Master's thesis

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

Christian Magnus Rand
Sander Kaalaas Østvik

2D Boss Fighter Exergame

The creation and evaluation of an exercise bike game to increase motivation for physical activity

Master's thesis in Computer Science
Supervisor: Alf Inge Wang
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Sammendrag

Fedme og overvekt er et økende problem i verden i dag og fører med seg en økt risiko for helseproblemer, samt enorme kostnader for land verden over. Antallet overvektige har doblet seg siden 1980, og en økning i antallet med en stillesittende livsstil har blitt utpekt som en del av årsaken. Treningsspill (exergames) har potensiale til å redusere tiden man sitter stille ved å kombinere det morsomme ved dataspill med elementer av fysisk aktivitet. Til tross for potensialet finnes det få treningsspill i dag som lykkes med å øke spillernes fysiske aktivitetsnivå over lenger tid.

I denne oppgaven har et treningsspill blitt designet og utviklet med mål om å øke det fysiske aktivitetsnivået blant personer som vanligvis ikke er motivert til å bedrive fysisk aktivitet. Et forstudie ble først gjennomført, der treningsspill, trening og spilldesign ble utforsket. Denne kunnskapen ble så brukt til å komme opp med et spillkonsept som kan spilles på en ergometersykkel. Konseptet ble så videreutviklet og den resulterende spillprototypen er en samarbeidsbasert 2D plattform-skytespill som tar i bruk spillmekanikker som ikke har blitt testet på Playpulse-plattformen tidligere.

Prototypen ble testet i et eksperiment med 13 personer. Testdeltakerne spilte spillet tre ganger, og data angående deres glede, engasjement og motivasjon ble samlet inn. Treningseffekten av spillet ble også vurdert i eksperimentet. Resultatene ble samlet inn gjennom spørreskjemaer, observasjoner, intervjuer og bruk av pulsmålere.

Resultatene viser at spillet er gøy og engasjerende, og at å spille spillet kan sammenlignes med å gjennomføre utholdenhetstrening med moderat til høy intensitet. Spillet lykkes derimot ikke med å motivere spillerne til å bli mer fysisk aktive. Spillets 2D-perspektiv og nytenkende kobling mellom fysisk tråkking og skytefunksjonalitet i spillet ble godt mottatt blant testdeltakerne, og kan regnes som vellykkede mekanikker for et spill på Playpulse-plattformen. Resultatene kan samtidig ikke generaliseres og brukes til å si noe om andre deler av befolkningen ettersom vår gruppe med testdeltakere bestod av få personer og inneholdt lite variasjon. Noen interessante tendenser ble likevel oppdaget blant resultatene. Hvis dette arbeidet skal videreføres bør spillet testes på en større mengde og også videreutvikles. Det kan også være interessant å undersøke om spillet har potensial til å kommersialiseres.

Abstract

Obesity and overweight are increasing problems in our world today, leading to higher risks of several diseases and huge costs for countries all over the globe. The number of overweight people has doubled since 1980, with an increase in sedentary lifestyles being identified as one of the causes. Exergames have the potential to combat the sedentary lifestyle by using the enjoyment of playing video games and combining it with elements of physical activity. Despite the potential, few exergames have managed to increase the physical activity amongst their players in the long term.

Through this thesis, an exergame has been designed and developed with the goal of increasing the physical activity levels of people who normally lack the motivation to exercise. First, a pre-study was conducted, exploring the realm of exergames, exercise and game design. This knowledge was used to decide on a game concept to be further developed and played on an exercise bike. The resulting game prototype is a cooperative 2D platform shooter which includes new mechanics not previously tested on the Playpulse platform.

The prototype was tested in an experiment with 13 people. Participants played the game three times, and their enjoyment, engagement and motivation were examined, along with the physical effect of playing the game. Results were gathered through the use of questionnaires, observations, interviews, and heart rate monitors.

The results show that the game is enjoyable and engaging and that playing it corresponds to performing aerobic exercise with moderate to vigorous intensity. However, the game does not succeed in motivating its players into being more physically active. Both the 2D perspective of the game and the novel way of mapping pedalling to in-game functionality were well received and deemed fit for the platform. The results can not be applied to a broader audience due to the limited size and lack of diversity in our test population. However, they show some interesting tendencies. For future research, the game should be tested on a broader audience and developed further. Checking possibilities for commercialisation could also prove interesting.

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PART I

INTRODUCTION

This part provides context and motivation for the project and serves as an introduction to the upcoming work. The research questions, goal, and methodology are also presented. The motivation and project and context sections contain some of the same content as in our specialisation project report [22], as they are based on the same task.

1 Motivation

The world is facing an increasing problem of obesity and overweight amongst its inhabitants. Since 1980, the amount of obese and overweight children and adults have doubled [23]. Obesity is problematic as it is associated with a higher risk of cardiovascular diseases, type 2 diabetes, several cancers, and many musculoskeletal disorders [23]. Beyond the health threats, obesity and overweight lead to huge medical costs for countries around the globe. It was estimated in 2012 that obesity-related medical costs exceed $209 billion annually in the United States [24]. An analytical report from 2019 estimated obesity-related costs to the society in Norway to be around 70 billion NOK annually [25]. A factor that has been linked to the rapid rise in obesity and overweight is the sedentary lifestyle many people have these days, where time spent on sedentary activities like playing video games and watching television averages eight hours a day amongst children and adolescents [26].

A possible part of the solution to reduce the time spent on sedentary activities, thus reducing obesity, is exergames. Exergames are video games that require the player to exercise or perform lighter physical activity while playing. This could make them suitable for people with sedentary lifestyles, especially those already familiar with video games, as they could continue to play video games while also increasing their physical activity levels. However, for the physical activity to provide health benefits, it should be performed at the right intensity and for the right duration, preferably several times during the week [27]. Unfortunately, few exergames manage to meet these requirements. Therefore, the challenge is to create an exergame, fun and engaging enough to motivate the player to keep playing the game regularly.

Looking beyond the public interest of making exergames to help battle obesity and sedentary lifestyles, we also have a personal motivation that will drive us throughout this project. We have both been interested in video games for most of our lives, and during our later years at university, we have also started looking into the making and development of games. To be able to design and develop a game over the course of our master's thesis and learn a lot about game development along the way is, therefore, very interesting to us. It gets even more appealing when we can make a game that serves a greater purpose through activating people with sedentary lifestyles. We recognise ourselves in the situation of lacking the motivation to exercise, but we also enjoy the good feeling you get after you are done exercising. Building a game that motivates people to be more physically active therefore seems like an interesting challenge.

2 Project and Context

The task given for this project is:

[ExerGames] Multi-player pedal-game *The goal of this project is to design and develop new game concepts for a game where an exercise bike is used as a game controller in addition to traditional game input through multiple buttons. In addition to input from buttons, the player should control the game through using her/his feet moving the pedals. The goal of the game is to both to have fun that can last over time as well as getting a physical exercise. The game should be implemented in Unity using a provided API for the exercise bike controller.*

This project and report constitute the master's thesis of the authors. The project is a continuation of the specialisation project done in the autumn of 2020 by the same authors [22]. The specialisation project consisted of a pre-study within the field of exergames and game design, and also presented a game concept. This game concept has been further developed and evaluated in this project. This report contains some of the written content previously presented in the specialisation project report. While adjustments have been made, most of the text in Part II, except for Section 8, have been gathered from the specialisation project report. In Part III, Section 15, Section 16, Section 17 and Section 18 has content that is based on some of the text found in the specialisation project report also.

The game presented in this report has been designed and developed to be played on an exergame platform called Playpulse. Playpulse began as a master's thesis project at NTNU, where two students put sensors, buttons and a screen on an exercise bike and made a game for it [28]. This has over the years been developed into a commercialized product and company.[1] An early version of the platform can be found at NTNU, campus Gløshaugen, which makes it possible to develop and test games for the platform. The easy access to hardware makes Playpulse a feasible choice of platform when making an exergame as part of a master's thesis.

The project took place during the Covid-19 pandemic. This had implications on the experiment design and the recruitment of participants for testing the game. Further details of the impact can be found in Section 21.

This task and research is part of the Game Technology for Health (GT4H) Network. As stated on their website the GT4H Network *"brings together knowledge and expertise about serious gaming for health benefits from different research groups across Departments and Faculties at NTNU. The aim of the network is to connect researchers and professionals both within and outside NTNU that develop or use game technology for health, in order to deliver high quality research and advance our knowledge at the best value possible"*.[2]

[1] https://playpulse.com/
[2] https://www.ntnu.edu/health/gt4h

3 Research Questions and Method

This section presents our research questions and the method we followed while doing the research for this thesis. Based on the given task presented in Section 2, we started by identifying a research goal which we then decomposed into several questions. These questions, along with the method shaped the rest of our research, which is presented throughout this report.

3.1 Research goal and research questions

Research goal: The goal of this thesis is to develop and evaluate a fun and engaging exergame with replay value for the Playpulse platform, for people that normally lack motivation to exercise, so that they increase their activity levels.

This goal has several implications for the design, development and testing of our exergame. Before even planning the design of the game, we will have to look into what constitutes a good exergame. After the game is made, we will have to look specifically at how fun, engaging, and physically exerting the game is. Lastly, we will have to check whether the game succeeds in increasing people's motivation to exercise. As such, our research goal was therefore decomposed into the following research questions:

RQ1: *Which methods and frameworks can be used to make an exergame fun and engaging?*
To make a game with great replayability, we have to make a game that is fun enough so that the player enjoys playing it. The nature of the gameplay must also be able to draw the attention of the player and make them engaged in the game. To achieve this, we will study existing theory on game design to identify methods and frameworks that can aid us in creating a fun and engaging exergame experience.

RQ2: *Which types of games are fitting for the Playpulse platform?*
When playing on the Playpulse platform, you are playing a game using an exercise bike. This requires us to think a bit differently when it comes to choosing our exergame concept. The Playpulse platform might have special requirements and limitations for which types of exercise, intensity levels and game genres that are suited for the platform. We will have to look into these aspects of the platform, to help us make an informed decision on which game concept to choose and further develop as a prototype.

RQ3: *What game concept on the Playpulse platform has the potential to motivate people to become more physically active and engaged?*
To answer this research question, we will have to look to the answers of RQ1 and RQ2 and combine the findings into one game concept that we believe will be fun and engaging and that will motivate the player to become more physically active. The game concept will then be further developed into a prototype game and tested with people.

RQ4: *How does our game affect the enjoyment of the player?*
For the game to make the player motivated to be physically active, the game should provide the player with a positive experience while playing. As a fundamental part of this, the game should be enjoyable to play. In the experiment, people will play our game and we will look closely at how the player enjoys the game.

> **RQ4.1:** *How does the amount of time spent on playing games affect the player's enjoyment of playing our game?*
> It is interesting to see whether a person's videogame background will impact their experience with this game. This subquestion will therefore look into how a person's experience and interest in video games affect their enjoyment of playing the game.
>
> **RQ4.2:** *How does the amount of time spent on exercise affect the player's enjoyment of playing our game?*
> It is interesting to see whether a person's exercise background will impact their experience

with this game. This subquestion will therefore look into how a person's habits of exercising affect their enjoyment of playing the game.

RQ5: *How does our game affect the engagement of the player?*
For the game to have replayability and for the player to give enough effort to receive health benefits by playing regularly, the game should be engaging. In the experiment, people will play our game and we will look closely at how engaged the player is while playing the game.

RQ5.1: *How does the amount of time spent on playing games affect the player's engagement when playing our game?*
This subquestion will look into how a person's experience and interest in video games affect their engagement when playing the game.

RQ5.2: *How does the amount of time spent on exercise affect the player's engagement when playing our game?*
This subquestion will look into how a person's habits of exercising affect their engagement in playing the game.

RQ6: *Does our game motivate players to become more active?*
This research question looks at the essence of our research goal, which is to motivate people that normally lack motivation to exercise. To answer this question, we will gather responses during our experiment to see how the game impacts the motivation of the people from the test population. We will also look at the game as a whole to determine if it has the potential to motivate people outside of the test population into becoming more active.

RQ6.1: *Can playing our game be considered exercise?*
For a game to be an exergame, it needs to have an aspect of exercise. Whether this game works as an introduction to exercise, or helps people increase their activity levels by playing this game over a longer time period, it is important that playing a session of this game can be considered exercise. To answer this, people will be monitored while playing, to get data on their heart rate, and will also be asked questions about their impressions of how exerting the game is.

RQ6.2: *How does the amount of time spent on playing games affect the player's motivation to become more active after playing our concept game?*
This subquestion will look into how a person's experience and interest in video games affect their motivation to become more active after playing the game.

RQ6.3: *How does the amount of time spent on exercise affect the player's motivation to become more active after playing our concept game?*
This subquestion will look into how a person's habits of exercising affect their motivation to become more active after playing the game.

3.2 Research method

This thesis follows a model of the research process that has been adapted from Briony J. Oates' *Researching Information Systems and Computing* [1]. The model of the process, where the specific parts used in our research have been highlighted, can be seen in Figure 1. The individual parts that make up our research method will now be explained in further detail.

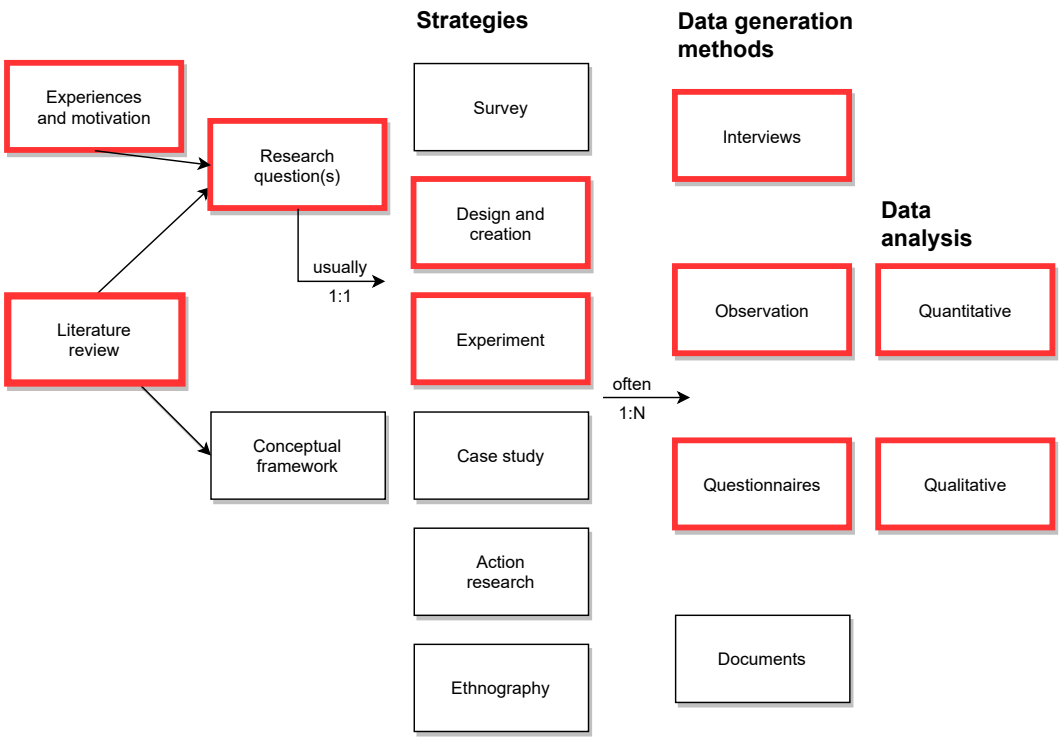


Figure 1: Model of the Oates Research Process, adapted from Figure 3.1 in *Researching Information Systems and Computing* [1]. The red outlines highlight the parts of the research process that are used in this thesis.

Experiences and Motivation: A researcher's experiences, interests and motivations are fundamental when it comes to choosing what to research. Their interest within a field and their motivation to solve a problem and contribute with something new are what drives them to do research.

For the authors of this thesis, a great deal of the motivation to do research comes from the fact that it is mandatory to write a master's thesis to finish our education. Furthermore, as described in Section 1, this specific task was selected due to the authors' interest in video games, and their curiosity about contributing new ideas to the field of exergames.

Literature review: A literature review consists of gathering and reading existing work that has been done within the chosen topic. It serves to study and identify the strengths, weaknesses, and gaps in previous work, and to place our work in context of what has already been done. It is also used to gather useful theories and methods, and build a bibliography that can be applied in the upcoming part of the research [29].

In our work, the literature review was conducted both to gather knowledge on what had previously been done within the field of exergames, and where there could be room for us to contribute with something new. It also brings light to useful methods and frameworks for designing fun and engaging exergames. The contents of our literature review are presented in Part II.

Research Questions: A research question either fully or partly represents the goal of a research. Motivated by real-world practical problems, the research questions are focused on specific topics where the researchers want to contribute with new knowledge during the research. Research questions are selected based on the experiences and motivations of the researchers, and often after an initial literature review, where it has been established what is already known within a field, and where there is a need for new knowledge and further research.

The research goal of this thesis was chosen as a combination of the given master's thesis task, the authors' interests in creating an enjoyable game, and the state of current exergames; there seemed to be room for more games targeted at people that normally lack the motivation to exercise. The

research questions were then derived from the chosen goal, and designed to give us further insight into specific exergame-aspects like enjoyment, engagement, motivation, as well as the impact of the players' background within exercise and video games. A presentation of the research questions is found in Section 3.1.

Design and Creation: Design and creation are one of six strategies from the Oates Research Process, serving as an overall approach to finding answers to the research questions. This strategy focuses on developing new artefacts that contribute to the field. The artifacts can either be *constructs* or *models*, presenting new vocabulary for explaining some phenomena within an IT-related domain, *methods* that describes processes or steps for solving problems, or *instantiations*, fully working systems used to demonstrate whether the underlying models and methods work [1, Chapter 8]. This strategy not only produces an artefact as output but also requires the development process to be documented, giving readers insight into the process.

To answer some of our research questions, and since it was also mentioned in the task, it was clear that we needed to develop a game prototype as part of our thesis. This corresponds with the design and creation strategy, where an instantiation artefact will be part of the outcome of the research.

Experiment: Experiment is another strategy from Oates' model. Experiments are investigating cause and effect relationships, and are performed in a controlled environment, like a laboratory, where you start with a hypothesis and aim to prove or disprove that hypothesis during the experiment. Experiments performed outside of the laboratory, in real-life settings where not all variables are as easily controlled, are called quasi-experiments [1, Chapter 9].

In our case, it is also clear that merely developing the game prototype will not be enough, as it will not help answer our research questions. The prototype also needs testing on real people, and therefore a quasi-experiment needs to be conducted. To read more about the experiment, see Section 21.

Interviews: Interviews are one of the data generation methods in Oates' model. An interview is a special type of conversation where one party is asking questions while another party is answering them. In Oates' model, interviews are a source for qualitative data, where a researcher will control the content and direction of the conversation and ask most of the questions. An interview can be conducted one-to-one or in groups [1, Chapter 13].

As a part of the experiment, we will conduct interviews with the participants to get their reactions and opinions about our game after they have played it.

Observation: Observation is a data generation method where participants are being watched and notes are being made of what they are doing. This is done to not only get a report from the participant about what they thought they were doing but to have an objective set of eyes more thoroughly report what was done. Using observation as a data generation method can help increase the validity of the study, as the researchers might get a better understanding of the context under which a phenomenon is being studied [30].

In our experiment, we will observe the participants and make notes of their reactions and expressions while they play, to collect data on how they are affected by the game while playing.

Questionnaires: A questionnaire is a pre-determined set of questions given to a respondent in a pre-determined order for them to answer. Depending on the question, answers are often given through text, via multiple choice, or through ticking off on scales reflecting the respondent's feelings and opinions. Questionnaires are mainly a source for quantitative data that the researchers can further analyse and interpret [1, Chapter 15].

We will use questionnaires as a data generation method to systematically gather answers from the participants and to collect their views and experiences on several aspects related to the game. Presenting all participants with the same questions allows for comparisons to be made of the answers.

Quantitative data analysis: The data collected from the data generation methods need to be analysed, to look for patterns in the data which can then be used to draw conclusions. Based

on the type of data received, this can be done in one of two ways. Quantitative data analysis is used when the data consist of numbers. Numbers gathered from questionnaires and usage logs are organized and presented in tables and charts, often after statistical techniques have been applied.

The questionnaires we use as a data collection method will produce a lot of numbers. We also plan to measure the participants' heart rate while they are playing, and that will also generate a lot of numerical data. As a result, we will have to use quantitative data analysis when looking for patterns within these data.

Qualitative data analysis: When the collected data consist of text or other media, there is a larger need for the researcher to interpret the meaning of the data beyond applying statistical techniques. Researchers will have to study the qualitative data and look for themes and patterns that are of relevance to the research.

For our thesis, we will have to perform qualitative data analysis on the qualitative data collected from the observations and interviews we will conduct as part of the playtesting of our game.

4 Report Outline

This report consists of seven parts, with a total of 37 sections.

Part I introduces the authors' motivation behind selecting and researching the topic of exergames. It further contains a description of the project and the context in which it takes place, along with the research goal, questions and methodology used for this project.

Part II contains a literature review on exercise theory, enjoyment and engagement within games, as well as the concept of exergames itself. It further contains an overview of relevant technologies within the field and previous exergames, before it closes out with a look at different game genres and a discussion on possible game concepts to further develop. This part is meant to gather useful theory and knowledge that can be applied during the game design process.

Part III presents the game design of the chosen concept in great detail. All the features and aspects of the game can be found here, and reasoning for the design choices are provided, anchored in the theory from Part II. The development process and software architecture can also be read about in this part.

Part IV covers the design and execution of the experiment, the data collection methods, and the aspects of the experiments that could affect the reliability and validity of the results.

Part V contains the results from the experiment. The results from the four data collection methods are presented, from respectively questionnaires, observations, interviews, and heart rate monitors.

Part VI consists of the discussion of the results and how different findings can relate to the research questions. To fit the research questions, the discussion is structured within the topics of enjoyment, engagement, physical benefits, motivation for physical activity and impact of gaming and exercise background. The part ends with a discussion of the project and technology used in this project.

Part VII is the last part and contains the conclusions, contributions and further work of the project.

PART II

PRE-STUDY

This pre-study was originally written during the autumn semester of 2020 for the specialisation part of this project [22]. It has been updated to fit this master's thesis but some content remains unchanged. The part presents applicable theory and previous findings within the realm of exergames and games in general. Relevant exercise theory is also included.

5 What Are Exergames?

Exercise games, or *exergames*, is not a new concept but has been around since the late '80s. The first commercial success came in 1998 with Konami's Dance Dance Revolution game, and a wide range of different exergames have been released since. In simple terms, an exergame is a video game that also functions as a form of exercise by having the player move their body to control the game.

The term "exergame" has been used to describe many types of games. In addition, people have described these exercise games with a handful of terms, like gamercising, exertainment, and fitness games, not just as "exergames". Thus, in 2010, Oh and Yang wrote a paper trying to unify this genre. Here, they give a more precise definition of what an exergame is. They came up with the following definition: "An exergame is a videogame that promotes (either via using or requiring) players' physical movements (exertion) that is generally more than sedentary and includes strength, balance, and flexibility activities. Exergaming is an experimental activity where playing exergames, videogames, or computer based is used to promote physical activity that is more than sedentary activities and also includes strength, balance, and flexibility activities" [31].

As the definition above states, the game needs to promote physical movement and elicit some exertion from the user. Still, the game does not have to be about exercise, nor does it need to be upfront about being an exergame. In Sinclair, Hingston and Masek's paper [32], they propose a Dual Flow model (see Section 7.3) when developing exergames. This model suggests that seamlessly integrating the exercise part of the exergames into the game's fun aspects will more likely lead to a successful exergame. Thus, it is clear that the "exercise" part in exergames primarily refers to the game's outcome, not the game itself.

6 Exercise Theory

For the players to achieve health benefits from playing an exergame, the type, intensity and amount of exercise that is performed when playing the game must be following some proper guidelines. The first decision that needs to be made is the type of exercise the player should perform when playing the game. According to Harvard Health Publishing, there exist four different categories of exercise. The categories are aerobic exercise, strength training, stretching and balance exercises [33]. In this task, we are going to develop a game for the Playpulse platform. While further explained in Section 11.5, Playpulse is an exercise bike with a screen and controllers in the handlebars. This automatically makes the choice of exercise category easy for us, as aerobic exercise is the only appropriate type of exercise to perform on an exercise bike. However, as aerobic exercise is a broad category, we will now look further into different types of aerobic exercise and the requirements for performing them correctly.

6.1 Aerobic exercise

Aerobic exercise, also known as endurance training, are activities aimed at improving breathing and heart rates. Examples of aerobic exercise are running (see Figure 2), cycling, and dancing. Through regularly performing aerobic exercise, you keep your heart, lungs, and circulatory system healthy [34]. As mentioned in our motivation (see Section 1), there is an increasing problem of obesity and overweight in the world today. Obese people have a higher risk of cardiovascular diseases, type 2 diabetes and several cancers. When performed regularly over the long term, aerobic exercise both helps reduce obesity, as people start exercising and improve their fitness, and it also reduces people's risk of heart disease, type 2 diabetes and breast and colon cancer [33].

The recommended amount of aerobic exercise is 150 minutes per week when performing moderate-intensity activities. This amount can be halved to 75 minutes if the exercise is of vigorous intensity. The 150 minutes can be spread into several workouts over the course of a week, but each of them should at least be 10 minutes long [27]. When a person is performing moderate-intensity exercise, their heart rate should be between 50 % to 70 % of their maximum heart rate. When performing vigorous-intensity exercise, the heart rate should be between 70 % and 85 % of their maximum heart rate.

Figure 2: Two women doing aerobic exercise through running [2].

6.1.1 High intensity interval training

High-intensity interval training (HIIT) is a form of aerobic exercise where you workout very intensely for a short period of time and then have a less intense period before you repeat the pattern several times. The demands for a HIIT is that during the intense intervals, you achieve a minimum heart rate of 80 % of max, and between the intervals, the heart rate should be below 70 %. Different set-ups of HIIT exist, but a common form is four intense intervals lasting 4 minutes each, with a 3 minutes less intense interval in between each intense one [35]. A study found that just performing one HIIT session of 23 minutes a week can give overweight people better health benefits than performing a 30 minutes long moderate-intensity workout three times per week [36].

6.1.2 Minimal threshold for health benefits and fat burn zone

For many people, especially those that are just starting with exercising, HIIT might be too demanding. It is therefore important to look at the other side of the scale and identify the lower intensity levels at which exercise can occur. In WHO's 2020 report on guidelines on physical activity, they write that performing physical activity, even of light intensity, instead of spending time being sedentary, provides health benefits [27]. According to the report, light-intensity physical activity includes slow walking and other activities that do not lead to a substantial increase in heart rate.

However, if the performed activity is of moderate intensity and the person keep increasing their heart rate until they reach around 60 % of maximal heart rate, they start to enter the fat burn zone, where the body taps into the fat stores for energy. This exercise will be more effective for losing weight than just performing light-intensity physical activity. A study tried to determine the maximal fat oxidation of people, which is the point of intensity where the body of the person is breaking down the most fatty acids. It was found that while there are individual differences, one can be quite certain that a person's maximal fat oxidation happens between 60.2 - 80 % of their maximal heart rate [37].

6.2 Measuring intensity level

To measure the intensity level of the exercise a person is performing, the person's maximum heart rate must be known. While the ideal way of finding the maximum heart rate is to have the person perform extremely exerting exercises and then measure the highest heart rate they achieved, there also exist several formulas for calculating the estimated maximum heart rate for a person. For this project, the formula by Nes et al. [38] has been selected. It is chosen as it has a smaller margin of error than some of the more commonly used formulas for estimating maximum heart rate [38]. The formula is given by $211 - 0,64 \cdot age$.

After the person's maximum heart rate is estimated, it is then possible to calculate the heart rate range that corresponds to a person's intensity level. As an example, take a 30-year-old person that wants to perform moderate-intensity exercise. The person's estimated maximum heart rate is $211 - 0,64 \cdot 30 = 191,8 \approx 192$ bpm. To stay at an intensity level between 50 % and 70 % of their maximum heart rate, they should therefore have a heart rate between 96 and 134 bpm while performing the exercise. A pulse watch or a pulse belt can be used to measure the person's heart rate during the exercise.

6.3 Summary

As we see, there exist several ways of performing aerobic exercise, and the amount that is needed per week depends on the goals of the person and the intensity and percentage of maximum heart rate that is achieved during the exercise. This is something we have to keep in mind when designing how much and how intense activity should take place when playing the game. A game that only demands moderate intensity when playing will have to be played for longer over the course of a

week, and the game sessions might need to be longer themselves or the player must be tempted to come back to the game often. If we aim for 75 minutes of vigorous-intensity exercise, it consequently needs to be played less each week. However, it becomes more important to come up with game mechanics that encourage the player to pedal fast for a long time. Similarly, for HIIT, the game also needs encouraging mechanics, but it also has to be put into thought how to create a mechanic that keeps the player's heart rate over 85 % of max for some short period of time. Some existing exergames have already focused on aerobic exercise and targeted different levels of intensity, like Pokemon Go, Pedal Tanks, Pedal Kart and Lane Rider. Section 12 will present these games, and they will be kept in mind when we later on brainstorm our exergame concepts.

7 Frameworks for Enjoyment in Games

If the player of our exergame is to get the desired health effects, the player needs to play often enough and for long enough sessions. It is therefore important to make the game highly enjoyable so that the player would want to keep playing the game regularly. Decades of research on video games has contributed with theories on enjoyment in games and identified different elements that could be put into the games to make them more fun.

This section presents some well established frameworks that are be useful when designing games, which are: GameFlow, Challenge, Fantasy and Curiosity, and Dual Flow.

7.1 GameFlow

GameFlow is a model that can be used to evaluate player enjoyment in games [39]. The model consists of eight elements that each comes with some criteria that need to be fulfilled in order to achieve enjoyment within a game. GameFlow is building upon a concept called flow and tailoring it for use in the context of games. We will therefore first present the flow concept before the eight elements of the GameFlow model is described.

In 1990, Mihaly Csikszentmihalyi presented his 20 year long study on the states of optimal experience. Through questionnaires and interviews with thousands of respondents, he tried to figure out what caused people to feel concentrated and to deeply enjoy something. He discovered a state of consciousness called flow, which he described as "a state of concentration so focused that it amounts to absolute absorption in an activity" [40]. To reach the state of flow, Csikszentmihalyi presented eight elements that need to be present when a person is performing a task:

1. We confront tasks we have a chance of completing.
2. We must be able to concentrate on what we are doing.
3. The task has clear goals.
4. The task provides immediate feedback.
5. One acts with deep, but effortless involvement, that removes from awareness the worries and frustrations from everyday life.
6. One exercises a sense of control over their actions.
7. Concern for the self disappears, yet, paradoxically the sense of self emerges stronger after the flow experience is over.
8. The sense of duration of time is altered.

Based on these eight elements, Sweetser and Wyeth created GameFlow [39], containing eight slightly altered elements that adapted the concept of flow to use it within the context of games:

7.1.1 Concentration

The first element of GameFlow is concentration. A game should require concentration to be played, and the player should also be able to concentrate on the game, meaning that the game should be able to quickly grab the attention of the player and keep that attention over time. For this to be achieved the game should provide lots of stimuli to the player. However, the stimulus also needs to be meaningful and worth paying attention to.

When trying to keep the player stimulated, by for example providing them with lots of tasks, it is important to maintain a good balance. The tasks help keep the player busy and engaged, but

it is important that the tasks feel meaningful and necessary. Failing to do this can produce the opposite of the wanted effect. Players should not be burdened with unimportant tasks and should be able to focus on the ones they want or need to concentrate on. A design choice that could help increase concentration is creating detailed game worlds while reducing the game interface. This helps draw the player into the game and frees them from having to focus on non-essential elements within the game.

7.1.2 Challenge

The second GameFlow element is challenge. Here, the essence is making the game feel challenging by matching the skill level of the player. As different players have different skill levels, the game should also provide different levels of challenge to cater for a broad audience. Furthermore, as players will likely get better at the game by playing it, the challenge in the game should also increase throughout time to match the player's level.

This increase in challenge is meant to keep the game fresh and make sure that it does not become too easy and repetitive over time. By increasing the difficulty of the tasks that the player is faced with, the player is kept on their toes and need to challenge themselves to progress further. This increases a player's satisfaction in a game, which comes from accomplishing difficult tasks and allowing them to test and master their skills to overcome challenges in the game [39].

7.1.3 Player skills

The element of player skills is concerned with how the game supports the player in developing and mastering their skills. To experience flow, the player must feel that their skills are matching the challenge of the game. When playing a game for the first time, the game must facilitate the learning of necessary skills to succeed in the game. Then, over time, the player should be rewarded for developing their skills, making them motivated to keep improving. Some advantageous design choices are to use an interactive tutorial and easy to learn mechanics and interfaces, as well as providing online help that the player can access outside of the game.

7.1.4 Control

When playing a game, the players should feel that they are in control over their actions in the game and they should be able to control both the character's movements and interactions. Furthermore, they should feel a sense of control over the input devices of the game and of mechanics like pausing, starting and saving the game. Another aspect of giving the player the feeling of control is through making sure that they can not perform actions that are damaging to the game, and also that if they make mistakes, they should be supported in recovering from them.

It is also important that the player feels that they are in control of the game world, in a way that their actions matters and shapes the game world. The linear nature of many games should be hidden, giving the player the opportunity to play the game the way they want. By allowing experimentation and freedom the game makes the players more emotionally immersed in the world. A sentence nicely summing up the element of control is "the player should feel like they are playing the game, not being played by it" [39].

7.1.5 Clear goals

Games must have an object or goal in order to feel meaningful, but to achieve a state of flow while playing, it is also necessary for these goals to be clear. There should be an overriding goal presented to the player early on in the game in a clear and straightforward manner. In addition, separate levels could have their own immediate goals and obstacles that the player can overcome while they are working towards the main goal. This gives the player a feeling of progression even though the overriding goal seems far away.

7.1.6 Feedback

Within games, players should be presented with appropriate feedback at appropriate times. Immediate feedback after an action helps improve the concentration of the player which in turn is essential for achieving flow. Feedback could be given about the progress or distance towards the main or immediate goals in the game and players should use this information to determine where they stand and what they need to do to further progress. Necessary feedback should be presented through interfaces or through sound so that the player always knows their status or score in the game.

7.1.7 Immersion

Immersion is all about how invested the player becomes in the game and the game world. Their involvement in the game should be deep but at the same time effortless. The game should be able to capture the attention of the player in a way that they become less aware of themselves and their surroundings and could experience an altered sense of time [39]. Games are by many seen as an escape from the real world and should be a source into an emotional and visceral personal experience that the player does not get in their everyday life. Audio, narrative and graphics all play an important part in drawing the player into the game.

7.1.8 Social interaction

The last of the eight elements of GameFlow is social interaction. This element is different, as it is not based on Csikszentmihalyi's concept of flow, but rather on the social nature of human beings. As the GameFlow model suggests, games should support and enable social interaction between players. This includes making players either cooperate or compete against each other within the game, but also creating enjoyment outside of the game through chat and online forums and leaderboards. By making players able to discuss, compare scores, and watch others play, a whole virtual community could be made around the game, increasing the enjoyment and time the players spend on the game.

7.2 Challenge, fantasy and curiosity

In 1980, Thomas W. Malone presented a paper where he described three categories of characteristics that make games fun, namely challenge, fantasy and curiosity [41]. Even though Malone's goal was to provide guidelines for instructional computer games, the three categories and their belonging characteristics have been proven to be important for video games in general as well. When designing a game, it is therefore important to pay attention to the balance of the three categories within the game, to make the game as fun and enjoyable as possible.

7.2.1 Challenge

For a player to feel challenged in a game, the game must have a goal. However, the player should be uncertain of whether or not it is able to attain the goal. If the game has a very simple and straightforward goal, there would be no challenge to it. Therefore, Malone presents some characteristics that can help in creating an appropriate goal. In simple games, goals should be obvious and compelling, either through the use of fantasy or visual effects. In a more complex game, it is important to have varying goals with different levels of difficulty. Goals are also better if they are connected to the fantasy in the game. Lastly, it is important that the game provides performance feedback, which allows the players to tell if they are getting closer to the goal.

Beyond containing appropriate goals, games should also have an uncertain outcome, as it is boring for a player to know the outcome of the game as soon as it starts playing. Malone points out four ways to achieve uncertainty in games:

- **Variable level of difficulty:** The game should be playable at different levels of difficulty. The difficulty could be chosen by the game through matching the player's skill, by the player itself or by the skill level of the opponent a player is facing, when playing against other humans.
- **Multiple level goals:** There should be several different levels of goals in the game. Beyond just a basic goal, which may have a certain outcome, the player should be challenged by additional levels of goals. To use a racing game as an example, a basic goal may be to just drive to the finish line. However, an additional goal may be to reach the finish line without crashing or within a given time. This *speeded response*, as it is called, is one of two popular meta goals to have in games, with the other one being *score-keeping*.
- **Hidden information:** Hidden information is a feature used to provoke the curiosity of the player and contribute to the challenge of the game. The game hides some information from the player and only selectively reveals it as the game goes on, making the outcome more uncertain along the way.
- **Randomness:** Introducing randomness into the game is another way of making the outcome of the game uncertain. Many gambling games are successful based on this principle of randomness, and randomness can also be used to increase the uncertainty in other games genres as well.

Lastly, the reason why goals and challenges capture the interest of the player is because it engages their self-esteem. Through succeeding in a game, the player gets the same positive feeling as she or he gets when succeeding in an activity in real life. Likewise, the player's self-esteem might lower if they fail in the game. This shows the importance of having different levels of difficulty within the game. It allows us to cater to an audience with different levels of skill. Furthermore, it is also important that the feedback in the game is presented in a way that does not damage the player's self-esteem.

7.2.2 Fantasy

Games are often set in a fictional setting. Examples are adventure-like game-worlds, superhero characters or strange events. These all make up the fantasy within the game, and the fantasy helps the game become more interesting. When selecting a fantasy for a game, it is important to consider the target audience, as different players might prefer different types of fantasies.

Malone distinguishes between intrinsic and extrinsic fantasies, which tells about the interactions that are possible between the player and the fantasy. In extrinsic fantasies, the fantasy in the game is affected by the player's skill, but not the other way around. If the game has an intrinsic fantasy, however, the player's skill would also be dependent on the fantasy. The use of feedback is a way to achieve this. Take the racing game as an example again. If the game includes arrows on the ground which shows the most optimal route or gives a warning to the player when it is braking too soon before a turn, the player would be able to improve their skill by looking at what the fantasy tells it.

An intrinsic fantasy is said to be found more interesting by the player than an extrinsic one. One reason being that intrinsic fantasies helps the player connect the use of their skill to something in real life. Furthermore, fantasies are also important because of the emotional influence they have on the player. Malone points out that games with themes that evoke more emotions in the players are more popular than games with less emotional fantasies. It can therefore be beneficial to select an emotion-evoking fantasy for a game.

7.2.3 Curiosity

Curiosity in games is about the motivation the player has to further learn or explore something within the game. It is important to keep the player curious to make them immersed and want

to keep playing the game. To achieve this, Malone points out that the environments in the game should have an *"optimal level of informational complexity"* [41]. This means that the game should take the player's existing knowledge into consideration and provide environments that are not too complicated nor too simple. Malone states that there are two different kinds of curiosities a game can evoke: sensory curiosity and cognitive curiosity.

Sensory curiosity can be triggered by audio and visual effects in games. In games, there are four ways to use these effects. The first is to use sound and graphics as decoration which increases the look and feel of the game. The second is to use these effects to enhance the fantasy in the game. Beyond just being decorative, these sound and visual effects evoke associations to the fantasy, which can be quite captivating. Furthermore, the effects can be used as a reward, either by playing a sound or showing a nice graphic when the player achieves something in the game. Lastly, audio and visual effects can be used as representation systems, where they give some information to the player. This can be in the form of a health bar on the screen or a change in the soundtrack when a player enters a dangerous area in the game.

Cognitive curiosity is about people's satisfaction with having perfect cognitive structures in their minds. To achieve this, they need completeness, consistency and parsimony within the topic they are focusing on. Therefore, if a game holds back some information so that it appears incomplete, inconsistent or unparsimonious, the player will then become determined to keep exploring to find the missing information and make their cognitive structures better.

Lastly, Malone reiterates the importance of proper feedback. The feedback should be surprising so that it engages the curiosity of the player. As the feedback differs from what the player expected, the player might be inclined to continue exploring the game to get a better understanding. Also, in situations where the player should learn something from feedback, it is important that the feedback is constructive and helps them along the way.

7.3 Dual Flow

In 2007 Sinclair, Hingston and Masek wrote a paper in which they presented Dual Flow [3]. The background for their research was that, at the time, there did not exist much research on how to design exergames. They, therefore, looked to both sports science and game design principles to identify success factors for creating enjoyably exergames that also manages to give the player a good workout. The result was Dual Flow, a model that looks at the dimensions of attractiveness and effectiveness and how they can be balanced to design the best exergames (see Figure 3). We will now take a further look at these two dimensions.

7.3.1 Attractiveness

The dimension of attractiveness is concerned with how fun and engaging a game is. Instead of presenting their own guidelines for designing an attractive game, Sinclair et al. reference several existing frameworks and models related to game design, including Challenge, Fantasy, Curiosity, Flow, and GameFlow. The authors encourage the reader to lean on these existing models when designing an exergame. However, they do point out the importance of keeping the attractiveness balanced. As can also be seen in Figure 3 it is important to have a correct balance between the challenge in the game and the skill required from the player. This balance keeps feelings like anxiety and boredom away and instead helps the player reach a state of flow.

