyment, and were also physically exhausted during the play session. None of the players were able to complete all of the levels. All of them unlocked level 4 and had to quit due to fatigue, as they had been physically active for more than 45minutes. Completing levels made the players excited, and gave them self-esteem to run away from the dinosaurs in the game. Achievements and items in the game increased the engagement. Players wanted to buy things they needed to complete level 4, and were also curious about how it worked. Additionally, achievements in the game was also a motivation to play the game.

> *"I want to buy the Portal item in the game to complete one of the achievements. That is because I am a gamer!"*

All players solved level 1 by running straight south. Level 2 was solved by running away from the dinosaur at a high pace. However, participants won level 3 differently. Most participants ran southwards to get away from the closest Pterodactyls, then either east or west, to run away from the other coming from the southwest. One player ran straight north at a very fast pace, thereby getting both dinosaurs behind him.

As mentioned earlier, the physical activity in the game lasted about 45 minutes or more. The players were tired after level 3 with low energy left to play level 4. All of the players began with moderate jogging at level 1. The speed of the jogging increased as the levels in the game became more difficult. Some players increased their speed as they encountered buildings to get in the right position to run away from the dinosaurs.

Regarding different smartphones, some of the participants experienced some minor bugs in the game. One of the bugs was sensor magnetometer calculation. On the Huawei smartphone, the magnetometer acted differently as the

north direction changed during the playtesting. The Samsung smartphones had not this issue. Additionally, there were inaccurate measurements of the GPS location tracking. Two of the participants observed the unusual dinosaur movements, but did not report it as a bug because they assumed it was natural. The flaws did not impact the experience of the gameplay.

23.2 Interviews

A semi-structured interview with 39 questions was conducted after the playtesting. The questions in the interview were predefined. Some could be either probed or guided, depending on the given answers. Each question dealt with one of the following aspects: background, gameplay, physical, motivation, enjoyment, engagement, technical, or future play.

23.2.1 Background

All of the interviews started with questions about the player's background. Thus to make an idea of how much the player had experience with exercise and games. Table 23.1 shows questions concerning habits of exercise, video game, and knowledge about exergames.

Table 23.1: Background questions on the interview

ID	Question
Q1	Do you play video games? If so, how many hours, and what sorts?
Q2	Do you exercise? If so, why, how often and what kind of?
Q3	Do you know what an exergame is? If so, which exergames do you know?
Q4	Which exergames have you played or are playing?
Q5	What do you think of combining exercise and video games?

Every participant responded that they were playing video games every day for more than 3 hours, with a variation between 3-5 hours. What kind of games they played varied, but FPS and MMORPG were the most popular. Video games were a part of their daily lives.

Before the covid-19 outbreak, almost every participant exercised more than four times in a week. The workout was primarily a workout of strength in a Gym. One of the participants trained once a week aerobic workout to get ready for an upcoming half marathon.

To most of the participants, the term exergame was unclear. Only two of them had a certain knowledge of it. When explaining the term to the participants who did not know, they knew immediately and came with explanations right away. All of the players were familiar with Pokémon GO, and some were familiar with Xbox Kinect and Wii Fit. Pokémon GO was the exergame in which all of the players had experience. Two of the participants had also played other exergames such as GeoCashing, Just Dance, and Xbox Kinect.

All of the test participants agreed that combining exercise and games was a good idea to make people more physical activity. The test participants argued that people might want to exercise more because games can be addictive. It could also help gamers to be more physically active as they spend a lot of time sitting in front of the computer. One of the participants said that he knew people from his social network that became more physically active because of Pokémon Go.

23.2.2 Gameplay

The next part of the interview consisted of questions regarding the gameplay. The intention of the questions in Table 23.2 was to find out the players' experience and opinions about the game.

Table 23.2: Gameplay questions on the interview

ID	Question
Q6	What do you think of the game?
Q7	What did you like about the game?
Q8	How would you like to compare this exergame with other exergames you know?
Q9	What do you think about the cardio exercise in the game?
Q10	Were you aware of your surroundings while playing the game?
Q11	What do you think of the graphical interface of the game? Was it intuitive?

The first question about the gameplay was what the participants thought about the game. Most of the participants shared their views on the game and went through their perspectives in depth. All of the participants expressed that the game was fun. Some of them enjoyed running away from dinosaurs, while others enjoyed running in the game at different speeds. One of the participants responded that the participant had seen the movie Jurassic Park which made the game even more enjoyable, as the participant was thinking about the film while playing the game.

When it came to their opinion on what they did like about the game, there was a wide range of responses. Positive things listed were advancement, running away from dinosaurs, becoming physically, and collecting achievements.

The participants replied by contrasting Dino Radar with other exergames that the exergame was more complicated than other exergames they had been playing. Many participants compared Dino Radar to Pokémon Go. Some said it was interesting that none of the exergames was like Dino Radar and said it is hard to play an exergame like Dino Radar, which was physically demanding.

Many of the participants were conscious of their surroundings because of the landscape and the physical environment. They said they had to look out for obstacles, and prepare their running route while playing the game. One of the participants encountered a passerby telling the participant something while playing the game, which took the attention of the participant a bit away from the game. However, the same participant shared that the soundscape may have improved the experience and may have reduced the perception of

the surroundings if the play had continued for a more extended time.