Regarding the attractiveness, Sinclair et al. also emphasized the role that the input device of the game plays in making the game attractive. For a player to achieve a state of flow where they focus solely on the game, it is important that the input device is something that does not require a lot of attention to use. While an exercise bike might work, as the player is quite stable and it is easy to use, a treadmill quickly becomes unsuited, as the player must also focus on not running into the edges of the treadmill while playing, breaking their immersion in the game.

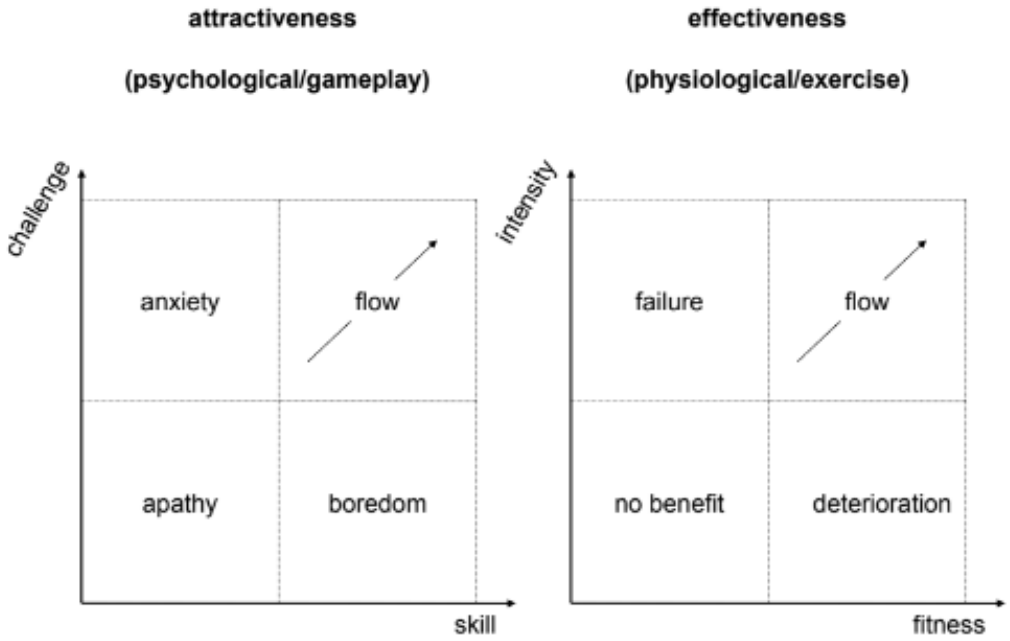


Figure 3: The Dual Flow model for exergames [3]

7.3.2 Effectiveness

The effectiveness dimension of Dual Flow is all about having the correct exercise type and intensity in the game. A designer should follow general guidelines on intensity, length and regularity of exercise to make sure that the player is actually getting health benefits from playing. It is also important to keep in mind how the characteristics of the exercise should change as the player increases their physical condition over time. To keep the effectiveness of the game in balance, so that the player can enter a state of flow, the game needs to have a level of intensity that matches the fitness level of the player, as can also be seen in Figure 3.

7.4 Summary

When designing an enjoyable game, there are several factors to keep in mind. The GameFlow-model, which is based on Csikszentmihalyi's Flow theory, states eight elements that help make a game interesting and enjoyable: concentration, challenge, player-skills, control, clear goals, feed-back, immersion, and social interaction. These elements all tackle important areas to get right. In addition, in Malone's paper, he concludes with the keywords challenge, fantasy, and curiosity being essential for a game to be fun. The Dual Flow model further builds on the GameFlow model and expands its usage to exergames. This model suggests a necessary balance between both challenge and skill, and fitness and intensity. For a player to achieve flow in an exergame, both of these need to be in equilibrium. The content of these three frameworks will offer us great guidance when designing our exergame later on.

8 Engagement in Games

If we are to achieve our research goal, it is not enough to just motivate a player to begin playing our game, they need to stay engaged in the game to keep playing it. To do so, we need an understanding of what engagement means in terms of video games. This section, therefore, presents the concept of engagement in games, along with some guidance on how engagement can be achieved in a game.

8.1 Continuation desire

When looking at literature, engagement in games is a concept that is both described and measured in various ways. It is often denominated as a multidimensional concept, related to other concepts such as flow, GameFlow (see Section 7.1), immersion, enjoyment and user engagement [4; 42]. One fundamental aspect of engagement is said to be *continuation desire*; the desire to continue playing a game. While motivation is what convinces players into beginning to play a game, engagement is what keeps their interest, and focuses on what makes people want to continue playing [4]. Schønau-Fog and Bjørner [43] argue that the continuation desire is a prerequisite for many of the other experiences that are found while playing, such as flow, immersion and enjoyment, as these experiences will never occur if the player does not want to continue playing in the first place.

8.2 Designing for engagement in a game

Several researchers have put effort into explaining engagement in games and concretise the concept in such a way that frameworks and models can be made for how to make a game engaging. This subsection will present two different ways to look at engagement in a game, one framework and one method focusing on six types of causes of engagement.

8.2.1 The OA3 framework

The OA3 framework [4] is showing how objectives, rewards and emotions are important for keeping a player's engagement. People were surveyed on their views on the components, categories and triggers that are involved with engagement and the desire to continue playing. From the analysis of the responses, it was suggested that player engagement can be described as a six-step process, called the player engagement process (PEP). The PEP was then visualised through the OA3 framework (seen in Figure 4).

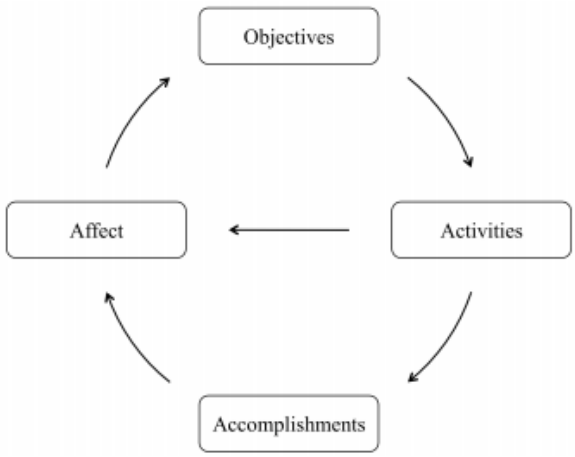


Figure 4: An illustration of the OA3 framework, showing the relations between the different components of the framework [4].

The OA3 framework consists of four components, each of which can be further separated into different categories:

- **Objectives** Objectives are about what players want to achieve in the game. *Extrinsic* objectives are e.g. challenges and quests set up by the game, while *intrinsic* objectives are goals made up by the player, like defeating a game without getting hit. Players often stay engaged as long as there are new things to do, so a game that keeps giving new goals to the player increases their desire to continue playing.
- **Activities** Activities are concerned with what a player wants to do to reach the objective. Several categories of activities exist, whether it is *solving* a puzzle, *sensing* environments and audio, *interfacing* with interesting controllers like in Guitar Hero or Wii Fit, or *exploring* the game world. Many players like *experimentation* through modifying the game or customizing characters, *creation* of their own levels in the game, and *destruction* of buildings or killing opponents. The last three activities in the OA3 framework are *experiencing the story*, *experiencing the characters*, and *socializing* through communicating and sharing activities with other players.
- **Accomplishments** When the objective is finally met, most players need something in return to stay engaged in the game. This can either be *achievements* in the form of new items or unlocks, *progression*, to allow the players to grow stronger and unlock new objectives, and *completion*, allowing the players to fully finish either the game itself or a component within it.
- **Affect** The final component of the OA3 framework is concerned with the emotions a player is experiencing when performing activities and getting accomplishments. The emotions are categorized as *positive affect* like enjoyment and success, *negative affect* like boring and frustrating, and *absorption* through getting so immersed that the game feels like an escape from the real world.

Looking back to the GameFlow framework presented in Section 7.1, some of the components in the OA3 framework can seem to be overlapping with some of the elements from GameFlow. Especially the objective component have similarities to the clear goals element. These overlaps show how enjoyment and engagement are closely related within games, and that it could be possible for certain clever parts of the game design to increase both enjoyment and engagement in one go.

8.2.2 Six types of causes of engagement

Schønau-Fog and Bjørner [43] present a different way to look at how to make a player want to continue playing a game. They talk about six types of causes of engagement that each makes the player engaged in a different way. All six causes are not present in the game at the same time, as it varies on the gameplay, and different players might react better to some causes than others. The six causes are:

- **Intellectual** Encompasses creativity and intellectual challenges and activities. A player might want to continue playing to solve puzzles and overcome intellectual demanding tasks that require problem-solving skills, planning and strategic thinking.
- **Physical** A player might desire to continue playing due to the physical activity that is required for playing a game. This can range from wanting to become more skilful at using a regular gamepad, to playing exergames or using the full body for games that require such.
- **Sensory** This type of cause of engagement is related to the stimulation of the player's senses while playing. Some of the causes of sensory engagement can be audiovisual, haptic effects, controlling and exploring within the game.
- **Social** Social engagement causes are concerned with player-to-player interaction. The interaction can happen either within or outside of the game, through multiplayer worlds, shared objectives, communication and recognition of game accomplishments.

- **Narrative** The story and characters within a game might create curiosity, excitement and suspense in such a way that the player wants to continue playing. A range of narrative tools can be used to make the player invested in the story and thereby make them engaged in what happens in the game world.
- **Emotional** The sixth type of engagement causes is emotions. Events that happen in the game or the overall tone and setting of the game are often put in the game to cater towards the player's emotions. Through making a player emotionally invested or immersed in the game, their will to continue playing might increase.

When looking at the the six types of causes of engagement, it is easy to spot similarities to some of the GameFlow elements. Both the intellectual and physical type of causes are somewhat related to the challenge and player skills elements of GameFlow, as players can be challenged either intellectually or physically, especially in an exergame, and they can also improve their skills in the game, whether it is related to doing an activity in the game or mastering the physical game controls. Furthermore, the narrative and emotional types do both relate to the immersion element of GameFlow, as a strong narrative and a game that awakens emotions in the player often also succeeds in immersing the player in the game. Lastly, it is quite clear that the social type of engagment cause is strongly overlapping with the social interaction element of GameFlow. With GameFlow and the six types of causes of engagement having several similarities, we do not have to specifically design game elements that will fulfill each of the causes and GameFlow elements individually but can rather focus on designing good game elements that will encompass several of the related GameFlow elements and engagement causes.

8.3 Summary

This section has given us a better understanding of the concept of engagement within video games and especially highlighted the aspect of continuation desire. The OA3 framework and the six types of engagement causes have been presented and show two different views of what is important to include in a game to make it engaging for the player. When designing our game, it will be useful to know the importance of continuation desire and the difference between motivating a player to begin playing and keeping them engaged. Both the OA3 framework and the six engagement causes will be kept in mind when we design the features and content of our exergame.

9 Mechanics for Increasing Enjoyment and Engagement in Games

This section presents two types of widely used game mechanics that can help increase the enjoyment and engagement in a game. Getting an insight into the theory behind the mechanics, along with examples on how to include them in our game will prove useful when we are to later on design our own game.

9.1 Rewards

In a paper by Wang and Sun [44], they discuss the importance of reward systems in games and how they work. A reward can be anything that the player finds rewarding in a game. Examples are items received for doing a task, unlocking achievements, being displayed on a leaderboard or even finding Easter eggs (hidden treasures and parts of a game). Rewards play an important role in video games for keeping the players motivated. The motivation could, for example, be progressing in the game to unlock new map areas or showing off one's position on the leaderboard. In Begy and Conslavo's paper [45], the reward system of the game Faunasphere is discussed and compared to more traditional MMOGs. They conclude with reward and achievement systems being a broad term that needs to be discussed in a context. E.g. in Faunasphere, the achievements are all focused around the game's fiction rather than obtaining power in the game-world. They also discuss how the Faunasphere's reward system does not promote social interactions to the same extent as more traditional games. Trading and similar mechanics are present, but not necessary to the game. These differences could be a reflection of what the demographic of the players find motivating; casual smartphone players might be less motivated by social aspects than other "traditional" players.

According to Wang and Sun, there are four main categories of reward systems:

- advancement
- review – e.g. looking through previous rewards for memories and entertainment
- sociality – e.g. talking about the reward, funny cosmetic rewards, showing off rare items, etc.
- cooperate/compete – e.g. sharing or hoarding powerful items

These categories all help bring motivation to the player in some way. As mentioned, different demographics might be motivated by different features. Thus, not all categories need to be present in a game, but rather those that seem fitting for motivating the player base. Reward systems, achievements in particular, also help to bridge different games together by having comparable statistics among games [46]. In game-portals like Steam [47], achievement and game score, even between games, is a major focus.

One interesting aspect of rewards is that they can provide fun even before the reward is activated by just providing the challenge [44, p. 8]. However, it is essential to keep in mind that the reward's quality or usefulness should increase with the delay necessary to achieve it. This scaling is to avoid anxiety or displeasure from the player's side. Koster, in his book from 2005, writes that "people enjoy learning, but tend to be lazy; [...] [they] tend to give up" [48], which is why a balanced reward system is crucial.

Jakobsson mentions in his paper on Xbox Live achievements [49] how achievements can create a dichotomy between players. Players that "hunt" for achievements were not uncommonly referred to as "achievement whores" by those who do not care as much about achievements. He also talks about how achievements systems can be a motivator themselves regardless of the gameplay involved. An example of this was the xBot [50], a machine built by a player to be able to complete two tedious achievements without the player having to do anything himself.

9.2 Social mechanics

The social part in and around a game is another significant area that can affect the enjoyment of the game. Social mechanics can also play a big role in motivation and continued play of a game. As mentioned in the previous Section 9.1 on rewards, "sociality" is one of the four categories of rewards in a game. Being social can for many be enough of a motivator to play the game, and for others, the social part will usually count as a bonus. Social mechanics also add new layers to the game, either by making competitive games less predictable by competing with real humans or by having fun discussing the game, both while playing and afterwards. The competitive part also adds the wish to outrank your peers to the mix.

Social mechanics can also have a practical impact on the gameplay. Take rewards as an example. Often, rewards require gathering a sufficient amount of information to be able to crack a puzzle and unlock it. This kind of reward encourages social interaction. Different players might have discovered separate parts of the puzzle, but together they may have the complete picture. Social interaction and idea-sharing will then allow them to solve the puzzle together [44, p. 8].

On the other hand, we have so-called "social games". These are games played on social media sites. These games use social mechanics as a draw for new players, indicating that sociality is desirable in the game. However, in a paper by Consalvo [51], social games and their social mechanics are discussed. These games usually incorporate social features such as gifting and friend bars with visitation possibilities. Still, the paper concludes with deeming the elements as "quite limited in how they allow players to be social with one another." The same topic is discussed by Adam et al. [52]. Here, they also conclude with social aspects being a significant contributor to success in a casual game: "adding social features increases monetization, engagement and usage across both Facebook and mobile platforms."

Depping and Mandryk write about how multiplayer games affect relationships with regards to cooperation and interdependence [53]. Games can make us feel socially connected. In 2016, 54 percent of the most frequent gamers played socially as a way to bond with friends or strangers. This gives a clear indication of the importance of social aspects in games. We also see the value of social play reflected in today's game developer industry. Over the previous years, we have seen a massive increase in online-based multiplayer games like Fortnite and Call of Duty: Warzone. Depping and Mandryk found that both cooperation and interdependence lead to stronger bonding between players. However, they are not dependent on each other, which means that games can leverage both concepts to fit their game and promote the best social experience for players.

9.3 Summary

Rewards and social mechanics both help make a game enjoyable and desirable. Reward systems help bring short term motivation to the player by giving the player goals along the way, as well as giving the player a reason to complete the different challenges in the game. Social mechanics are closely linked to rewards. They can add a competitive part to the game, thus having the reward of, for example, being displayed on the leaderboard. Sociality also adds the possibility of working together to achieve goals, and, of course, the possibility of being social, which for many can be a motivation to play the game in itself. When designing our game, these aspects will all be considered, and those most relevant will be incorporated into the gameplay. This will increase our chances of developing a fun and engaging exergame with a lasting replay value, which is the goal of this project.

10 Player Types

A player type is a category for a certain kind of player. It is often based on traits the player has or the motivation behind their actions. The most well-known player type classification is the one made by Richard Bartle [54]. He proposed a classification consisting of four types:

- killers – Killers get their enjoyment in games from causing distress to other players. Earning points is often necessary to be able to cause real havoc, and socialising can help to exploit players weaknesses or to share strategies with other *killers*, but the main goal is still to cause distress.
- achievers – This player type mainly enjoys aspects revolving around gathering points and achievements. Exploring and socialising are used as means to gather information to gain more points etc.
- socialisers – For socialisers, the game mainly functions as a meeting ground for socialising. Socialisers are interested in people and want to create lasting relationships. Exploration and points are only used as ways to keep up with other players' talk.
- explorers – Explorers enjoy learning everything about a game and its mechanics. This includes unlocking all available and hidden areas, finding Easter eggs and potential game bugs, and discovering things other players haven't.

Other classifications than Bartle's exists, however. Ip & Jacobs presents a categorisation that divides hardcore and casual gamers [55], Lazzaro writes about four keys to fun games with easy fun, hard fun, altered states, and the people factor [56], and Tseng categorises players into aggressive gamers, social gamers, and inactive gamers [57]. In a literature review by Hamari et al. [58], these different papers and studies on player types are compared. By looking at similarities between different classifications, they come up with seven dimensions for player categorisation: Achievement, Exploration, Sociability, Domination, Immersion, Gaming intensity and skill, and In-game demographics.

The classification proposed by Bartle has received some critique. The literature review by Hamari et al. proposed some issues with the method. It is suggested that these classifications should be on a scale. Players are not necessarily one of the four Bartle categories but could be a mixture of each. Bartle has, however, later stated that this was his initial intention. Another point mentioned is the fact that your player type does not necessarily transfer between games. This means that the categories might not map to a person in general, but is dependent on multiple other factors. It is also worth mentioning that most of these categorisation papers are looking at MMORPGs, which could limit the results. The reason for player type categorisation is usually marketing. Due to the issues described above, some have suggested that marketing towards a player avatar might yield better results than the actual player.

11 Technology Review

One thing that makes most exergames less available than regular video games is the need for specialised equipment. The typical hand controller or mouse and keyboard are usually insufficient for tracking the user's body throughout the game. Besides, making a controller that will fit any exergame is challenging – especially without making it too expensive. Both of these challenges are hard to avoid. Because of this, most exergames make their own controller or add-on for their specific game. Sometimes these controllers will be open to other developers, but the adaptation is usually not vast. Because of this, it is crucial to make good, versatile, and relatively cheap controller technology to succeed.

Throughout the years, many different concepts and styles have been tested. The Wii console brought games requiring physical movement to the mainstream, and smartphones expanded the possibilities even further with all its available sensors and GPS tracking. Body tracking games, like the EyeToy-platform, brought a new paradigm to the exergame genre and incorporated full-body movement. The Kinect platform refined this type of technology and brought with it new ways of thinking about exergames. AR and fitness trackers are combined with gamification, expanding further on what we see as an exergame. This section will go through some of the more successful controllers and technologies for exergames, including Playpulse, the platform used in this project.

11.1 Wii Fit Balance Board

The Wii Fit Balance Board for the Nintendo Wii is one of the more successful exergame technologies out there. Nintendo had sold over 42 million units in 2012, four years after its release. The Wii Fit Balance Board is a flat board similar to a household bathroom scale (see Figure 5). It consists of four pressure sensors that together can track the users centre of mass.

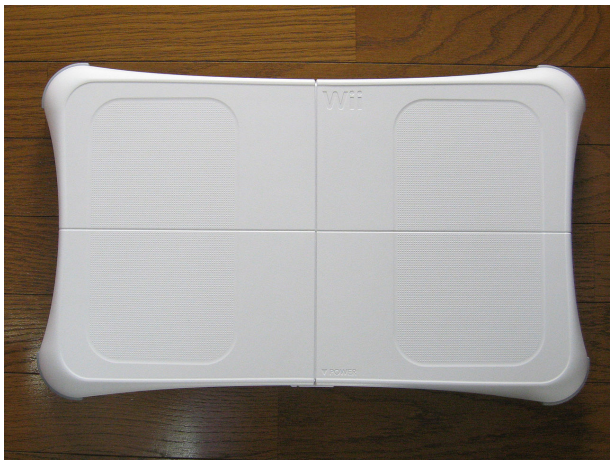


Figure 5: The Wii Fit Balance Board seen from above [5]

As mentioned, the Wii Fit Balance Board became quite successful, and the list of games available is extensive [59]. The board has also shown to help improve balance, with studies concluding with it being better than no exercise and comparable to programs made for improving balance [60].

11.2 PcGamerBike

The PcGamerBike [61] is an exercise bike (see Figure 6) made by 3D Innovations which functions as a video game controller. It connects via USB and lets the user control movement in games based on pedal speed, thus being usable over a vast area of games. The idea is to have gamers play their usual games but seamlessly add some exercise to the session. The device also keeps track

of calories burnt and distance cycled, among others. Since this product is sold as a controller, it does not integrate a tailored exercise experience into the games played, but this also gives the user more freedom regarding game selection and usage style. The product also received the 2007 International CES Innovations Design and Engineering Award [62].

Figure 6: PCGamerBike Mini

11.3 Expresso Go Upright

The Expresso Go Upright [63] made by Expresso is a stationary interactive exercise bike. It is a complete setup and features a touchscreen, steerable handlebar, adjustable resistance based on gears, WiFi, and exclusive content from Expresso (see Figure 7). It includes both biking simulation and built-in video games. The player can do virtual rides on 43 different tours worldwide, and they contain leaderboards and challenges. The video games consist of different game modes, e.g. coin collection, and they should function as High-Intensity Interval Training (HIIT). The Expresso platform also integrates with the popular workout service Strava [64]. This integration lets Expresso users show off their achievements, join challenges and even makes competition between real-world cycling and virtual cycling possible.

Figure 7: Expresso HD Upright Bike [6]

Not much research has been done on the Expresso platform. Still, one study by McGloin and Kimberly [65] tested the controllers of the platform based on video game experience concerning realism, enjoyment and naturalness. They found that video game experience led to the controllers feeling more natural, but the tour itself did not feel too realistic. Both immersion and controller naturalness had a positive influence on the enjoyment of the experience. The study also linked the level of immersion to having a positive effect on the exercise experience in itself.

11.4 Blue Goji Infinity

The Blue Goji Infinity [66] is an exergaming treadmill with a built-in screen and VR capabilities (see Figure 8). The product is not yet released. It is under development by Blue Goji and Team6 Game Studios [67]. The treadmill is self-propelled, meaning the user decides the speed when running by pushing the treadmill belt backwards themselves. This feature makes playing competitive racing games possible as players themselves can impact the pace, unlike normal treadmills. It features different levels of resistance as well, allowing for the feel of running uphill or on diverse terrain. The VR compatibility makes the experience even more immersive, allowing players to feel like they are in the game and not think about the exercise part. The Infinity uses the GojiCare platform, which runs Windows and has support for third-party games [7].

Figure 8: A person using the Blue Goji Infinity [7]

Since the device is not publicly available yet, not much research has been done on the Blue Goji Infinity. Still, according to their website [66], the product could prove very useful for rehabilitation and exercise for elders. The device has built-in safety bands that strap the player to the centre of the mill. In addition to this, the treadmill has two parallel handlebars. These two, in combination, mitigates the possibility of falling while using the device, making it safer to use for physically challenged people than regular treadmills.

11.5 Playpulse

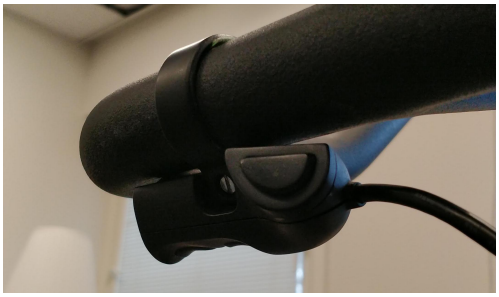
Playpulse [8] is an exergaming bike and platform. Kristoffer Hagen and Stian Weie made the first prototype. They came up with and developed the idea as part of a master's thesis at NTNU in Norway. The platform consists of an exercise bike with added sensors to the pedalling mechanism. There are also buttons on the handle and a touchscreen in front of the player to display the game. The bike comes with a selection of games that focus on hiding the fact that the player is exercising, thus focusing on the gamer demographic to motivate physical activity. One of the games bundled with the bike is Pedal Tanks (see Section 12.5). The company also plans on opening up the platform to third-party developers in the not-so-distant future.

The platform has shown promising results when it comes to health benefits. In the founders' master's thesis [68], similar effects to HIIT was achieved when playing the game. Later studies [12; 11] have also shown promising potential for Playpulse as a viable platform for exergaming. The platform has also been received well by its intended users [69].

The Playpulse platform will be used for our game concept in this project. There has existed several versions of the Playpulse platform. The one currently in the works (see Figure 9) has a changed controller layout compared to the one available for this project. The newer version incorporates traditional controller buttons on the right side and a joystick on the left side for more precise steering (see Figure 10 (c)). The one available in this project uses less precise left and right digital buttons to steer (see Figure 10 (a, b)). It has six buttons in total, three for each hand, and an RPM sensor for the pedalling.

Figure 9: The newest Playpulse platform [8]

(a) Front, left side. Two buttons



(b) Back, left side. One button.

(c) Joystick left and traditional controller buttons on the right [70].

Figure 10: This project's Playpulse controllers (top) and the new Playpulse controllers (bottom).

11.6 Summary

There exists a lot of different exergame technology, and this section has shown a handful of them. Most of the ones seen here are stand-alone products relying on games made specifically for the platform. A successful example of this is the Wii Fit Balance Board made by Nintendo, which has sold many units. Smaller companies do not have the advantage Nintendo does. Still, some of them are starting to be noticed. Both Expresso and Playpulse are up and coming in the market within the realm of exercise bikes, though their focus is a bit different. The Goji Blue Infinity features a new approach to the exergame market using a custom treadmill. Studies on these kinds of devices lean in favour of being positive. In this project, the Playpulse platform will be used.

12 Existing Exergames

As mentioned in Section 5, there exist a wide range of exergames, with the first one created over three decades ago. One common factor seen in many exergames is the need for specialized controller equipment for the game. This necessity could make the games less available than alternatives due to the higher buy-in. An overview of different controller technologies can be found in Section 11. This section will look at previous exergame concepts. Doing this will give a quick overview of what has been done before and how well it worked. In this project, an exercise bike will be used as the controller for the game; therefore, the section will include some generally important exergames but mostly games made for exercise bikes.

12.1 Dance Dance Revolution

Konami's Dance Dance Revolution (DDR) [71], first released in 1998, is by many considered the first major success within the genre of exergames [72]. DDR is an arcade dancing game using a dancing pad with four pressure plates as a controller (see Figure 11). The player will see a constant stream of directional arrows moving towards an activation area on the screen. The four plates each correspond to a direction, i.e. left, right, forward, and backwards. The game's objective is to press the correct arrow plate at the precise time when the arrow is in the activation area of the screen.

Figure 11: Arcade version of Dance Dance Revolution

The game achieves exertion by physically having the player move to press each arrow plate. Also, to activate the pressure plate, a certain amount of force is needed, thus adding even more to the physical aspect of the game. In a study by Murphy et al. [73], DDR was found to help overweight children around ten years old to improve both flow-mediated dilation (FMD), aerobic fitness, and mean arterial pressure (MAP). FMD rose to 5.56±5.04 % compared to the control groups 0.263±4.54 %. For MAP, the pressure was decreased to 5.62±7.03 compared to the control groups 1.44±2.16 mmHg. On a graded exercise test, the time improved from the control's 12.83±68.10 seconds to 53.59±91.54 seconds.

12.2 Nintendo Wii Fit

Wii Fit made by Nintendo [74] in 2007 is an exergame for the Nintendo Wii console (see Figure 12). It is also considered a significant success and is, 13 years after its release, the eighth-most sold console game of all time with over 43 million copies sold [75]. Wii Fit consists of several *mini-exergames* that incorporate different exercises and uses the proprietary Wii Fit Balance Board (see Section 11.1) as a controller. These mini-exergames ranges from straight-up workouts to actual games.

Figure 12: A Wii Fit mini-exergame being played by a Nintendo employee [9]

For example, the yoga and strength exercise games work more as a training guide and log than an actual game. The Aerobic and balance parts of the Wii Fit game has more gameplay with games such as slalom, heading footballs, tightrope walking, and more.

Even though Nintendo designed the Wii Fit for the consumer market, it has also done well in the clinical and rehabilitation areas, with studies showing positive results when using the Wii Fit platform both for patients and as an exercise [76]. A study conducted by Nitz et al. tested the Nintendo Wii Fit's claim to improve balance, strength, flexibility, fitness and general well-being. The test included ten women aged from 30 to 58 years. The participants did a 30-minute session twice weekly for ten weeks. The results showed that both balance and lower limb muscle strength showed significant improvements, but the other supposed improvements were not significant. Another study by Graves et al. [77] showed that Nintendo Wii Fit elicited higher heart rate levels than sedentary gaming, an equivalent to light-to-moderate intensity, but not to the level of walking or jogging on a treadmill. The results also showed that using the Wii Fit was a more enjoyable experience than using the treadmill.

12.3 Pokémon Go

Pokémon Go [78], made by Niantic and released in 2016, is an augmented reality exergame based on Nintendo's Pokémon concept (see Figure 13). In the game, players collect different creatures, called Pokémons, and use them to fight in virtual gyms. The Pokémons are scattered around on a real-world map, and the player needs to be close to the Pokémon's map location to attempt capture. This forces the player to move around in the real world, thus making this an exergame. A maximum move speed is set for when the player can play the game. This limitation prohibits people from cheating by using vehicles. The game also contains items that need a certain amount

of kilometres walked to be unlocked.

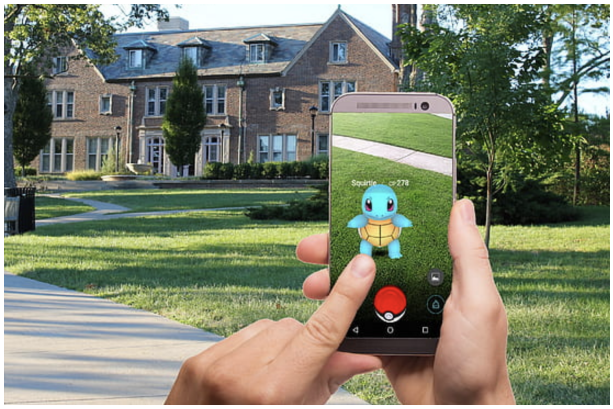


Figure 13: Pokémon Go

Studies conducted on Pokémon Go has shown that playing the game increased activity in the short term compared to people not playing the game, but long term effects are not as clear [79]. The same conclusion is shown in the study conducted by Althoff et al. [80]. Here, a large scale quantitative study is done on 32,000 Microsoft Band users over three months. The results showed that Pokémon Go, over a 30 day period, leads to a significant increase in physical activity. Particularly engaged users had an average increase of 1473 steps a day in the period. They also found that Pokémon GO is popular in the not-so-active community, while already physically active people usually use one of the four popular mobile health apps. Howe et al. [81] found that physical activity increased the first week to an average of 955 additional steps, but then over the next five weeks gradually dropped back to pre-installation levels. In a literature review by Wang [82], the same results were confirmed. The game has a significant positive effect on the player's physical, social and mental health, but the effect is only applied as long as the player actively plays the game. This paper also concluded with people giving up the game due to technical challenges, slow progress, and lack of variation.

12.4 Zwift

Figure 14: Zwift gameplay on a computer with stats on an iPhone [10]

Zwift is a Massive Multiplayer Online (MMO) training simulator (see Figure 14) for running and cycling [10; 83]. It is more of a virtual world for training than a game but incorporates elements of gamification. In Zwift, players can ride together or solo, compete in races and join events. The player needs a treadmill or a bicycle and a proprietary cycling trainer to use Zwift. When playing, players can rank up in level by performing well, and they earn in-game currency per mile ran or ridden. This currency can be used to upgrade aesthetics such as jerseys and colours. Zwift also has

power-ups, another typical element from racing games. During races, players can collect power-ups that do everything from making the in-game character lighter or reduce their drag to making them invisible. The more expensive cycling trainer also adds adaptive resistance when cycling to better simulate hills and drag. Zwift has become quite successful within its market with over a million accounts in 2019 [84]. Still, due to Zwift's simulating nature, the game might be most fitting for those already interested in running and cycling and not as much to others. The available research on Zwift is unfortunately limited, but what little exists [85; 86] seem to hint at Zwift being more used and popular among athletes and other already active people.

12.5 Pedal Tanks

Pedal Tanks is a co-op multiplayer game for the Playpulse platform (see Section 11.5) [8]. It was developed in 2015 as part of a master's thesis at NTNU [28] and has since been worked on and updated to become its own product. The game is based on *Capture the Flag*, a game where two teams fight to capture the opposing team's flag, usually located at their base, and bring it back to their base to gain points. Players can also shoot and destroy other tanks to remove them from the battleground temporarily. In Pedal Tanks, players play as tanks (see Figure 15) in teams of two and use an exercise bike as a controller. Both moving forward and charging the projectile, i.e. determined the length and power to shoot with, is controlled by pedalling on the bike. Faster pedalling leads to higher velocity and more power from the canon. Steering and other input are done with buttons on the bike handle.

Figure 15: Pedal Tanks gameplay [8]

The creators have drawn inspiration from other popular video games and incorporated well-liked features. For example, there are several classes of tanks to choose from in the game. Some of these classes are only unlocked after levelling up in the game. This mechanic adds to replayability by making each game more unique and making the player want to improve in the game to level up.

The results of a study conducted on the game's exercise and enjoyment level [68] showed positive results in the short term but did not have enough data to conclude in the long term. The study consisted of eight participants playing the game over three days. During gameplay, the average heart rate for the participants was 162 BPM, which is equivalent to moderate/high-intensity exercise. Participants also reported a higher enjoyment when playing the game than taking a walk, and the enjoyment level did not change drastically over the three days of playing. Berg et al. [87] did a six-month study of the game's impact on health. Here, participants in the exergaming group were given a Playpulse cycle and were told to use it whenever they wanted. The study concluded with not showing any statistical improvements between the exergaming and control group. This was primarily due to the Playpulse bike being used an average of 12 times during the six months, indicating that, even though players found the game enjoyable, this type of gameplay alone might not be enough to motivate players to exercise regularly.

12.6 Pedal Kart

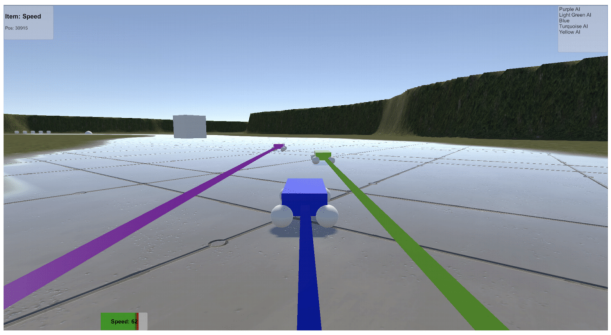


Figure 16: Pedal Kart gameplay session with two NPC-players in front [11]

Pedal Kart is an exergame developed by students at NTNU as a master's thesis [11]. The game is made for the Playpulse platform (see Section 11.5). It is a multiplayer racing game with NPC-racers (see Figure 16) and has taken inspiration from the popular Nintendo game Mario Kart. In the game, players race each other around a track for two to four laps. Power-up items are scattered around the track and picked up by players to either boost themselves or slow down other players. There are also obstacles to avoid on the track. Players pedal to drive forward; pedalling faster means moving faster. The game also has a hard cap for pedal speed at 75 % of maximum RPM. Pedalling more quickly than this will increase acceleration at a slower pace but not lead to a higher top speed. The turning radius decreases when speed increases to avoid the player pedalling at max speed the entire race. This means the player will need to slow down to make the sharpest of turns.

During the study done on the game, four participants played the game in 30 to 60 minutes sessions over three days. They rated the game as being high intensity, with an average score of 8.6 out of 10. The game was also deemed challenging and enjoyable, with an average of 7.8 and 8.4 out of 10. Hearth rate data collected showed an interval pattern but was too inaccurate to provide any conclusions on its own. Subjects also reported that the multiplayer aspect of the game was a significant contributor to their enjoyment.

12.7 Lane Rider

Lane Rider is also a game developed as a master thesis at NTNU [12]. It is a racing game inspired by endless runner games such as Temple Run [88] and uses the same platform as Pedal Tanks and Pedal kart, Playpulse (see Section 11.5). In Lane Rider, two players race to the finish line against each other. On the way, they have to avoid obstacles, both stationary and moving ones, by changing between the three lanes available (see Figure 17). On the way to the finish line, the player can also pick up power-ups to either boost themselves or impede the other player. The player has to pedal to move forward, and pedalling faster maps to faster movement; this applies up to a max point indicated by a power indicator bar. Different hill sections are added to the track to add variation in pedal speed and avoid having the player pedalling at the maximum effort the entire race. When going uphill, the player will have to pedal up to 40 % faster to achieve max speed.

Figure 17: Lane Rider gameplay [12]

In the study [12] conducted on the game, the results showed that the game did not reach the desired intensity level but had potential. The average heart rate for players was between 128.1 BPM and 134.7 BPM during the three days, which is not enough to qualify for high-intensity training. A maximum heart rate over 160 BPM was observed for all days, meaning that the game might achieve high intensity with the right changes. The game also seemed to motivate the participants somewhat, and enjoyment from the game increased over the three days.

12.8 Summary

This section has looked at existing exergames. These games show a wide variation in possibilities for exergames while also offering some similarities. For example, most of the games use fast-paced action to make the player physically engaged in the game. The game selection also shows that not all games can achieve the level of intensity needed to be useful as an exergame. If the game wants to achieve HIIT, it is crucial that the player has motivation throughout the game to push him- or herself to the max over short intervals.

13 Game Genres and Technology Limitations

This section will look at many of the different game genres that exist today. Furthermore, it will look at the ways the Playpulse platform might limit how games are played on the platform. Having these limitations in mind, the game genres that are most suited for being played on the Playpulse platform will be presented towards the end of the section.

13.1 Game genres

The overview of game genres presented in this section is based on previous literature studies on game genres taken from three master's theses from NTNU based on game development and exergames. The theses are written by Mikalsen in 2017 [89], Dalseth in 2017 [90], and Skjæran in 2018 [11].

Genres:

- **Role-playing games (RPG)** – In RPGs, the player controls a character that can improve and change over time, often in open worlds that allows the player to move quite freely around. Over the course of the game, the player embarks on several missions that progresses the story narrative in the game. Through fighting enemies and completing tasks, the player receives rewards that can be used to improve the character. Examples of RPGs are The Elder Scrolls V: Skyrim and The Witcher 3: Wild Hunt.
- **Simulation games** – Simulation games is a broad category of games where the essence is that some real life aspect gets simulated in the game. Some examples are The Sims series, which simulates everyday life, SimCity, which simulates city planning, and Microsoft Flight Simulator, which simulates being pilot of an aircraft.
- **Sports games** – Sports games are also simulation games, but has become so popular in today's gaming culture that it deserves its own genre. Most sports games are just a virtual representation of a real life sport, with game series like FIFA, Football Manager and NBA2K. In addition, some sports games might include elements of fantasy like Rocket League (see Figure 18) and the Mario & Sonic at the Olympic Games series.

Figure 18: The Witcher 3: Wild Hunt [13] (left) and Rocket League [14] (right).

- **Strategy games** – Strategy games require planning and skillful thinking in order to overcome tactical and strategic challenges. Many strategy games puts the player in a godlike position where it can control the attacking and defensive capabilities of either a base, an army, or both, and must then withstand or attack other bases and armies in the game. Two examples of strategy games are Starcraft 2 and the Civilization series.
- **Action-adventure games** – Action-adventure games is yet another broad genre of games. However, some common denominators are that the games includes combat of some sorts, either melee or ranged, where the reaction times of the player is important. Furthermore, they have a story that progresses throughout the game, and often includes puzzle-solving and

exploration. Examples of action-adventure series are Uncharted, God of War and Assassins Creed.

- **Shooters** – Most of the gameplay is centred around the player's use of ranged weapons to defeat enemies. The gameplay can be quite hectic and often demands good aiming and reaction abilities from the player. Can either be played in a first person or third person perspective. Some examples are Call of Duty and Borderlands.
- **Stealth games** – In stealth games, the player must for the most part use strategy and stealth to maneuver a level, and to avoid confrontations and combat. These games are often slower paced than their action adventure counterpart, as the player has to take its time in planning routes and avoid enemies. Two examples of popular stealth series are Metal Gear Solid and Splinter Cell.
- **Survival horror games** – Survival horror games draw many similarities with both stealth games and action-adventure games. A survival horror game has an eerie setting and often include enemies that exceed the player in strength, so that the only option is to run or hide. Often, puzzles are required to be solved in order to progress, and in some cases the player get the option to fight back as well. Examples are Amnesia: The Dark Descent and the Resident Evil series.
- **Music games** – Games where music is a fundamental part of the gameplay. This genre includes a lot of variety, from games where the player "plays" the music, like in the SingStar or Guitar Hero series, to games where the player is reacting to a rythm, like in Beat Saber or DDR (mentioned in Section 12.1).