The respondents to the graphical user interface (GUI) was that it was all fine. As they were all familiar with the today's GUI of games, suggestions of GUI enhancements such as animation consistency, map features, and dinosaurs made as figures in the game, and replacing the radar with augmented reality were suggested. Because of the game's GUI in the play session, it left the participants a little confused about how the game worked while they were playing at the very start. One participant stated that the participant was being used to the viewpoint of the Pokémon GO, where the player's location in the game updates as the player is moving in the real world. Therefore the gameplay interface was not intuitive because of this familiarity. Some players also failed to see the T-Rexes because they were brown and would fit in with the game's black background. The Design of the other functionalities in the game was intuitive, except for the map GUI.

23.2.3 Physical aspect

Table 23.3 displays the specific questions which have been posed during the interview. The questions concerned aspects of the physical part of the game, such as insensitivity, progression, and comparisons.

Table 23.3: Physical aspect questions on the interview

ID	Question
Q12	How intense was the game, physically?
Q13	What was the progression across the stages of difficulty?
Q14	How long breaks did you take between the levels?
Q15	How would you compare this game with other physical activities?
Q16	Did you push yourself when you were physical active in the game?
Q17	Do you think the exergame could have replaced a workout session?

As mentioned earlier, all the participants responded that the game was physically intensive, more physically intensive than the exergames they knew about. The progression of difficulty increased as new levels were unlocked.

The participants said they could jog with a moderate speed at level 1 in the game, and when they progressed to level 2 and 3, they had to increase

the speed to complete the levels. Two of the participants commented that they had to run at a fast pace at level 2, and one of them suggested that level 2 could have been on a different mode with two modes in the game, one with high speed and one with a moderate pace. Some participants suggested that the difficulty curve might have been to steep.

The participants answer to how long break they have taken in the game varied during processing. The most popular response was whether the first break was shorter than the other one, and they were having trouble calculating their break length. If they had to guess a period time, on the first break, most guessed around 3 minutes, and the others, 5 minutes. The explanation for their long break was that they had spent the breaks thinking and preparing for the next level.

It was stated that the game was most similar to a running exercise in all forms as long-distance and interval training when compared with others with physical activities. How the attendees replied varied. Every test participant did push themselves during the game to run, mainly to run away from the dinosaurs.

Four of five participants said that the game could replace a workout session if there were more levels in the game. Some of the participants mentioned that the game lasted as long as a normal exercise session and could have the same effect as if you were taking a run outdoors. The last participant that had another opinion of the replacement argued that the players would have been too focused on the game, and the game would not be efficient enough to be an exercise session. It would, therefore, be tiresome to plan where to run in each level, the game dictates where players will run while a person outdoors can run freely anywhere in a real-life scenario without any concerns.

23.2.4 Motivation

Table 23.4 displays questions that concerns the aspect of motivation in the game. In the interviews, there were four questions regarding to this topic.

Table 23.4: Motivation questions on the interview

ID	Question
Q18	What were your goals in the game? (do they answer physical activity before probing? If not, probe)
Q19	What motivated you to achieve your goals?
Q20	How was the difficulty of achieving these?
Q21	Did achievements or items in the game make you motivated to play?

The test participants' goals in the game were primarily complete the levels. Two of the participants had a goal to get achievements, and one of them had the purpose of collecting all the achievements. The driving force behind these objectives was either to clear the levels or to collect enough Dino Coins to buy items. One of the participants also stated that one of the reasons for achieving the goals in the game is the physical impact of playing the game too.

All participants expressed that it was harder to achieve their goals as the game progressed, but reaching their goals was not a problem. The participant who had the goal of completing all the achievements indicated that the game should have had more difficult achievements, as the participant thought that few achievements were challenging to obtain.

Achievements and items in the game motivated all the players to play the game, whether the participants had varied motivations. One participant was motivated by gaming intuition. Another participant was excited to unlock rewards as the participant liked completing the task, while another participant expressed the need for items to complete one of the game's levels.

23.2.5 Enjoyment

The next questions in the interview covered the aspect of enjoyment of the game. Table 23.5 displays the questions regarding to enjoyment.

Table 23.5: Enjoyment questions on the interview

ID	Question
Q22	Did you enjoy playing the game?
Q23	What part did you enjoy the most?
Q24	What part did you enjoy the least?
Q25	How was your curiosity about the game?
Q26	How did the sound in the game play along the gameplay?
Q27	Was there any satisfying moments in the game?

All of the participants claimed they enjoyed playing the game. One of the participants experienced rainy and cold weather during the playtesting. The participants said it reduced the enjoyment of playing the game.

Their response to what they enjoyed most in the game varied. One participant enjoyed most of being physically involved when playing the game. In contrast, another participant enjoyed most of running away from dinosaurs, yet another enjoyed using objects in the game to help them win. When it came to what the participants enjoyed the least, most replied that the game's graphics was the biggest drawback of the game. Another part that the participants enjoyed least was the relationship of awarded Dino Coins and the completion of a level as they felt it was "unfair" distribution.

There were several answers in the game on the curiosity of the players. One of the participants was curios about the Dino Dex.

> *"The Dino Dex made me curious about the dinosaurs. It made me more interested in items to see if the effect differs from dinosaurs"*

Another participant was curious about the difference between the expensive and cheap power-ups and expected that the more expensive one is more powerful than the cheapest one. Other elements that made some of the participants' curios were that various dinosaurs were involved in the game, and the game was explored to get a better understanding. All participants figured out that the dinosaurs differed in size and color. Two participants speculated that the smaller dinosaurs were faster. None of the participants figured out all the dinosaur attributes explained in Chapter 13, like vision, walking, and running.