Figure 19: Call of Duty Modern Warfare [15] (left) and Guitar Hero III [16] (right).

- **Party games** – These games are developed for local multiplayer, where several players are playing in front of the screen at the same time. The games often consist of several smaller minigames where the players are playing against each other individually or in teams. Examples of party games are the Mario Party and Jackbox Party Pack series.
- **Idle games** – Idle games are games that allow the player to progress in the game even when they are not playing. Many of these games have the player playing for 5-10 minutes in which the player activates some tasks. To continue, the player then has to wait for those tasks to finish, which can often take several hours or days. Luckily, these tasks are still progressing even when the game is closed. Some popular idle games over the years are FarmVille and Cookie Clicker.
- **Platform games** – A big part of the gameplay in platform games is to move from one platform to another in order to progress, while avoiding environmental hazards. The player has to be careful and strategic with their movement and jumping when maneuvering the platforms, and might also face an enemy or two along the way. Some popular examples of platformers are the Super Mario Bros. and LittleBigPlanet series.
- **Massively Multiplayer Online games (MMO)** – MMOs are games that allow hundreds, or even thousands of players to be a part of the same world and play together. Very often, the games have a lot of similarities to RPGs, and therefore the term MMORPG is just as popular as MMO. Examples of MMORPGs are World of Warcraft and RuneScape.

- **Racing games** – Whether it is story driven racing games like the Need for Speed series, more realistic racing simulators like the Gran Turismo series, or more competetive arcade-like racing games with power-ups like the Mario Kart series, racing games are all about racing in vehicles.
- **Infite runners** – Infinite runners is a game genre that has become quite popular on mobile over the last years. The goal of the game is to get as far as possible on an infinitely long track, gaining the most points along the way. When the player looses, it has to start from the beginning again, however, some games allow to purchase upgrades between the rounds, to make it easier to reach further the next time. Some popular examples are Doodle Jump and Temple Run.

13.2 Technology limitations

When using a keyboard and mouse when playing video games, the player has a lot of options of buttons to use, as well as a precise mechanism for aiming. When using a game controller for the most popular consoles today, the layout includes two thumb-sticks and at least twelve buttons.

As already mentioned in Section 11.5, the version of the Playpulse platform that we are going to develop a game for has the following controller inputs: a button for each thumb, two more buttons for each hand (so six buttons in total), and input from the pedals. If we compare this to the two most popular input devices for gaming today, we see that the Playpulse controller is at a disadvantage with its limited number of buttons.

While most types of games could probably be tweaked in a way so that they would support being played using only these seven types of input, one can argue that not all of these games would be equally enjoyable for the player. A key part of making a game enjoyable on the Playpulse platform is to make sure that the pedalling translates into something that feels natural in the game. The pedalling should be an important aspect of the gameplay as well, so that the player should be required to pedal quite often in order to get the necessary level of exercise.

13.3 Genres suited for Playpulse

After looking at the limitation of input possibilities that comes from the Playpulse controller, it becomes clear that some game genres might not be suited for the Playpulse platform. Also, due to the pedalling mechanism's importance in achieving the right exercise, some game genres then become more feasible than others when thinking of a natural mapping between the pedalling and what it does within the game. In Table 1, presented below, the previously mentioned game genres are evaluated based on the feasibility of making an enjoyable exergame for the Playpulse platform within that genre. While all genres could probably work on the Playpulse to some degree, our evaluation is based on finding the most suitable genres for us to use for our concept game in this thesis.

Table 1: The different game genres with comments on to which degree they are suited for the Playpulse platform.

Genre	**Comments**	**How suited for Playpulse?**
RPG	RPGs are often quite comprehensive and has game systems that demands a lot of different input. It is also difficult to come up with an intuitive mapping between the pedalling and its function in-game. It can therefore be difficult to provide a full RPG experience on the Playpulse platform	Low

Simulation games	Simulation games often demands a lot of the player's attention, reactions and planning skills, and it might be difficult to add physical exercise on top of that. It can also be difficult to map the pedalling to something meaningful in the game. It could of course be possible to simulate riding a bike, but these game concepts already exist, and the player could also just ride a bike in real life.	Low
Sports games	Besides pure cycling or running games, it is difficult to imagine using pedals to simulate playing some other sport. It is however possible that a good mapping can be found, and getting exercise through playing a game about sports could also feel natural to the player. With a creative idea, the genre could therefore be brought to life on the platform	Medium
Strategy games	Strategy games often require a lot of input possibilities and are also in many cases slow paced with a lot of thinking involved. Not exactly the best terms for an exergame that is aiming to raise your pulse.	Low
Action-adventure games	These games are often grand in scale, and might not be the best to play sitting on the Playpulse bike. While some of the more action-packed moments might raise the player's pulse, the games are often balanced out with slower sequences and exploring, which is less suiting for exercise.	Low
Shooters	A full fledged shooter like Call of Duty is probably not possible to create for the Playpulse platform, as the controller is limiting the aiming capabilities of the player. If you only allow aiming along one axis however, like in Pedal Tanks, then it is possible to have a shooting mechanism. As this has already been done, it is not a genre we will consider for our concept.	Medium
Stealth games	Slow pace stealth does not go hand in hand with rapid pedalling, so this genre is not suited for the Playpulse platform.	Low
Survival horror games	While the more fast paced chasing scenes work well with pedalling, survival horror games also have slower parts to build tension, and it is difficult to imagine how to make an exergame out of this genre. A game focusing on escaping from threats could perhaps fit the Playpulse.	Medium
Music games	A rythm based music game could work well with pedalling, as the player could have to match the bpm of the music to progress through the song. Then buttons could be pushed to match a pattern, like in Guitar Hero or something along those lines.	High
Party games	A party game with a large variation of minigames that each makes the player use the pedalling for something fun and intuitive could be a very good fit for the Playpulse platform.	High
Idle games	Idle games does not necessary need so many options for input, so the Playpulse controller could be sufficient. The game could demand the player to visit each day to progress, and thereby also make sure the player exercises regularly. However, it is important that the exercise done on the daily visit is of a high enough intensity and duration.	High
Platform games	There can be many variations within the platform genre. Both fast-paced boss fighters and precise platform jumping games are possible. Pedalling could be used for different types of movement or shooting in this genre. The platform genre should be feasible for a fun and engaging game for the Playpulse platform.	High

MMO	For MMOs, the feasibility depends entirely on how the base game is. Advanced RPGs might be impossible due to lack of input options, while a marathon MMO where players run together with thousands of others could very well be made. The fact that the game is massively multiplayer in itself should not be limiting.	High
Racing games	In racing games, pedalling can easily and intuitively be mapped to the vehicle or character's forward or backward momentum. It is, however, important to make sure that the one who pedals the fastest is not always the winner. Ignoring this would exhaust the players too fast and remove skill from the game. With this aspect in mind, the racing genre should work very well.	High
Infinite runners	Infinite runners should be easy to map intuitively to the controllers, e.g., powering a propeller or making the character run. When using this genre for an exergame, it is important to balance it and add elements of variation. The player's stamina should not be the only thing that affects how far the player gets as this removes skill and only depends on fitness. Considering this, infinite runners should work well on Playpulse.	High

13.4 Summary

This section first starts with a general overview of game genres before discussing how fitting each genre is for the Playpulse platform. Limiting factors are few available input buttons and no precision input method on the device. The analysis found complex games like in the RPG and simulation genre to be less suited, while more fast-paced and social genres like racing games, platform games, and party games to be highly fitting for the platform.

14 Discussion of Concepts

Throughout this project, several possible game concepts have been discussed and proposed. Some of these were quickly discarded due to apparent flaws or game-breaking restrictions. The Playpulse platform used in this project only has six buttons and the pedalling mechanism available to the player, thus severely limiting which games are realisable. However, some game concepts survived the evaluation process and were regarded as both possible, interesting and able to provide a certain level of physical activity. These will be discussed here. The one chosen to be developed will be explained in greater detail under Game Concept – 2D boss fighter inspired by Cuphead (see Section 15) and is omitted here.

14.1 2D side-scrolling platformer

This idea is built around the classic 2D platformer genre, including game franchises such as Super Mario Bros., Castlevania, and Mega Man (see Figure 20). In the game, the player would work their way through a course, defeating enemies, navigating obstacles, and solving puzzles along the way. Jumping from platform to platform and exploring the map would be large parts of the game, and hidden treasures, shortcuts, traps, and other elements could be built into the gameplay.

Figure 20: Original Mega Man gameplay – A classic 2D platformer [17].

The game would incorporate the Playpulse controllers by using the pedals to build up momentum. The amount of momentum built up would be indicated by a bar on the screen. This momentum would not instantly be applied to the character but only when the left or right movement buttons on the handlebar are pressed. There would also be a jump, a punch, and an interact button on the handlebar. This kind of controller functionality allows the player to start with the desired speed when jumping platforms without building up speed in a preceding runway. It also allows for an unusual challenge on the player's side in determining the speed needed to make certain jumps without over or undershooting them.

This idea was, in the end, abandoned due to some key factors. The Playpulse bike at our disposal has pedals with inertia, meaning they will not stop pedalling instantaneously. This mechanic could lead to a frustrating player experience when the character would need to quickly change from rapid movement to slow movement or vice versa. In general, a platformer game must have intuitive and responsive controls. If not, the player might feel that they are not the ones failing at the game, but the game fails them, ultimately making the player displeased. It was also hard to find an engaging two-player mode for this kind of game. A race to the end could be possible but might not suit the genre too well.

14.2 2D vertical endless runner

For this idea, we focused on making the pedalling input from the player do something that felt intuitive within the game. One solution was to have the pedals power the rotors in a helicopter. This idea was further expanded to having the in-game character use pedals to power a one-person helicopter. The game concept built around this would be a 2D endless runner, where the player has to escape from something that is chasing it. This genre has become quite popular over the last decade, especially on mobile devices, with Temple Run (see Figure 21) and Jetpack Joyride as two examples.

Figure 21: Gameplay from the game Temple Run on Android [18].

Many current endless runners are either sidescrollers, where movement happens from the left towards the right of the screen or games where the playable character runs into the screen. Our game would be a vertical variant of this genre, where the player would move towards the top of the screen while avoiding the bottom. The player would control a helicopter inside a volcano while escaping from lava that is rising from below. Pedalling faster would make the helicopter rise more quickly towards the top of the screen. As the player moves higher and higher in the volcano, several obstacles would appear. These could be spikes or lasers that would force the player to change its pedalling power to move further up or down on the screen to avoid these hazards. The buttons on the Playpulse controller would be used to move the helicopter sideways.

As for multiplayer features, it was thought that the volcano could have two separate vertical lanes where one player would be in each lane. The players could then click buttons on the walls of its lane or interact with other mechanisms to activate hazards in the other player's lane. The players would play against each other, and the goal would be to survive for longer than the other player.

The 2D endless runner idea was abandoned as it did not seem to offer enough variation in the gameplay – this applies both during a single round and in the long run. Endless runners ask the player to do the same task repeatedly for as long as possible, and it can quickly become repetitive. Since the player needs to regularly play our game to gain health benefits, the game must offer enough variation to be enjoyable in the long term. It seemed that other game concepts had more potential for succeeding in this regard, and the endless runner idea was therefore discarded.

14.3 New game mode for Pedal Tanks

One early idea was to develop the already successful Pedal Tanks game further (see Section 12.5). Pedal Tanks is the game for Playpulse that has shown the most potential as an exergame so

far. It had players show high-intensity exertion levels during workouts and achieve a HIIT curve throughout the game session. The game only includes one game mode: capture the flag. It could be an exciting project to check if better game modes exist, game modes that create a more effective workout session, under the same tanks concept and game engine.

One example of this could be a mode inspired by the coin-runners battle mode in Mario Kart. In coin-runners, the players, including NPCs (non-playable characters), compete in collecting the largest amount of coins before the timer runs out. Coins are scattered around the map, and more of them will sequentially be spawned throughout the game. Players can also collect items around the map that will either help themselves or impede other players. An example is the green shell, a projectile item that can be launched directly towards other players. If the shell hits, it will make the hit player lose a certain amount of their coins. Other players can then collect these lost coins.

Figure 22: Four player Coin Runners on Nintendo Wii [19].

This idea was, in the end, abandoned due to it being too similar to Pedal Tanks' principle. The results gained from choosing this project could be interesting but might more likely not give us as much information as a completely new concept would do. This realisation led us to choose something different.

14.4 Summary

After discussing possible games for the Playpulse platform, four main concepts were left, whereby one was chosen. Only the discarded ideas are discussed in this section.

The first one is a 2D side-scrolling platforming game where the player must use the pedals to build momentum. This momentum is released only when the player presses the button to move left or right. This feature allows the player to start moving fast without having to build up speed. The idea was discarded due to the controllers probably being too complicated and frustrating, and since multiplayer does not fit in nicely.

The second concept is a 2D vertical endless runner. Here, the player would pedal to propel upwards in a volcano while escaping the ever-rising lava. The game would be a competition between two players playing the same track. While raising upwards, the player would also need to avoid different obstacles and projectiles. The idea was, in the end, discarded due to it being too repetitive in the long run.

The third concept was to further build on the already existing Pedal Tanks game. This game has proven successful. Thus creating a new game mode for it could provide interesting insight. This idea was, in the end, discarded for being too similar to the previous master's thesis on Pedal Tanks.

PART III

GAME DESIGN AND IMPLEMENTATION

Based on findings in the pre-study, a game concept was chosen. This part covers the concept (originally developed and described in the specialisation part of this project [22]), and describes the game design, exercise choices, and development process for the prototype.

15 Game Concept – 2D boss fighter inspired by Cuphead

This section will explain the concept chosen to be developed and later tested in the master's thesis. Details and specifics will be explained in Section 16 and Section 18.

The chosen concept is a 2D static-screen boss fighting game. The idea is mainly inspired by the boss fights from Studio MDHR's game called Cuphead [91] (see Figure 23). The main objective of our game is to beat different bosses. Each boss fight will be a different level. These levels consist of the boss, the players, and a level environment. The bosses are designed to represent different household technology gone rogue due to some unknown reason. The player, a small cartoon fox, is tasked to defeat these corrupt appliances and restore harmony to the different areas of the home.

Figure 23: A Cuphead boss played in single-player mode [20].

The game is meant to be played as a cooperative two-player game, but playing alone will still be possible. The two players will play as a team to achieve their common goal of defeating the boss. They do this by damaging the boss and learning the nooks and crannies of the game together. Particular actions from one player will also affect both of them, upping the stakes.

The players damage the boss by shooting at it, and when the boss's health reaches zero, the players have won the level. While playing the level, the boss will shoot different projectiles and launch other attacks at the players. These attacks will hurt the players, and when they reach zero health points, they may try to revive themselves or die (more about the death mechanic in Section 16). Thus, the players have to avoid projectiles and other attacks while still damaging the boss to win. How fast the player shoots will be determined by pedalling speed, forcing the player to pedal to win. The players can also switch between two different states. In one state (grounded state), they are a grounded character running and gunning, while in the other state (flying state), they equip a helicopter-like backpack. This state allows the player to gain altitude, making it possible to shoot the boss while at the top of the screen or avoid ground-borne attacks. Flying speed will also be determined by pedalling, making the player unable to fly if they pedal too slow.

The boss will go through different stages in the level, where each stage consists of some alterations or additions to the boss's move set. The stage change will happen at a specific health point for the boss. When a level is beaten, the players are rewarded with stars depending on their performance. These stars unlock new levels. Some stars are achieved based on how fast they beat the level, while others on in-game skills.

This idea was chosen due to some key factors. When discussing different concepts, this idea was the one most clearly fit for the platform. No breaking flaws were found, and those remaining were either solved or not of a significant scale. Besides, this concept is very different from previously tested games on the Playpulse platform. Both authors also enjoyed the actual game Cuphead, which brings both motivation and interest into the project. Hopefully, the game should also prove to be pretty challenging and intense, which, expectedly, translates to an engaged player who pedals at a high pace throughout the match.

16 Game Design and Prototype

In this section, most of the features available in the game prototype are described. The section also includes a few mechanics not included due to time limitations. A general overview image of the game can be seen in Figure 24.

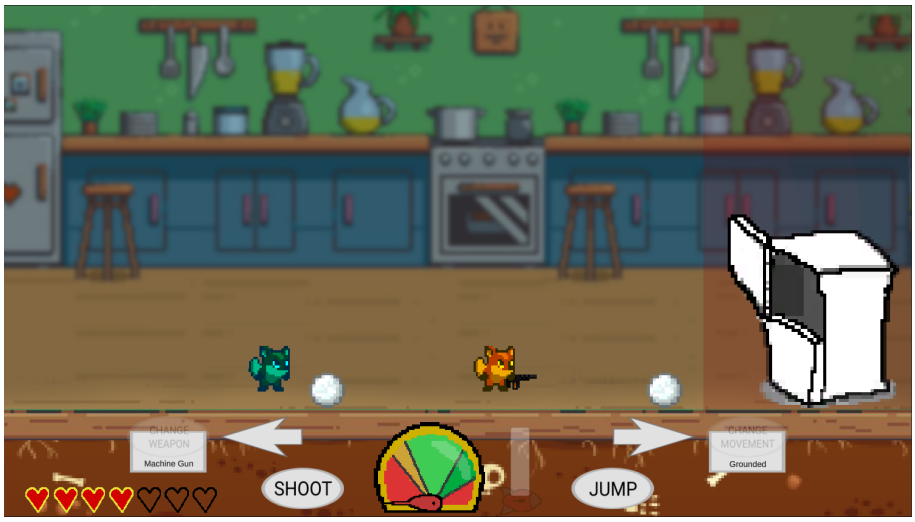


Figure 24: Level one featuring two players in the grounded state fighting the boss in phase one.

16.1 Controller mapping

Figure 25 gives an overview of the mapping between controller buttons and function in the game. Specifics details about the different functionalities are given later in this section.

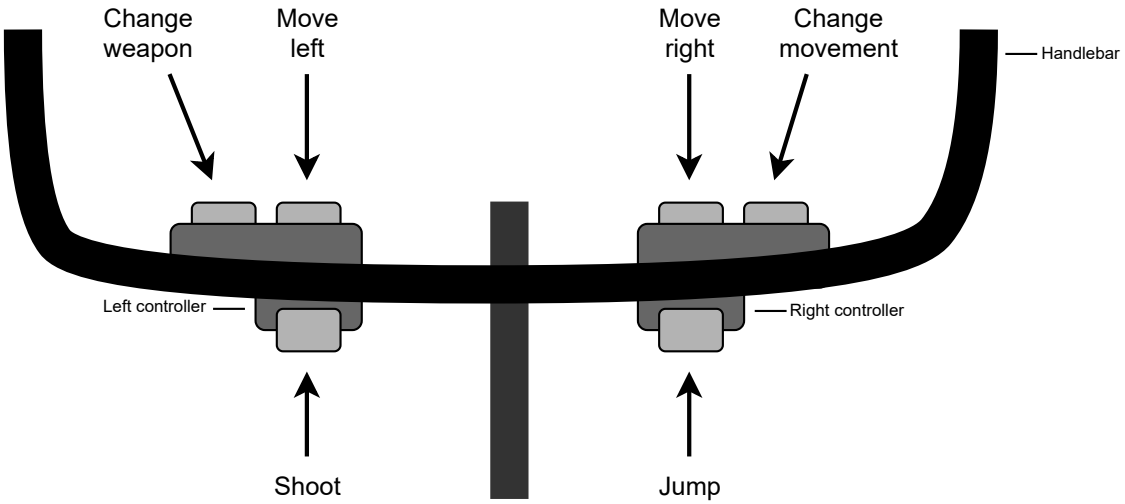


Figure 25: Controller mapping for the game.

16.2 Player movement

Movement in the game was customised to fit with the available Playpulse platform. The platform adds some limitations and challenges on how to make intuitive and responsive controllers. The Playpulse platform available has six buttons (see Section 16.1) and a pedalling mechanism. Three

of the buttons will go to handling movement, and pedalling will partly be used as well. Movement is split into two states: grounded and flying. The reason for this is to make the game more varied. Letting the player change state during the game adds both more strategy and choice to the game. The flying state will also shift the play and controller style, requiring more skill than without the implementation.

16.2.1 Grounded state

Lateral movement is handled by a button on the left and right side of the handle. These will move the player in the desired direction regardless of their movement state. Also, a third button, located on the right side, is used for jumping. Jump height is determined by how long the player pushes the jump button. Figure 24 show the player in a grounded state.

16.2.2 Flying state

In the flying state, the player equips a helicopter-like backpack (see Figure 26). Lateral movement is still handled by the left and right buttons described in Section 16.2.1 but pedalling is no longer mapped to shooting; now, pedalling maps to rotor speed. The rotors will only rotate while the jump button is pressed, which allows the player to keep their pedalling momentum and have the player fall simultaneously. The player must reach a minimum pedalling threshold to rise (indicated by the Pedal Gauge in Section 16.5.1). While pressing the jump button, faster pedalling leads to an increase in vertical speed and vice versa.

Figure 26: Level two with the player in a flying state.

16.3 Combat

Combat is the heart of the game. It involves the player(s) and the boss, each with their move and attack set, and each level consists of a separate boss battle. The player wins when they eliminate the boss. To do this, the player has to damage the boss till it loses all its health points. At the same time, the player must dodge and avoid all attacks sent by the boss. The boss will go through two stages of attacks. A new stage is triggered after the boss loses a certain amount of their health.

16.3.1 Player attacks

The player's attack set consists of two different types of shooting. This set applies both to the grounded and the flying state. The two different weapons to choose from are a rapid-firing machine

gun and a more heavy rocket launcher (see Figure 27). For the machine gun, the shooting rate is determined by how fast the player pedals. Specifics about this can be found in Section 16.5, but generally, pedalling faster means faster shooting. One bullet from the machine gun deals 40 damage points and travels at a speed of 15. The rocket launcher works somewhat differently. A loading meter determines when the player can launch a rocket. When the meter is filled, a rocket is available; otherwise, it is unavailable and pedalling fills the meter while the weapon is selected – more about this in Section 16.5. The rocket deals 200 damage points and travels at a speed of 5. The main objective of the rocket is to take down shielded objects and bosses (see Section 16.3.3), which can not be hurt by the machine gun bullet.

The light gun will shoot at a constant rate in the flying state, set at the slowest of the three paces available. The constant rate is due to pedalling now being mapped to rotor speed in the helicopter-like vehicle. For the rocket launcher, the same applies. The meter fills automatically when the weapon is selected, and pedalling will not affect it.

Figure 27: A player firing a rocket towards the boss in level three.

16.3.2 Boss attacks

The boss attacks will vary from level to level, but the general principle stays the same. Mainly, the boss will shoot projectiles of different sorts. These can either follow a predetermined pattern or be launched directly towards the player. The boss may also spawn stage hazards such as spikes from the floor, hazards from the sides, and similar attacks. Attacks will also differ depending on in which stage the boss is. Altering attacks is done to make the battle less monotonous and more enjoyable. Much of the game's philosophy is in the player learning how the different boss attacks work and avoiding them once learned. Because of this, attacks will be somewhat predictable when launched. Attack order will, however, not be. In Section 7.1, clear goals and seemingly achievable tasks are listed as essential for achieving GameFlow. By making boss attacks somewhat predictable and allowing the player(s) to learn more and more about them, the game will feel a lot more achievable. It is, however, important to not make it entirely predictable, as this takes some of the sense of skill out of the game.

The boss character will be able to span one out of three main areas at a time: grounded, in the middle of the screen, and near the top of the screen (see Figure 28). Some bosses will physically move between different areas during a phase, while others are stationary. Variety in the boss position will mix up the levels and allow for more variation. Bosses switching position within a phase also forces the player to change position and pay attention to achieve a good score.

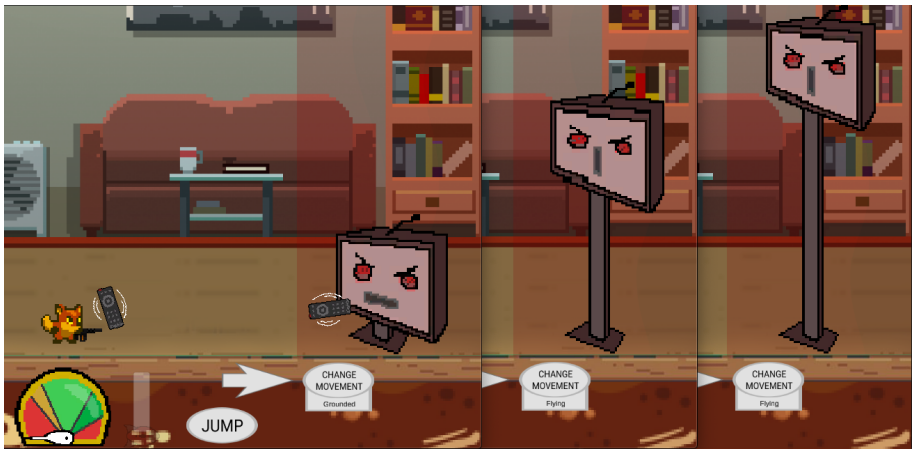
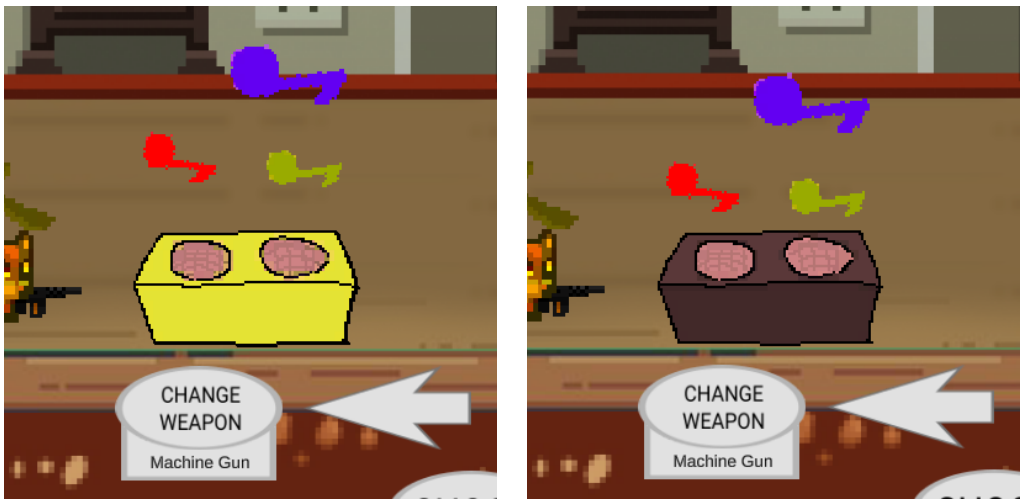


Figure 28: Level two showing the boss in all three different positions.

16.3.3 Shielded state for objects and bosses

Certain objects and bosses can be in *shielded* state. This state hinders standard machine-gun bullets from doing damage. A blast from the rocket is necessary to either destroy the object or remove the shield. Objects currently protected by a shield is indicated by flashing yellow. The shield is included to add more variety to the gameplay and give the rocket launcher a genuine purpose. It also adds more possibility for strategic cooperation where one player can focus on taking out shields while the other deals damage to the boss.



Yellow flash on Yellow flash off

Figure 29: A speaker object protected by shield. Only a rocket can destroy it.

16.3.4 Health points

Both the player and the boss will start with a fixed number of health points (HP), and neither can acquire more while playing a level, except for achieving a revive (see Section 16.3.5). A player in easy mode starts with seven HP, and each hit from a boss attack will deduct one HP. The boss will start with 13,200 HP and will lose 40 HP from each bullet from the machine gun and 200 HP from the rocket launcher. HP for players will be indicated on the screen, but boss HP will not. In medium and hard, player HP is reduced to 5 and 3, and boss HP increases to 19,800 and 26,400.

As a deliberate design choice, the remaining health for the boss is not displayed. The reason for

this is to make the game more challenging but also to make the experience more rewarding and surprising. The idea is that seeing the progress bar reveal how close the player(s) were to beating the boss after dying will be motivating (see Figure 30).

Figure 30: A progress-bar showing how close you were to beating the boss, as well as a marker for phase two (the red flag) is shown on death.

16.3.5 Reviving and death

If a player loses all their HP, they will get a chance to revive themselves. This feature will add motivation to players close to finishing the level, make levels last longer, and add short sections of high-intensity pedalling throughout each game session. Reviving works by having an indicator show up when a player dies (see Figure 31). This indicator has a timer on it counting down and a vertical loading. This bar fills up when the player pedals, and if it reaches the top before the timer runs out, the player is granted a new life with three to one health point depending on the difficulty setting. Completing a revive will decrease the timer and become progressively more challenging each time either one of the players loses all health. In the end, this will make it impossible to gain a new life forcing the game to end eventually.

Figure 31: The player in a revive mode state.

16.4 Power-ups

The game includes two types of power-ups; these unlock new functionality in the game. The first one is a feather (see Figure 32 (a)). This power-up unlocks the flying state for the players. It appears in level one after completing phase one of the boss battle. Before collecting this power-up, the "CHANGE MOVEMENT" button is greyed out. The second power-up is a rocket (see Figure 32 (b)). This power-up unlocks the rocket launcher and allows the player to fire rockets. It is found in level two after completing phase one of the boss battle: As with "CHANGE MOVEMENT", "CHANGE WEAPON" is also locked before this power-up is collected. Power-ups are carried along chronologically, meaning that power-ups collected in level one can be used in level two and three but not vice versa.

(a) (b)

Figure 32: Power-ups available in the game.

16.5 Pedaling meters and controller UI

The pedalling meters are essential UI elements responsible for providing helpful feedback (see Section 7.1.6) to the player about their input.

16.5.1 Pedalling zone meter (gauge)

The indicator for pedalling zone is displayed using a gauge. The pointer shows how much effort, i.e. pedalling speed, is inputted by rotating from left to right. The background of the gauge-pointer has five different zones: red, yellow, light green, dark green, and red again (see Figure 33). Each zone represents some effect on the player. For the machine gun, no shooting will happen when the pointer is in a red area. The gun will fire when the needle is in a yellow or green area as long as the shooting button is pushed. Yellow is the slowest, and the darker the green zone, the faster the shooting rate will be. The rocket launcher is not affected by these zones, only pedal speed (see Section 16.5.2). When the player is flying, the same zones reflect rotor speed, not shooting rate. This change means that shooting will happen at a fixed rate equivalent to the light green zone, no matter the pedalling effort.

16.5.2 Rocket launcher ready meter (vertical loading bar)

For the rocket launcher, the indicator works a bit differently. Rather than showing an indicator of effort, a vertical loading bar will show how close the player is to have a rocket available (see Figure 33). A yellow rim is displayed on the rocket symbol when the meter is filled, and a rocket is then available to the player. When the rocket is used, the loading level will fall to zero again. The meter will fill up based on how fast the player is pedalling, but only while the rocket launcher weapon is selected. When in the flying state, pedalling will not affect the filling rate since it will fill at a constant rate.

Figure 33: The two pedalling meters. Pedalling zone meter (left), Rocket launcher ready meter (right).

16.5.3 Controller UI and HUD

A controller overlay is put at the bottom of the screen to improve the user experience. This overlay serves two purposes: working as a reference map to players unfamiliar with the controller layout and as a head-up display (HUD) indicating which controller inputs are available. In addition to the controller UI, a few other elements are also present in the HUD (see Figure 34). The players remaining HP, the pedalling zone meter and the rocket launcher ready meter are displayed among the controller overlay. These are there to provide necessary feedback about the player's current state.

Figure 34: The HUD always present at the bottom of the screen.

16.6 Level design

The level design stays pretty static from level to level, where changes primarily result from bosses attacks and movement. All levels will use a static camera design, i.e. the camera – what the players see on the screen – will not move. This choice means the players will not be able to move outside the screen. It is done for two reasons: it gives the player a complete overview of the current stage and attacks from the boss, and it makes the games multiplayer aspect simpler and easier to grasp when both players see the same screen. Secondly, the level will be made up of two vertical areas. One bottom grounded area (G) and a flying area (F) (see Figure 35). Some levels will have a Boss Area, indicated by a red tint, where the boss resides. Entering this area will damage the player. Apart from this, the level design will be plain ground to walk on.

For this prototype, three levels were made in total. Level one includes a refrigerator boss shooting projectiles from the ground in phase one and the air in phase two. The player unlocks flying in this level. For level two, the boss is a flat-screen television. This boss can move freely between three height levels in both phases. It shoots different projectiles at the player, and, in phase two, it also spawns a speaker object equipped with shielding (see Section 16.3.3). Level three is against a car boss. This boss has two places it can switch between by driving across the scene. Switching places also works as an attack for this boss. This boss is, for the entirety of the level, equipped

with shielding.

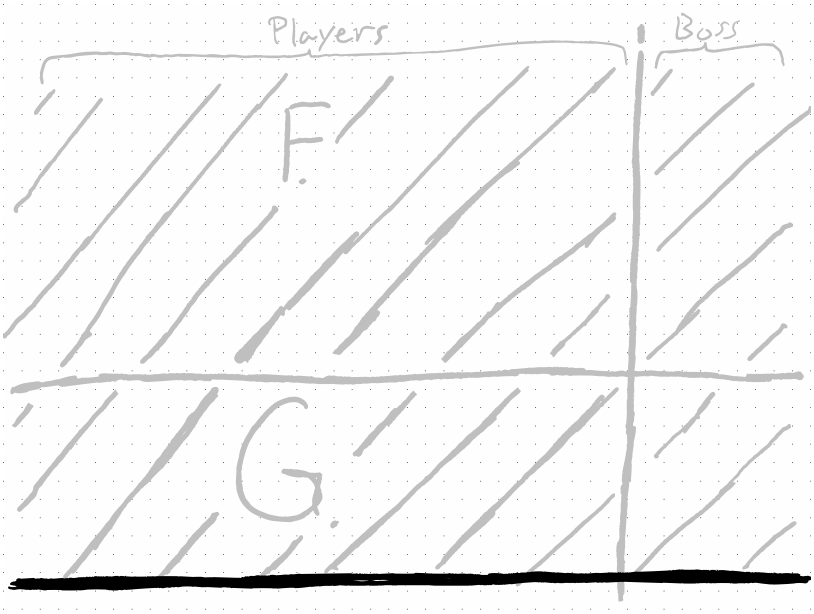


Figure 35: A drawing of the layout grid for a generic level.

16.7 Aesthetics

An aesthetic theme was created for the game to achieve more immersion and better fantasy for the game. This theme is based on the 8-bit pixel-art style introduced in the '80s and '90s, which has become popular in modern indie games. Character design for bosses and projectiles are all original work by the developers. Backgrounds and the player sprites are, however, not but are collected from the Unity Asset Store. Having a recurring theme in the game should help with immersion and, thereby, engagement in the players. It also helps to bring the game together and feel like a complete package.

16.8 Difficulty

Each of the three levels included in the game can be played at three difficulty settings: easy, medium and hard. This option is added for two main reasons: it provides new content to the participants who manage to beat all three levels before the third session is finished, and, for so-called "trophy hunters", it provides functionality for them to excel and show off their skill by collecting stars (see Section 16.10 on rewards). Due to time limitations, changing difficulty only provides simple modifications to the experience; players start with fewer hearts, receive fewer hearts on revive, and bosses start with more HP. However, these changes still make the level harder to beat and hopefully provide acceptable content for the most skilled players.

16.9 Multiplayer and single-player

The game is designed so that both single- and multiplayer mode is available when playing. The only factor that changes is the boss's HP. This change is necessary to make sure the level is not significantly harder when playing alone. Otherwise, there are no in-game elements specifically catered towards neither single-player nor multiplayer. The great thing about this is that the game will be playable by a larger audience and not only be limited to play sessions when a group of people get together.

As mentioned in Section 7.1.8 and 9.2, social mechanics and interactions are an essential part of a video game. They can, if done right, help elevate the game to a higher level of enjoyment. Because of this, it is still imperative to have the possibility of playing with others. Especially for an exergame, where the developers want the players to forget about the exhaustion of playing the game, social interactions can be a huge help. In this game, communication can help players advance further by helping each other recognise boss attack forms and alert the other player. Discussion on how to better approach the boss is also likely. Besides, players could feel more obligated to do their best when playing with others as losing no longer only affects them. Therefore, the game is still recommended to be played as a cooperative multiplayer game.

16.10 Rewards and achievements

When completing a level, the player(s) will receive between one and five stars (see Figure 36). The number of stars was initially going to depend on factors such as the number of times the player got hit, time spent on the level, the number of times they died, and similar measures. However, time limitations reduced this down to time spent on the level and not using any revives. These stars are used to unlock new levels. The planned functionality was to have the number of stars needed to unlock the next level increase when the player got further into the game, meaning that merely completing a level might not always be enough. This strategy adds more replay value to the game, as replaying the same levels could make a difference. This feature was also dumbed down due to time limitations. The current implementation unlocks the next level as long as the player(s) has one or more stars on the previous level. The next difficulty is unlocked when the player(s) has one or more stars on all levels at a lower difficulty. Still, some players might want to get five stars on all levels. Also, getting a variable reward after completing a level can motivate many players and make them want to improve more (see Section 9.1).

Other features discarded due to time limitations are achievements and unlockables; see Section 16.14.

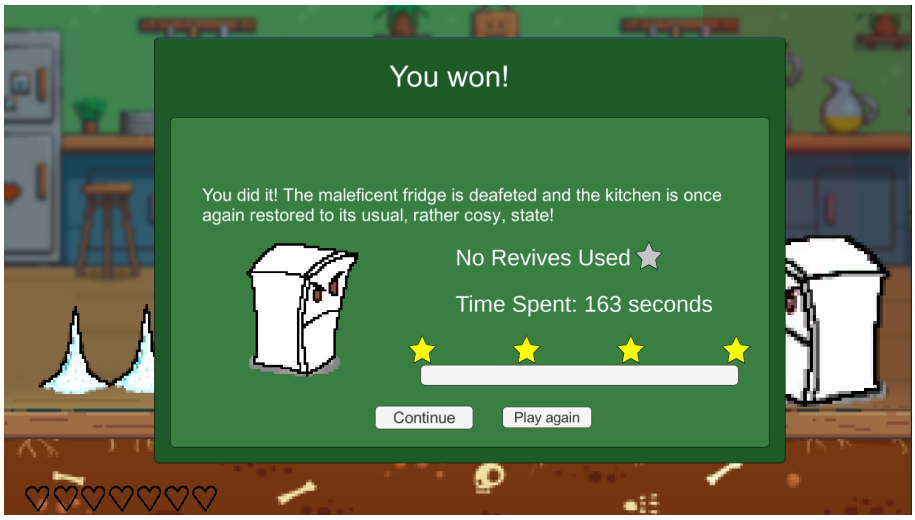


Figure 36: The player(s) receiving four stars ("No revives used" star missing) after completing level one on easy.

16.11 Progress and saving

To avoid frustration and encourage multiple play sessions over a longer time interval, the game will save players progress. This feature makes it possible for the player(s) to complete the game without doing everything in one session and helps with motivation since the player(s) can play when they most feel like it.

Saving is done after each completed level and is done for both players. The save is reflected in the level select screen (see Figure 37), where unlocked levels from the previous session will be available next time the game is launched.

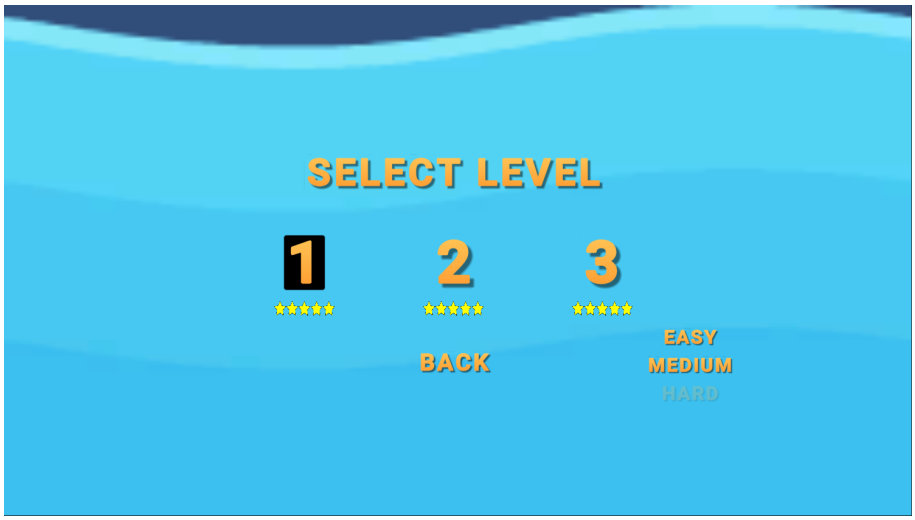


Figure 37: Level select screen with five stars on all levels (easy).

16.12 Sound

The game includes several sound effects to make the experience more enjoyable as well as to provide feedback. A different sound is played depending on whether the machine gun bullets damaged the boss or was destroyed. The same applies to the rockets. There are also sound effects for the player taking damage, dying and successfully reviving, as well as background music. It is worth noting that this feature was added late in the development process and not ready before session three of the user testing.

16.13 Playing the prototype

This section explains how the player goes about playing the prototype during testing sessions.