The participants' answers regarding to the sound in the game were mostly positive. Four of the participants liked that the sound varied, and the phone's vibration was more potent as the dinosaurs got closer to the players, which made them tell the player he or she needed to move more quickly. One player pointed out that the sound was a little distracting as the participant wanted to listen to music while playing the game. Consequently, the participant suggested a button that could suppress the sound in the game so players could listen to their own music.

There were various satisfying moments for the test users. All of these experienced either by completing a level or by having enough Dino Coins to purchase an item.

> *"I was very happy when I had enough money to purchase the most expensive item in the game."*

> *"Completing Level 1 was very rewarding. Completing the other levels gave me self confidence."*

23.2.6 Engagement

The following questions in Table 23.6 concerns the aspect of engagement of the game.

Table 23.6: Engagement questions on the interview

ID	Question
Q28	Did you feel in control of what you were doing in the game?
Q29	Did you feel any improvements of your skills while playing the game?
Q30	How realistic did the game feel?
Q31	Did achievement and the shop encourage you to play more?
Q32	Did the feedbacks in the game help you?
Q33	How was your progress in the game?

For some of the participants, getting control over the game was difficult. They thought the game's gameplay was different as they were used to, which made it difficult for them to understand at the beginning. But as the game

progressed, they felt getting more control over the game. The player's engagement also concerned the improvement of their skills. When the game progressed, players felt their skills had improved when they got a deeper understanding of the game and adapted to the game mechanics.

Many of the participants felt that the game was slightly realistic. When the dinosaurs came closer, the explanation was that the dinosaurs' roars played along with their fantasy. The other participant that did not feel the game realistic explained that the game's graphic might have been not good enough to play on their imagination.

The shop and achievements motivated players to play more. Each participant said they required an item to complete one of the levels. This thinking drove the players to re-complete levels that they have already achieved to collect enough Dino Coins to purchase items from the shop.

The participants said that the feedback was beneficial. When the dinosaurs got closer, they heard a louder dinosaur sound and vibration, which functioned as a warning signal, and they needed to speed up to be able to run away from the dinosaurs.

The participants' responses to their progress were very similar. Most of the participants said they started right on the levels and kept going until they were stuck. They started exploring shop when they lost and had attempted a level many times. The participants also explored the game while they were having a break after completing or losing a level to analyze. The progress in the game was very similar with some minor differences.

23.2.7 Technical

Table 23.7 displays questions that covers the technical aspect of the game.

Table 23.7: Technical questions in the interview

ID	Question
Q34	Did you encounter any challenges/difficulties between the game and your surroundings?
Q35	How well did the phone track your movements?
Q36	Did you experience any bugs when playing?
Q37	Do you think you could have figured a way to cheat in the game?

All participants said that they faced difficulties as they played the game outdoors. One common challenge of running outdoors was that physical objects became obstacles. It made the game more complicated, as the game's dinosaurs could get through obstacles, while the players had to run around the same constraints. Another difficulty that was faced by a test participant was the landscape when running. When the participant had to run for a particular direction, the participant had a few times to run uphill, which made the game more challenging and exhausting as the speed of the dinosaurs are independent from the real world. The corollary to this mechanic is that the dinosaurs will not run faster downhill. None of the participants used this to their advantage.

Two players felt the phone tracked their movements well, while others responded that the responsiveness of the location tracking was a bit off. One stated that the game could have been more real-time (lower latency).

> *"My movements and the player in the game movements did not update precisely real time. It was hard for me to tell my distance from the dinosaurs."*

The participants' responses regarding bugs when playing the game was that some of them had some issues with locking the screen. This minor bug made it inconvenient for players to re-open the game. Another bug that two of the participants faced was the compass. One of them used a magnet phone cover, which made the compass in the game spin. The other participant had the bug that the north direction changed while playing the game.

Cheating in the game was not a problem for the participants. They all answered they could have used a car or a bicycle to cheat in the game. Three of the participants also reported that they could adjust the device's GPS position to run away from the dinosaurs to win the game. None of the players cheated at the game during the playtesting.

23.2.8 Future play

Before the interview was finished, we asked the participants two questions about future play. The questions are displayed in Table 23.8

Table 23.8: Improvements questions in the interview

ID	Question
Q39	Do you have any suggestions for improvements?
Q40	Is this a type of game that you would consider to play regularly if it was further developed?

The first question regarding the future aspect was about if the participants had any suggestions for improvements. All the recommendations were about game features and additional material in the game. The most common proposal for change was graphical user interface changes to make the game less complicated and intuitive. Another common suggestion was to strengthen the association between awarded Dino Coins and the degree of completion.

Lastly, all the participants answered that they could have considered playing the game if further developed. The chance to continue playing the game would have increased if more levels, items, and features had been added. Two of the participants said that adding it into their fitness schedule would improve their daily exercise, as the game was a bonus next to the exercise portion.

23.3 Additional data

This subsection presents additional data from some of the test participants during the playtesting. The presented data is inaccurate and roughly estimated from different devices.

One of the participants of the playtesting had an activity tracker (Garmin forerunner 235) equipped during the playtesting. From Figure 23.2, the average heart rate during the playtesting was about 108 beats/second. The defined values are time interval values of the playtesting before and after it took place. The illustration displays a heart rate that was around 80 beats/second before the game, and a top peek at 165 beats/second. The number of steps taken during the playtesting was approximately 4500 steps. This value is a rough estimate from the user as the value is an approximate calculation from the user.

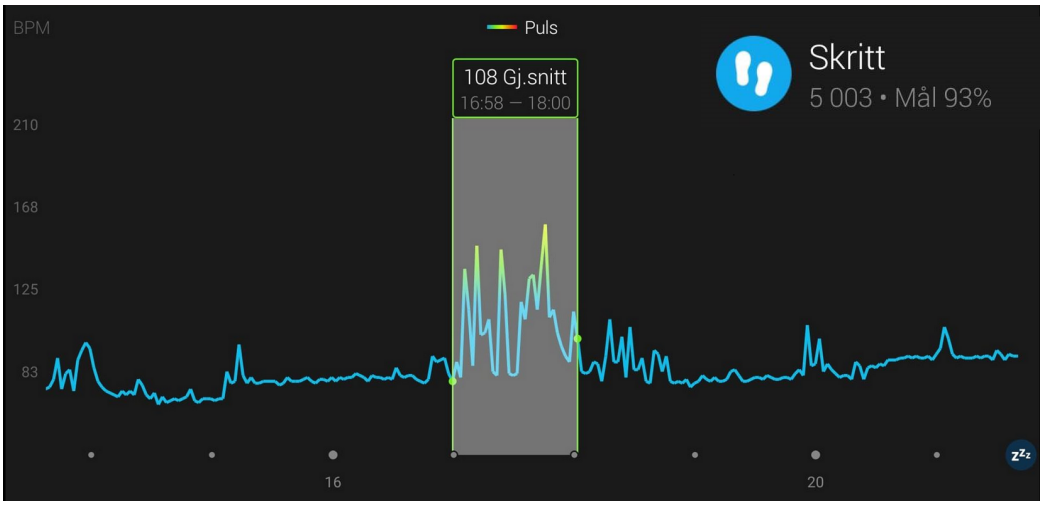

Figure 23.2: BPM values of one of the test participants

Two participants that got their activity tracked had a smartphone to track their number of steps during the playtesting. One of the participants had a total amount of 4565 steps during playtesting (see Figure 23.3), while the other one had roughly more than 4000 steps (see Figure 23.4). The colors of the bars on the Figure 23.3 displays if the participant achieved the steps from walking or running. Light blue indicates that the participant was running, while dark blue means that the participant walked. The given values in the Figure 23.3 displays that 51% of the total steps (5176 steps) that were acquired from the specific day were from running while the rest was from walking.

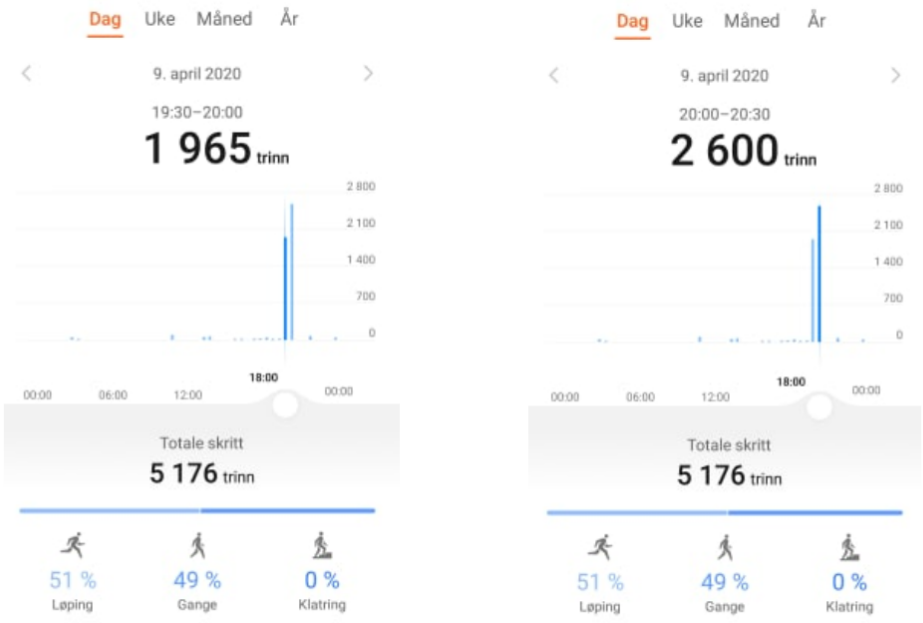

Figure 23.3: Number of steps from one of the test participants

Figure 23.4: Number of steps from one of the test participants

Chapter 24

Validity and Reliability

The result of using the opportunity sampling method is biased results and non-generalized results from the experiment's findings. This chapter will discuss what effects and biases might have affected the outcome of the research.

Hawthorne effect is the effect where the participants will adapt their behaviors due to their awareness of being observed [87]. During playtesting, the participants were aware of being observed by us. The Hawthorne effect might have influenced the result of the data in a positive direction as players were aware of being observed.

Pygmalion effect is the effect of the participant's performance due to other expectations [88]. Because participants were in our social circle, there were possibilities for bettering the game than generally if there were others who conducted the research. Since we knew their background and their physic, it would not be any surprise if they performed as best they could to show off their skills.

Demand characteristics is a term in cognitive psychology where the participants adjust their behavior due to their interpretation of the study's purpose [89]. This characteristic could cause a bias in favor of a passivity towards the game. The participants might have wanted to help us as much as possible to achieve the best possible grade from the master thesis.