Since this is a networked multiplayer game (see Section 19.4.1), the players have to be on the same network to play together. In our case, this was done by physically connecting an Ethernet cable between the two computers. When on the same network, one player will work as the host, and the other will join as a client. The host player chooses a level and presses “host session”. The other player then chooses the same level and presses “join session”. When playing as the client, a small caveat is that some lag might be experienced due to the game’s networked nature. The lag is not substantial enough to make the game unplayable. However, it would have to be reduced to a point where it is not noticeable had this game been released.

When the players are connected and join in a game, the host starts the game by pressing “start game” or pressing the “CHANGE MOVEMENT” and “CHANGE WEAPON” buttons at the same time. When the game starts, no more setup or extras is needed from the players until both players die or win. When they die or win, they can either play again or choose a different level to play. Playing a different level requires a new setup of host and client.

In the prototype, each level was designed to last around 4 minutes, with playing times between 3 to 6 minutes being possible, all depending on how well the players would do in the game.

16.14 Design features not implemented in the prototype

Due to time limitations during development, not all planned features could be implemented into the prototype. This section covers a brief description of those features:

Different intensity levels – Originally, each level was supposed to play at a choice of a couple of different intensity levels. This feature intended to make everyone, regardless of fitness level, get a workout fit to their performance abilities. These different levels could be set to reach, e.g. 60–75 % of maximum heart rate for one choice and +75 % for another.

Dynamic pedalling zones – To have the game behave more like interval training and vary the intensity throughout the level, the different pedalling zones were planned to change dynamically. This means that hitting the dark green zone would not always be at a fixed rpm but could at some point require faster or slower pedalling.

Achievements – To encourage players to improve, add replayability, and motivate players with rewarding situations, an achievement system was planned for the game. These achievements could include completing a level without getting hit, completing a level under a certain amount of time, finishing all levels, and similar events. Achievements are also a great source of motivation for many players, and receiving rewards is for many a pleasurable experience (see Section 9.1).

16.15 Summary

The game design for the 2D boss battle game is based on theory from Section 7. The game features a player or players and a boss in a battle. The players will shoot either a light or a heavy gun projectile at the boss, while the boss will have several different attack moves. The player can either be grounded or in a flying state. Pedalling is used to determine shooting rate in a grounded state and upwards velocity in a flying state. If a player dies during battle, they have a chance of reviving themselves by pedalling. Each level will give the player(s) between one and five stars upon completion; these stars are used for unlocking new levels. Each level can be played multiple times, either to gain more stars or to be played at a greater difficulty. The game is possible to play both in a single-player and a multiplayer mode. Game progress will be saved.

17 Theory Behind Game Design Choices

Many of the game design choices described in Section 16 are made based on the theory related to enjoyment and engagement that are presented in our pre-study (see Part II) . When designing our game, existing theory on game enjoyment, replayability, and exercise aspects in exergames were considered. Looking at previous work should make our choices more likely to succeed. Using findings from previous studies also lets us avoid common mistakes.

17.1 GameFlow

To make players more or less forget about the exercise part of the game, they need to achieve a state of flow. We try to achieve this using Sweetser and Wyeth's GameFlow model (see Section 7.1). The game developed in this report lets the player(s) concentrate on the task at hand by having simple controls and gameplay that is easy to grasp. This should hopefully let the player focus entirely on the game. The game has a significant amount of challenge. In addition to the game itself being pretty hard, boss fights also get increasingly difficult with new levels. The player can, in addition, choose to play the same level again with a higher difficulty after completion. To get past these bosses, the player must improve their skills and learn the attack and move set of the boss. A tutorial will be present when playing the game the first time, letting players develop their skills before the first match. The controls should be simple and easy to grasp, and the player has complete control of player movements. An overarching goal will be provided through the theme of the game, and sub-goals will be to defeat the bosses one by one. These goals are presented early on and should be very clear to the player. The game provides feedback using different visual and audible elements, such as the needle in the pedalling zone meter turning red if pedalling too slow and different sounds for hit and miss when shooting. Finally, the game is a multiplayer game, thus adding social interactions to the experience. All these elements will, hopefully, help the player(s) reach a state of flow while playing.

17.2 Challenge, fantasy, and curiosity

In Thomas W. Malone's paper (discussed in Section 7.2) on what makes games fun, he focuses on three concepts: challenge, fantasy, and curiosity. As mentioned in the paragraph above, the game should provide sufficient challenge to the player. E.g. the addition of random elements in the battles adds the feeling of challenge. It makes it so players cannot merely memorise the exact attack pattern. Since the game will be developed as a prototype, fantasy might suffer somewhat due to insufficient time for proper aesthetics and storyboarding. However, there should be enough of a plot developed to have the player(s) engaged in what is happening. Sensory curiosity is provided through sound and graphics in the game, and cognitive curiosity via the player(s) wanting to unlock the next level to find out what the next boss is like.

17.3 Dual Flow

Sinclair et al. wrote about Dual Flow (see Section 7.3), a continuation of the GameFlow model for exergames. The first of the two parts in Dual Flow is attractiveness. In principle, this element is the same as Sweetser and Wyeth's GameFlow model, which we have already covered. The second element is effectiveness, which looks at the exercise part of the game. The game in this project initially tried to fulfil effectiveness by letting players choose the levels overall intensity level, thus allowing them to choose more demanding sessions as they progress. This feature was, however, abandoned due to lack of time. The level will also include variations in intensity throughout the battle to make the exercise session more efficient. This variation happens naturally by different phases requiring different intensity and revives giving short intensity spikes.

17.4 OA3 framework

The OA3 framework (as detailed in Section 8) shows how objectives, rewards and emotions are important for engaging the player in a game. As the extrinsic objective part from the objectives-component of the OA3 framework is closely related to the clear goals element of GameFlow, this part has been covered by the same measures as the clear goals element, which is to have an overarching goal presented through the theme of the game, with sub-goals of defeating each boss one by one. As for the intrinsic objective, where players make their own goals, we believe the difficulty and reward parts of the game allow the players to aim for getting all five stars on a level or completing a level without taking a single hit. As for the activity component, when building upon our initial concept idea, it became clear that our game was best suited to include the three categories of *interfacing* with special controllers (the Playpulse bike), *destruction* through killing bosses, and *socializing* through the cooperative nature of the game. The activity categories of experiencing the story and characters were planned to be a part of the game but were cut due to limited development time, while the rest of the activity categories were deemed unfeasible to add, as they would significantly change the concept of the game. With regards to the accomplishments component, we wanted to add all three types, but in the end, the achievement part had to be cut, and only *progression* through unlocking new levels and *completion* through being able to fully complete a level with five stars was added to the game. Progression and completion are still quite limited in our prototype and would be significantly expanded upon if we had the time. Through having aspects of our game adhere to the objectives, activities and accomplishments of the OA3 framework, we are hoping to be able to achieve the *positive affect* and *absorption* responses from the players, as the affect component of the OA3 framework outlines.

17.5 Six types of causes of engagement

Another engagement-increasing method presented in Section 8 is the six types of causes of engagement. As several of the types of causes are overlapping with elements from GameFlow, through designing parts of our game to fulfil the GameFlow elements, we subsequently had included some of the types of causes of engagement in our game. The challenge of the game can be seen as an *intellectual* type of cause of engagement, as it can be a complex task to evade all projectiles and defeat the boss. As our game is an exergame it naturally has a *physical* engagement cause. It is also possible that our game can have a slight *sensory* cause for engagement through audio and a lot of visual elements on the screen at the same time, yet, this has not been a focus while designing the game. The *social* type of cause, however, has been an integral part of our game design, which the cooperative nature of the game shows. The second to last type of cause, *narrative*, was for a long time something we wanted to have in our game, but as we had limited time, our game, unfortunately, lacks a story. Finally, it is a possibility that players get frustrated due to the high difficulty, and therefore also quite happy when defeating a boss, which can lead to an *emotional* cause of engagement in certain players. Our main focus when designing the game has however been on the intellectual, physical and social causes of engagement.

17.6 Rewards

As written about by Wang and Sun, rewards bring motivation and sub-goals to the player(s) [44] (further detailed in Section 9.1). When completing a level in this project's game, the player(s) will receive between one and five stars. These are used for further unlocking of new levels. The stars are given based on battle performance and will thus function as a reward to the player(s). In addition, achievements were planned but eventually discarded due to insufficient time. These features add an aspect of reward, which could add motivation and replay value to the game.

17.7 Social mechanics

One of the mechanics for increasing enjoyment and engagement presented in our pre-study was social mechanics. For many players, being social in relation to playing a game can increase their enjoyment and motivate them to play the game more (see Section 9.2 for more details). The benefits of having social aspects in a game are also identified in GameFlow through the social interaction element, in the OA3 framework through the socializing activity category and through the social type of cause of engagement. With this in mind, we designed for cooperation to be a big part of our game, where the game is mainly meant to be played by two players at the same time. We hope this cooperative setting will foster communication between the players and make them help each other and push each other to perform better, making the game experience more enjoyable and engaging.

17.8 Summary

This section has presented how enjoyment and engagement-related theory has been used as a basis when designing some of the features of our game. Elements from GameFlow played a big part when deciding on the challenge of the game, the controllers, and how goals and feedback should be presented to the player. Challenge, fantasy and curiosity both overlap with the challenge from GameFlow, but also informed us on how to include sensory and cognitive curiosity in the game. The DualFlow framework has been especially important when designing and balancing the physical intensity of the game. Both the OA3 framework and the six types of causes of engagement have helped us include certain elements in our game that will increase engagement. Lastly, both reward mechanics and social mechanics have been added to the game. Through making sure our game has features that adhere to the aforementioned theories, we hope that our game as a whole will be enjoyable and engaging for the players.

18 Exercise Design

This section will detail the design of the exercise part of the 2D boss fighter exergame. It shows the thought process that is behind the selected intensity level of the exercise and the specific mechanics in the game that will encourage the player to exercise through pedalling on the Playpulse bike.

18.1 Intensity level of the exercise

As described in Section 6, the best fitting form of exercise on the Playpulse bike is aerobic exercise. Aerobic exercise can be performed with different levels of intensity, based on the average heart rate of the performer throughout the exercise session. This game is meant to activate people that otherwise live a fully sedentary lifestyle and do not exercise at all. Therefore, the game aims to push the player into having an average heart rate of over 50 % of its maximum heart rate during a game session. This puts the exercise into the moderate-intensity category. Even though Section 6.1.2 showed that light-intensity physical activity does have health benefits when replacing sedentary activities, we want to help the players in reaching moderate intensity during their exercise, to get closer to the recommended activity levels. If it so happens that the game feels too physically demanding at times, the player can choose to give less effort, thereby placing them in the light-intensity activity zone. We felt, however, that it did not make sense to design the game with only the light-intensity activity level in mind, as this level can easily be reached through other measures such as slow walking.

Looking further at physical activity recommendations, the recommended amount of moderate-intensity aerobic exercise is 150 minutes per week. This is however not something the game is directly trying to achieve. While one of the goals of the game is to be fun and engaging, making the player want to play it regularly, the game will not be judged as a failure or success based on whether or not it is being played for 30 minutes, five times a week. If it manages to activate and motivate inactive people into exercising more, then it can be considered a success.

Another thing to keep in mind is the DualFlow model from Section 7. As the player is playing the game over several months, the player's fitness will improve. For the game to still be effective, and make the player achieve the state of flow while playing, the required intensity when playing the game needs to increase. The initial game design contained mechanics that would allow the game to be played at different intensity levels. Due to limited time, this feature was cut. A description of these mechanics follows: To accommodate DualFlow, the game will let the player choose between three levels of intensity before beginning to play the game. The easy level of intensity will be the default one for people just starting with the game. Based on the player's age, which determines the player's max heart rate, the mechanics in the game will have a sweet spot that requires a certain rpm from the exercise bike pedals so that the player will have a heart rate of 50 % - 60 % of their max heart rate. This exact rpm sweet spot will have to be discovered and balanced while the game is developed. Furthermore, the moderate and intense intensity levels in the game will require a higher rpm from the pedals, which results in average heart rates of 60 % - 75 % and 75 % +. The different values of rpm and average heart rate are subject to change during the development process of the game.

18.2 How this is achieved in the game

A game session where the player(s) play four levels, defeating four bosses, is supposed to last around 20 minutes. Each individual boss fight will therefore take an estimated 4-5 minutes to beat, but the time can vary depending on the actions of the player. During these battles, the player is supposed to be active most of the time. The game has several mechanics to ensure this.

18.2.1 Player movement and combat

As mentioned in Section 16, the player can freely choose between two different movement states during a boss fight; grounded and flying. When the player is in the grounded state, the pedals of the exercise bike is fully controlling the weapons of the player.

- **Machine gun:** When the player is grounded, and the rapid-firing machine gun is selected, the gun will fire as long as the player is pedalling above a certain speed while holding the shoot button. The player can shoot this gun all the time (while selected), also while moving and jumping. As the player would want to damage the boss as much as possible, this should be an incentive to keep on pedalling all the time while this weapon is selected. The fire rate of the weapon will depend on the gauge as described in Section 16.5.1. This means that pedalling faster will make the gun shoot faster, in turn allowing the player to defeat the boss more quickly, and receive more stars on the level. This should be a further incentive for the player to pedal as fast as they can most of the time, as long as they are not too exhausted. **Note:** There will be an upper limit where the gun will no longer shoot if the player pedals too fast. This is to ensure they do not exhaust themselves too quickly and to ensure that one cannot simply win the game by being in very good shape and pedal intensely until the boss is defeated.
- **Rocket launcher:** When the player is grounded, and the rocket launcher weapon is selected, the pedalling is used for reloading the weapon, as described in Section 16.5.2. As the player would want to shoot a rocket as often as possible to damage the boss, the player should then pedal all the time while having the rocket launcher selected, in order to reload the weapon. As with the machine gun, pedalling faster will have an impact, making the rocket reload faster. The rocket launcher does also have a minimum pedalling speed required to progress the reload, and a maximum pedalling speed at which it does no longer reload.
- **Flying:** When the player is in the flying state, the pedalling is no longer controlling the weapons but is instead controlling the helicopter that the player is sitting inside. When pedalling quicker than a minimum threshold, the pedalling will give power to the propeller of the helicopter, and when the jump button is pressed, this power is turned into upwards movement. Pedalling faster will allow the player to move upwards with a higher velocity, and therefore avoid obstacles easier. This should motivate the player to pedal at all times while flying, to have the power of upwards movement at its disposal, with certain spikes of pedalling faster when they want to move upwards even quicker.

Although the game mechanics encourage the player to pedal at all times to get the most out of the movement and weapons, the goal is not to have the player stay at the same rpm for five minutes straight. The gauge that decides how fast the light gun shoots will have the ability to dynamically change the required rpm to hit the rapid-firing sweet spot so that the player's tempo is changing throughout the game.

18.2.2 Revive mechanism

When a player has taken enough hits and lost all of their health points, they enter the revive mode, where they get a chance to be revived and brought back into the game. To do so, they will have to pedal at a very high tempo for a short while, to fill up the revive meter. The time limit of how quickly the meter needs to be filled will be shorter and shorter for each time. A further explanation of the revive mechanic is found in Section 16.3.5. The idea behind the revive mechanism is to push the player into giving a very high effort for a short while, to vary the intensity of the gameplay and add variety to the player's use of the exercise bike throughout the game session.

18.3 Summary

When designing the game, it was decided that the game should push its players into having an average heart rate of at least 50 % of their maximum heart rate, as this puts the exercise into the moderate-intensity category. To achieve this, the game was designed to consist of several rounds lasting 4-5 minutes each, requiring the player to be active for most of the time. The machine gun, rocket launcher and flying game mechanics will encourage the player to keep pedalling, while the revive mechanism will provide sporadic spikes of increased intensity.

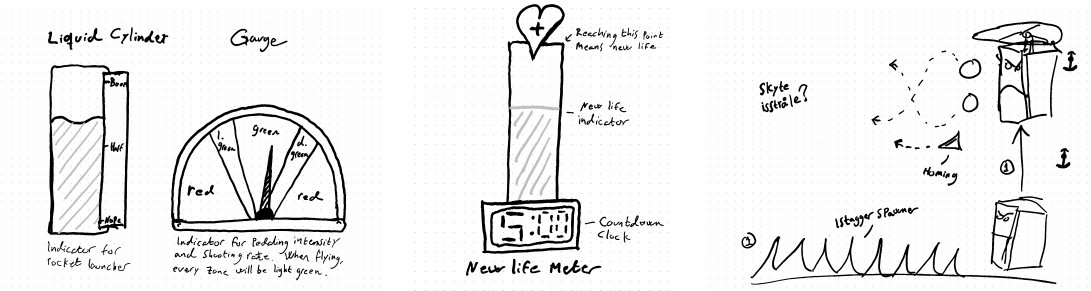
19 Game Development

This section covers the different aspects of the game's development process. This includes everything from the planning phase to the user testing before the experiment. Information about software and frameworks used in the development are also included.

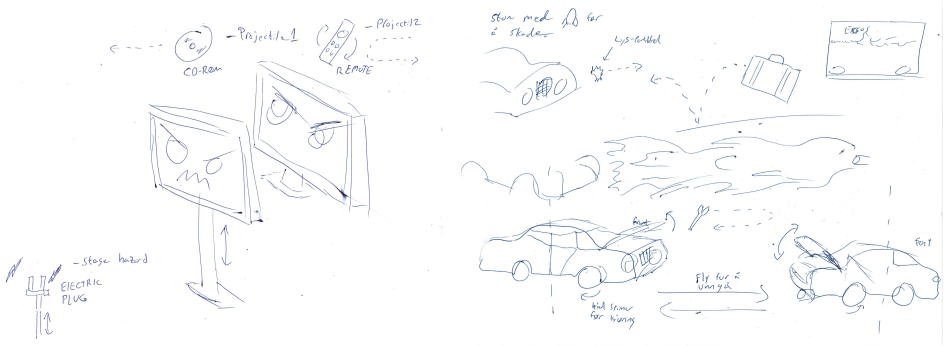
19.1 The development process

The development process took approximately three months in addition to the planning phase. The game concept and main ideas were created in the planning phase. The concept was chosen based on factors learned from Part II on creating enjoyable games and exergames but also in regards to previous games made for the Playpulse bike. An essential aspect of the project is learning about and exploring new possible games for the platform; thus, our game concept differs significantly from previous Playpulse games.

During the planning phase, ideas were sketched out (see Figure 38) and talked through. Much time was used to figure out a good way to make the exercise aspect incorporated so that players feel like they choose to exert themselves instead of feeling forced. These ideas and plans were made into functional and non-functional requirements; these are found in Section 19.2.



Pedalling zone and rocket meter | Revive-meter | Level one sketch



Sketches from level two (left) and level three (right).

Figure 38: Sketches made in the planning stage of the game.

The game was developed using Unity (see Section 19.4) due to its excellent documentation and available assets. The requirements from the planning phase were made into concrete tasks in a planning board. This planning board had each task in one of four states: todo, in progress, testing, and complete. Player movement and underlying boss logic were first prioritised. External assets were used for the player character, while all boss artwork is original. Secondly, grounded combat features were tackled. This included planning and creating different projectiles and move-sets for the boss and creating the firing logic for the players rapid-firing, light-damage and slow, heavy-damage weapons. Creating a general Level Manager for overhead when playing a level was also necessary at this point. The Level Manager keeps control over the states of players and the boss

and makes everything function together.

Further, the flying state was implemented for the player, followed by the revive-mechanism. With underlying boss functionality and player moves completed, making new levels became quicker. Creating new bosses, projectiles, and assets were the main focus continuing. Parallel to this, networked multiplayer functionality had to be added. Networking was done using Mirror (see Section 19.4.1), a High-Level API based on the deprecated UNET by Unity. Implementing networked multiplayer took a while longer than expected, forcing us to prioritise features when looking at our requirements. After networking, level selecting, saving functionality, user interface, and general QA was the focus. This continued until the user test (see Section 19.3). The most significant feature added after the user test was sound and music. The sounds were royalty-free sounds fetched from Unity's asset store.

19.2 Requirements

During the planning stage of the development process, a set of functional and non-functional requirements was agreed upon to help guide the development in the right direction. The requirements are based on background theory from Part II and discussions on how the game should look and feel to provide the right experience to the player. The requirements can be found in Table 2 and 3. The functional requirements are prioritised to "high", "medium" or "low" based on importance and the time available in the project. This means that something rated "Low" is not unimportant but that higher prioritised features must be finished before work on this requirement starts. Not all requirements were implemented in the final prototype; more about this in Section 16.14.

19.3 User testing

The week before the first session was set to start, a user test with two participants not in the main experiment was conducted. This test worked both as a test to reveal game-breaking, not yet found bugs, and practice for the actual sessions. The user test consisted of the participants playing through all three levels while providing feedback and comments on the experience while gaming and afterwards.

19.3.1 Received feedback from the session

Several pieces of useful feedback were given in the user test. The test also made it possible to observe the session and see where participants fail, get confused or need guidance. The most important findings are summarised here:

- The controllers on the handle are not intuitive to find for the player. An explanation of the setup, including showing where the thumb buttons are located, is necessary for the players to begin playing.
- The boss area had a bug where the player would get stuck inside it.
- The flying mechanism was said to be "a bit too slow", making the controllers feel less responsive.
- An HP bar for the boss was requested.
- Sound for firing and hitting the boss was requested.
- A comment was given about not knowing if it was better to use the rocket launcher or the machine gun.
- The animation hinting at the boss from level three driving across the screen and switching side was said to be too short to be noticed.

Table 2: Functional requirements for the prototype to be developed.

Functional requirement No.	**Description**	**Priority**
FR 1	The player character must be controllable by the Playpulse bike	High
FR 2	The player must have these six interaction modes – excluding pedalling – via the Playpulse bike: jump, shoot, move left, move right, change movement state and change weapon	High
FR 3	Pedalling speed on the Playpulse bike must map to shooting speed in grounded state	High
FR 4	Pedalling speed on the Playpulse bike must map to flying speed in flying state	High
FR 5	Pedalling speed mapping to fire rate and flying speed should dynamically change throughout the level	Low
FR 6	Pedalling speed must be visually communicated to the player	High
FR 7	The player must be able to switch between grounded state and flying state when the feature is enabled	High
FR 8	The player must be able to switch between a rapid firing light damage weapon and a slow heavy weapon when the feature is enabled	High
FR 9	Some boss projectiles and boss states must only be destroyable by the slow heavy weapon	Medium
FR 10	The player(s) must be rewarded after completing a level based on some performance measure of how well they did in-game	Medium
FR 11	The player(s) must be able to replay a level both on completion and failure	Medium
FR 12	The player(s) must be shown their progress in a level if failing that level	Medium
FR 13	The player must start with a fixed number of health points depending on difficulty	Medium
FR 14	The player must enter a revive mode when losing all health points.	High
FR 15	Failing the revive mode must lead to the player dying	High
FR 16	Succeeding the revive mode leads to a new life with a fixed number of health points depending on difficulty	Medium
FR 17	The game leads to failure if all players die	High
FR 18	The boss must be able to shoot projectiles of different sorts	High
FR 19	The boss can be in two different states, an attack mode and an idle mode	High
FR 20	The order of attacks (idle included) from the boss should be random and never the same two times in a row	High
FR 21	Boss attacks must include both projectiles fired from the boss and stage hazards spawned somewhere in the stage	High
FR 22	Each boss attack must have a unique identifiable visual cue happening before the attack	High
FR 23	The boss must be able to switch between two or three positions during a level	High
FR 24	The game must be playable as both multiplayer and single-player	Medium
FR 25	The two clients, when playing multiplayer, must communicate with each other via network	High
FR 26	The player(s) should be able to save their progress in the game	Medium
FR 27	The player should be able to select between three different difficulties for each level	Medium
FR 28	The player should be able to select between different intensities (physical exertion) for each level	Low
FR 29	The game should include sound effects and music	Low
FR 30	The player should be able to earn achievements	Low

Table 3: Non-functional requirements for the prototype to be developed.

Non-functional Requirement No.	**Description**
NFR 1	Playing a level should take between 3–5 minutes
NFR 2	The player(s) should not be able to finish a level on their first try
NFR 3	The player(s) should be able to understand and recognise the visual cues after a level play-through
NFR 4	The lag between sever and client must be less than 100 ms

- Seeing the speaker projectile in level two flashing yellow was said to be too hard due to a too small change of colour.
- Extending the invincibility period after being hit was requested.
- The test showed it necessary to inform participants about not pedalling too fast to avoid harm due to inertia in the bike wheel.

19.3.2 Changes made after the user test

A few changes were made to the game and session plan based on observations and feedback received in the user test. Firstly, the session will now start with an explanation of the controller's physical position. Since the physical aspect of the controllers is outside the control of this project, doing this will not change the validity of our data. A safety warning will also be given about the exercise bike's inertia. Further, several minor game bugs, including getting stuck in the boss area, was fixed. Flying speed was increased, and the invincibility period and the animation in level three were extended. The speaker projectiles were also updated with a new yellow-flash design that more clearly communicated their state.

The feature request about the HP bar was ignored due to this being a deliberate design choice in the game. The sound was not added before session three due to time constraints. Better signalling of the strength of the rocket versus the machine gun bullet was also not done due to insufficient time.

19.3.3 Other things learned from the user test

The user test was a great addition to the development process. It confirmed that the game was in a good enough state to be tested and made it possible to add some final tweaks to the game. Had the process been redone, user testing would have been a regular part of the development. Many good comments about the game were given (not all are listed here) but many had to be discarded due to the remaining time being way too short to implement them. Had the request and improvement suggestions been given to us earlier, many of them would have made it to the game.

19.4 Unity

When developing the prototype for this game, the game engine and developer platform Unity [92] (see Figure 39) was used. This choice is based on several factors such as ease of use, available documentation and tutorials, downloadable assets, and maybe most importantly: it is the game engine used for the development of all previous Playpulse games (see Section 11.5). Unity is a game engine with support for both 2D and 3D game development. It uses the Entity Component System (ECS) [93] paradigm. Unity features a drag-and-drop interface with many components pre-installed with the system, such as physics engines. Custom scripts are written in C#.

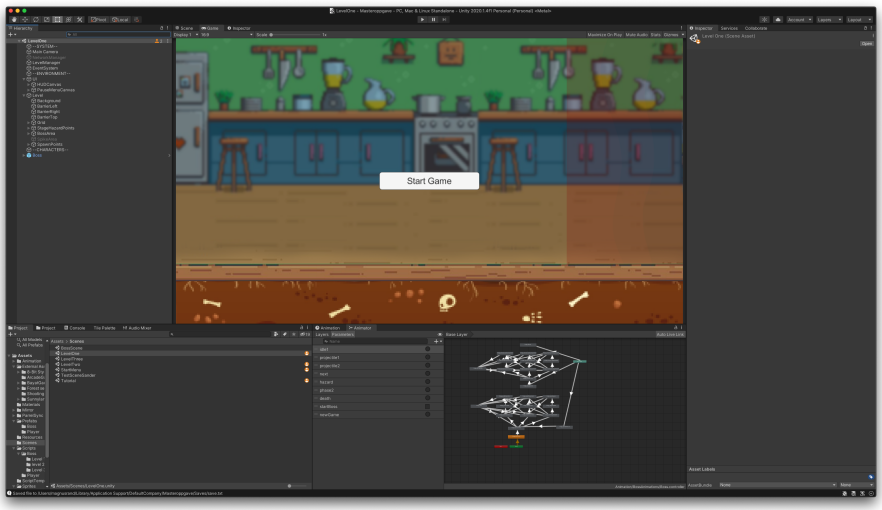


Figure 39: The Unity game engine user interface as of 2021

19.4.1 Online functionality – Mirror

Since this game is a multiplayer game, some networking functionality is necessary. We have chosen to go with Mirror Networking [94] for this. Mirror Networking is built upon Unity's own deprecated networking tool called UNET [95]. UNET is much used and functions almost the same as Mirror. UNET documentation can therefore be used in addition to Mirror documentation when developing with this library. Mirror Networking works by having one computer work as the host, and the other computers, called clients, connecting to this host-computer. Code for the server and clients is handled in the same script, and the correct code parts are executed based on if the computer is a server or a client. For communication between the server and clients and vice versa, two strategies are used: Commands and Client RPCs[3]. Commands are functions called by a client but run on the server. A Client RPC is the opposite: a function called on the server that runs on all clients. A more in-depth explanation of these and other features provided by Mirror are available in their documentation [96].

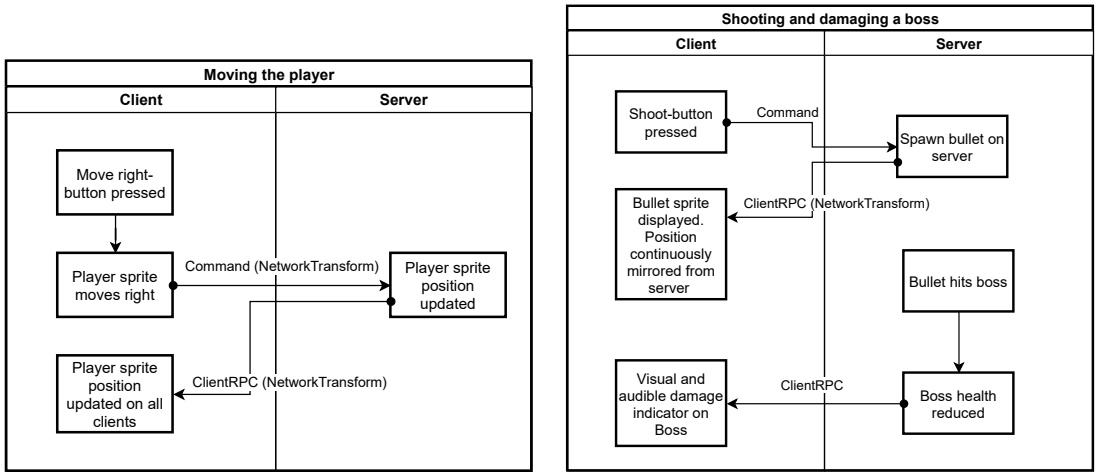


Figure 40: Sequence diagram showing how the clients and the server communicates in two given scenarios.

[3]RPC stands for Remote Procedure Call.

In our game, most game logic is handled on the server and mirrored to the clients. The main exception is with player movement and input. To avoid uncertainty about the state of a networked object in the game scene, Mirror uses a property called *authority* to determine who can modify the position and stats of networked objects. By default, the server has authority over all networked objects. There is, however, one exception: the local player. Since the client has authority over the local player, the client can alter the local player's state. Figure 40 (a) shows a sequence diagram with the process of moving the player. The diagram separates what happens on the client and what happens on the server into two vertical lanes. In this example, when the player presses the button to move right, the player moves locally on the client. When this happens, the NetworkTransform component – an available Mirror component that syncs positions to the server – connected to the player reacts to this movement and sends a command to the server. This command updates the server's position for this player before sending a Client RPC via the NetworkTransform to all other clients with information about the new player position.

For objects without authority, the procedure is more like in Figure 40 (b). Here, the goal is to shoot a bullet and damage the boss. To do this, the player presses the shoot button, which sends a command to the server. This command spawns a bullet on the server version. The bullet on the server then sends a Client RPC via the NetworkTransform on the bullet to all clients. This Client RPC makes sure the bullet is displayed on all clients, and the NetworkTransform continually mirrors its position to the clients using Client RPCs.

19.5 Summary

The development process consisted of initial planning and discussion before settling on a final concept. This concept was then made into prioritised functional and non-functional requirements. During the development of the game, the prototyping method was used. Using this method means that no sprint schedule or similar routine based tools were used. Requirements were instead implemented continuously based on their priority. A user test with two participants not in the upcoming experiment was conducted near the end of the development cycle. The user test gave helpful insight, and a few fixes and changes were made to the game before the experiment.

For development, Unity with the High-Level API networking library Mirror was used. Unity was chosen due to much available documentation and because previous games for the Playpulse platform were developed using Unity. Mirror works with the Host-client model where one player becomes a host other players (clients) connect to this host.

20 Software Architecture and Design

This section serves to give a deeper understanding of underlying mechanics and their relations to each other in the game. Here, a simplified overview of the game's architecture design and how the finite state machine controlling the bosses work can be found.

20.1 Game architecture

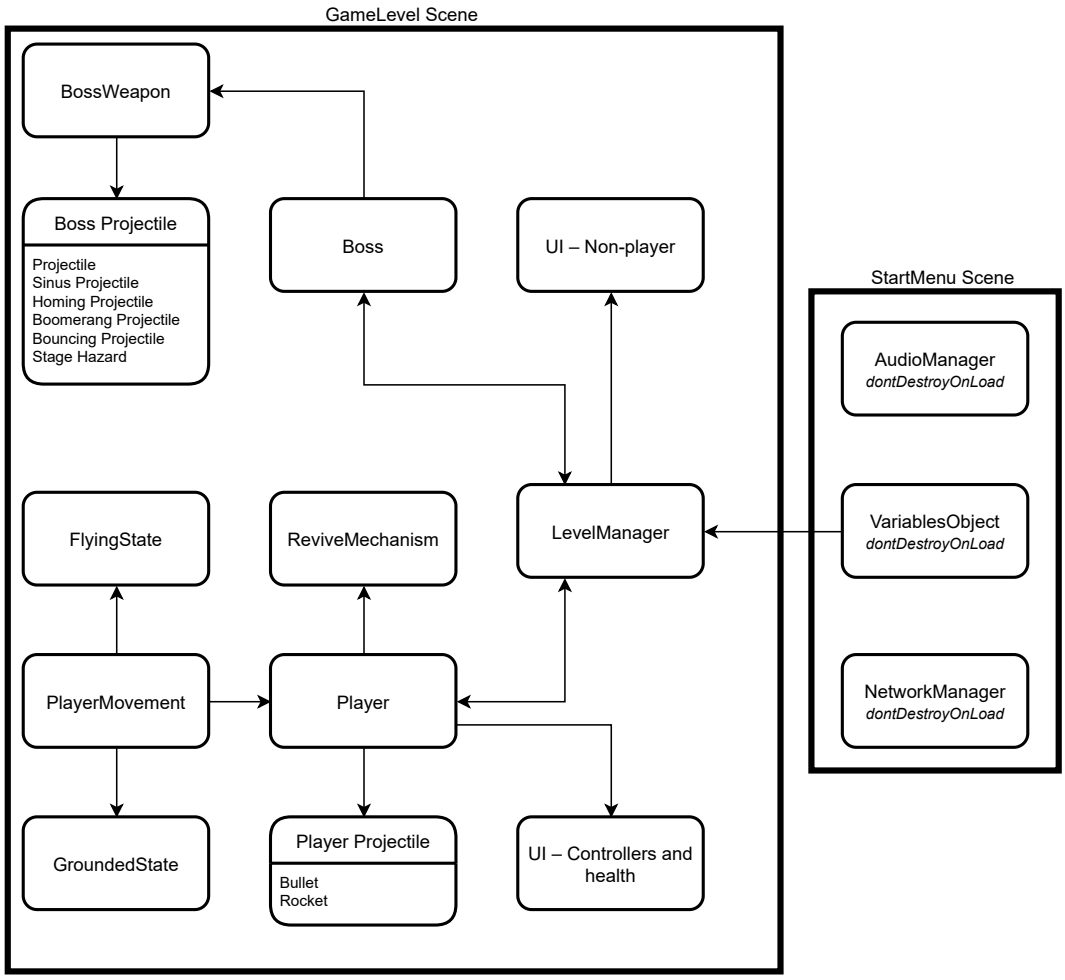


Figure 41: A simplified class structure diagram relating to scenes.

Figure 41 shows a simplification of the class structure in the prototype. The classes are placed within a scene container to show where they are used.

The StartMenu scene is the landing scene when loading the game. This scene is not online but works to establish a host for the clients to connect to. Three classes of importance are set up here, the AudioManager, the VariablesObject, and the NetworkManager. All these objects/classes are loaded with the *dontDestroyOnLoad* property. This property makes sure the instance does not get deleted on a scene change.

- The **AudioManager** handles music and sounds in the game. It is only used by the server and plays sounds for all players. The dontDestroyOnLoad property makes sure music can play between scenes.

- The **VariablesObject** has the task of storing variables inputted before entering a game. This task mainly includes storing the selected difficulty and applying it to the next loaded scene in the prototype.
- The **NetworkManager** is a class included in Mirror (see Section 19.4.1). It handles overall network logic and communication between server and clients.

The GameLevel scene is where the actual game is played. This scene is networked, and the server controls the majority of what happens here – see Section 19.4.1 for an explanation of this. This scene can be divided into five main categories: the Player, the Boss, the LevelManager, the UI, and the *dontDestroyOnLoad* objects from the StartMenu scene.

- The **Player** class and classes related to the Player class handle logic relating to a specific player. The classes keep track of health points, moving state, which weapon is chosen, if the player is reviving, and similar tasks. State information in this set of classes is sent to the LevelManager. This information sharing is done to have a complete overview of the game's state in the server handled LevelManager. Each player is also fitted with UI logic. Showing controls, displaying pedalling speed, and similar visuals relating to the specific player are therefore handled in this part of the software.
- The **Boss** class and related classes handle logic and statistics related to the boss. As with the Player classes, state information about the boss is sent to the LevelManager. A Finite State Machine handles the logic for the boss – see Section 20.2 for details.
- The **LevelManager** class is the brain of each level and it runs on the server. This class keeps track of everything in the game and triggers level specific events such as phase changes for the boss, power-up spawning, blocking not yet unlocked features, displaying end-game UI, and similar tasks. It also houses all settings, such as health points for different levels and difficulties.
- The **UI** consists of all UI not relating to the specific local player, which includes the game won and game over screens. The information for these visuals is sent from the LevelManager.
- The dontDestroyOnLoad objects are objects that carry on between scenes. In this case, it consists of the classes discussed from the StartMenu scene: AudioManager, VariablesManager, and NetworkManager.

20.2 Boss logic and architecture

The logic behind all three bosses is handled in a *Finite State Machine* (FSM). An FSM makes creation, planning and visualising the logic much more manageable, mainly since a boss usually follows a state-based pattern already, consisting of a finite set of attacks and states the boss can enter. In Unity, the most practical way to create an FSM is using the Animation panel. Each of the boss' states is represented as an animation, e.g. an animation of the boss standing still for the idle state. Unity then allows the developer to create conditional transitions between these states. Each state can also include a script that is run only while the state is active. This script makes it possible to randomly choose between the outgoing transitions, allowing for controlled random boss behaviour.

The logic behind the boss in level one can be seen in Figure 42. The FSM starts with an intro animation that waits for the game to start. After starting, the state will choose one of the four outgoing transitions: idle, projectile1, projectile2, or stage_hazard. Each of these states has an intro state playing a visual cue to warn about the next attack before switching to the attacking state (unless idle is chosen). After a random time interval, the attack state is exited, and it transitions to an outro state. This outro state plays the intro state animation backwards before randomly choosing one of the other three attack or idle states – it will not choose the same state twice.

When the boss loses enough health points, the LevelManager will send a signal to the FSM, making it transition to phase two – in Figure 42 this is the upper cluster of states. The logic in phase two works precisely as in phase one explained above. When the boss reaches zero health, another signal is sent from the LevelManager, and the death state is reached.

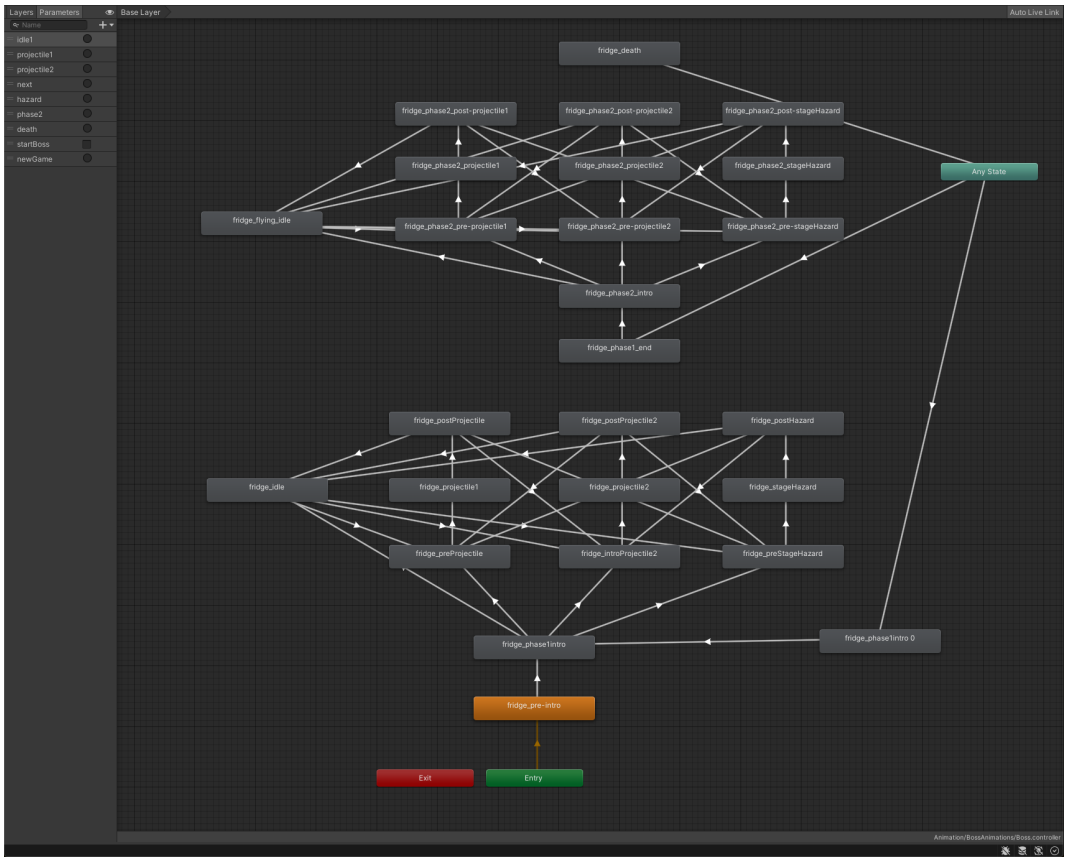


Figure 42: The Finite State Machine for the boss in level one.