Observer bias is a form of detection bias [90]. This bias is familiar as the Hawthorne effect. Participants are aware of being observed and therefore act differently to how they normally would.

Familiarity bias is where people make familiarity decisions to remain in their comfort zone [91]. Because participants were either a friend, a relative or an acquaintance might have affected the results by answering favorably to us in the interview.

Part V

Discussion & Conclusion

The final part of the project will discuss the results of the research and will be addressed to a conclusion on the research questions from Chapter 3.

Chapter 25

Discussion

This chapter covers our discussion of the exergame design and the results of the test participants during the playtesting.

25.1 Exergame Design

When it comes to the Dino Radar exergame, some flaws may be in the game design. The concept of exergame is relatively new in the research area, which makes this field of study limited research and literature documentation.

Due to limited documentation and resources, there may have been an absence in designing the exergame Dino Radar. Some game design frameworks have been applied to the game to improve the user experience like *GameFlow* from Section 10.3 and *Tom Malone's theory on intrinsic motivation* from Section 10.1 that many game developers use. The game design frameworks are for games in general and not for exergames in particular. Because of this, the exergame Dino Radar may have had some weaknesses in the design process.

25.2 User Perception

This section presents the result from observations and interviews of the test participants' perception of the exergame Dino Radar.

25.2.1 Background

The test participants' background in video games and exercise were very similar. All of them spent at least 3 hours each day playing video games, and all of them except one exercised strength at least three times a week. None of them knew precisely the meaning of the term exergame, but some had an idea. All of the participants enjoyed playing the game Dino Radar, and all of them had at least played one exergame before the experiment, Pokémon

GO. Their reason for playing exergames was to gain physical benefits or to have fun. This shows us that the potential in exergames is vast. Combining games and exercise can give players a similar enjoyment as a regular video game while getting the same amount of activity as a daily exercise.

The background questions show us that exergame is not a familiar term among people, but it can be played by people who like video games and who do or do not exercise.

25.2.2 Gameplay

From the results of interviews and observations, exergames can give the same positive emotion as a regular video game. All the participants agreed that the game was fun, and enjoyed the different elements in the exergame. The biggest challenge of playing the exergame was understanding the game mechanics. Participants reported that the gameplay was more complex than the other exergames they knew. This was something we had assumed because we used the GameFlow framework and wanted the player's skill to improve with gradually increasing difficulty on levels steadily.

The players played the game very similarly, but their pattern on achieving their goals differed. Most of them concentrated on clearing all the levels, while one of the participants focused on items and achievements. All of the levels that they managed to complete were replayed to collect more Dino Coins. Replaying the same level did not discourage them as their motivation to buy an item held them ongoing. The players chose different items to clear the levels. The people who were using Hourglass and Fog struggled to complete level 4. These power-ups were useful at earlier levels. This finding suggests that the items need more balancing, as the Portal was significantly more potent than the other power-ups. The participants who bought the Fog and Hourglass might have been discouraged as they were struggling much more than the ones who purchased the Portal.

Regarding immersion in the game, the players' response to the game's fantasy was mixed, as their perception of the dinosaurs differed. One participant mentioned the movie Jurassic Park, which made the participant think about the dinosaurs from the film while playing the game, and, therefore, might have had a more significant effect on the fantasy. Better immersion is one of the categories of GameFlow (See Section 10.3). Personal differences in how

immersed can explain the different degrees of immersion they become in fantasy. The participants suggested improving the graphics in the game while others suggested introducing augmented reality to get more people immersed in the imagination.

25.2.3 Physical aspect

The game Dino Radar promoted players cardio exercise by motivating them to run away from dinosaurs in the game Dino Radar. From the observations, it was clear that the players got a lot of physical activity by looking at their body language of the breath and sweat. They also took some breaks during the game to rest up their energy. In the interviews, they all responded that the game gave an intensive workout session. We had also collected some data on the number of steps from three of the players (see Section 23.2.8). The data shows that all of them had at least 4000 steps from the play session, and one of them had an average BPM of 108 beats/second. The number of steps gained of playing the game covers more than half of the recommended steps, as a study by *JAMA Internal Medicine* found that taking 7500 steps/day are sufficient enough to reduce certain health conditions [92]. Even though they were exhausted after playing the game, all of the players enjoyed playing Dino Radar. This finding shows us the potential of physical benefits an exergame can provide. By playing the game for an hour covers almost half of the recommended number of steps.

All of the players responded that they tried to push themselves during the playtesting. The reason was their wish to complete the levels. This finding is an important factor when exercising. As the performance in exercise increases, the results from exercising does also increase.

When asking players to compare the exergame with other exercises, they mentioned that the game was quite similar to a long-distance run, and two of them said it also could be an interval run. All the participants exercised at least once a week. Only one of them performed cardio exercise as the others felt this kind of training was boring. When asking the players if they could replace a workout session with playing the game, many of them were enthusiastic to try new content and updates. For this reason, games such as Dino Radar has the potential to promote cardio exercise enjoyably.

25.2.4 Motivation aspect

The player's goal in the game was clear, to complete the levels in the game. All followed the primary purpose of the game, which was clearing the levels. Some participants were interested in the sub-goals of unlocking items and achievements, while others focused more on the main goal. The process of achieving these goals were mainly the same. They started first to clear levels, then unlocking achievements and items. There was one participant that had a different order of obtaining the goals. The participant started with unlocking achievements as the primary goal, and had sub-goals like completing levels and getting an item, as necessary to unlock one of the achievements. Therefore, playing the game can be different depending on the motives of a player.

25.2.5 Enjoyment aspect

From *Tom Malone's theory on intrinsic motivation*, players can obtain enjoyment from curiosity, challenge, or fantasy. To be enjoyable from curiosity, Malone states that games should have an optimal level of information complexity to be enjoyable. Thus, players will become curious and interested in learning the game. During the game, players were curious about the levels, dinosaurs, and items, and did not entirely figure out how they worked in the gameplay session. This curiosity might have encouraged them to play more to learn more about the game.

The observations and interviews also showed us that players could achieve enjoyment in other ways than curiosity, which were self-esteem and clear goals. Thus, the findings show that exergames can be enjoyable in the same way as a regular video game.

25.2.6 Engagement aspect

On the aspect of engagement, the results were mixed. From the observations, the participants were engaged from playing the game due to their mindset of clearing their goals. The players pushed themselves as they were running to beat the dinosaurs. Some of the players got engaged by the soundscape as when the dinosaurs appeared closer, they stressed out and increased their running speed. The participants were mostly favorable to the sounds and vi-

bration in the game, providing feedback, and understood that the dinosaurs got louder if they were closer.

On the interview, some players felt like they had low *control* when first starting out playing the game. The game forced them to run in one direction, and it was difficult to tell direction as they were not familiar with the game mechanic as some players thought the red pointing-line in the compass was the running direction. Consequently, some of the players became a bit discouraged. After playing the game for a while, they felt more in control of the game, resulting in different playstyle. Players used different strategies to complete the levels, buy different power-ups, and choose different routes, consistent with the criteria of control in GameFlow. The finding shows that engagement in exergames works in the same way as a regular video game.

25.2.7 Technical aspect

Using smartphones to exergames worked well during the playtesting. None of the players dropped the smartphones or had problems with holding the smartphone while running. The most crucial sensor was the GPS that worked well on all of the devices on the playtesting. None of the test participants questioned the GPS while playing as they saw no issues with the GPS. However, the use of the magnetometer to help players to locate directions had some problems and was device-specific. One of the participants had their north direction changed while running away from the dinosaurs. At the same time, another participant also had an issue with the magnetometer as the participant used a phone cover made of magnet. A solution to this problem could have been implementing a graphical user interface with a map feature displaying the player's location, such as Pokémon Go or adding trails of the players in the game.

Even though the GPS was inaccurate as it had an inaccurate measurement that was not discovered by the players, the most challenging of the technological aspect was the physical objects like buildings. Physical obstacles increased the player's awareness of their surroundings, as the dinosaurs did not have to worry about them, while the players had to. This issue goes against the GameFlow framework, and may cause the players to feel less enjoyment. However, the issue could also increase the uncertainty of clearing the level, making the game more challenging and, thus, increasing satisfac-

tion.

25.2.8 Future aspect

As this game was a prototype, many of the suggestions for improvements were expected, like adding more levels, achievements, and items. We also expected that the participants suggested the user interface should be more intuitive and have better graphics, as this was also not thought of as critical functionality when making the prototype. Changing the reward system of the Dino Coins was a great addition. Awarding Dino Coins based on distance traveled (which the game already measures due to achievement tracking) regardless of surviving was a significant input, as this will prevent the player's self-esteem from decreasing when losing a level.

25.2.9 Validity and Reliability of the results

The validity and reliability of the results can be questioned as the participant recruitment was of opportunity sampling. Family members, acquaintances, and friends were used as test-participants to test the game. The results of this type of sampling method could have affected the results in a positive direction, as there are biases and effects from this sampling method (see Chapter 24).

Chapter 26

Conclusion

The thesis is a continuation of the specialization project we conducted in autumn 2019 to understand the exergame concept. We did a literature review of existing exergames, technologies, and game engagement. We tested technologies and investigated game design frameworks to understand how our game could track body-motions and figure out how the game could be enjoyable. All these findings acquired from the specialization project have been applied in this thesis to create our own exergame *Dino Radar*. The goal of this thesis was to investigate the physical impact and enjoyment of an exergame in measuring the quality of the game and evaluating different aspects. The result of the process has given us answers to our research questions:

RQ1: What is the physical effect of playing a location-aware exergame?
To address this question, we conducted a prestudy to learn about exergames, which was later applied to create our exergame Dino Radar. Then, we carried out user testings of the exergame to assess the physical impact of the gameplay. The tests showed us that the game was physically intensive and comparable to running exercise. Data measured from some of the test participants was the number of steps and BPM. The number of steps showed that the participants who measured their steps acquired at least 4000 steps from playing the game after 45 minutes. Besides, one participant had a BPM average on 105 BPM with a top peak of 168 BPM. Even though the data was roughly estimated, the data from the playtesting shows that the gameplay has high physical intensity.

RQ2: How is the player's motivation affected of playing a location-aware exergame?
In the prestudy (Part II), we discussed theories about how players could be motivated to play exergames. The solution was to implement features in the game to utilize internal rewards to encourage players. In Dino Radar, this

was included through implementing multiple levels, achievements, items, and dinosaurs. The feedback from observation and interview revealed that the players were motivated in different ways from playing the game, with the primary motivating factor being to unlock more levels, as the players were curious to what dinosaurs would be on the next level. Other factors that affected the player's motivation was to be able to buy power-ups in the shop, and unlock achievements. Buying power-ups was a motivation to help the players to clear challenging levels, and unlocking achievements was a motivation for the players' self-esteem.