20.3 Summary

The architecture of the game is divided into two main scenes: the StartMenu and the GameLevel. The StartMenu scene is not networked and sets up the host and client connection in addition to sound and level variables like difficulty. The major classes here have the *dontDestroyOnLoad* property which means they carry over to other scenes. The GameLevel scene holds classes related to the gameplay. Functionality for the player's movement and the bosses attack modes are here together with a class call LevelManager which controls what happens in a level and keeps track of player and boss statistics.

Boss logic is done using a Finite State Machine in Unity's animation panel. Each state responds to a boss animation with a connected script handling logic in that state. Each completed state will randomly transition to a new state excluding the one just finished.

PART IV

THE STUDY

This part presents the design and execution of the experiment, where people got to test the game. The methods and categories used for data collection are also presented, along with the aspects of the experiment that could affect the reliability and validity of the results.

21 Experiment Design and Execution

This section presents the design, execution and some of the circumstances surrounding our experiment. Specific measures had to be taken due to the ongoing Covid-19 pandemic, which also impacted our abilities to gather participants for our experiment.

21.1 Covid-19 repercussions

As this experiment took place during the Covid-19 pandemic, specific preventative measures against getting infected needed to be performed as a part of the experiment. We got to use NTNU's UX-lab, which provided a large and open space with a steady stream of fresh air during the experiment. In addition to this, the following measures took place during the experiment:

- The exercise bikes were placed 3 meters apart from each other.
- The exercise bikes were cleaned and disinfected before and after each use.
- Observations were performed at a distance of at least two meters from the subjects.
- Computers used for answering questionnaires were cleaned and disinfected before and after each use.
- The heart rate monitors used by the subjects were cleaned and disinfected before and after each use.

21.2 Experiment Design

As mentioned in Section 3, it was clear that we needed to conduct an experiment to get the answers we wanted for our research questions. As we only have access to the two Playpulse bikes located at campus Gløshaugen at NTNU, and our game needs to be played using these, this determined that we needed to perform a physical experiment at Gløshaugen where people came to play our game. For quantitative data collection we opted for heart rate monitors to look at the physical intensity of playing the game, and questionnaires, as they easily allow us to gather a participant's view on several topics in a short time. Furthermore, as the experiment were to be executed in person with the participants, this gave us an excellent opportunity for qualitative data collection as well, as we could observe and interview the participants as part of the experiment.

In the design of the experiment, each participant will play the game in 3 separate sessions, so that we can get data on how the game is experienced over time. As our game is a cooperative game for two players, two participants will always play together. Each participant will also wear a heart rate monitor. It will be equipped at the start of the session, to allow for some minutes of reading their resting heart rate. After they are done playing the game, the monitor will be unequipped. Each session lasts up to one hour and the individual sessions include the following:

- **Session one:** Starts with a short introduction to the experiment, heart rate equipment, Playpulse bikes and the game. The two participants then play through the tutorial of the game. After the tutorial is done, the participants play the game for 20-30 minutes. They have to play at least 20 minutes, and are informed when they have done so, and can then choose to keep playing for a maximum of 30 minutes. After playing, each participant answers a questionnaire individually. Following this, both participants are interviewed simultaneously at the end of the session.
- **Session two:** If the participants want to, they can replay the tutorial from the last session. Then they play for 20-30 minutes, before each answering a questionnaire individually. There is no interview in the second session.
- **Session three:** The participants play for 20-30 minutes. Then they each answer a questionnaire by themselves. At the end of the session, both participants are interviewed together.

21.3 Norsk Senter for Forskningsdata (NSD)

As we had to collect and process personal data electronically as part of our experiment, we had to report our project to NSD and inform them of our planned procedures for data collection and storage 30 days prior to when we could begin collecting the data. Each participant also had to sign a consent form before we were allowed to start collecting their data. The consent form informed the participants about the data collection, the experiment, and their rights, and can be read as a whole in Appendix E. Our plan for processing personal data was considered by NSD to be following the privacy regulations. The most important points in the plan were:

- Data to be collected during the experiment is personal data (name, age, gender, e-mail address, background information), heart rate data, data about the participant's perceived experience of playing, and also pictures and voice recordings.
- All data will be anonymised, and it will not be possible to identify any of the participants in our report.
- The data will be stored encrypted on non-personal hardware, where only the researchers and supervisor can access them. All data will be deleted when the project ends.
- It is voluntary to participate in the experiment. All participants will be informed about their rights and need to give their consent before the data collection can begin.
- Participants can request insight into their collected data, and they can at any time choose to withdraw their consent and no longer be part of the experiment.

21.4 Sample of participants

To avoid any bias effects, participants for experiments should normally be sampled randomly. In addition, large sample sizes are more ideal than smaller ones, in terms of being able to produce more statistically reliable results. Unfortunately, due to Covid-19, it proved difficult to get a sufficient number of participants, meaning that it was not possible to randomize participants. This led to a convenience sample being used for this experiment, where the recruited participants were known to the researchers.

Figure 43: Setup of the experiment

21.5 Experiment execution

The experiment took place in the UX-lab at Gløshaugen during week 15 and 16 of 2021, with 20 sessions distributed on 7 days. The setup of the experiment can be seen in Figure 43, and an image of one of the participants during the experiment can be seen in Figure 44. In total, the experiment had 13 participants, and all partook in 3 sessions, except for one, which had to cancel its third session. The participants informed the researchers of when they were available those two weeks and were then put into teams of two so that the same participants would be on the same teams each session. However, there was one rescheduling in the middle of the experiment period, so the participants in two of the teams got new partners during their second session. Also, as there was an odd number of participants, one participant played with one of the researchers during its first session. For the second session, the participant asked to play alone, to experience the game as a single-player game. This participant did not play the third session.

The participants in each team were allocated to either the right or left bike in the room, and used the same bike all three sessions, except for two teams, where the participants specifically requested to switch bikes during the last session. The reason being that the left bike did have some lag during gameplay due to network latency, which some of the participants pointed out. This comes from the nature of the network architecture, where the right machine would serve as host and the left machine as a connecting client. There were also some complaints towards the later sessions that some of the buttons on the controllers of both bikes did not properly register button presses.

Figure 44: One of the participants during the experiment

21.6 Summary

To test our game, we designed an experiment where the participants would play our game for three sessions. The participants were be observed while playing, answered a questionnaire after each session, and partook in an interview after the first and last session. Due to the Covid-19 pandemic, certain preventative measures had to be taken during the experiment, and our abilities to gather a large and randomized sample were severely hindered. In the end, we had 13 participants for our experiment, all of which were known to the researchers. Before starting the experiment, we also had to report our project to NSD and inform them of our planned procedures for data collection and storage.

22 Data Collection

Four different types of data collection were used during the experiment. Following Oates' research process as presented in Section 3, we wanted to be able to do both quantitative and qualitative data analysis on our results, and our data collection methods were selected to allow for such. These methods will be presented in this section along with reasoning for how they might help answer our research questions.

22.1 Data categories

Looking back to our research questions in Section 3 we see that to answer some of them, we need to collect data on several specific topics during our experiment. The topics are enjoyment, engagement and exercise. Furthermore, as was found in our pre-study in Part II, several elements can be put into games to make them more fun and engaging, some of which we have included in our game. As we would like to evaluate the effect of these elements, we, therefore, need to gather data on the additional topics of multiplayer, controllers, gameplay, difficulty and flow. To collect data that could be relevant to these topics, we created several data categories to help us structure our data collection.

22.1.1 Enjoyment

Related research question: **RQ4** *How does our game affect the enjoyment of the player?*

To answer our fourth research question, we needed to gather data specifically on how the participants enjoyed the game. The feeling of enjoyment starts as an emotion within a person but is in many cases also expressed physically in ways that are noticeable to others. Therefore we wanted to get both the participants' subjective opinion on how they enjoyed the game, as well as objective data on how they expressed themselves while playing.

22.1.2 Engagement

Related research question: **RQ5** *How does our game affect the engagement of the player?*

The data in this category is helping answer our fifth research question. As presented in Section 8, engagement in games is a multifaceted topic that relates to a player's motivation, wish to perform well, focus and desire to play the game again. We wanted to collect data from the participants on several of these aspects, as well as observing them, to get an impression of the participants' engagement in the game.

22.1.3 Exercise

Related research question: **RQ6.1** *Can playing our game be considered exercise?*

To help answer this research question and letting us know if our game had the proper exercise part that is found in an exergame, we needed to monitor the exercise effect of playing our game. This data category consists of perceived exercise effect, which is the participants' own opinion on how exerting the game felt, quantitative data from heart rate monitors, and observations of how tired the participants looked during the experiment.

22.1.4 Multiplayer aspect

Related research questions:
RQ4 *How does our game affect the enjoyment of the player?*

RQ5 *How does our game affect the engagement of the player?*
RQ6 *Does our game motivate players to become more active?*

As Section 9.2 states, social mechanics in games can help enhance the experience for the players. As a result, we included a multiplayer aspect in our game, namely two-player cooperation. We wanted to see how the multiplayer aspect affected the players' enjoyment, engagement and motivation when playing our game, and therefore we needed to collect data on how the participants experienced the multiplayer aspect of the game.

22.1.5 Controllers, gameplay and difficulty

Related research questions:
RQ4 *How does our game affect the enjoyment of the player?*
RQ5 *How does our game affect the engagement of the player?*
RQ6 *Does our game motivate players to become more active?*

The controllers, gameplay and difficulty of a game are factors that greatly impact the overall impression of a game and subsequently impacts how a game is enjoyed by the player. We wanted to get feedback on how the players experienced our game design choices and therefore needed to collect data on these topics. This category consists mainly of subjective data from the participants, but also some objective data, as we wanted to observe whether participants expressed satisfaction or frustration with the controllers, gameplay or difficulty while playing.

22.1.6 Flow

Related research questions:
RQ4 *How does our game affect the enjoyment of the player?*
RQ5 *How does our game affect the engagement of the player?*
RQ6 *Does our game motivate players to become more active?*

As presented in Section 7.1, the GameFlow model can be used for evaluating the player enjoyment in games. This model was also used to inform some of our game design choices. As such, we wanted to gather data on how the participants experienced each of the eight elements of flow, to see whether our game contained the right mechanics for allowing the player to achieve a state of flow while playing.

22.2 Questionnaire

A questionnaire was selected as a data collection method as a source of subjective, quantitative data. The participants answered an online questionnaire right after playing the game. The content and order of the questionnaires were the same for all participants. The questionnaire consisted of 26 statements, that could be answered using a 5-point Likert scale, ranging from "Totally disagree" to "Totally agree". Using a Likert scale was chosen as it is a frequently used psychometric tool to measure a participant's level of agreement towards a statement [97]. The statements were all related to our different data categories, where each category had at least two statements. In addition, the questionnaire also contained 10 other questions, 3 of them which were open questions, to allow the participants to give more full-bodied answers. The questionnaire in session one also had an additional 11 questions collecting information on the participants' background and exercise- and gaming habits (see Appendix A).

The statements in our questionnaire mapping to the flow data category were taken from Jackson and Marsh's Flow State Scale [98]. The Flow State Scale is meant to be used as a tool for measuring flow in a physical activity setting. The scale originally consists of 36 statements, representing the 8 elements of flow, along with a ninth element of "Autotelic Experience". To not make our questionnaire too long, we chose to include one statement from each of the 9 elements in our data collection. The statements we chose can be seen in Table 4. A full overview of the statements in

Table 4: The Flow State Scale statements used in our questionnaire

Flow element	**Statement**
Challenge-skill balance	I was challenged, but I believed my skills would allow me to meet the challenge
Action-awareness merging	I did things spontaneously and automatically without having to think
Clear goals	My goals were clearly defined
Unambiguous feedback	I had a good idea while I was performing about how well I was doing
Concentration on task at hand	My attention was focused entirely on what I was doing
Sense of control	I felt in total control of what I was doing
Loss of self-consciousness	I was not concerned with what others may have been thinking of me
Transformation of time	Time seemed to alter (either slowed down or speeded up)
Autotelic experience	I found the experience extremely rewarding

our questionnaire and the data category they belong to is presented as a part of the results, in Section 25.

22.3 Observations

Observing the participants while they were playing served as a source of qualitative data. While both questionnaires and interviews generate subjective data from the participants, observations provide objective data, as someone other than the participants are watching their behaviour and expressions and interpreting their experience. In our experiment we used overt observation, meaning that the participants were aware of the fact that they were being observed [1, Chapter 14].

During the observations, we wrote down what the participants said, how they behaved, how they played the game, and how visually exerted they seemed. We also had a checklist with potential actions related to all data categories but flow. Each time a participant performed one of the actions, it was noted in the checklist. The full checklist used during the observations can be found in Appendix D.

22.4 Interviews

Interviews were used as another source for qualitative data. All participants participated in the interviews, which were held at the end of session one and session three. The participants in each team were interviewed together but were asked to answer individually and make sure their opinion was expressed, not only agreeing to what the other participant said. The interviews were conducted in a semi-structured manner, where a list of questions on different topics was prepared beforehand to help guide the conversation. The topics were chosen to match our data categories of enjoyment, exercise, multiplayer aspect, and controllers, gameplay and difficulty.

The questions in the interviews were formulated to stimulate the participants into giving longer answers and give reasoning for their thoughts. The idea of the interview was to get a good impression of how the participants experienced the game, through getting much more detailed answers than the questionnaire provides. The interviews were also recorded so that the researchers could give their full attention to the conversation while it took place, instead of taking notes.

22.5 Heart rate monitors

To help measure the exercise effect of playing the game, we wanted to monitor the heart rate of the participants while they were playing. This quantitative data will be used along with the qualitative

data regarding perceived exercise effect gathered from the questionnaires and interviews to form an image of how exhausting it is to play our game.

In previous exergame master's theses, a Fitbit Charge 3 wristband has been used to measure the participants' heart rate while playing. These were also the devices we had available for use before starting our experiment. While reading through some of the earlier theses, it was discovered that many of them complained about the accuracy of the Fitbit wristbands in their own experiments. It was also referred to previous research on the accuracy of the wristbands, stating that the Fitbit Charge 2, a closely comparable product to the Charge 3, has been evaluated as inaccurate [99], and can possibly underestimate the heart rate by up to 30 BPM compared to a different heart rate measurement method, the Electrocardiography (ECG) [100]. Based on this, it was decided to acquire new devices for heart rate monitoring. The selected device was the Polar H10. It monitors heart rate through ECG using a chest strap and is considered very reliable [101]. An illustration of the use can be seen in Figure 45. Unfortunately, the devices were not received in time to be used during the first session, and the Fitbit Charge 3 was therefore used during the first sessions, as is further explained in Section 28.

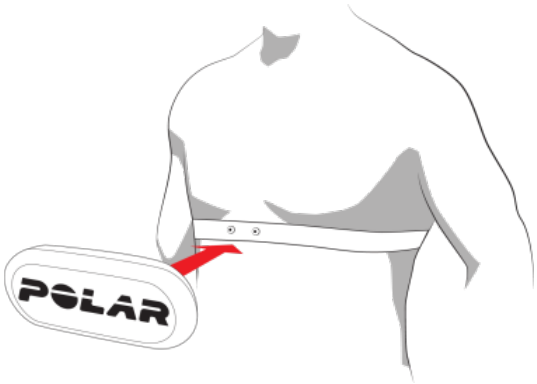


Figure 45: Illustrated use of the Polar H10 chest strap and sensor from the user manual [21]

22.6 Summary

This section has presented the four types of data collection that were used in the experiment. The types are questionnaires, observations, interviews and heart rate monitors. It also presented the data categories used to structure and group together questions and data on specific topics to help with answering the research questions.

23 Reliability and Validity

This section includes aspects of the experiment that can have impacted the results and presents how the sample used in the experiment limits the wider applicability of our findings.

23.1 Familiarity bias

The recruitment for the experiment mainly happened in the researchers' social circles, which led to all of the participants in the project being friends and acquaintances of the researchers. Due to the pre-existing social bonds, it is possible that some of the participants felt inclined to provide more positive feedback about the game than they otherwise would have done.

23.2 Quality of heart rate monitor data

The Polar H10 heart rate monitor is considered very reliable, with a signal quality of around 99.5 % compared to the gold standard of heart rate interval measurements [101]. However, in the experiment, the two H10 heart rate monitors had to be paired to a device, on which a user had to be made with a set age, gender, height and weight. The same user was used for all participants, meaning that the monitor might have reported slightly incorrect heart rates for some of the participants, as their age, gender, height and weight deviate from the user on the device.

23.3 Modifications during the experiment

Between the first and second session, some bugs in the prototype were fixed. Before the third session, sound was added to the game, as this was initially planned to be in place before the first session. These changes were made to bring the quality of the prototype closer to the planned design. It is possible that the bug fixes and inclusion of sound in the game can have impacted the participants' impression of the game in later sessions, compared to session one.

23.4 Sample size and diversity

When collecting quantitative data, it is important to have a large sample if the results are supposed to be an indication of what the majority of people think. For qualitative data collection, a smaller sample can be tolerated, as the opinions of the individuals are more important. This experiment only had 13 participants. While some assumptions about the game can be made from the qualitative data, the quantitative data can not be used to conclude with anything beyond the scope of these 13 participants. Furthermore, a representative sample that reflects the diversity found in the general population is also preferable if the results are to be used for concluding about the general population. The sample in this experiment contains mostly males, all around age 23, thus rendering the findings of this project unsuited to be applied to a wider population.

23.5 Summary

This section has shown how familiarity bias, using the same Polar user for different participants, and modifications made to the game between sessions can have impacted the results from the data collection. Due to a small and almost uniform sample of participants, findings can not be applied to the general population.

PART V

RESULTS

This part presents the results gathered from the study's questionnaires, interviews, observations, and hearth rate sensors. The data is presented in categories based on the research questions.

24 Test Population

The information in this section is gathered from the questionnaire answered in session one.

The experiment had 13 participants, with all participants finishing two sessions and all but one finishing three sessions. There were eleven male and two female participants, and their age ranged between 21 and 26 years. The selection was a mixture of friends and other students at NTNU. Since this game is likely to be played by friends, participants who knew each other were put on the same team if possible.

Table 5: Relevant background info given in session one's questionnaire.

Gender	**Age**	**Actively exercises (more than 3 hours/week)**	**Actively plays video-games (more than 3 hours/week)**
Male: 11 participants	21–26 yrs	Yes: 9 participants	Yes: 10 participants
Female: 2 participants	Average: 23.5 yrs	No: 4 participants	No: 3 participants

Table 6 shows the average and median times and hours of exercise and video gaming among the participants. We only see minor differences between the average and the median within exercise numbers, indicating no significant outliers among the participants. The difference is more considerable within video gaming but still minor. The highest number recorded for gaming per week was 14, while the lowest was 0.

Table 6: Average and median numbers for exercise and video gaming per week.

Description	**Average**	**Median**
Times exercising per week	3.3	3
Hours of exercise per week	5.4 hrs	4.5 hrs
Hours of video games per week	7.6 hrs	10 hrs

Based on the answers, the group was split into two groups twice. The groups were based on how much the participants exercise and how much they play video games. The exact spilt for exercise was set at participants exercising more than or equal to three hours per week in one group and less than three in another group. This split put 69 % in the first group and 31 % in the other. For video games, the split was set at more than three hours in one group and less than three hours in another group. This put 77 % in the first group and 23 % in the other. This is summarised in Table 5.

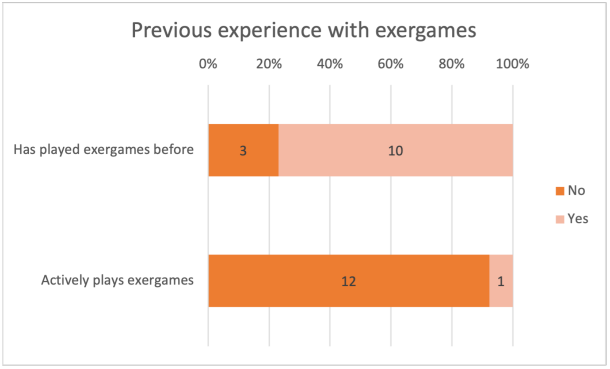


Figure 46: Questions regarding previous and current experience with exergames.

The participants were also asked about their previous and current experience with exergames. Most participants had played exergames previously. However, only one participant still actively played exergames at the time of the session (see Figure 46).

24.1 Summary

This section has presented relevant background data about the test population. The data includes information on gender, age, current level of exercise and video gaming, and previous and current experience with exergames.

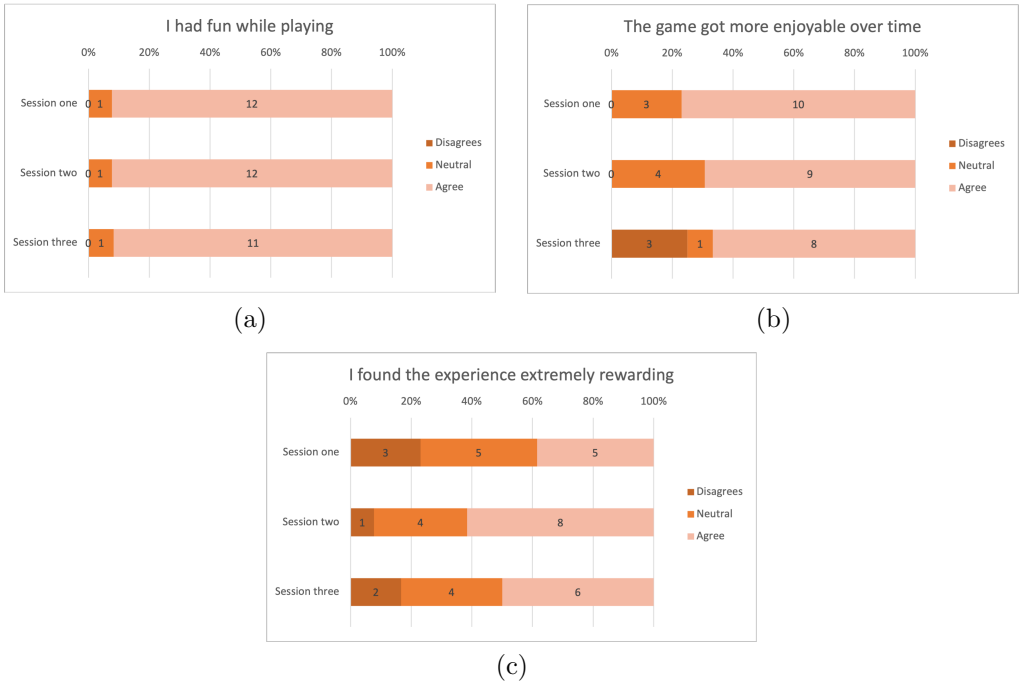
25 Results from Questionnaires

Results from the questionnaire are summarised here; complete results are available in Appendix B. The participants answered the questionnaire three times in total, once after each play session. Session three contains one fewer participant than session one and two.

25.1 Enjoyment

Answers from the three sessions to all questions regarding enjoyment are summarised in this section.

The first enjoyment-related question asked whether the participants had fun while playing that session. *In all three sessions, one neutral answer was given each time, while the rest agreed to have had fun while playing.* The neutral answer came from a different participant each time (see Figure 47 (a)). The question on whether the game got more enjoyable over time had most participants agree but saw a negative trend over the three sessions. However, this trend is not statistically significant. After the first session, 77 % of participants agreed, while 23 % were neutral. The next session saw 69 % of participants agree and 31 % neutral. After the third session, 67 % of participants agreed to the game becoming more enjoyable over time, while 8 % (one participant) were neutral and 25 % of the participants disagreed (see Figure 47 (b)). The statement "I found the experience extremely rewarding" saw quite evenly distributed answers after the first session, followed by a spike of "agree" in the second session, where 62 % of participants agreed, before falling slightly after the third session (see Figure 47 (c)).



(a) (b)

(c)

Figure 47: Enjoyment-related questions from the questionnaires.

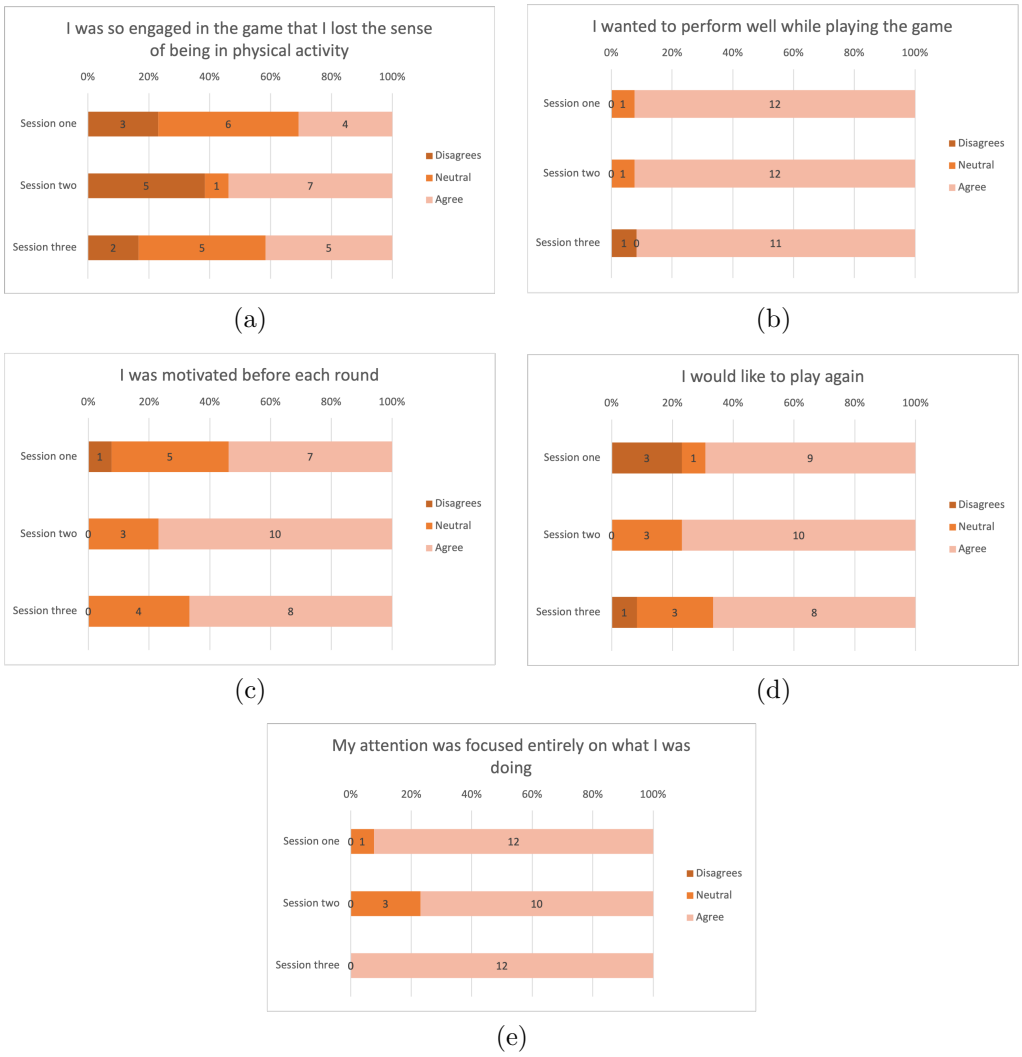


Figure 48: Engagement-related questions from the questionnaires.

25.2 Engagement

The participants' answers for all three sessions to questions relating to engagement are summarised here.

When asked if the participants got so engaged they lost the sense of being physically active, 30.7 % agreed while 23 % disagreed (see Figure 48 (a)). This result does not change drastically during the subsequent sessions. Session two sees more participants on both "agree" and "disagree", while session three goes back to the starting point. Participants consistently said they wanted to perform well while playing, with $\tilde{9}2$ % agreeing in all sessions (see Figure 48 (b)). *When asked if they were motivated before each round, only one participant in total over the three sessions disagreed.* Between 54–77 % agreed between session one and three (see Figure 48 (c)). Most participants answered that they would like to play again – 69 % agreed after session one, which stays relatively unchanged in the following sessions (see Figure 48 (d)). In Figure 48 (e), it can be seen that participants felt very focused on what they were doing while playing. No participants disagreed with this statement, and between 77 % and 100 % agreed.

25.3 Exercise-related questions

Answers from all sessions to exercise-related questions from the questionnaire are summarised in this section.

The majority of participants said they found this exercise form more motivating than cycling without the game. This statistic does not change much over sessions, with between 54 % and 75 % agreeing (see Figure 49 (a)). Only 15 % (two participants) disagreed at the maximum in a session. The question regarding if they would rather play this game than practice regular exercise showed opposite results (see Figure 49 (b)). Here, it starts with 38 % on both the agreeing and disagreeing side of the statement but ends up in session three with 58 % disagreeing and only 8 % (one participant) agreeing. *The answers for whether the game motivates participants to become more active is also on the disagreeing side* (see Figure 49 (c)). *38–54 % disagrees with becoming more motivated, while only 8–31 % agrees.* There is no significant trend or change in the data for this question. *Participants answered that they felt they were exercising – it ranged between 83 % and 92 % agreeing for all sessions* (see Figure 49 (d)). When asked to rate the exercise intensity, all sessions were deemed moderate to high in intensity, with one participant rating the last session as "very high" (see Figure 49 (e)).

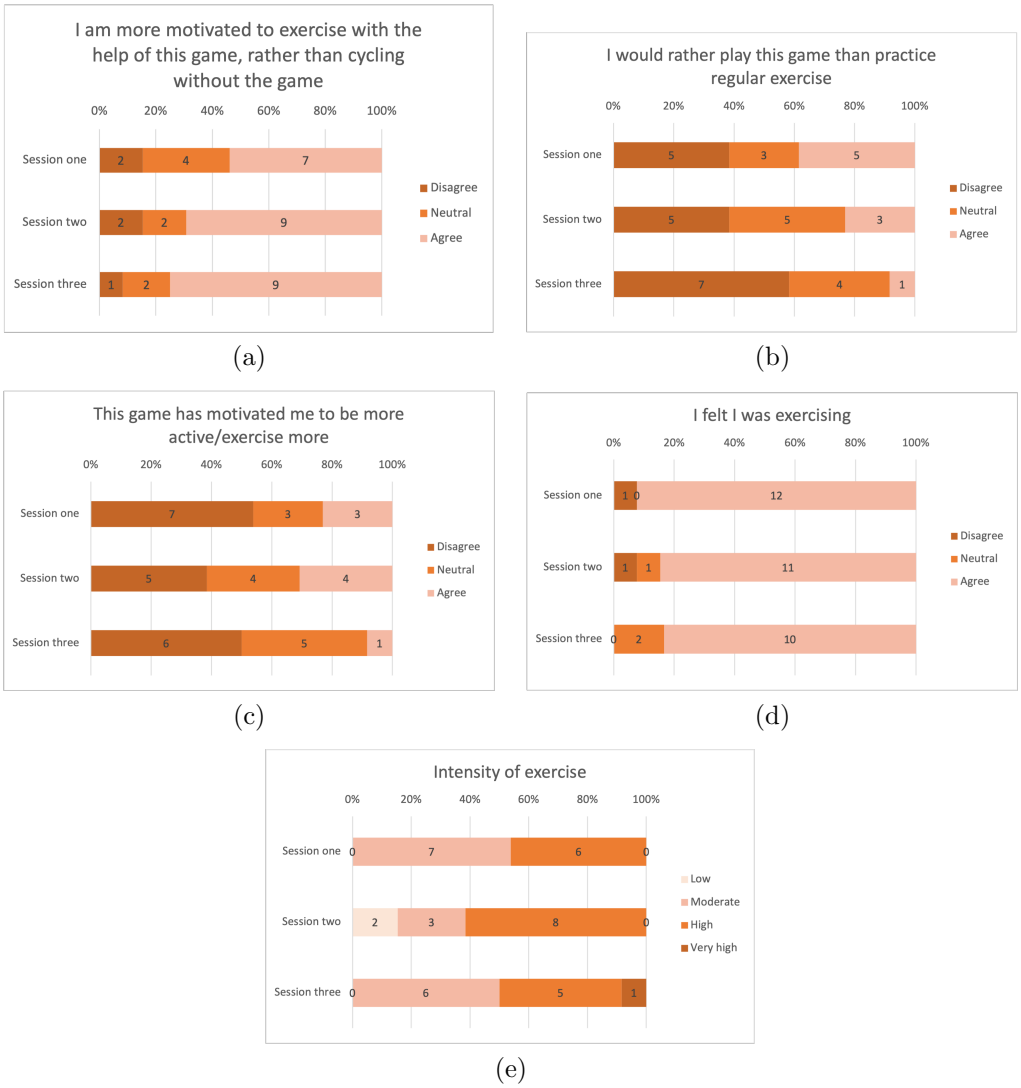
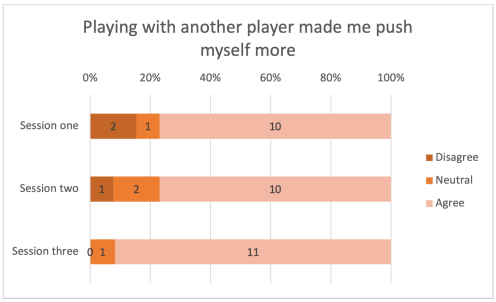
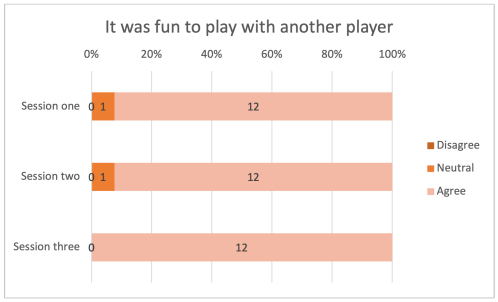


Figure 49: Exercise-related questions from questionnaires.



(a)



(b)

Figure 50: Multiplayer-related questions from questionnaires.

25.4 Multiplayer aspect

Answers to questions tackling social mechanics and playing together with another player are summarised in this section.

The questions related to multiplayer in the questionnaire are seen in Figure 50. *Figure 50 (a) shows that virtually all participants enjoy playing with another player during all sessions.* Figure 50 (b) reveals that playing with another player makes almost all participants push themselves harder than without that player.

25.5 Controllers, gameplay, and difficulty

Participants' answers to how they experienced the controllers, general gameplay, and the game's difficulty are noted in this section.

In the questionnaire, participant's answers showed that difficulty is generally regarded as fitting for the game. Almost all participants said they were challenged but believed their skills would allow them to meet the challenge (see Figure 51 (a)). The answers stayed almost stationary throughout all sessions.

The game itself was rated pretty clear to understand. Most participants agreed to the game's goals being clearly defined and that they understood what to do (see Figure 51 (b, f). How well they were doing in-game was rated less clear. The answers are split almost equally among "agree", "neutral", and "disagree" in the first session. In the next session, two more participants switched to "disagree". In the last session, the trend turned, and a majority now chose "agree" (see Figure 51 (c)).

For controllers, Figure 51 (d) and (e) shows that a lot of the participants found the controllers hard to learn and generally not in control of what they were doing. However, Figure 51 (d) shows that doing things in the game becomes progressively more spontaneous and automatic. *All participants answered "Yes" to the pedalling feeling natural considering the in-game response* (see Figure 51 (h)).

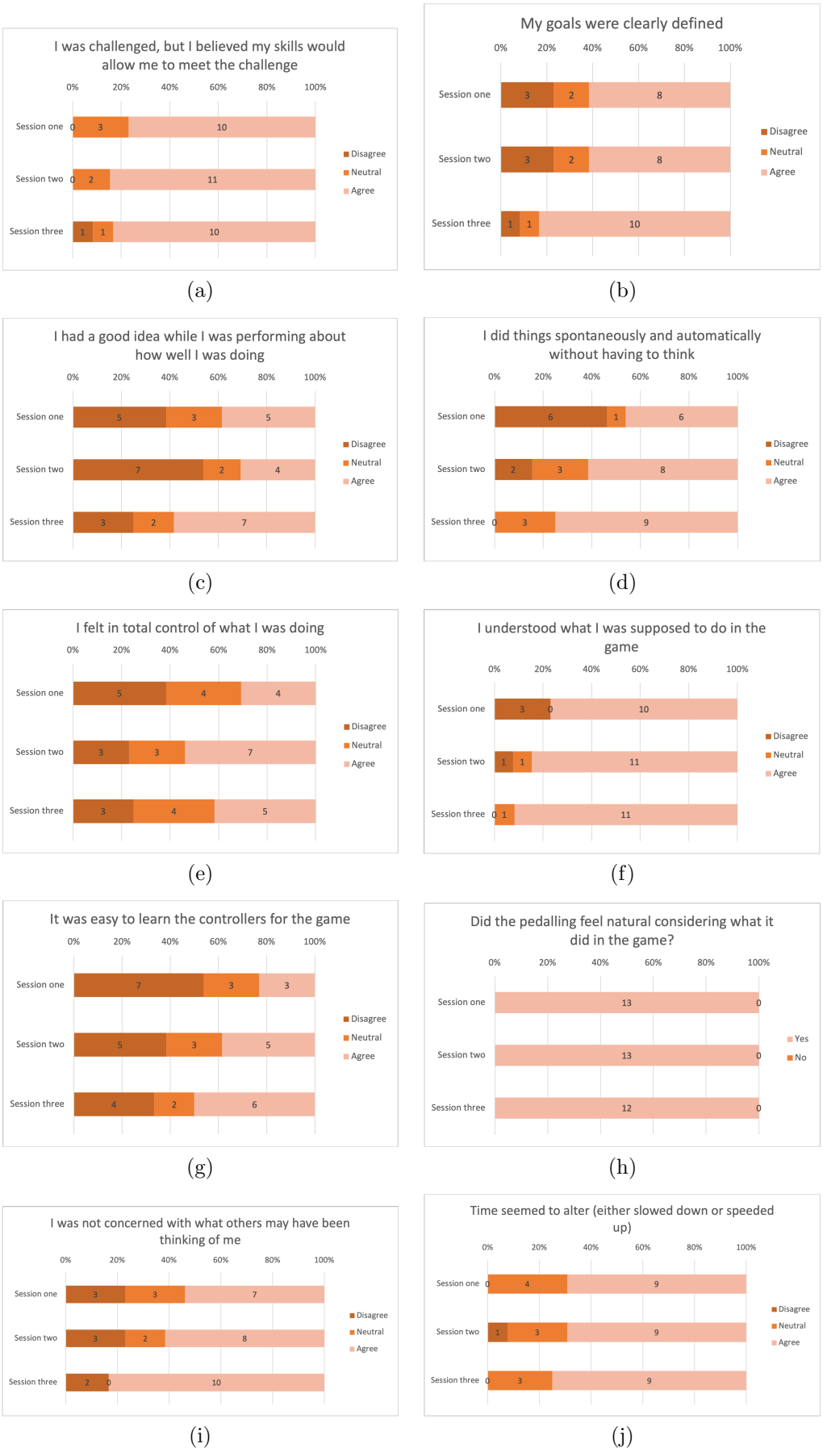


Figure 51: Controller, gameplay, difficulty and Flow-related questions from questionnaires.

25.6 Flow

Answers to all questions regarding Flow and GameFlow (see Section 7.1) are summarised in this section. As little was said regarding flow during the interviews, a summary of those results are also included here.

The distribution of answers for the nine statements from the Flow State Scale can be found in the following figures: Figure 47 (c), Figure 48 (e), Figure 51 (a, b, c, d, e, i, j). Some notable results include: almost all participants agreed that their attention was focused entirely on what they were doing, each session (see Figure 48 (e)). When asked if they felt in total control of what they were doing, less than 50 % agreed during session one and three, while 53 % agreed after session two (see Figure 51 (e)). Each session, 9 of the participants (69–75 %) agreed that time seemed to alter while they played (see Figure 51 (j)). The results of the flow questions from the questionnaires will be further examined in detail in Part VI.

During the interviews, statements related to some of the dimensions of flow were also made. Three participants specifically stated that they forgot that they were exercising while playing. One of them also said that the game felt immersive and that they forgot the time while playing. One participant said that it felt effortless to achieve the light-green intensity level of pedalling in the game. On the other hand, participants gave several comments about aspects of the game that break immersion at times, hindering the player from achieving flow. Two participants said they got exhausted from having to pedal too intensely, which made it more challenging to focus. Numerous players also mentioned that they sometimes forgot which buttons on the controllers did what, which took their focus away from the game. In addition, four participants also said that sometimes too much is happening in the game, which gets confusing and could make them forget to pedal.

25.7 Summary

This section has presented relevant data from the questionnaires in session one, two, and three. The questionnaire in session one also included a preliminary background information part; this data is presented in Section 24. The data covers findings on enjoyment, engagement, exercise, multiplayer aspect, controllers, gameplay, difficulty, and flow.

26 Observations from Playtesting

This section contains observations of the participants from each of the three sessions. The section provides an objective report on what the participants did and how they acted during the sessions. The observations have been divided into subsections focusing on exercise and effort, engagement, enjoyment, and cooperation. Session three contained one fewer participant than session one and two.

26.1 Enjoyment

Observations made on enjoyment – such as laughter and positive surprise – from the sessions are noted in this section.

26.1.1 Session one

During the sessions, we paid attention to whether the participants seemed to enjoy themselves and noted how many times they expressed joy, frustration and seemed positively surprised. Out of the 13 participants, 62 % of them were visibly having fun during the first session. Of the remaining 38 %, only 8 % (one participant) did not seem to enjoy the game, while the 30 % remaining seemed neutral in their enjoyment of the game. Nevertheless, *85 % of participants did both express joy and seemed positively surprised at least once during the session.* It was registered that 54 % of the participants laughed during the session, with one participant laughing four times. On the other hand, 62 % of the participants expressed frustration while playing. The frustration was either aimed at the difficulty of the game, the controllers, or some bugs in the game. In some cases, the frustration did seem to negatively impact their overall enjoyment of the game.

26.1.2 Session two

During the second session, there were a lot fewer observable reactions from the participants. 46 % of participants showed almost no reactions while playing. They did neither express much joy nor frustration and seemed neutral regarding their enjoyment of the game. The remaining 54 % of participants visibly showed signs of having fun. This includes the participant who did not enjoy the game in the previous session. That participant even said, while playing, that the game was more fun to play this time around. *All but one participant (92 %) showed either joy or seemed positively surprised at least once during the session.* One participant did express joy four times while playing, however. This participant's laugh was the only one recorded in the second session. The session also had fewer expressions of frustration. Only 23 % of participants complained about the difficulty, and just one participant was frustrated with the controllers.

26.1.3 Session three

The third session had the lowest amount of observable reactions from the participants. *Only 17 % of the participants visibly seemed to have fun, while the remaining 83 % seemed neutral.* It was noted that 50 % of participants showed moments of joy, and 25 % seemed positively surprised at least once while playing. Regarding frustration, only 33 % of participants complained about the difficulty; two of these had also complained about the controllers.

26.2 Engagement

This section covers the participants' visual signs of engagement during the play session.

26.2.1 Session one

During the first session, the engagement could be interpreted through the participant's effort, motivation to keep playing, and communication with the other player. One team had hardly any communication, while the rest of the teams interacted more with each other during the playtesting. One team expressed themselves enthusiastically when they achieved certain things in the game. *Several teams gave each other warnings about dangers in the game, and two teams went as far as discussing strategies and sharing tips during their short breaks.* As for motivation to try again, one participant said they were too tired and did not find the game fun, and therefore did not want to play longer than the minimum of 20 minutes. *All the other participants seemed motivated to give a level another go; one team even expressed that they looked forward to playing in the next session.* Most of the participants also gave a solid effort while playing and got tired and somewhat exhausted, as shown in Section 26.3.1.

26.2.2 Session two

Session two saw three teams discuss strategies and sharing tips before they started playing and during their breaks. *Almost all teams notified each other of cues in the game and gave warnings while playing.* 15 % of participants gave a visibly low effort while playing, while most other participants seemed to give a higher effort than last time, with some participants visibly pushing themselves hard. With motivation, it was a little mixed. Some of the participants really showed motivation to complete a level, while others expressed little motivation to keep going. Overall, there seemed to be quite an increase in interaction and sharing of strategies and warnings and a noticeable increase in effort. The motivation level was similar to what seen in session one, but with more individual differences; some were more motivated than previously, and some less.

26.2.3 Session three

All the teams had some level of interaction during the third session, with one team only interacting once, two teams sharing strategies, and four of the teams warning each other of coming dangers in the game. *This session also saw two teams coordinate their pedalling into the dark-green zone before they began the game.* One participant audibly responded to getting hit in the game, while another re-enacted the game's shooting sounds with his voice. As for motivation, most participants seemed highly motivated to finish levels this time around and therefore wanted to try again after dying. Lastly, most participants gave much effort during the revives, but beyond that, the general level of effort seemed lower compared to session two. Five participants visibly gave a high effort, while one gave a particularly low effort after finding a game exploit that required almost no pedalling.

26.3 Exercise aspect and observed effort

This section covers the observations made on how much the participants visually exert themselves during the sessions.

26.3.1 Session one

Observations from session one showed that most participants got tired and somewhat exhausted from the session. They did not exert all their energy while pedalling but were still averaging around a 5/10 level of exertion (where 10/10 is being so tired you almost pass out). Most participants got low to high perspiration rates, but some participants stayed dry during their session. The revive-mode aspect of the game showed spikes in intensity among some players, where several gave all they could during the revive moments. Increased and audible breathing was also commonly observed among players during their last ten minutes of playtime. The first period of ten minutes showed most players nearly visually unaffected by the pedalling.

26.3.2 Session two

Observations from session two generally found participants pushing themselves harder. This is especially clear during revive-mode when most participants, to some degree, pedals near maximum speed. Perspiration and moderate breathing are present during the last ten minutes of almost all participants. *Many participants needed a drinking break between levels, but a few found it necessary even in the middle of a level.* Two participants expressed surprise when hearing how long time they had been cycling. A couple of participants did not put in more effort this session than last, but they did not exert themselves less either.

26.3.3 Session three

Session three showed a more considerable variation in exertion than previous sessions. Most participants showed a slight drop in the effort put into the workout, but many were still pretty exhausted at the end of the session. Perspiration and moderate breathing were also common in the last ten minutes. A majority still pedalled at maximum pace when entering revive mode. However, they gave less pedalling force during fly mode – mainly due to players noticing that pedalling does not map to the weapon's firing rate. Two participants did not become visibly tired during this session at all. The session also had fewer teams playing more than the mandatory 20 minutes.

26.4 Multiplayer aspect

Interactions between players, cooperation and other visual signs of social interaction observed during the sessions are noted in this section.

Observations during gameplay sessions gave information on oral and physical interactions between participants in a team. The amount of interaction varied a lot from team to team. The general trend from session one to three was that those with some interaction tend to have more interactions in later sessions while those with few interactions stay at that level throughout. Still, most teams were quiet for the majority of the session.

The average team had a couple of interactions during a 20–30 minute session. These usually consisted of warnings of coming attacks, tips and tricks, strategic planning between games, and small comments about things happening in-game. Strategic planning was seen more in later sessions. *Some cheering when winning was also seen, e.g. "Wooo!" sounds and high-fives.* If one player died before the other, that player sometimes cheered on the other one. Interactions could also happen when the teams felt close to beating the boss, e.g. *"We have him now!"*. One participant apologised to his team player for "having a terrible start."

26.5 Summary

This section has covered observations made by the authors during the experiment. The observations focused on visual and audible signs of, e.g. tiredness, fun, boredom, excitement, and so forth. The findings are divided into subsections on enjoyment, engagement, the exercise aspect and observed effort, and the multiplayer aspect. Each subsection presents data from each session separately.

27 Results from Interviews

Interviews for this project was carried out two times: after playing in session one and after playing in session three. They focus on the players' subjective experience of the session and pinpoints certain areas we would like the participants to elaborate on. Session three contains one fewer participant than session one and two.

27.1 Enjoyment

Answers for how much the participants feel they enjoyed the different sessions are given in this section. As previously mentioned, no interview was conducted after session two.

27.1.1 Session one

During the interviews following the first session, *77 % of participants said they thought the game was fun and that they enjoyed playing it.* Two participants said that having to exercise while playing made the game not very enjoyable for them. However, they believed that if the game were to be played with a regular controller on a couch, it would have been fun. The one participant that did not seem to enjoy the game also confirmed this in the interview. The participant said the game has the potential to be fun, but in its current state with bugs and frustrating controllers, the participant does not want to play again. Another participant also complained about the controllers becoming uncomfortable, which negatively affected the enjoyment towards the end of the session.

23 % of participants said the high difficulty made it less fun initially but that the game got more enjoyable throughout the session as they became more used to it. 31 % made claims about the difficulty and how it impacted their enjoyment, with half of these stating the game felt unfair at times since some projectiles had such a complex movement that they felt impossible to avoid. This negatively impacted their enjoyment. The other half had an opposite view, claiming the great difficulty contributed to the fun, and if they were to play for longer, the difficulty should increase. *46 % of the participants pointed to the cooperative nature of the game as an aspect that made it more fun.* Lastly, when asked about upcoming sessions, one participant who enjoyed this first session was unsure how enjoyable upcoming sessions would be due to a possible lack of replayability. However, 23 % of participants responded that they imagined the following sessions to be fun, given that they got to play new levels.

27.1.2 Session three

In the interviews following the third session, *75 % of participants said they enjoyed playing the game that session.* When asked which session they found the most fun, different answers were given. 17 % said the first session was the most fun, as the game felt new and there was more progression and not repetitiveness. 50 % of participants said they enjoyed the third session the most, mainly because they had gotten more used to the controllers and felt they began to master the game. Of the remaining 33 % of participants, half of them thought all sessions were equally fun, and the other half thought that the second session was the most fun, as that was the sweet spot between learning the controllers and the game not becoming too repetitive.

Several participants mentioned that for the game to be fun over a more extended period than these three sessions, it would need more levels and new mechanics to avoid becoming too repetitive. The controllers would also need to be improved. As for the difficulty, while some seemed to find it daunting during the first session, 25 % specifically stated that the continuously rising difficulty over the sessions and playing on medium or hard difficulty in later sessions increased their enjoyment of the game. One participant said the lag on the player-two machine did somewhat negatively impact the enjoyment. Lastly, 17 % of participants specifically said the addition of sound made it more enjoyable.

27.2 Engagement

This section summarises answers to questions asked about the participants' own experience of engagement during the sessions. No interview was conducted after session two.

27.2.1 Session one

The interviews allowed for more insight into the participants' engagement, as they mentioned things affecting their engagement that was not easily visible during the observations. Two participants from different teams said the bugs in the game made them demotivated to play more. Another participant pointed to the high difficulty, saying it made them feel less engaged in the game. On the other hand, a different participant said that the high difficulty made them more motivated to defeat the boss, thereby making them more engaged. *Many teams said they were motivated to give a high effort and reach the dark-green area of the pedal-gauge to shoot faster.* Three of the teams said the cooperative setting of the game made them more engaged since they wanted to perform well to not let down the other participant.

27.2.2 Session three

The interviews after session three echoed some of the opinions from the previous interviews while also offering new perspectives. *All but one team mentioned that the cooperative nature of the game drove them to perform better.* Revive-mode was especially motivating and made participants want to pedal fast in order to make it. Some participants said the lack of new levels during session three made the game feel repetitive and less engaging. Two participants said the time it took to complete some levels, which took over five minutes, made it feel repetitive and less motivating after a while. This was especially evident if one player died early and the other player remained alive and played alone for a long time. It was suggested that adding an indication of the boss being close to dying at the end of the levels would probably make the game more motivating. While some participants would have liked more levels, a few participants felt enough motivated and engaged by the content already available. One team was very motivated to get five stars on all levels with easy difficulty, while another team wanted to complete as many levels as possible on higher difficulties. One participant claimed they preferred getting five stars on a level over playing a new level. It was also suggested that being able to compare score against other teams, like with a leaderboard, would make the game even more engaging.

Some participants pointed out that they learned when it was beneficial to pedal quickly and pedal slower during the three sessions. *This made them exert less effort during the later sessions since they knew when there was no need to pedal quickly.* At the same time, the participants got more and more used to the controllers, which allowed them to focus on the game and become more engaged with what happened on the screen. *67 % of the participants also specifically pointed out that their mindset before starting a session impacted how much effort they gave significantly.* Some treated it like an exercise session and gave much effort, while others went back to study afterwards and did not want to become too sweaty. This made them deliberately give less effort while playing. Lastly, the game also had sound effects in this session, and most participants pointed out that this change made them more engaged in the game. Some said they liked the sound-feedback of how fast they were shooting and that they could adjust their pedalling speed accordingly.

27.3 Exercise-related questions

Answers given to questions regarding the participants' experience of the exercise and physical exertion during the sessions are noted in this section. No interview was conducted after session two.

27.3.1 Session one

The interviews confirmed many of the observations from the session. Players reported being tired after the session but not exhausted. *Players also mention that an increase of intensive periods in the game or extended playtime could likely make this into a full-fledged workout.* They also mentioned they pushed themselves more with this type of exercise than just indoor biking by itself. On the other hand, two participants mentioned they would have exerted more and gotten a better workout by cycling outdoors on a real bike. The lack of any statistics showing their performance was said to be a demotivation for some participants. The fact that they are there to exercise was by one participant said to push them to give more than they otherwise would in the game.

27.3.2 Session three

Interviews from session three had many participants saying they gave more physically in the previous session than in this one. Multiple reasons were given, including learning there is less point in pedalling fast in flying mode, that the participant is more willing to become sweaty at a late session since they are going home and not studying afterwards, and not being as motivated to play the game anymore. Still, a couple of participants said the opposite and reported higher intensity in this session. Two participants noted the intensity of the entire session to be just where it should be and that anything higher could make the game less enjoyable. Being able to control resistance themselves was also mentioned as a positive feature. Four participants said their attitude towards exercising that session significantly impacted how much effort they put into the session. According to them, they would have given more had they been in a workout mindset.

27.4 Multiplayer aspect

How the participants found the experience of playing the game with another player and answers to questions regarding this is summarised in this section. The following results are the general takeaways from interview questions about the multiplayer aspect of this game in session one and three; no interview was conducted after session two.

Nearly all participants said playing this game with another player increased their enjoyment and also the physical effort put into the game. Many said that they did not want to ruin their teams chance of winning and therefore pushed themselves harder. One participant (participant 4), who tried playing single-player in one session, said that single-player was preferable, and another said that single-player with implemented leaderboard would personally be more enjoyable.

The cooperative part of the game was deemed lacking. All players who enjoyed playing with others said that more interaction and dependencies between the players had been better and a wanted feature. Several participants said that even though they play the same game, they are not really playing together as a team. One participant said that working together in the grounded state is hard when all they do is shoot at max pace. Another participant said, "*The closest you get to interaction with the other player is using them as a shield.*" It was also mentioned that the amount of interaction decreased with the sessions but playing with another person was still a lot better than playing alone. Many participants also said they did not think this game would work as an online game where people in different places play together.

A large portion of the participants said that some way of comparing their score to other teams than their own would be a welcome feature. Many said this would have made them push themselves more to get all stars on a level – the current state weakens the competitive spirit. The same applies to comparing the two players in the team and seeing how well and how much effort they put in compared to their teammate. They said additions like this would potentially make them push themselves harder. Being able to see the other player's lives and generally being able to help each other out in different situations (e.g. revives) would be a good addition.

27.5 Controllers, gameplay, and difficulty

Participants' answers to interview questions regarding controllers, the gameplay experience and game difficulty is summarised in this section. No interview was conducted after session two.

27.5.1 Session one

In session one, the participants, in general, found the controllers to be pretty frustrating to learn. *They mentioned frequently pressing the wrong buttons, putting mental effort into each press, and feeling strains in wrists and hands after continuous usage.* However, they did mention that they got somewhat used to them towards the end of the session. *Having a mapping of the controllers on-screen was said to be a big help.* A more interactive tutorial is suggested as a way to learn the controls better.

The participants are in general positive to the gameplay mentioning that it is "*fun*", "*easy to get into*", "*cool*", and "*a good genre.*" Still, they are unsure about the replay value and find the bugs left to be very frustrating and a source for less enjoyment. One participant said that had the game been played with a conventional controller on a couch, it would definitely be fun.

Difficulty-wise, most participants found the game very hard in the beginning. They said there is a steep learning curve and that dying when new elements are introduced is frustrating but also motivating. Many participants said they felt the difficulty was where it should be and that the level is doable, even if they did not complete it this session. Some participants said that an easier introductory level could have been better for motivation and learning.

27.5.2 Session three

After completing session three, most participants said they had a pretty good grasp of the controllers. For most, they were not hindering their performance anymore. Still, reports of them being uncomfortable were present, and when very tired from pedalling, they become harder to use again. One participant mentioned that all controller mechanics still are not explained well enough throughout the game. A better explanation of these during a tutorial would be a welcome edition.

Many participants said they still find the game as fun as previous sessions but not as exciting and fresh. A smaller group said they find the game too repetitive at this stage and longed for new content. The bosses are, for example, mentioned to be too similar to each other. A majority said being fluent at the controls was a significant factor in making the game more fun now. A few participants said adding features that display their effort put into the round to compare themselves against each other and other teams would increase their enjoyment.

The addition of sound to the game in session three was received very positively. All participants said the sound worked great as feedback for the bullets and when the player took damage. The background music was said to be motivating but also not noticed and too slow for some. A team who did not play with sound on any of the sessions said they found the lack of sound to be good since it made it easy to talk during play sessions.

For difficulty, participants said the game got progressively more challenging in a good way. The difficulty, in general, was deemed suitable. However, most participants found level one to be the hardest of the three, especially phase two, with projectiles moving in a double sinus pattern. Harder difficulty modes got mixed feedback, with some finding them to be repetitive and less motivating than new content. A few others said they liked playing the same level again and perfecting their score. Multiple participants also said that the game would not be as fun had it not been as difficult.

27.6 Summary

This section has presented results gathered from interviews conducted after play sessions. Interviews were done after session one and session three but not after session two. The data reflects the participants' subjective experiences of playing. It is divided into subsections on enjoyment, engagement, the multiplayer aspect, controllers, gameplay, and difficulty.

28 Results from Heart Rate Monitor

Heart rate results show data from session two (excluding participant 7 and 8) and session three (excluding participant 4). Data from session one is omitted due to not having sufficient enough quality to be reliable (see Section 22.5). The first session was recorded using a FitBit Charge 3 wristband, while session two and three used a Polar H10 chest strap. An example of the Fitbit's lower quality: the data from the Fitbit used on participant 11 showed an average heart rate of 89 bpm in session one. The following two sessions gave an average of over 140 bpm without the participant looking significantly more tired. The Polar H10 is considered very reliable [101], so the Fitbit data will be discarded. Therefore, only observations, interviews, and questionnaire data will be used from session one.

28.1 Session two

Heart rate data from session two showed a maximum heart rate between 160 bpm and 200 bpm. All participants did, to some degree, show an interval curve in their data with intervals ranging from three to six minutes. The session in total got an average heart rate ranging between 140 bpm and 160 bpm after the first peak was achieved (see Figure 52) and 144 bpm over the entire session. The lowest average among the participants was 127 bpm, and the highest was 178 bpm. *The highest recorded heart rate in this session was 200 bpm*, while the lowest maximum was 165 bpm. Seven of the participants reached or is close to their maximum values already at the first interval. Four participants stayed at or close to their maximum value for the majority of each level play-through. In addition to a chart showing all session readings in one graph, all individual participant readings can be found in Appendix C. Please note that participants 7 and 8 are missing from this data since the Polar H10 was not yet available during their second session.

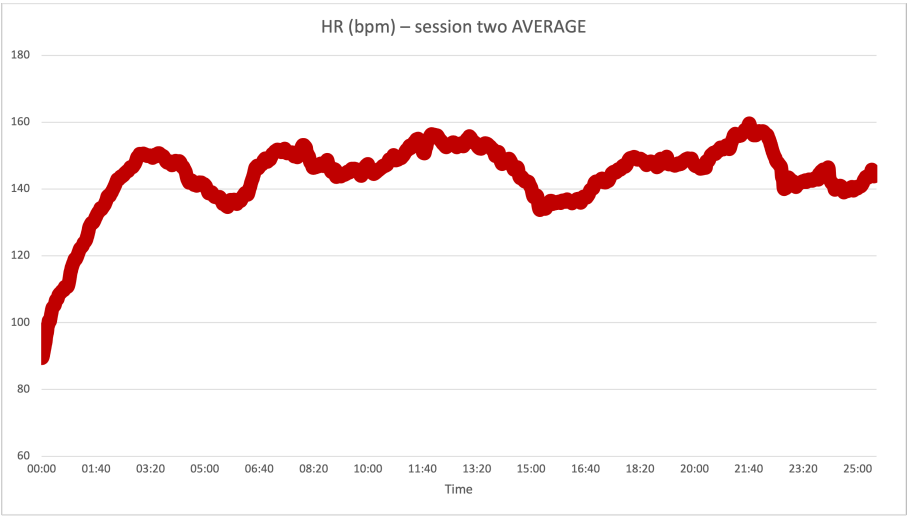


Figure 52: Average heart rate for participants in session two

28.2 Session three

Heart rate data from session three showed an average heart rate swinging between 140 bpm and 160–170 bpm after the first peak was reached (see Figure 53). *The entire session averaged out to be 144 bpm.* Among individual participants, their average heart rate for the session was between 129 bpm and 166 bpm. *The highest recorded heart rate in this session was 192 bpm*, while the lowest maximum was 155 bpm. This session also showed a slight drop in the intervals amplitude among all participants except participant 9, 10 and 13. The amplitude drop averaged at six bpm. The average increase for participants 9, 10 and 13 was 16 bpm. Only four participants reached or were very close to their maximum at their first interval compared to seven in the previous session.

Please note that the overlap of participants with heart rate data between session two and three is not perfect; this session does not include participant 4 but includes data from participant 7 and 8.

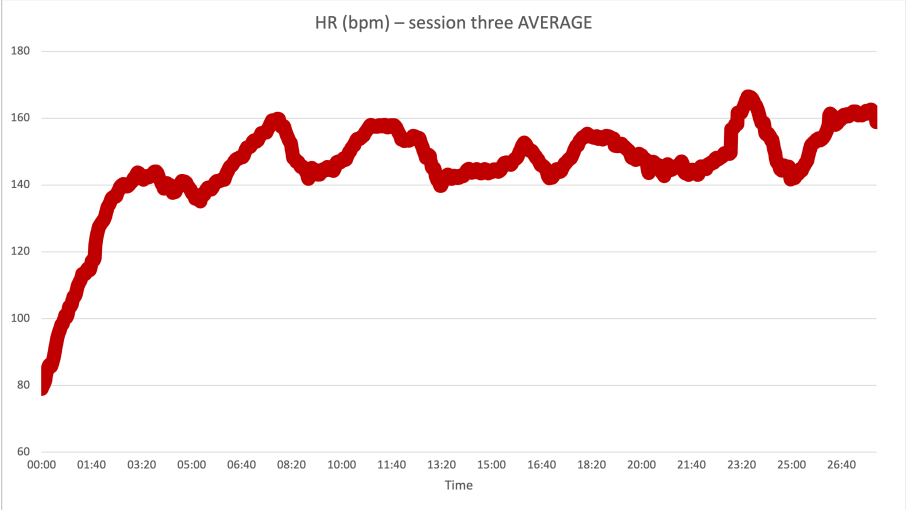


Figure 53: Average heart rate for participants in session three

28.3 Summary

This section has presented heart rate data collected during the play sessions of the experiment. Data from session one is not included due to its low quality. Session two and three present average numbers, maximums, and minimums and highlight some trends from the data. A collection of all heart rate data is available in Appendix C.

PART VI

DISCUSSION

This part includes discussion on the results from Part V. The discussion is divided into six sections based on the research questions, and all sections contain a summary of the findings at the bottom.

29 Evaluating how the Game Affects Enjoyment

This section discusses how the participants' enjoyment was affected by playing our prototype game during the sessions (**RQ4**).

Results from the questionnaire reveal mostly positive sign when it comes to enjoyment. All but one participant said they had fun playing the game each session (see Figure 47). In addition to this, most participants said the game got more enjoyable over time. These answers are a solid indication of the game being enjoyable and fun. Since the participants also reported the game getting more enjoyable over time, there might be real potential for this concept. Whether the participants found the experience extremely rewarding was not as clear cut. However, very few said they disagreed with this statement. For a difficult game like this, where much focus is put on challenge (see Section 7.1.2 and 7.2), the players must find the game rewarding when first winning. Therefore, the low number of participants disagreeing indicates that the game does not completely fail at this, at least. Ideally, the number of agreeing participants should have been higher. Some areas that could affect this are the inclusion of more rewards, such as achievements, and making an easier introductory level. The current first level could be deemed too hard and thus demotivating for some. These points are something to keep in mind if this idea is developed further.

Observations showed much of the same as the questionnaire. There was only one participant who visually did not have a good time. In session one, eight participants showed enjoyment; in sessions two and three, the number was seven and two. The remaining had neutral expressions during play-testing. This decrease over time could indicate that the game's novelty wears off after the two first sessions. The visual excitement might be replaced by deeper concentration. As participants improved, it was observed that they seemed more focused on what happens in the game. The lack of novelty and better knowledge of the controllers could be what allows this. Less visual enjoyment might, consequently, not necessarily mean less enjoyment.

On the other hand, it could also mean the game got less enjoyable. However, participants themselves reported having fun while playing (see Figure 47 (a)). In addition, observations did not show participants having an unpleasant time while playing. High numbers of excitement and positive surprises from the participants also back this up. The game seems to be able to elicit positive emotions in its players. Finally, the participant who visually did not seem to enjoy their first session said they enjoyed playing the game in session two. All these points add up to positive observations on enjoyment.

The story is much the same for interviews following the play sessions. Ten and nine participants said they had fun playing in session one and three. Two of the participants who did not say they had fun explained it was since they had to do endurance training, which they did not enjoy. They stated that had the game been played on a couch with a regular controller, it would have been fun. By just including exercise, these players reported the game as less enjoyable. If this is enough to worsen the experience, it could mean that the game might not be a good match for those who have no initial interest in exercise. Since the Playpulse platform requires getting on an exercise bike and potentially putting on gym clothes, completely hiding the fact that the game is a workout might be very hard or impossible. If this is correct, it could have significant implications when choosing a target audience for this platform. The last participant who did not enjoy the game said it was only caused by game bugs and frustrating controllers, meaning that a smooth and comfortable experience could make or break games for this platform.

Multiplayer is mentioned as a contributor to enjoyment by most participants. It is said to both bring team spirit and motivation to the game, and all but two participants said that physically having the other player in the same room was essential to their enjoyment. The other two said that single-player would be equally or more fun than multiplayer. Those who liked multiplayer said that even more cooperation would make the game more enjoyable, which is worth noting. Lastly, the amount of content available seems to be a contributor to the players' enjoyment. After session three, several participants said that they found the game fun when there was new content but did not enjoy replaying levels as much. This need for new content could be because players get more used to the previous levels. Replaying them could require less focus and make them more aware of being tired and the fact that they are exercising.

Other factors that could affect enjoyment include controllers, difficulty, and network lag. Almost all participants said or gestured that they found the controllers frustrating and challenging to learn at some point. Some participants also said they found them uncomfortable to use. Poor controllers likely made the experience of playing worse and limited enjoyment. Participants nonetheless reported getting more and more used to them, and most did things automatically by session three. The difficulty might also have been too high initially, thus limiting the fun in session one. The act of learning the new controllers and mastering level one at the same time was deemed challenging by some participants. A solution to this could be to have a more manageable introductory level that lets players thoroughly learn the controls before learning the game. Another factor is network lag. Playing as the client adds extra difficulty to the game since the client sees the game a few milliseconds later than the host. This lag was reported by many client-side players and was seen as quite frustrating and unfair. Limiting network lag to an unnoticeable level could therefore help increase the enjoyment of the game.

The most important findings on the game's effect on participants' enjoyment are summarised in the following list:

- Questionnaire results show clear results of participants finding the game fun and more enjoyable over time. Few participants find the experience unrewarding.
- Observations show most visual signs of enjoyment in the first session, with later sessions showing more focused players than in session one.
- Most participants report the game as fun in interviews. The exceptions said that the inclusion of endurance training made them not enjoy it. This could mean that the platform might not fit player with no interest in or a strong dislike for exercise.
- Bugs and uncomfortable controllers can ruin the enjoyment for some players – a smooth and polished game is therefore essential.
- Multiplayer is reported as an enjoyment and motivation booster. Most participants wanted more ways to collaborate in the game.
- Bad controllers, too high difficulty, and noticeable network lag can contribute to a worse experience for the player and are important elements to get right.

30 Evaluating how the Game Affects Engagement

This section discusses and evaluates how our game affects the engagement of the people playing it (**RQ5**).

Looking back to Section 8 of the pre-study, continuation desire was found to be an essential aspect of engagement in games. Furthermore, since engagement in games is a multidimensional concept closely related to other concepts like Flow, immersion and user engagement (see Section 22), data had to be designed with regards to these concepts. Therefore, the engagement is evaluated based on the participants' given effort while playing, cooperation with the other player, immersion in the game, their experience Flow, and continuation desire.

Most questionnaire statements on engagement received an overwhelmingly amount of *"Agree"* answers (see Figure 48). Regarding the statement *"I was so engaged in the game that I lost the sense of being in physical activity"* (see Figure 48 (a)), less than 50 % of the participants agreed overall. At first glance, this might indicate that most players did not become engaged in the game since they had the sense of exercising while playing. However, it could be argued that since the Playpulse platform is an actual exercise bike that players have to mount to play and since most participants got a high heart rate, masquerading the fact that players are also exercising while playing could be very hard or maybe impossible. This is opposed to, e.g. Pokemon Go, where the physical activity is achieved through walking normally without gym equipment which might not be perceived in the same manner. Thus, we feel the distribution of answers to losing the sense of being physically active is expected.

Two other statements in the questionnaire, *"I was motivated before each round"* and *"I would like to play again"* (see Figure 48 (c, d)), are statements more closely related to continuation desire. Both statements saw an average of over 60 % of participants agreeing over the three sessions, with very few disagreeing. This might indicate that the game contains certain engaging components that create a continuation desire for the players. It is also backed up by most players being motivated to and wanting to play another round.

Special attention was given to the physical effort exerted by the participants, their motivation, and how much they cooperated with their teammate. As for the physical effort – how fast and often the participants were pedalling – participants seemed to exert themselves the most in the second session. Lower exertion in session one could be due to participants being new to the game and unsure of the game's mechanics. An overwhelming start could take focus away from pedalling. The second session somewhat confirmed this. Participants generally understood how the game worked this session, and many gave a higher effort while playing. The participants had also learned that pedalling faster means faster shooting, which means defeating the boss faster. Understanding this mechanic seemed to motivate some participants to pedal faster. Another, less predictable, reason for higher exertion in session two was attitude. Two participants said during the interview that they treated the second session as more of an exercise session than session one and thereby had the mindset to give more effort. The second session also saw more participants bringing gym clothes, and fewer went back to studying afterwards. This made them more comfortable with giving a higher effort and sweating more.

Since familiarity with the game led to higher exertion, it might be expected that session three saw even better results. However, this was not the case – instead, participants generally gave less effort in session three. Several of the participants were pedalling significantly slower when their character was in flying mode. They had learned that pedalling does not affect fire rate when flying and saw less reason to pedal fast. Two participants on separate teams also found an exploit in the game. The exploit allowed them to stay still in the air without getting hit, significantly reducing the need for pedalling to fly around. While the exploit can be characterised as a bug, the low incentive to pedal while flying seems more like a design flaw. The idea behind the game mechanics was to incentivise players to keep the pedal-gauge needle in the dark-green zone by pedalling fast and staying active. For flying, the incentive was faster movement speed. However, the experiments showed that the game in its current state does provide the desired incentive to pedal while flying.

Overall, motivation and cooperation observed during the experiment showed participants motivated

to play the game and start a new round after dying. This observation matches answers from the questionnaires to a large extent. When asked if they wanted to continue playing after the minimum of 20 minutes had passed, they answered yes in 60 % of the cases. Ideally, for continuation desire, more teams would have answered "yes". However, it is also understandable that some players got too exhausted to continue or felt that the game with its limited content became repetitive. Both these points will decrease their desire to continue playing. For cooperation between players, much communication, hazard warning, tips sharing, and strategy planning was observed. It was exciting to see these reactions from the participants, and we think it shows how the cooperative nature of the game has contributed to increasing the engagement while playing.

Interview results do not give much data on the overall engagement players felt while playing. However, participants identified certain aspects of the game that they thought increased or decreased their engagement while playing. These aspects were related to the cooperative setting, the difficulty, and the repetitiveness of the game. All but one team mentioned that the cooperative nature of the game drove their engagement upwards. This finding correlates with observations and strengthens the indication of a cooperative setting increasing engagement.

After the first session, one participant said the game was so challenging that it made them less engaged. However, another participant got more engaged, saying the great difficulty increased their motivation to defeat the boss. After the third session, no one complained about the difficulty, with most agreeing it was at an appropriate level. This game is inspired by Cuphead, which is a very challenging game. The game in this project is, therefore, designed to be difficult as well. However, if some find the game so challenging that they do not want to continue playing, this is an unwanted effect. It could, therefore, be an idea to have an even easier difficulty selection or provide more manageable levels in the beginning before ramping up the difficulty.

Some participants said they got less engaged due to the game being repetitive. This was somewhat expected since the prototype only consisted of three levels, which many participants replayed several times on higher difficulties. There would be many more levels in a full version of this game, which hopefully would lessen the repetitive feeling. Something more unexpected was feedback on the playtime for a level. Some participants almost lost their interest to continue towards the end of a level. The game does intentionally not have an HP bar for the boss, but several participants still suggested adding some indicators of remaining boss health to increase motivation towards the end of levels. This feedback is valuable and indicates that the current length paired with no signs of progress in the end-game might discourage people from continuing playing, which is unwanted.

The evaluation of Flow is mainly done through the questionnaire results from the Flow State Scale. Only two statements had less than 50 % of the participants agree: *"I had a good idea while I was performing about how well I was doing."* and *"I felt in total control of what I was doing."* (see Figure 51 (c, e)). The answers to the first statement are somewhat expected since the game is deliberately designed not to include a health bar for the boss or other signs of progress than getting to a new phase. However, as mentioned previously, some participants became less engaged by the lack of a boss health bar, which means this design choice might work against the "unambiguous feedback" element of Flow and GameFlow; its place in the game might need to be reconsidered.

Regarding the "sense of control" element of Flow, only 42 % of participants agreed and almost 30 % disagreed. These answers are also understandable since the controllers physical position and setup on the outdated Playpulse bike felt unnatural even to us. Finding a natural mapping between the buttons and what they would do in the game proved very difficult. This likely led to 42 % disagreeing with the statement *"It was easy to learn the controllers or the game"* (see Figure 51 (g)). This statistic shows how important easily understandable controllers are to increase engagement within a game. It should, however, be noted that every participant answered "yes" to the question *"Did the pedalling feel natural considering what it did in the game?"* (see Figure 51 (h)). Since pedalling is used unconventionally in this game compared to previous projects, this is very interesting and promising.

Even though many statements from the Flow State Scale got a high share of "agree" answers, the game does not yet manage to give the players a feeling of Flow for long. Unnatural controllers and a lack of progress feedback are interrupting the state of Flow for many players. This is also reiterated during the interviews, where participants said they sometimes forgot which buttons did

what, leading them to lose focus in the game. Around 30 % of participants also said that sometimes too much was happening simultaneously, which made them confused and, in turn, made them forget to pedal. This further decreased their chance of achieving Flow.

The following list contains the most important points to take from the discussion on how our game affects engagement:

- The players overall seem to be engaged in the game while playing.
- Many players are aware that they are exercising, and this can break immersion. It is, however, difficult to hide the exercise aspect due to the nature of the Playpulse platform and the high intensity in our game.
- Players had a high continuation desire, with over 60 % noting in the questionnaire that they were motivated and wanted to play again. 60 % of participants also wanted to play for longer than the minimum 20 minutes.
- As players got more used to the controllers and the game during the second session, their physical efforts increased. The overall efforts were lower during the third session since players had found loopholes that did not require them to pedal as much as intended.
- Players' mindsets and external factors like going back to studying afterwards affected how much effort some participants gave in the experiment.
- There was much communication between participants. Warning each other about hazards and planning strategies was the most common. 84 % of participants said the cooperative setting of the game increased their engagement.
- Even though the game gets promising results related to flow, some issues with feedback and controllers decrease the players' chances of reaching the Flow state while playing.
- Several aspects of the game could be improved to increase engagement. Easier difficulty initially, less repetitiveness, better feedback to the players, better controllers, and encouraging them to pedal more while flying are some.

31 Evaluating the Physical Benefits of the Game

This section will evaluate if playing this game has any potential physical benefits for the player and can be considered exercise (**RQ6.1**).

When evaluating the physical benefits of the game prototype, there are two main areas to look at: the participants' perceived exercise effect and the measurable and objective data. We will first look at the participants' perception.

There are a couple of questions on exercise in the questionnaire (see Figure 49). Firstly, the participants were asked if they felt they were exercising while playing (see Figure 49 (d)). Here, an overwhelming majority said they did. In addition, nearly all participants rated the session to be moderate to high intensity, with almost half rating it as high. These two results indicate that playing the game will be considered as an exercise by the players. The fact that the intensity is rated as high as it is indicates that the players exert themselves quite a bit while playing. High exertion is a good indication of the game having physical benefits.

Observations showed participants getting tired while playing. Many participants had audible breathing and started to perspire, and some needed one or more drinking pauses during the session. Most of these signs were not present until after the first ten minutes of playing, but this is normal unless doing a very vigorous exercise. These visual sign of exertion points to the same as in the questionnaire: the players get physically tired by playing this game. It was also observed that many players pedal near max speed multiple times when entering revive mode. This high intensity pedalling session is very likely to increase heart rate and get the player tired. Having the revive mode seems to be an excellent choice due to this. The player will enter the revive state usually four to five times each during a typical play session. Having these intensity spikes distributed throughout the game is highly likely to contribute positively to the physical benefits of the game.

In the interviews, participants reported being tired after the session but not completely exhausted. Numerous participants report the sessions to be too short to be considered a complete workout. However, had it been closer to 40–50 minutes, it would have sufficed, they said. Still, some participants said that playing more than 20–30 minutes would have been too much for them, and they considered the current length to fit. One participant who exercises a lot said that if the sessions were longer, it "would have been a mild cardio workout", but that "*for someone who does not work out, it would have been extremely tough.*" How tired players get after playing would probably be better suited for all had different intensity choices been implemented. This feature would allow all to choose an intensity that would have them end up closer to the same level of tiredness at the end. Nevertheless, it shows that the game has the potential of getting different types of player tired if tweaks to intensity or session time are made. Several participants said that they considered this exercise form and length appropriate as a warm-up and could see themselves using the game for this purpose at a gym. Although several participants say they had more to give and said the game would work as a warm-up, it might be that some do not want to admit to becoming exhausted after playing a game.

When looking at the heart rate (HR), a more objective measurement of exertion will be given. To figure out where the participants in general lay on an intensity scale, we first need to know their estimated max HR. Based on the formula found in Section 6 and the ages of participants being between 21 and 26 years, the estimated max HR should be around 195 bpm. The average HR graph (as seen in Figure 52 and Figure 53) shows the HR mainly swinging between 140 and 160 bpm. This HR is equivalent to 72–82 % of max HR for the participants. As mentioned in Section 6.1, moderate intensity is classified as 50–70 % of max HR while vigorous intensity is 70–85 % of max HR. This means that the game, on average, gets players to a vigorous intensity level during a session. In practice, this means that some participants have higher HR and some lower, but a lower HR is still likely to be at moderate intensity throughout the session. Figure 54 (a) and (b) shows examples of two participants, one with a very high average HR and one with a relatively low HR. The lowest recorded average from sessions two and three is 123 bpm, equivalent to 63 % of max HR, which is in the middle of moderate intensity. This indicates that the game is playable at both a moderate and vigorous intensity level, making it available to a larger audience.

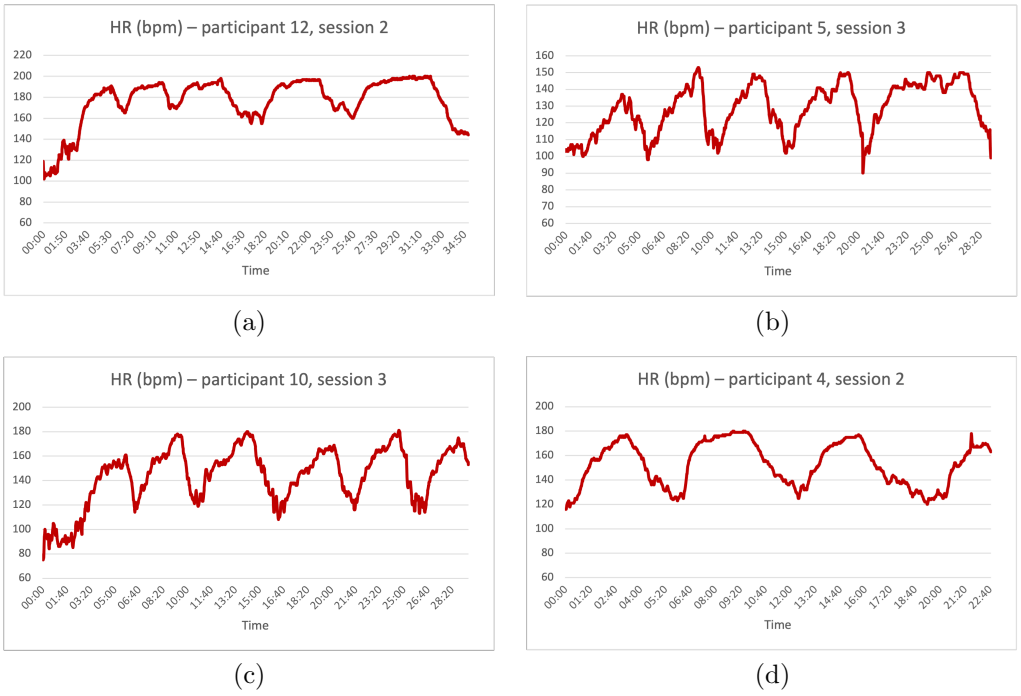


Figure 54: HR graphs showing high and low averages and interval patterns.