RQ3: How is the player's enjoyment affected of playing a location-aware exergame?

From the prestudy, the game design frameworks *GameFlow* and *DualFlow* were investigated as it was a design tool to measure and evaluate the enjoyment of a game. Therefore, we implemented elements of flow through our exergame Dino Radar to offer players satisfaction in playing. As a result, the players from the playtesting enjoyed exercising while playing our exergame to some extent. The players had clear goals, and the game was challenging as the players' skills improved during the game. Some players were not able to complete some levels on the first attempt, but after re-attempting the levels, they managed to complete it. The players' concentration and immersion were a bit weak due to their awareness of their surroundings and passersby. However, all the players enjoyed playing the game even though some of the game elements related to flow were weak.

RQ4: How is the player's engagement affected of playing a location-aware exergame?

In the prestudy, we investigated Thomas Malone's framework of games and engagement. We found that the elements challenge, curiosity, and fantasy were essentials in games to provide player engagement in games. This made us implement game mechanics and visual and sound effects to ensure engagement. The result from the playtesting was that most of the players were engaged in playing Dino Radar. They were particularly engaged when trying to run away from dinosaurs. The players pushed themselves when dinosaurs were nearby, and became stressed when they started to hear roars from the dinosaurs, indicating that the players were in danger. This warning from the sounds made the players' pace increase when escaping from the dinosaurs. Another element from the game that engaged the players were the items.

The players became engaged when they were able to buy power-ups because of their curiosity by trying to figure out what the power-ups did. On the other hand, they were less engaged with the fantasy and the player control in the game.

RQ5: How does the gameplay affect the game experience of playing a location-aware exergame?
The feedback from the playtesting showed that the gameplay has an impact on the game experience of playing a location-aware exergame. Regardless of the aspects that positively influenced the exergame Dino Radar, the game was a little complicated and had game mechanics for which players did not have any experience. All of the players compared Dino Radar to Pokémon GO and imagined that the player's position would be updated like in the game Pokémon GO. Because of this expectation, some players became confused and a bit frustrated. This issue adversely impacted the user experience because it impacted both satisfaction and interaction.

RQ6: What are the challenges of playing a location-aware exergame?
From the development process and user testing, findings showed that sensors gave inaccurate measurements. The GPS had an inaccuracy up to 100m, and the magnetometer gave different values to the north direction on different devices. The players were unaware of the inaccurate GPS, but the challenge of using the magnetometer was more evident as the north pole changed during the playtesting for some users. Besides, playing a location-aware exergame required a lot of space, which causes players to have to play outdoors. The challenges that were found of playing outdoors were physical objects such as cars and buildings that became an obstacle to players.

To conclude this work, Dino Radar showed us the ability of exergames to promote physical exercise while enjoying the game experience. The Dino Radar game had a significant physical effect on the players, and there is potential that an exergame like Dino Radar can provide health benefits, by examining the gathered data from the experiment. An exergame that can be built with a perfect combination of exercise and fun play can have the potential to make people work out more, benefiting their health.

Chapter 27

Further Work

Testing the application on iOS to include iOS users would be the next step of this project. Dino Radar is a cross-platform application and should, therefore, work on iOS. Making the game available on iOS makes it easier to reach out to a broader target group and test on a more extensive and more representative group of users.

Games have always room for improvements, and there are no limitations of creativity or updates. Updates that are possible to improve the exergame are:

- Improve the graphics and animation of the game
- Add more levels in the game
- Reduce the complexity to make it easier for elders and kids
- Award Dino Coins for distance traveled
- Add more items in the shop
- Balance the items
- Add more ambient sound and sound effects in the game
- Use an online server to save the game state to protect data if the data is lost locally
- Add user registration
- Deploy multiplayer mode
- Score tracking in the game for both singleplayer and multiplayer
- Adjust mathematical variables in the game to make sensors more accurate

The list of possible updates is extensive, with no limits. Implementing the updates would be time-consuming and requires a lot of testing to ensure the compatibility of the new features. We think that implementing new features and make the sensors more accurate would improve the game vastly. However, the game itself is not only that can be developed, but also a new and improved experimental study of the game:

- More testing conducted on a broader and representative sampling group
- Random sampling
- Quantitative data of testing to generate data to usable statistic
- Measurement on the cardiovascular output or heartbeat to measure the physical effect

Combining this new research with the proposed changes would produce new data findings that would be more reliable on the user satisfaction and the physical effect.