These results could also point to the intensity level being too high for our target audience. The target audience is people with little to no exercise in their everyday life. Therefore, making it possible to play at a lower intensity could be preferable. It would also play well with theory from DualFlow (see Section 7.3). DualFlow says that the game should let players gradually reach new levels of intensity to progress physically. Lowering intensity would also allow the game to be played in longer sessions without fatiguing the players. More extended playtime would get the players closer to completing the WHO's recommendation of 150 moderate activity minutes – however, that is not the goal of this project.

By looking more closely at two HR graphs from participants, it is possible to see some promising patterns. Figure 54 (c) and (d) shows two participants' heart rate during a session. These graphs clearly show an interval pattern with (c) consisting of six intervals and (d) four intervals. Each interval is playing through a level until win or failure. To count as HIIT, the participant must achieve 80 % of max heart rate when in an interval and less than 70 % of max when in-between. For these participants, they are pretty close to achieving this. They both stay above 156 bpm (80 % of max) for the most part during intervals and stay below 136 bpm (70 % of max) for short periods in-between intervals. HIIT has many known health benefits (see Section 6.1.1), so having results as close to HIIT as this then give clear indications to the game having physical benefits.

The following list contains a summary of the most important findings on the physical benefits of playing this game:

- The participants themselves report the play sessions to feel like exercise and rate the intensity to be moderate to high.
- Participants show visual sign of tiredness when playing the game, such as audible breathing and perspiration.
- In interviews, participants report the sessions as too short to count as a proper workout but find it fitting as a warm-up.
- Some participants are very tired after 20 minutes while others have more to give. Being able to select intensity for a level could solve this.

- The average HR for participants stays at the lower vigorous level for most of the session, and all participants reach a moderate level of intensity when playing.
- Playing the game follows close to a HIIT pattern

32 Evaluating the Impact the Game has on Players' Motivation to do Physical Activity

This section will evaluate the impact the game has on the players' motivation to do physical activity (**RQ6**).

When evaluating how the game affects motivation to do physical activity, playing the game will itself be regarded as physical activity (see "Evaluating the Physical Benefits of the Game" in Section 31). This means that sign of increased motivation for either traditional physical activity or playing this game will be considered as positive traits.

65 % of the participants agreed and 13 % disagreed with the statement, *"I am more motivated to exercise with the help of this game, rather than cycling without the game"* (see Figure 49 (a)). This shows that the game can be a good tool for increasing players' motivation for exercising on an exercise bike. Even some who said they strongly disliked training on exercise bikes answered positively to the statement above. Still, this result can not be applied to physical activity in general since the statement specifically asks about exercise bikes. Their answers can instead be interpreted as such: If they *had* to use an exercise bike, playing this game would be preferable, but with a free choice of physical activity, participants might not choose this exergame.

Results from *"I would rather play this game than practice regular exercise"* (see Figure 49 (b)) back this up. Here, 45 % of participants disagreed, and only 23 % agreed in total over the three sessions. Since many of our participants exercise regularly, these results are somewhat expected. It is not easy to create an exergame that is so enjoyable and engaging that players would rather play it than continue playing their team sport or do their well-established exercise program – especially since these are connected to social benefits and routine. On the other hand, it seems like those with little regular exercise would prefer this over regular exercise – at least in the first session. Their opinions changed during later sessions, perhaps due to the game's novelty fading. How an exercise background affects motivation will be further explored and discussed in Section 33.

The questionnaire statement most related to this section's research question is *"This game has motivated me to be more active/exercise more"* (see Figure 49 (c)). To this statement, only 21 % agreed while 47 % disagreed. Straight away, it looks like the game does not succeed in motivating most of its players into doing more physical activity. This might be true for our test population, but not necessarily for our target audience. Many of the participants in the experiment exercised several times weekly. It then makes sense that they do not become motivated to be even more physical from playing our game. This is in line with the game design. It aims to motivate those who initially do not exercise and not reinforce the motivation of those who already do. However, when looking at the participants with less exercise, only a few agreed when asked if they got more motivated. This might indicate an underlying reason or attitude for why some people do not want to exercise. If that is the case, a significant barrier must be overcome to successfully motivate these people to be more physically active.

From the observations and interviews, a few qualitative data points were made regarding motivation for physical activity. In one session, a participant said they had booked the timeslot following the playtesting session at the local gym to use the game as a warm-up. Another participant continued to pedal even after dying in the game and in-between levels to maximise the workout. The participant also increased the resistance on the bike and said this was to get more exercise effect out of the session. Several participants said they treated the second session more as an exercise session than just a play session (see Section 30). This indicates that our game might have some role in motivating its players into exercising more or harder. However, the participants might have shown this behaviour since they already were part of the experiment and had "promised" to do physical activity three times by playing the game. Therefore, the motivating effect might have come from the experiment itself and not from the game. It is hard to say for sure if we would see similar results outside the experiment or if the game's motivation applies to people outside our test population. Especially for the target audience if they are playing voluntarily in their free time.

The general takeaway from these results and discussions is that the game does not motivate players

to become more active. However, the questionnaire statements shown in this section are related to exercise. As emphasised at the beginning of this section, being motivated to play this game could indirectly count as motivating the players to do physical activity. Looking back to the engagement-related statements *"I was motivated before each round"* and *"I would like to play again"* (see Figure 48 (c, d)), we see that participants might be motivated after all. 65 % of them agreed to the first statement and 71 % to the second. With this in mind, the participants in our experiment might view the game differently based on which purpose it should serve. If it is to be used for exercising, most people would rather not play the game. However, if used for entertainment, a majority of people want to play. This both shows that the exercise part of the game could be improved and that it might be smart to focus on the entertainment sides of the game when presenting it to new players. By first getting them hooked on the game, physical activity will follow as a result of the playing. Because of this, it makes more sense to focus on the entertainment sides of the game – especially when presenting it to the target audience. Highlighting the game-related parts of an exergame rather than the exercise parts will likely be more effective in getting people in the target audience to try the game.

The following list contains the most important findings from our results and discussion of how the game impacts its players' motivation to do physical activity:

- The game does not overall seem to motivate people to become more physically active.
- Most participants would play this game instead of just riding an exercise bike, while few participants would play this game over practising regular exercise.
- The test population consisted of many people who exercised regularly. The game did not manage to increase their motivation. However, this is not the game's goal since it is made with a different target audience in mind.
- It seems that people view the game in two different ways based on its purpose. When used for exercise, they are not motivated to play it again. When used for entertainment, they would like to play again.
- If an emphasis is put on the entertainment side of the game, people in the target audience might be more motivated to play it regularly. Since the game is considered physical activity, the players would increase their physical activity levels by playing the game.

33 Evaluating how a Gaming and Exercise Background Affects the Experience of the Game

This section will evaluate how the player's background and previous experience with gaming and exercise affect their experience of playing the game. This discussion is related to:

RQ4.1: *How does the amount of time spent on playing games affect the player's enjoyment of playing our game?*
RQ4.2: *How does the amount of time spent on exercise affect the player's enjoyment of playing our game?*
RQ5.1: *How does the amount of time spent on playing games affect the player's engagement when playing our game?*
RQ5.2: *How does the amount of time spent on exercise affect the player's engagement when playing our game?*
RQ6.2: *How does the amount of time spent on playing games affect the player's motivation to become more active after playing our concept game?*
RQ6.3: *How does the amount of time spent on exercise affect the player's motivation to become more active after playing our concept game?*

When evaluating how a gaming or exercise background affects different measures of the game, the group was twice divided into two groups. For exercise, the threshold was set at exercising less than or more than three hours per week. Ideally, this threshold would have been set even lower, but the group with little exercise only contained four participants even with this separation. For gaming, the threshold was set at playing games for three hours or less for one group and more than three for the other. Here also, the separation gave one group containing only four participants. This group held those who do not use much time on games.

The discussion will be based on two main areas, data from the questionnaire and statements from participants either during gameplay or in interviews. The quantitative data from the questionnaire was processed to change the Likert scale into numbers (Totally disagree = 1, ..., Totally agree = 5), averages for the questions in each group were calculated, and the numbers were compared. The difference needed to be marked was set to at least 1.

33.1 Impact from having an exercise background

When looking at the data from the questionnaires, the results showed surprisingly small differences between the two groups. Table 7 lists all questions with a difference of more than 1.0; only six questions in session one, two questions in session two, and no questions in session three met this requirement. This means that no general trend was found in the questionnaire regarding exercise background. From session one, one can see the outline of a pattern. All questions with a marked difference had a lower score for those with little exercise than those with much. The questions in regard can be categorised into questions on enjoyment and questions on control. Although the signs are not clear, it could indicate a higher threshold to start playing this game if they do not have a background in training. This could be caused by the game mechanics and controls being more challenging to learn if the game makes them very tired. If it takes more effort and time to learn the controllers, it also takes more time to play the game as intended, thus lowering the enjoyment in the beginning. This finding also makes sense considering most of these differences are gone by session two. Most players should be comfortable enough by this time to be able to play as intended. It is also worth noting that by session three, no question has a significant difference, indicating that differences from background fade away after a few sessions. However, these trends are not strong and should be taken with a pinch of salt.

Table 7: The difference in average score for participants who exercise more and less than three hours per week.

Session one			
Question	*Much exercise*	*Little exercise*	*Diff.*
I would like to play the game again to improve my score/skills	4.11	3.00	1.11
I would like to play again	4.22	2.75	1.47
I felt in total control of what I was doing	3.22	2.00	1.22
I was not concerned with what others may have been thinking of me	4.22	3.00	1.22
I understood what I was supposed to do in the game	4.11	3.00	1.11
It was easy to learn the controllers for the game	3.00	2.00	1.00
Session two			
Question	*Much exercise*	*Little exercise*	*Diff.*
My attention was focused entirely on what I was doing.	4.55	3.5	1.05
I felt in total control of what I was doing	3.77	2.25	1.52
Session three			
N/A			

Another observation that might be worth noting is regarding the question in Figure 49 (b). In session one, five participants say they would rather play our game than practice regular exercise. Three out of those five participants are in the group that gets relatively little exercise. This finding could indicate an initial interest in a product like this for people with little exercise in their lives. This does, however, not last and changes in later sessions. By session three, the number of participants that agree is down to one in total. There could be several reasons for this. One reason could be that the game prototype is too repetitive, making participants lose interest in using this as a replacement for regular exercise. Another possible reason is that the participants might not like using exercise bikes to exercise and realises that the game is not enough to make them forget this. Lastly, it could be that they liked the game but did not like this approach to exercise and made that discovery over the three sessions. It also makes sense that those who exercise much will have less interest in changing their current workout routing, team sport or hobby in favour of playing this game. Spending much time on something is usually an indication of enjoying that thing.

From interviews, one comment was worth noting. A couple of participants said they did not like exercise bikes as a type of exercise and therefore did not like this. This could mean that it might be difficult for this platform to recruit those with an initial bias against exercise bikes, even if the game is both enjoyable and engaging in itself.

33.2 Impact from having a gaming background

For participants with a gaming background versus those who do not, there were even fewer differences in the questionnaire (see Table 8). Session one and two had two questions with a difference of one or more, and session three had none. From these few results, it is hard to make any accurate claims that are not just guesswork. However, the data might point to that those without a gaming background are more positive to this game in the beginning and would like to play it again, but later converge with those who play video games. However, the trend might not be accurate due to the minor differences in the data. Nevertheless, if it is accurate, it does make sense that those who spend much time on video games will have higher expectations of a game than those who do not and might be less impressed by a prototype such as this game. Otherwise, no link between a gaming background and their experience was found in the questionnaire.

Table 8: The difference in average score for participants who play video games more and less than three hours per week.

Session one			
Question	*Much gaming*	*Little gaming*	*Diff.*
I would like to play the game again to improve my score/skills	3.44	4.5	1.05
I found the experience extremely rewarding	2.88	4	1.11
Session two			
Question	*Much gaming*	*Little gaming*	*Diff.*
I was challenged, but I believed my skills would allow me to meet the challenge	4	5	1.05
Time seemed to alter (either slowed down or speeded up)	4.44	3	1.52
Session three			
N/A			

From interviews, there was one finding worth noting. A few participants familiar with the inspiration for this game, CupHead (see Section 15)), had a positive attitude going into the play sessions and gave positive feedback afterwards. This could indicate that a background in gaming, especially within this genre of games, could positively affect the experience of the game. It is, however, necessary to stress that familiarity with CupHead was not asked about to all, so there is no information to compare this against the opposing group. A couple of participants said they rather play the same level again to get all the stars than play a new level. This kind of behaviour fits under the player type "achievers", meaning that including stars and performance based achievements are likely to work as a motivator for players under this type.

33.3 Summary

The most important findings from this section are summarised based on research question in the following list:

Findings relating to **RQ4.1** (Gaming background and enjoyment):

- No clear sign were found, but having a gaming background might make you expect more from the game. These high expectations are not necessarily met by this prototype, thus lowering their enjoyment.
- Having experience and interest in games similar to this concept might have positive influences on the player and make them enjoy the game more.

Findings relating to **RQ4.2** (Exercise background and enjoyment):

- Not having a background in exercise could make the start phase of this game more frustrating and less enjoyable. This might be due to the players becoming too tired to learn the controllers and game at the same pace as those who exercise.
- Having an strong initial dislike against exercise bikes seems to lower players enjoyment when playing the game on Playpulse, regardless of how good the game is.

Findings relating to **RQ5.1** (Gaming background and engagement):

- Participants with a gaming background expect more from the game. Not having a gaming background then makes you more engaged in the first session since your expectations are lower. This trend does not last and those who do not game fall down to the same level as the gamers.

- Certain player types, like “achievers” are more engaged when the game includes performance based unlockables.

Findings relating to **RQ5.2** (Exercise background and engagement):

- No connection was found between a background in exercise and engagement. This is likely due to the two not being related.

Findings relating to **RQ6.2** (Gaming background and motivation):

- No connection was found between a background in gaming and the motivation to become more active after playing the prototype. They are likely not dependent on each other.

Findings relating to **RQ6.3** (Exercise background and motivation):

- Those who spends little time on exercise has an initially higher interest for this type of exercise than those who exercise often. However, this fades away during the next sessions. The game concept likely has potential, but the potential fades due to repetitiveness and lack of content.

34 Discussing the Project and Technology

This section will discuss the technology used in this project and the execution of the project itself.

34.1 The Playpulse platform

Using the Playpulse platform went pretty well in general. In this project, the prototype device initially created for the masters' thesis on Pedal Tanks (see Section 12.5) was used to test the game. Working with this went well regarding setup and implementation – the system was plug-and-play like any other ordinary hand controller. Certain issues and limitation were, however, observed. Firstly, the controllers for this prototype device were not optimal. Much feedback was given about them being uncomfortable and hard to get used to. In addition to this, some buttons started to show wear and tear during the session, e.g. on one bike, the thumb button on the left side would have a hard time registering the push if it was not pressed on the right side of the button. Other feedback worth noting with the platform is the inertia in the spinning wheel being potentially hazardous, the seat being uncomfortable and the wish for a way to track chosen resistance, i.e. a wattmeter. Feedback regarding the controllers and the platform from participants is valuable to this project and field. However, the Playpulse team are currently promoting their new version of the Playpulse exercise bike with redesigned controllers, meaning that most feedback received in this project is probably not that useful anymore. Having access to the newest version of the Playpulse platform would be very advantageous to both the developers and the Playpulse team. Hopefully, later projects will have access to this new platform.

34.2 HR measurement

In previous projects, a FitBit Charge 3 wristband has been used to measure the participants' HR. This device has in several previous projects been reported to be unreliable and heavily underestimate the HR. For this reason, new chest-strap HR bands were acquired. Unfortunately, they were delayed and did not arrive before session one. This lead to the FitBit being used this session. The data produced was, however, not satisfactory and had heavily underestimated the HR for all participants. The data from FitBit was also hard to export and analyse. This lead to the data being discarded, which was very unfortunate. The data later collected from the Polar H10 seemed very accurate and was easy to export and analyse.

34.3 Development process

When developing the game, the prototyping method was used. This method involves making a simple but working version of our game based on our ideas and sketches. This process is meant to be relatively quick and is not meant to make a perfect product. For the most part, this method worked well for the project, but there is one area where improvements could have been made. A couple of days before the first session, a user test was conducted. This test gave valuable feedback about the state of the game and suggestions for features and fixes. This test was done late since the idea was to present a complete, working prototype to the testers. Had the process been repeated, more user tests would be performed before the prototype was nearly finished. Doing this would have helped optimise the experience and improve areas such as controllers and fix remaining bugs.

34.4 Unity and Mirror

Using Unity to develop this project worked very well. Documentation and guides were easy to find and follow and made the process simpler. The use of Git was avoided due to previous experience with the two platforms not working well together. Instead, Unity's proprietary collaboration tool was used. This tool is much more primitive than Git, but it worked well for a prototyping project

with two developers like this. For network functionality, Mirror (as presented in Section 19.4.1) was used. This process was also simple overall, but certain features took a long time to implement due to insufficient knowledge about the tool. It was also hard to limit network lag in the game when using Mirror – this led to the game not being as enjoyable as it should have been.

The following list contains a summary of the discussion on the project and technology used in the development:

- Using the Playpulse platform went well, but controllers were not optimal. They were described as uncomfortable and hard to learn. Some buttons also started to show wear and did not function as well as they should have.
- Due to delivery issues, the Fitbit charge 3 was used in session one for HR data. This data was so unreliable that it was not used. The data from Polar H10, used in session two and three, was very reliable. Ideally, this HR monitor should have been used in all three sessions.
- Prototyping was used as the development method. This method generally worked well, but more user tests than one near the end of development should have been done.
- Using Unity for the development of the game was a great success. Using Mirror for networking also went pretty well but took more time than expected to implement and introduced unwanted network lag.

PART VII

CONCLUSION AND FURTHER WORK

This part contains the conclusions for the research questions and the research goal stated in Part I of the project. The part also lists this project's contributions and suggestions for further work.

35 Conclusion

In this section, we present our conclusions by providing answers to our research questions and research goal.

RQ1: *Which methods and frameworks can be used to make an exergame fun and engaging?*
In the pre-study of this report, we presented several frameworks related to enjoyment and engagement in video games. While other enjoyment and engagement based methods and frameworks exist, we believe we identified and selected a few established frameworks that could help us make our game fun and engaging. GameFlow builds upon Csikszentmihalyi's flow concept and presents eight elements and criteria that need to be fulfilled to achieve enjoyment within a game. Malone's Challenge, Fantasy, and Curiosity consists of three categories of characteristics that make games fun and presents the importance of an appropriate goal, an intriguing fantasy, and provoking the player's curiosity. Dual Flow, an exergame model building upon GameFlow, introduces attractiveness and effectiveness, two dimensions that must be balanced to make a good exergame. As for more engagement-related frameworks, the OA3 framework shows how the components of objectives, activities, accomplishments, and affect within games are related to each other and can help increase the engagement amongst the players. Lastly, Schønau-Fog and Bjørner's six types of causes of engagement highlights different ways in which players can become engaged in games. When designing our game we especially focused on the challenge element from GameFlow and Malone's theory, the accomplishments component from OA3, and social mechanics, which is also an element of GameFlow and a type of cause of engagement. This is reflected in the game's high difficulty, the star system and unlocking of new levels, and the cooperative nature of the game. These features are all added to the game in an effort to make it more enjoyable and engaging.

RQ2: *Which types of games are fitting for the Playpulse platform?*
The answer to this research question is also based on our findings in the pre-study. First of all, for an exergame to be fitting for the Playpulse platform, it needs to be based around aerobic exercise, as this is the only natural type of exercise to perform on an exercise bike. As for the type of game and gameplay, an analysis of different game genres was done (as found in Section 13). While all genres could probably work on the Playpulse platform to some degree, some are much more apparent to be a good fit. These genres are: infinite runners, racing games, MMOs, platform games, idle games, party games and music games. They are a good fit as they do not require complex input, provide natural mappings for the game's pedalling, and facilitate gameplay that seems feasible to play on the Playpulse platform. Through our work and report, we have at least shown that the platform genre is well suited for the Playpulse platform.

RQ3: *What game concept on the Playpulse platform has the potential to motivate people to become more physically active and engaged?*
Our answer to this research question comes in the form of the game concept presented in Section 15. Our concept is a two-player cooperative platform shooter where the players are fighting through several levels of boss-battles. The game offers the players two movement modes: grounded and flying. While grounded, the pedalling speed on the Playpulse bike controls shooting speed in the game, and in flying mode, the pedalling controls the helicopter rotors' rotation. As further detailed in Section 17, many of the aspects of the game are designed based on theory from enjoyment and engagement-related frameworks from the pre-study. We believe this results in a game concept that is so enjoyable and engaging that the players are motivated to play it again. The amount and intensity of pedalling needed while playing should also provide the players with a good workout. Therefore, through being motivated to play the game again, the players are also motivated to do physical activity.

RQ4: *How does our game affect the enjoyment of the player?*
When developing our game concept, the theory on enjoyment in games from the pre-study was used. Challenge, fantasy and curiosity were established as important aspects along with social mechanics and Flow. This theory was incorporated into the game by creating a consistent theme, making the game challenging but not impossible, making levels unlockable, and making it playable

as multiplayer. Results from the play session showed that the participants enjoyed the game. Nearly all participants rated the game as fun, and most thought it got more fun over time. These results stay almost unchanged over the three sessions. The game was said to be too hard initially but was deemed appropriate later. At that time, the difficulty contributed to the enjoyment. Multiplayer was also a contributor to the fun, with nearly all participants expressing it raised their enjoyment. Elements like difficult controllers, game bugs, network lag and repetitive levels retracted from the fun, but overall the was game rated to be enjoyable.

RQ4.1: *How does the amount of time spent on playing games affect the player's enjoyment of playing our game?*
There are slight indications from the results that participants who regularly play video games enjoy playing this prototype less. This could be due to higher expectations for the quality of the game. The trend disappears after session one when non-gamers' enjoyment go somewhat down. The participant's player type also seems to affect enjoyment. Some participants enjoyed collecting stars on a higher difficulty, while others preferred new content and found the former repetitive.

RQ4.2: *How does the amount of time spent on exercise affect the player's enjoyment of playing our game?*
Regularly exercising seems to have a positive effect on enjoyment in the beginning phase. This finding could be caused by the controllers and game being easier to learn when not very tired, thus allowing those fit to enjoy the game quicker. Having a predisposition against exercise bikes as a way of training also seems to lessen the enjoyment. These are not strong results, however, and are not conclusive.

RQ5: *How does our game affect the engagement of the player?*
The players of our game generally seemed engaged in the game while playing. This is confirmed through the different data collection methods. Since a slight majority of the players showed a desire to continue playing, the game somewhat succeeds in keeping the players interested and makes them want to play again. Elements of the game that the players highlighted as engaging are the multiplayer, difficulty, and pedalling mechanics, as well as seeing themselves improve and get better at the game. At the same time, issues with the game such as bad controllers, missing feedback, repetitiveness, a low incentive for pedalling while flying, and the game being too challenging in the beginning were said to lower players' engagement in the game. Despite these negative aspects, the players overall seemed engaged while playing.

RQ5.1: *How does the amount of time spent on playing games affect the player's engagement when playing our game?*
We see a slight indication that participants who regularly play video games are less engaged in the game's startup phase than others (similar to **RQ4.1**). Again, this trend could be due to avid gamers expecting more from games, making them somewhat disappointed and less engaged when playing an imperfect prototype. Another finding complementing this indicates that non-gamers seem to find the game more rewarding than the gamers initially. These trends disappear in later sessions. Certain player types that enjoy challenge and unlockables also seem to find the game more engaging.

RQ5.2: *How does the amount of time spent on exercise affect the player's engagement when playing our game?*
When looking at how time spent on exercise affects player engagement, no trends or links were found. This indicates that fitness and enjoying exercise does neither hinder nor enhance engagement for this type of game. However, due to the small sample size, there might exist undiscovered connections here.

RQ6: *Does our game motivate players to become more active?*
Based on our findings, our game does not directly motivate players to become more active. Players prefer this game over just using an exercise bike, but few players would rather play this game than perform their usual and preferred exercise. We can, however, not be entirely sure about this, as

many of the players in the test population already exercise regularly. Our game is mainly meant to motivate those that do not exercise, and therefore further testing on our target audience should be done. Furthermore, we did find that players were more motivated to play again if they viewed the game as entertainment and not exercise. This could indicate that it is possible for people who lack motivation for physical activity to become motivated to play our game repeatedly and increase their physical activity levels as a result.

RQ6.1: *Can playing our game be considered exercise?*
The results from the study show clear signs that playing this game can be considered a form of exercise. On average, participants had a heart rate (144 bpm) in the vigorous intensity level for the majority of the session. All participants had at least a moderate intensity level throughout the sessions. The play sessions also had participants very close to achieving high-intensity interval training (HIIT). Self-reporting by the participants put the workout at a moderate to high intensity. Nearly all participants said they felt they had exercised after the session, but it was deemed as a warm-up due to its relatively short duration of 20–30 minutes. With a longer duration, participants said they would think of it as a full workout. The intensity would have to go down to achieve this.

RQ6.2: *How does the amount of time spent on playing games affect the player's motivation to become more active after playing our concept game?*
No clear connection was found between playing video games and the motivation to become more physically active after playing this game. This conclusion is not entirely surprising since these factors are not naturally linked or related.

RQ6.3: *How does the amount of time spent on exercise affect the player's motivation to become more active after playing our concept game*
Results showed that those who do not exercise regularly initially showed a greater interest in this type of exercise than those who do not. This interest could indicate a potential market for this type of game. However, the trend does diminish in later sessions when those who exercise little become less interested in using this to exercise. This loss of interest could be caused by participants finding the game too repetitive or not liking this type of exercise, i.e. indoor cycling. The game likely has little impact on getting those who exercise regularly more motivated since they already are active and have training routines.

Research Goal: *The goal of this thesis is to develop and evaluate a fun and engaging exergame with replay value for the Playpulse platform, for people that normally lack motivation to exercise, so that they increase their activity levels.*
After discussing our results and finding answers to our research questions, we believe that our research goal has only been partly achieved through our work in this master's thesis. If we divide our research goal into smaller parts, the results tell us that the game is a fun and engaging exergame. The game also has some replay value, at least when the players think about playing the game for entertainment purposes and not as exercise. However, the part about increasing the activity levels of people that normally lack the motivation to exercise was not met. The research goal states that the game should motivate those who lack the motivation to exercise. Since the test population in our experiment was relatively small and, unfortunately, did not contain many people considered within our target audience, it is difficult to conclude confidently about this question. Still, amongst the participants that did test the game, there were indications that they did not become more motivated to get physically active by playing. It is still uncertain whether we would see the same results if the test was performed on a more extensive test population with more people lacking the motivation to exercise.

As emphasised in our discussion, due to the low number of people participating in the experiment, our conclusions can not be 100 % confident regarding the enjoyment, engagement, and physical effect of playing the game either. Especially not for a more general audience. However, the results showed solid indications for our conclusion in these areas; thus, we are confident that similar results would be found if the game was re-tested on a larger and more varied population.

36 Contribution

Two new sub-areas within exergames for exercise bikes have been explored by developing the game presented in this project. In addition, an exergame was created, and feedback for the Playpulse platform was collected. We were also contacted by Playpulse themselves about possible future use of our prototype.

New game genre and style – To our knowledge, no previous Playpulse-game, and few similar platforms have explored the realm of 2D games. Previous projects have concluded with 2D games lacking the necessary immersion needed. Most games have also been vehicle-related. Our game not only tests out 2D for the game and tries a non-vehicle related game genre for the platform but also shows that there is promising potential in these types of games.

New mapping for the pedalling – Our game tests out an unconventional mapping for the pedalling mechanic. Previous games tend to map pedalling to movement since this was regarded as the most natural. Our game uses pedalling to determine the fire rate for a gun, something entirely unrelated to movement. Still, all participants found this new mapping natural. This result can lead to greater variety within future Playpulse games since future ideas are less limited by controller restrictions.

The exergame developed – During this project, a working prototype of our exergame concept has been made. This game is possible to play, iterate on and learn from in future projects. The project also shows how the theory in the pre-study can be used in practice in an exergame. Additionally, the game proved able to be considered exercise by having participants stay at a high heart rate for a prolonged time.

Feedback for the Playpulse platform – The play sessions in this project produced lots of user feedback for the Playpulse platform and controllers. This feedback can be helpful in further development of the Playpulse device and coming games for Playpulse. In particular, based on feedback on the controllers, we suggest that they should be placed differently on the handlebar or even fully redesigned. A redesign has however been done in new iterations of the Playpulse platform, leaving this contribution less valuable, as it is based on an outdated Playpulse version.

Base for potential commercialisation of the concept - Towards the end of the project, we were contacted by Playpulse, as they had been informed about our game concept and found it interesting. They were intrigued about both the 2D perspective and how the pedalling was used in the game. Playpulse expressed a wish to have a look at the prototype and source code so that they could adapt it to the new version of their bike. This would then be used for internal testing and exploration of potential commercialisation opportunities.

37 Further Work

Due to time shortage, lessons learned during the project and factors outside our control, there is still more work that could be done to further explore this game concept and the Playpulse platform.

Fix and complete the prototype – Not all planned features were implemented into the tested prototype, and not all bugs were removed. Fixing the remaining bugs, limiting network lag, removing game exploits, and similar tasks are prioritised in further development. These fixes will help remove unwanted frustration from the game and make it possible to measure the game's efficacy more accurately. Secondly, adding the remaining features, like achievements and selectable intensity, needs to be done. All planned features are there to help with enjoyment and engagement. They are therefore essential to thoroughly test the game's full potential. When this is done, the next priority is: the flying mechanic needs to be redesigned to better encourage pedalling; visual signs about the boss' damage level in the endgame must be added for motivation; an interactive tutorial integrated into an easier level 0 that forces players to learn the controllers must be made.

Adapting the game to the new Playpulse platform – Playpulse is currently promoting a new version of their exercise bike due to launch in late 2021. This new platform includes, among others, improved controllers. Making this game work with the new platform could, therefore, fix many of the controller issues participants had in play sessions on the current platform.

New experiment with a larger, more varied test population – The experiment conducted in this project proved promising. However, due to a limited selection of test participants, it is hard to draw significant and general conclusions. Performing a more extensive experiment with many participants from both exercise, non-exercise, gaming, and non-gaming backgrounds would help with more conclusive results. It would also be preferable to draw the participants from a less homogeneous group than students at NTNU. E.g. middle or high school students could be an interesting population to test. A more extensive selection from the general population would also be interesting. Doing this would help check the game's potential in a variety of age groups and backgrounds. The experiment in this project found our game to be considered as exercise. Nevertheless, it would be interesting to run a more comprehensive study that looks at long term effects on health and exercise motivation. Current answers for exercise motivation are based on what participants think, not actual exercise habits in the following weeks after gameplay sessions.

Further development on the game – The game in its current state, even after the fixes and addition suggested in the paragraph "Fix and complete the prototype", is still not a full-fledged game. Continuing the game's development to make it into something complete and maybe sellable could be an exciting path forward. Some proposed features are:

- *Creating many more levels* – The game should be playable for around 10–12 hours in total before the same levels have to be replayed. New levels with unique mechanics and bosses must be made to achieve this. In addition, the different difficulties for each level should change more than just the boss' and player(s)' HP. Doing this will make the feature more interesting and increase replayability for levels.
- *Creating a story* – Currently, the game has a recurrent theme, but it still lacks a background story and progressing narrative. Adding a story to the game will help with motivation and might make the player feel more immersed. A couple of suggestion for a story could be: The player fights different electronics associated with a sedentary lifestyle to help the city from a health crisis. The little fox is angry at humans unnecessary consumption and pollution and takes matters into its own hands. A solar storm has swept over the earth turning all electronics malevolent, and the player is tasked with defeating the technology and bring peace back to their community. Of course, many other ideas for a background story is also possible.
- *Statistics* – A highly requested feature from the playtesters was statistics showing physical and in-game performance after a match. Participants wanted to know how well they had performed and how they compared to their partner. The pedalling effort, damage done to the boss, hits taken, revives completed, precision when shooting, heart rate, and other data can be put in such a summary screen. This feature could add motivation and enjoyment to

the game and valuable insight into how the player performed and how effective the exercise was.

- *Leaderboard* – Another highly requested feature was a leaderboard. Many players asked how they compared to other teams, and for many of them, beating the others was a big motivation. Adding a leaderboard would allow players to know how they compare and compete for the top position.
- *More cooperation* – Participants said they enjoyed the multiplayer part of the game but most requested the game to include even more cooperation. Adding new mechanics that require the players to work together or help each other out would be wise to add to the game. This feature would likely boost both the game's enjoyment and engagement.
- *Unlockables for the player* – To allow for a more personal experience, adding functionality for cosmetic and practical unlockables could be an excellent addition. The unlockables could include cosmetics such as different characters or clothes for the characters, or it could be practical items such as new weapons and power-ups. These unlockables could be based on reaching a certain number of stars or using stars as a currency to purchase them.

Further development of the Playpulse platform – During playtesting in sessions, a couple of suggestions for the Playpulse platform were given. Several participants said they wished the game could adapt to how much resistance they had chosen on the bike. The current version lacks any sensors for this. Adding a wattmeter or a similar sensor to measure performance could be a great addition. Following this, an adaptive resistance controlled by the game could also allow for interesting new mechanics for Playpulse games, e.g. higher resistance while moving up a hill. Finally, the inertia in the exercise bike's wheel could potentially be hazardous while playing exergames. Players pedalling at max speed who then try to stop quickly could end up hurting their legs. Changing this functionality to how it works on a regular outdoor bike could solve this problem. Adding these features to the platform could help further increase the enjoyment of using the platform.

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Appendix

A Questionnaire form

The questionnaire form given to the participants during the experiment is attached in the following pages.

Playtesting of game on exercise bike - Session 1

Thank you for participating in the playtest sessions of our exergame. We appreciate it!

Please fill in this survey to let us know how you experienced the game. The survey takes about 8 minutes to fill in.

* Required

Some information about you

1. What is your ID? (Ask the supervisors if you don't remember) *

2. How old are you? *

3. Gender *

- ◯ Woman
- ◯ Man
- ◯ Non-binary
- ◯ Prefer not to say

4. How many times do you exercise per week? *

5. About how many hours do you exercise per week? *

6. Which type of exercise do you do? *

7. About how many hours do you spend playing video games each week (smart phone and casual games included)? *

8. On which devices do you play? *

- [ ] I do not play
- [ ] PC/Mac/Linux
- [ ] Console
- [ ] Smart Phone
- [ ] Other

9. Have you played exergames before? (Such as WiiFit, Pokemon Go etc) *

- ◯ Yes
- ◯ No

10. If Yes, which ones?

11. Do you actively play exergames now? *

- ◯ Yes
- ◯ No

12. If Yes, which ones?

13. Enjoyment, Engagement and Motivation *

	Totally Disagree	Disagree	Neutral	Agree	Totally Agree
I had fun while playing	◯	◯	◯	◯	◯
The game got more enjoyable over time	◯	◯	◯	◯	◯
Playing this game while riding the bike is more fun than just riding an exercise bike	◯	◯	◯	◯	◯
I was so engaged in the game that I lost the sense of being in physical activity	◯	◯	◯	◯	◯
I felt I was getting better for each round	◯	◯	◯	◯	◯
I wanted to perform well while playing the game	◯	◯	◯	◯	◯
I would like to play the game again to improve my score/skills	◯	◯	◯	◯	◯
I was motivated before each round	◯	◯	◯	◯	◯
I would like to play again	◯	◯	◯	◯	◯
I am more motivated to exercise with the help of this game, rather than cycling without the game	◯	◯	◯	◯	◯
I would rather play this game than practice regular exercise	◯	◯	◯	◯	◯
This game has motivated me to be more active/exercise more	◯	◯	◯	◯	◯

14. Statements about the game *

	Totally Disagree	Disagree	Neutral	Agree	Totally Agree
I was challenged, but I believed my skills would allow me to meet the challenge	○	○	○	○	○
My attention was focused entirely on what I was doing.	○	○	○	○	○
My goals were clearly defined	○	○	○	○	○
I had a good idea while I was performing about how well I was doing	○	○	○	○	○
I did things spontaneously and automatically without having to think	○	○	○	○	○
I felt in total control of what I was doing	○	○	○	○	○
I was not concerned with what others may have been thinking of me	○	○	○	○	○
Time seemed to alter (either slowed down or speeded up)	○	○	○	○	○
I found the experience extremely rewarding	○	○	○	○	○

Impressions from the game

15. Statements about the game *

	Totally Disagree	Disagree	Neutral	Agree	Totally Agree
I felt I was exercising	◯	◯	◯	◯	◯
Playing with another player made me push myself more	◯	◯	◯	◯	◯
It was fun to play with another player	◯	◯	◯	◯	◯
I understood what I was supposed to do in the game	◯	◯	◯	◯	◯
It was easy to learn the controllers for the game	◯	◯	◯	◯	◯

16. Rate the intensity of the exercise from Very Low to Very High *

	Very Low	Low	Moderate	High	Very High
Intensity of Exercise	◯	◯	◯	◯	◯

17. Would you consider using this approach of exercise in the future? *

- ◯ Yes
- ◯ No

18. Could you please elaborate on why? *

19. Did the pedalling feel natural considering what it did in the game? *

- ◯ Yes
- ◯ No

20. Do you want to elaborate?

21. Does this type of game seem like a good choice to play on the PlayPulse bike? *

- ◯ Yes
- ◯ No

22. Could you please elaborate? *

Open Questions

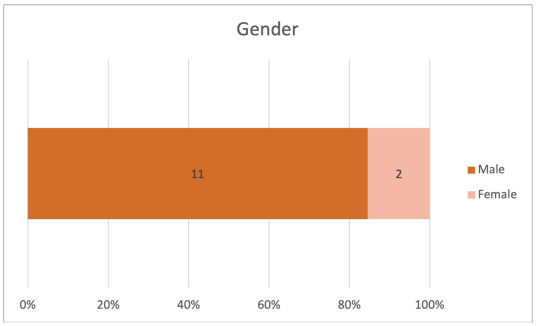
23. What did you like best about the game? *

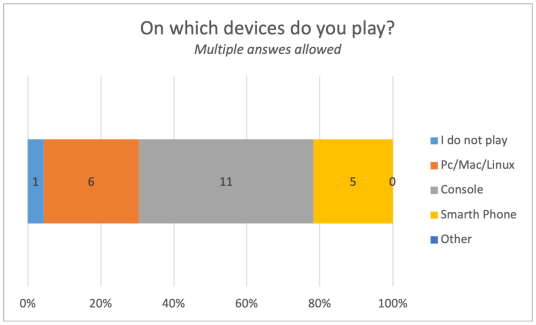
24. What did you like the least about the game? *

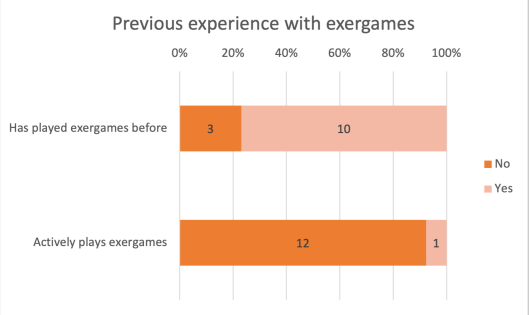
25. Any other comments or feedback?