Appendix A

Dino Radar User Manual

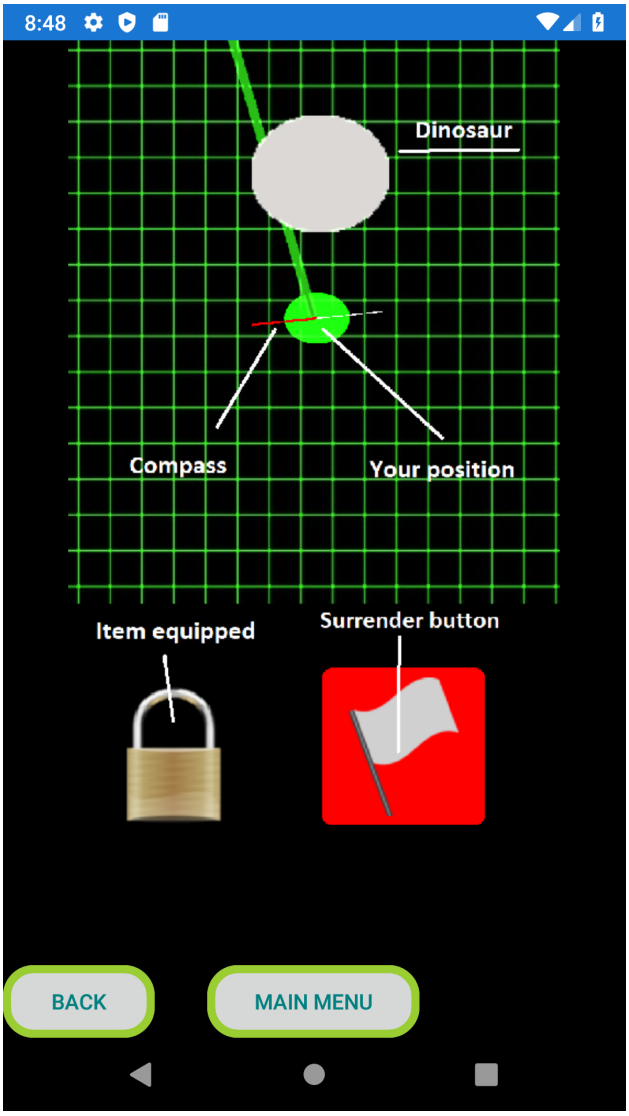

Figure A.1: Help View in the game

Dino Radar is an exergame that promotes physical activity through cardio exercise.

The Genre of the game is a location-aware game. This includes physical movement in the real world is tracked and mapped to the game.

The Green Circle is your position in the game and displays your distance from the dinosaurs, as illustrated in Figure A.1.

A Compass is located at the center of your position. This compass helps you with the moving direction. Moving north, south, east, west in the real world equals upwards, downwards, right, left on the screen of the phone.

The Game consists of multiple levels. Each level consists of different dinosaurs, and the player is rewarded with Dino Coins if the player wins or loses. The view in a game session can be divided into two parts. The half lower consist of buttons that a player can interact with. The red button is pressed if the player wants to surrender, and the other button is the equipped item. If there is a padlock icon that is displayed, it means the player has no item equipped. No actions are executed if this button is pressed while the padlock is displayed.

The other half in the game view is the game scene of the game where all dinosaurs and the player's distance from the dinosaurs are displayed. Levels in the game varies. The time duration, type of dinosaur, the dinosaur's attributes varies.

Achievements in the game can be seen on the achievement page. Each achievement is different and can be achieved by completing the criteria.

The Shop displays available items that can be bought. Items are bought with Dino Coins that can be achieved by playing levels.

Appendix B

Infection control measures - COVID-19

Due to the Covid-19 outbreak in March, the Norwegian government carried out infection control measures to mitigate the outbreak. Some of the measures that were taken into account from the government are:

- Good hand hygiene and cleaning
- Isolation
- Physical distance from others
- Cancellation of event and gatherings
- Reduce traveling
- Reduce contact frequency

Additionally, the Norwegian society was encouraged to stay at home and avoid social interaction outside their home to help the society stop the epidemy. More about the infection control measure can be read at [93].

Appendix C

Originally Experiment

In addition to research methods that are described in Chapter 20, we also planned to do a quantitative research of the data collection. The strengths of quantitative research is generating a lot of data and get a wide sample of test results. The method we planned to conduct included experimental research on around 20-30 individuals and execute a questionnaire/survey and measuring heartbeats of the individuals before and after the test to analyze the results. But due to the Covid-19 outbreak, we decided to restrict our experiment to 5-7 individuals and discard the idea of measuring heartbeats as the test individuals would have had to equip an activity tracker used by others. Therefore we focused on gathering qualitative data instead of quantitative.

Appendix D

Invitation to Research Participation

[NAME] You are invited by Håkon Arnø Hoff and Quit Phuong Bui to participate in the experiment for our master thesis about exergames. Research data will not be traced back to you in any way.

The time slot for the experiment is [DATE AND TIME] at [PLACE]. Before the test, you need to:

1. Download the game at `https://play.google.com/store/apps/details?id=com.companyname.dinomasterthesis4`
2. Show up in exercises clothes
3. Keep your phone charged and attach a sim card

Make sure to follow the health directory's recommendations of social distance (minimum 2 meters) [94].

In the experiment, you will be encouraged to play the game. You can quit at any time. We will make some observations. Afterward, you will be interviewed.

Appendix E

Test Participant Agreement

This document is a participant agreement between the test holders and the test subject.

The purpose of this study is to investigate the physical effect and engagement of the exergame Dino Radar. The game that is being tested is made by *Quit Phuong Bui* and *Håkon Arnø Hoff*. This study is a part of a master's thesis (*TDT4900*) at the institute of data science and information technology *IDI* at the Norwegian University of Science and Technology.

The process of this study will consist of playing the game Dino Radar at a location agreed between the testers and the participant. During the test, the test holders will observe the participants if possible. Later, an interview of the participant will be conducted. The whole process will take around 30-60 minutes.

The data that is collected is anonymous and used for research purposes in the master's thesis.

The participant is free to participate in the study and can abandon the study whenever he or she wants without permission.

I have read and agree to participate in the study

Signature *Location, Date*

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