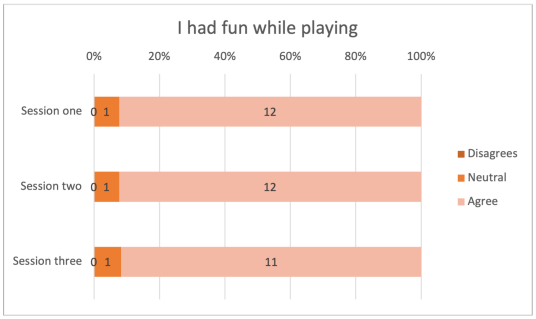
B Questionnaire answers

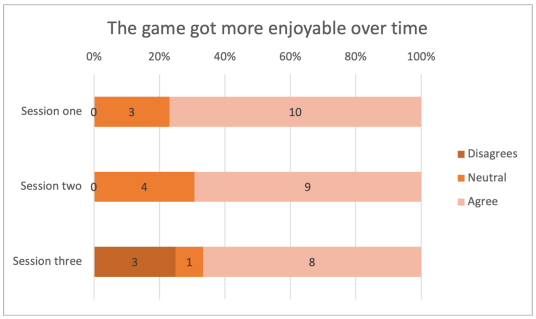
B.1 Part I – scale based answers

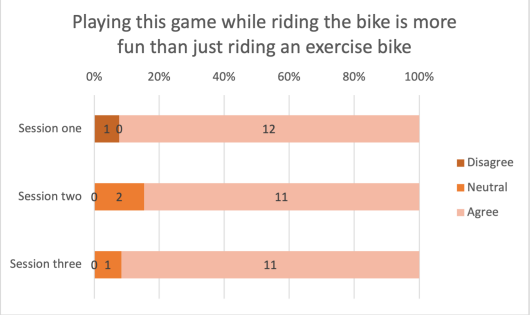


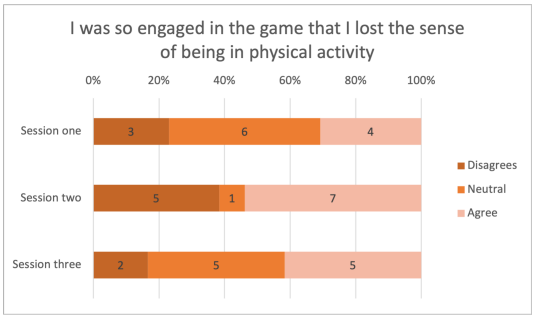


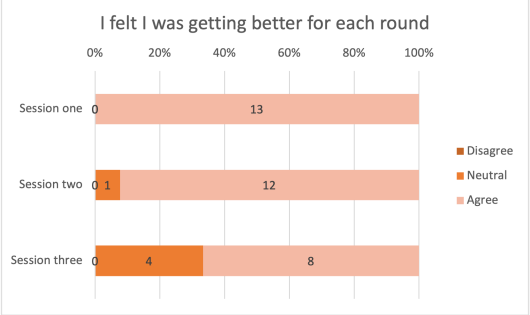


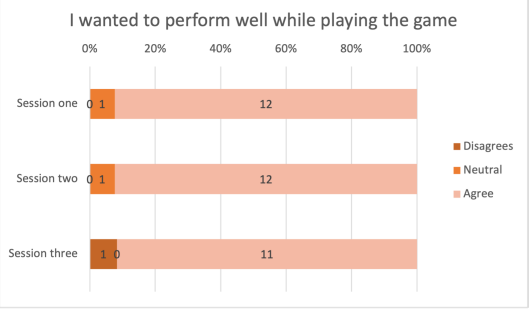


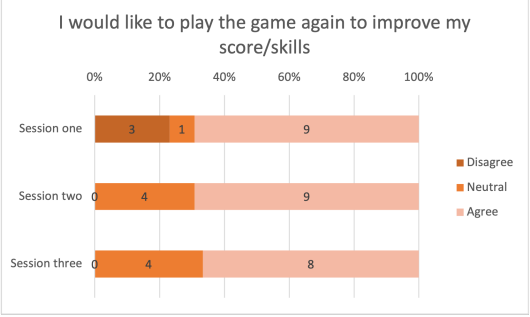


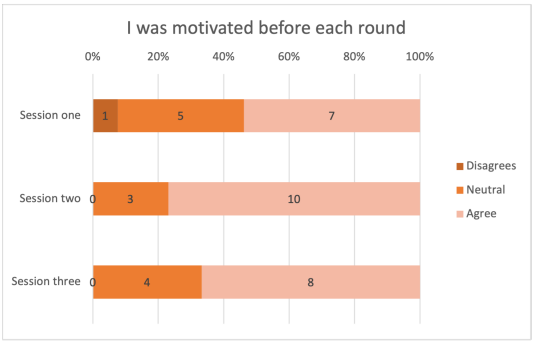


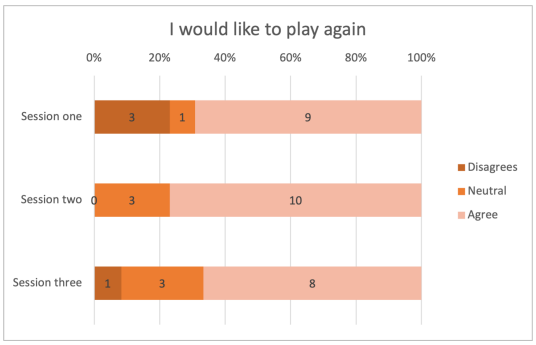


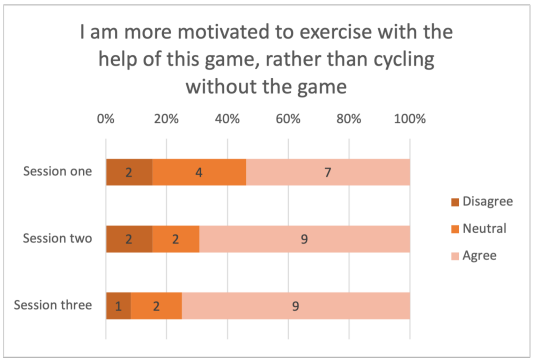


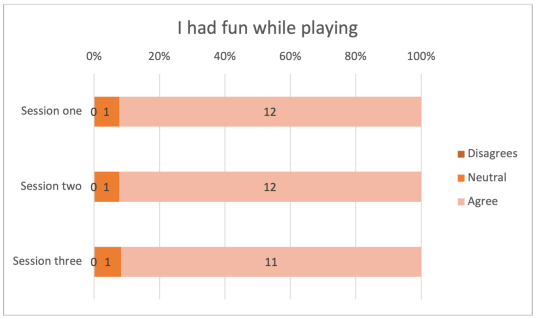


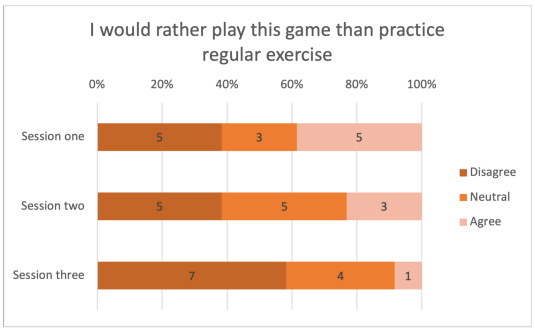


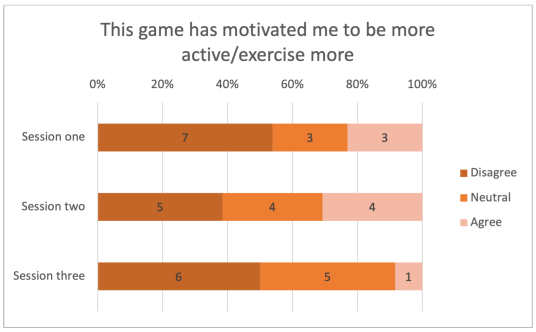

I was motivated before each round
0%
20%
40%
60%
80%
100%
Session one
1
5
7
Session two
0
3
10
Session three
0
4
8
Disagrees
Neutral
Agree

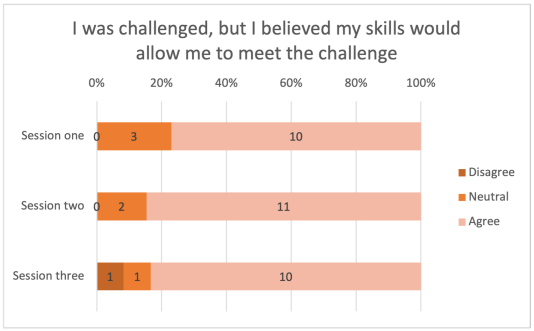

I would like to play again
0%
20%
40%
60%
80%
100%
Session one
3
1
9
Session two
0
3
10
Session three
1
3
8
Disagrees
Neutral
Agree

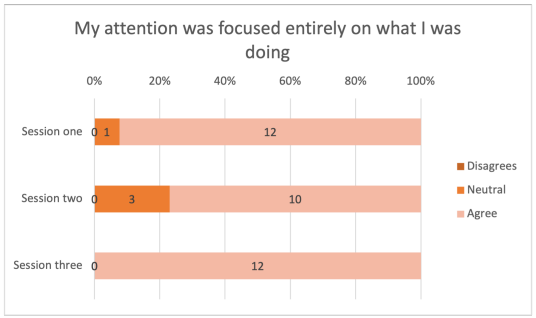

I am more motivated to exercise with the help of this game, rather than cycling without the game
0%
20%
40%
60%
80%
100%
Session one
2
4
7
Session two
2
2
9
Session three
1
2
9
Disagree
Neutral
Agree

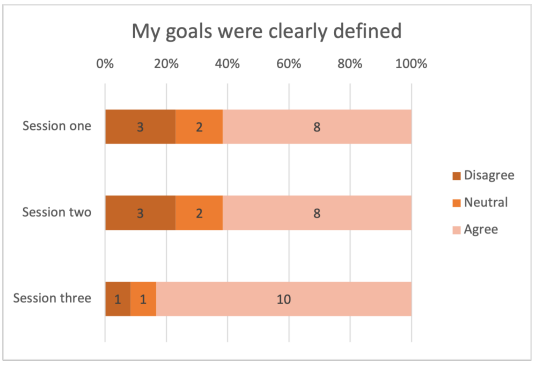

I had fun while playing
0%
20%
40%
60%
80%
100%
Session one
0
1
12
Session two
0
1
12
Session three
0
1
11
Disagrees
Neutral
Agree

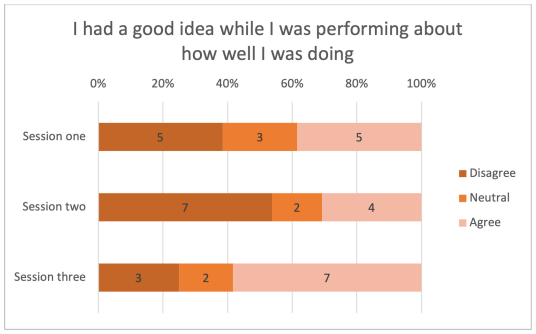

I would rather play this game than practice regular exercise
0%
20%
40%
60%
80%
100%
Session one
5
3
5
Session two
5
5
3
Session three
7
4
1
Disagree
Neutral
Agree

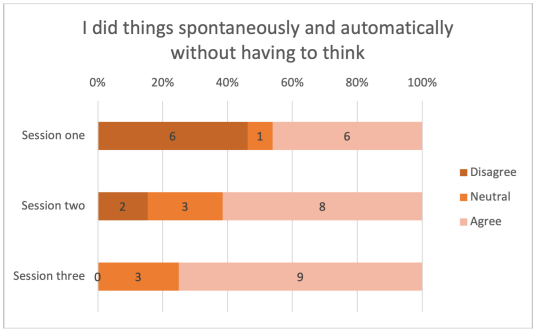

This game has motivated me to be more active/exercise more
0%
20%
40%
60%
80%
100%
Session one
7
3
3
Session two
5
4
4
Session three
6
5
1
Disagree
Neutral
Agree

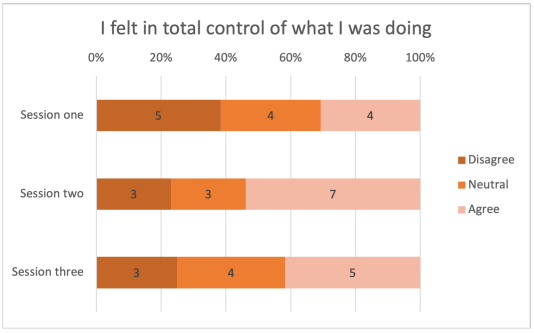

I was challenged, but I believed my skills would allow me to meet the challenge
0%
20%
40%
60%
80%
100%
Session one
0
3
10
Session two
0
2
11
Session three
1
1
10
Disagree
Neutral
Agree

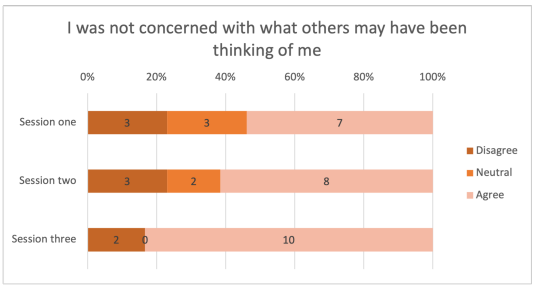

My attention was focused entirely on what I was doing
0%
20%
40%
60%
80%
100%
Session one
0
1
12
Session two
0
3
10
Session three
0
12
Disagrees
Neutral
Agree

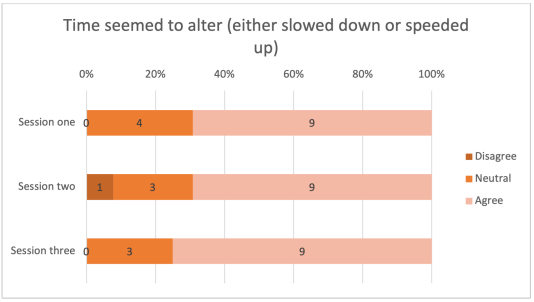

My goals were clearly defined
0%
20%
40%
60%
80%
100%
Session one
3
2
8
Session two
3
2
8
Session three
1
1
10
Disagree
Neutral
Agree

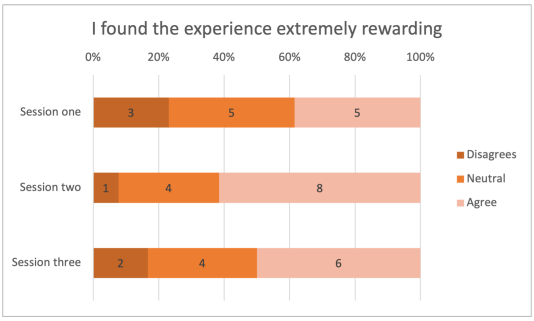

I had a good idea while I was performing about how well I was doing
0%
20%
40%
60%
80%
100%
Session one
5
3
5
Session two
7
2
4
Session three
3
2
7
Disagree
Neutral
Agree

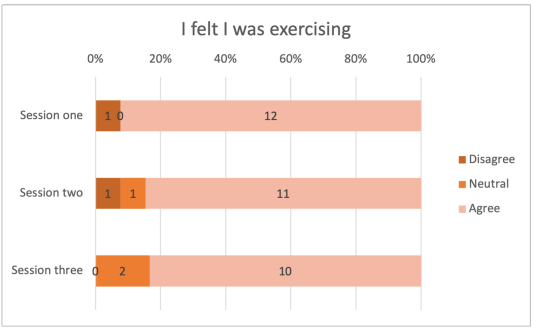

I did things spontaneously and automatically without having to think
0%
20%
40%
60%
80%
100%
Session one
Session two
Session three
6
1
6
2
3
8
0
3
9
Disagree
Neutral
Agree

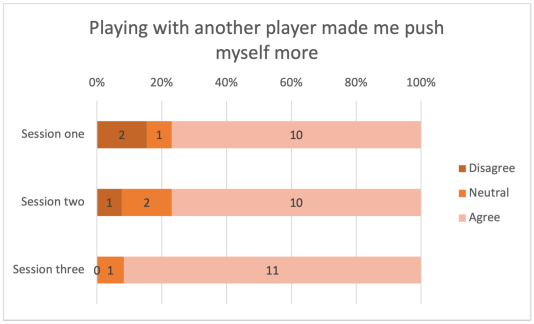

I felt in total control of what I was doing
0%
20%
40%
60%
80%
100%
Session one
Session two
Session three
5
4
4
3
3
7
3
4
5
Disagree
Neutral
Agree

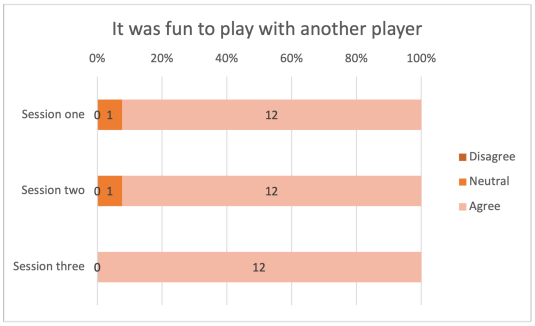

I was not concerned with what others may have been thinking of me
0%
20%
40%
60%
80%
100%
Session one
Session two
Session three
3
3
7
3
2
8
2
0
10
Disagree
Neutral
Agree

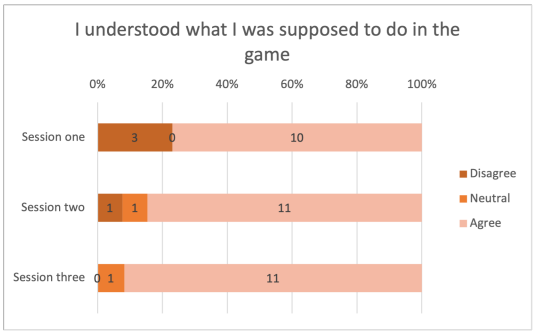

Time seemed to alter (either slowed down or speeded up)
0%
20%
40%
60%
80%
100%
Session one
Session two
Session three
0
4
9
1
3
9
0
3
9
Disagree
Neutral
Agree

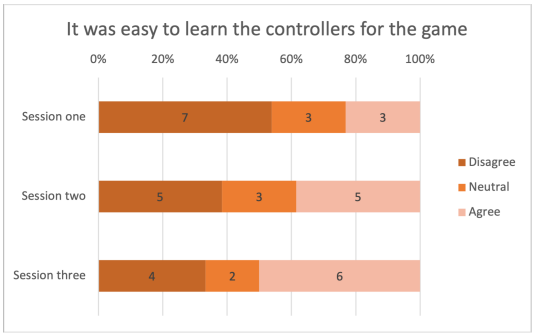

I found the experience extremely rewarding
0%
20%
40%
60%
80%
100%
Session one
Session two
Session three
3
5
5
1
4
8
2
4
6
Disagrees
Neutral
Agree

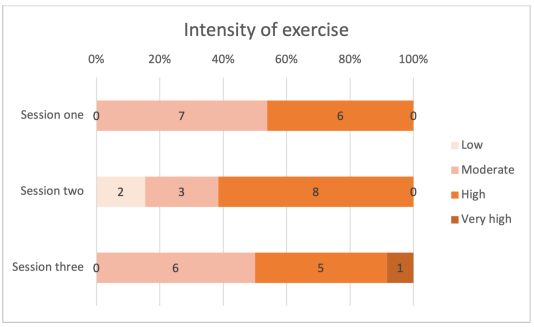

I felt I was exercising
0%
20%
40%
60%
80%
100%
Session one
Session two
Session three
1
0
12
1
1
11
0
2
10
Disagree
Neutral
Agree

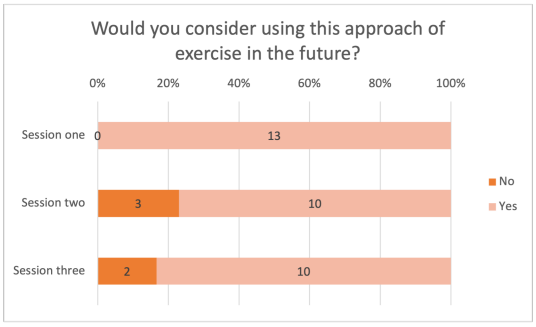

Playing with another player made me push myself more
0%
20%
40%
60%
80%
100%
Session one
Session two
Session three
2
1
10
1
2
10
0
1
11
Disagree
Neutral
Agree

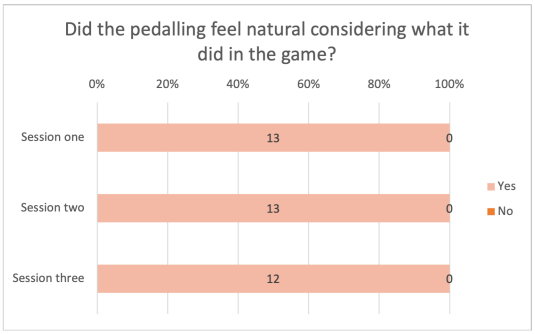

It was fun to play with another player
0%
20%
40%
60%
80%
100%
Session one
Session two
Session three
0
1
12
0
1
12
0
12
Disagree
Neutral
Agree

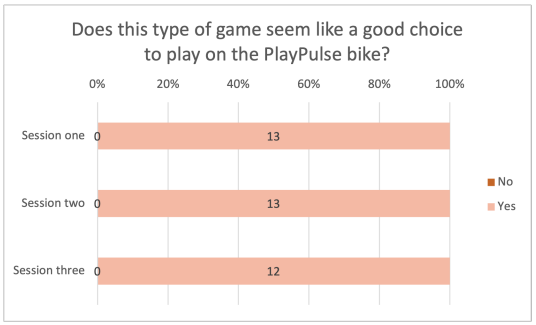

I understood what I was supposed to do in the game
0%
20%
40%
60%
80%
100%
Session one
Session two
Session three
3
0
10
1
1
11
0
1
11
Disagree
Neutral
Agree


It was easy to learn the controllers for the game
0%
20%
40%
60%
80%
100%
Session one
Session two
Session three
7
3
3
5
3
5
4
2
6
Disagree
Neutral
Agree









B.2 Part II – text based answers

2. How old are you?	4. How many times do you exercise per week?	5. About how many hours do you exercise per week?
21	4	6
24	3	6
23	5	7
24	1	2
25	0-6	0-7
24	1-2	2-4
21	5	5.5
26	0-1	0-2
23	3	2
24	3	10
24	4	4
23	4	4,5
24	6	15

6. Which type of exercise do you do?	**7. About how many hours do you spend playing video games each week (smart phone and casual games included)?**
Styrketrening for det meste	6
cardio, (XC skiing, cycling, jogging)	3
running and lifting	16
hiking/sit	0
Weight lifting (bench press, squat, deadlift, etc..) and conditioning (running/jogging)	7-14
strength	14
running and strength training	1-2
Full body strentgh	0-6
Joggingz, løpingz, tur, ski	1
Climbing	10
Running, Strength, Sports	12
Cardio (running) and strength	12
Weightlifting or low-intensity running	10

10. If Yes [I have played exergames], which ones?	**12. If Yes [I currently play exergames], which ones?**
WiiFit, Kinect, Pokemon GO	
Wii Sports and pokemon Go	
Wii sports, Pokemon Go, I use Strava often, if it counts	
wiiFit, Pokemon go	
Pokemon Go	
Zoombierun-etellerannet	
Pokemon Go for one summer	
Pokemon Go, Pedal Tanks, On Fire	On Fire
WiiFit, Ring fit adventure, Pokemon Go	
Barely played Pokémon Go. Played some dance dance revolution back in the day, played Eyetoy	

18. [Why would you (not) use this exercise form in the future]?		
Session one	*Session two*	*Session three*
Det var morsomt og jeg likte spillet	Fun game	I really like the idea of exergames
Compinting against others in the same session motivated me to excercise harder and to win/finish the game together.	I enjoy workingout outside	It is a fun way of workoing out
Different way of exercising. It was exciting	Yes, it was fun playing a game while riding the bike. But I exercise cycling itself is something I do not like.	It was fun doing something interactive while riding a bike. A lot more fun than regular spinning classes.
im usually bored while exercising, espesially when doing cardio. This made it more fun	fun	more fun the regular biking
I believe that if proper controllers with a well-adapted game can be implemented in a good way, it can make exercise more fun and rewarding.	This time it was more fun to play since I felt that I was in better control of what I was doing than last time.	no
Should be fun with better and more immersive technology, and different genre of game/high quality game i.e. CoD	Not into endurance workout. Enjoy gym (slifting weights more)	prefer different exercise types
morsomt, ble svett men ikke helt utstlitt	it was not challenging enough (physically) this time. As i lost less lives i had to push myself less. As you get better the challange does not increase with your level	not hard enough, easy to forget to cycle when focusing on dodging obsticles, especially on harder dificulties
It@sm ore fun to do something that requires my attention while working out	It is more fun to play a game than exercise	Mosrsom som alternativ til "vanlig" trening
Det var gøy, men for å gjøre det oftere/mer, så må spillet være godt nok (gøy, passe vanskelig osv.)	Mer gøy enn å sitte på en spinningsykkel uten noen form for input/underholding	It is fun. If I am to do a lower intensity exercise, this is a fun way of doing it.
It was a fun way of working out on a bicycle. Although I cycled at a low intensity, it made the workout more immersive.	It is a fun way of warming up with one or more friends.	Fun to play with others
I forgot that i was tired because i was so focused on playing the game.	Very immersive, you forget that you are exercising	Fun way of exercise
Fun way to exercise	Fun way of exercise	It is fun and I want to be number one
I would consider it for casual cardio exercise. Especially if I could see how much energy I expended during the workout session. I do cardiovascular activities to burn energy, so by knowing if I burned many kilojoules or few kilojoules I could consider if this type of exercise comes close to cycling the regular way.	Fun and good exercise. With the heart rate monitor I also saw it was effective, which made me believe in the exercise more.	

20. Do you want to elaborate [on why/why not the pedalling felt natural]?		
Session one	*Session two*	*Session three*
Baren på bånn gjorde at sykkelen var en del av spillet		
	It made sense that pushing yourself harder riding the bike meant that you became stronger in the game.	
was a bit confused in the flying part. did not remember if pedaling slower made me "drop down" faster or if it had no impact	a little bit confusing while flying	
god mapping mellom intensitet og "speedometeret" / revive funksjonen		
Mostly thought about having to pedal when I died, which helped increase my intensity a lot (I died quite frequently)	Faster pedaling feels like a natural way to revive	Ja og nei, de gangene jeg fokuserte ekstra mye på spillet glemte jeg å tråkke like intenst som jeg gjorde resten av tiden
Etter intense tråkk måtte man fortsette å tråkke pga. måten sykkelen fungerer. Den overgangen ble brå		The speedometer is good. I would like for it to accelerate more slowly though. This would make it easier to remain in the "fire faster"-zone.
	Pedalling had an impact on the gameplay, yet I experienced that the "speed"-meter from my pedalling should accelerate more slowly. This will prevent tinier spikes in intensity from tipping me over from dark green to red.	
It felt natural that the gun fired faster when I was pedaling faster		Did it automatically without thinking
It felt natural, but i had to remind myself to keep paddeling sometimes	did not feel natural to start with, but felt more natural the second session	jsut pedal, and be in the best zone on the acellerometer
	The acellerometer thing helps show how to pedal	

22. Could you please elaborate [on why/why this game fits PlayPulse]?		
Session one	*Session two*	*Session three*
Det med at hvor fort du sykler påvirker spillet fungerte bra i denne typen settingt, ettersom du måtte tenke på hvor mye krefter det var verdt å bruke	It seems natural	The idea behind the game is really good, but the controls are kinda clunky and the game is, understandably, not that polished

A 2D platform game makes sense in this context	The game made me sweat, and the pulsebike converted my input well to what i wanted to achivev in the game. I liked the sprint burst i had to do in order to revive my player	It fit the ourpose of cobining excerise and gaming
Intuitive and smart how pedalling affected how well your skills in the game was	Havent really tried other games, but this game made sense to play on the PlayPulse bike and it worked well.	Intuitive that the faster you rode the bike, the "stronger" you became.
fun game. Got a bit better each time. Just difficult/easy enough to want to keep playing	motivating	fun and easy!
This type of game may make it seem like the time goes faster while exercising, or making it more fun.	It can be used as a fun way to warm up before proceeding with other exercises. Note that the game is more fun when you feel like you have learned the controls. It was not very fun last time as the controllers were a bit hard to learn.	no
Hard to make different games on bike.	Fun enough, and hard to make a lot of different type of games on a bike.	no
var "lett" konsept selv om spillet ikke var lett og greit å fokusere på. Ikke for mye å tenke på når man sykla	natural controls	you have to pedal to perform better, soyou are motivated to be active
Controllers can be placed in a natural position on the bike, as opposed to e.g. while running	Relatively easy to reach the controllers (could be moved), and the pedaling was integrated in a natural way	Ja og nei. Kanskje flere elementer kunne blitt påvirket av hastigheten på tråkkingen(?) Feks. hvor fort man beveger seg til sidene.
Ja, men det ville også passet bra (kanskje bedre) om man skulle sprinte, sykle etc. fort bortover (typ. et race)	Ja, men race games er også godt egnet tenker jeg	It is a good introductory game. This is important because the controls need some time getting used to. Sometimes the controllers do feel unresponsive, this is bad.
It uses the speed of your pedalling in a good way. The hand controls were easy to understand, although they took some time getting used to. I imagine that when you have used the hand controls more, using the buttons in a different game would be easier.	It is fun and rewarding. Its controls are easy, which I think is important for this kind of game.	Appropriate level of physical activity compare to the length of gameplay
It was a fun and immersive experience		

Platform games fitted well with the exercise	Nice concept, and multiple ways of expanding it	good exercise, able to withstand a high level of cardiovascular activity over time and wanting to keep biking
Constant pedalling, keeps you at a moderate or high exercise level. I enjoyed the level of exercise.	it is fun and keeps you pedalling constantly	

23. What did you like best about the game?		
Session one	*Session two*	*Session three*
Selve spilltypen - altså at det er som cuphead	The biking aspect	The idea behind the game
To co-op game mechanics	To co-op part	The co-op
Challenging but not impossible. As well as the concept of exercising while playing	It was fun to play while exercising.	It was fun doing something interactive while exercising on the bike. It is more fun doing this than participating in a spinning class.
that it was team-based and that we got better	winning 8)) (i like that it is more then one level. makes me want to try the next	getting better. I also liked that is was sound to it this time.
The teamwork	The teamwork	the teamwork
Movement	Winning	idk
svetta veldig og merka jegt ble bedre	fun, hard, focus intensive	fun, challenging
Pew-pew-pew (sound would be fun though, please add)	When I was able to use the controllers naturally (it did not happen too often, as they are not super intuitive), as I felt like I was able to play "correct" when this happened	Motiverende når man virkelig vil klare noe. Det sosiale
At man tråkket jevnt for å kunne spille, samtidig som man måtte tråkke fort av og til	Det sosiale	Its difficulty. This time, playing on medium difficulty, we really had to focus on what was happening on the screen to be able to progress.
Its grounded controls.	The pedalling	Playing with others
The fact that it was coop	The co-op part	Multiplayer
The multiplayer aspect	The multiplayer	it is challenging (gameplay wise)
I liked that it was quite challengig. I also liked that I exercised.	the challenge	

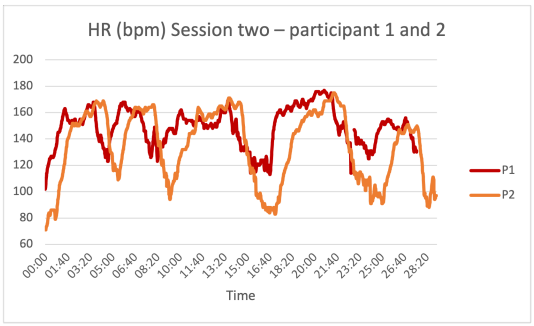
24. What did you like the least about the game?		
Session one	*Session two*	*Session three*
Det var noen bugs, som at istappene tok liv av deg i det du spawna	It became too easy, kinda clunky controls	the controls
Hard to understand the game controller	the controller	the controller

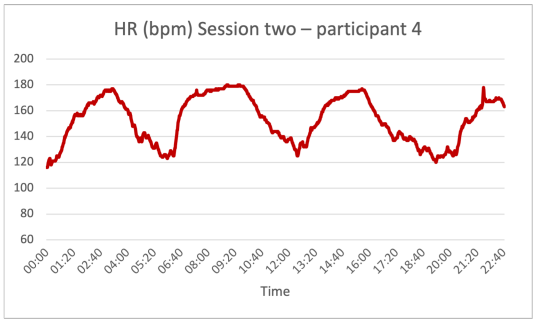
Small bugs. Did random jumps that I did not anticipate, and the icicles came random with no indications that I noticed of that they were appearing	Few levels so it does not necessarily mean that I would really like to repeatedly play the same levels again and again. But I would like to come back to try to beat the last level.	Maybe after the three levels the game might become too repetitive. I cannot see myself doing this one-two times a week for a whole year.
the second part. was a bit difficult to fly	getting tired	getting tired:/ not figuring out how to not die on level one:/
Invisible hitboxes,	To learn the controlers	the controllers
Movement	Letting a team mate down, or not being able to help a team mate. Ex when a team mate has used all his revives, it would be nice to help out.	letting team mate down
vanskelige controllers	the controllers were painful on the wrist after a while	clunky controllers
The position of the buttons on the controller. Also, some of the gameplay was less intuitive, like the range of the things on the ground that made you jump involuntarily, and the fact that the flying things that followed you despawned after a while	The controllers	Vanskelighetsgraden
Visste ikke status på bossens liv underveis	Vanskelig å forutse bossen sin oppførsel, og lite kontroll på hvordan man gjorde det. Gjør det vanskeligere å motivere seg for å få flere stjerner	Its difficulty. For phase 2 of the refrigerator, it felt really hard to dodge all projectiles. If we did not have the "safe zone" at the bottom left of the screen, we would
That the bazooka did not reload when it was tucked away,	It feels slow and unresponsive because I feel my character moves too slowly.	
The lag that made the object hit me even though it didn't look like it in game	The lag causing objects to hit you when it doesn't look like it (Fixed in session 2 :D)	Controls
The controls were not as inutitive	Controls	not seeing the hp of the boss, nor seeing other players' scores
The fact that I could not know how much HP the boss had left, I had no idea if I was close to completing the level or not. It demotivated me.	the lack of healt in the enemy	

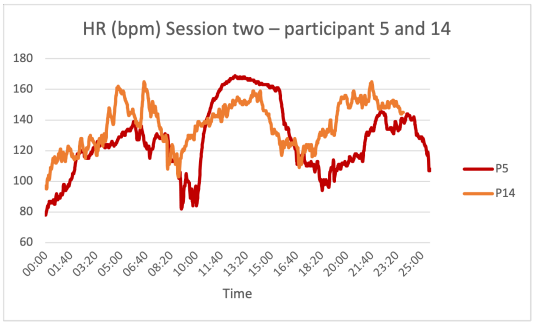
25. Any other comments or feedback?		
Session one	*Session two*	*Session three*
good luck!!		
nah		

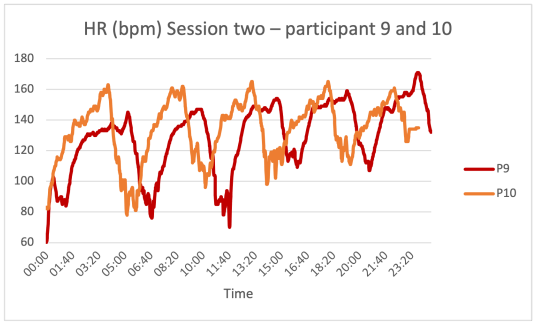
lite ergonomisk kontoller	when you get the hang of the controlles you can keep a moderate intensity all the time so the workout isn't that good	
	I played alone	
		Good music. To make the game more fun to play I would advise you spend some time balancing the difficulty.
Good graphics	Make my character move faster, maybe? Display boss health. After defeating a boss the game should display the damage dealt by each player.	Very fun and immersive game that could be a good alternative to regular warm-up activities before strength exercise
		Few bugs in selection of difficulty
Was a fun experience and a good workout!	Felt rewarding to improve and to get 4 stars!	fun game
It was sometimes difficult to control the character to do multiple things at once, such as changing a weapon whilst loosing altitude while trying to dodge a projectile.	Fun game, would like to play again, also with a hiscore list of all other players. I want to be the very best.	

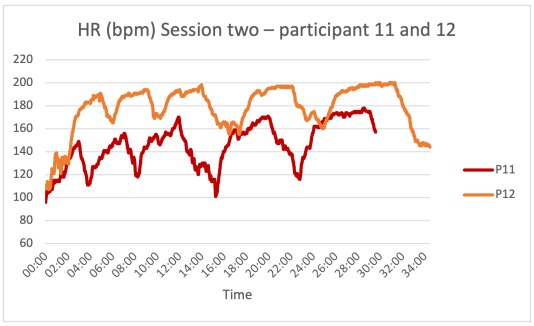
C HR readings

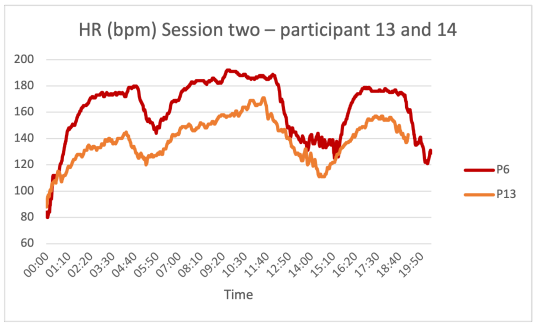


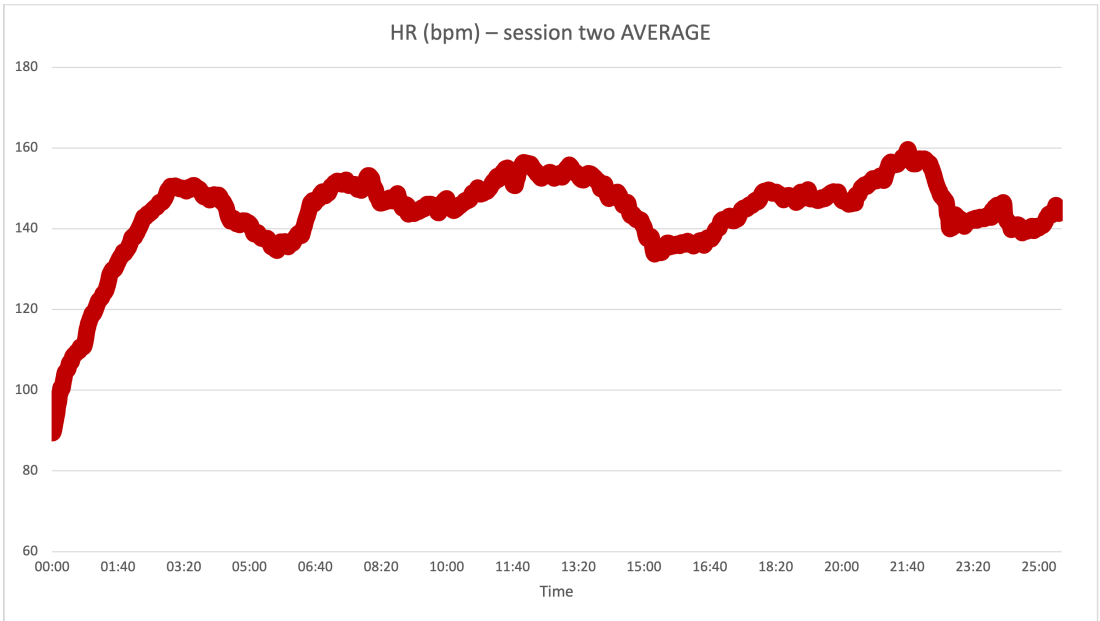


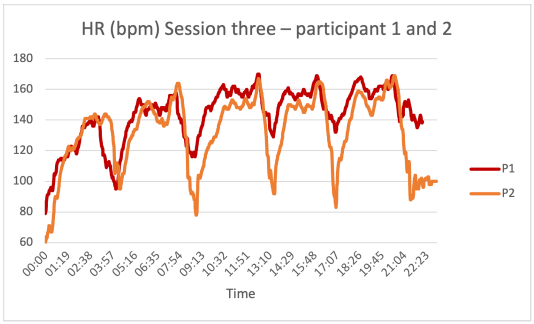











HR (bpm) Session three – participant 1 and 2
180
160
140
120
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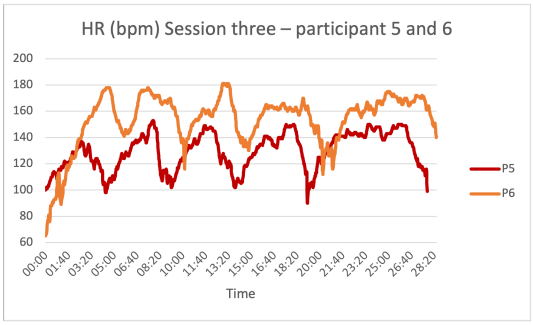
80
60
00:00 01:19 02:38 03:57 05:16 06:35 07:54 09:13 10:32 11:51 13:10 14:29 15:48 17:07 18:26 19:45 21:04 22:23
Time
P1
P2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Time
P5
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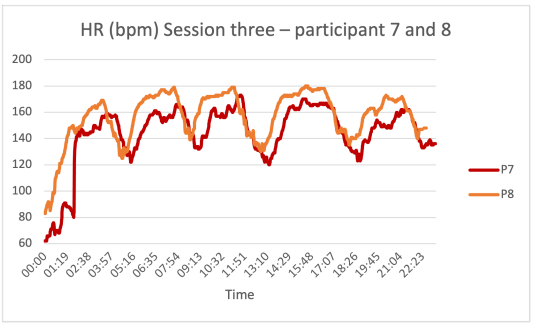
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Time
P7
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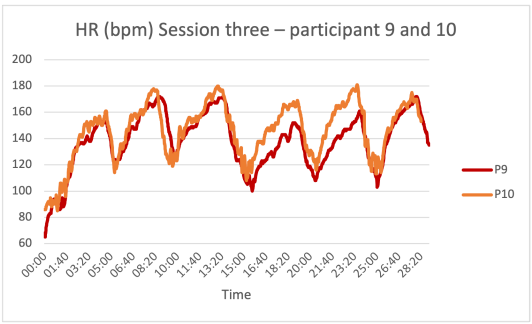
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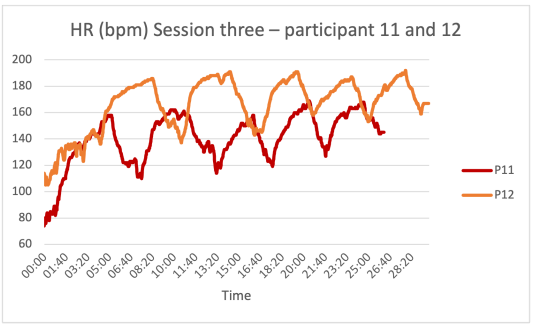
00:00 01:40 03:20 05:00 06:40 08:20 10:00 11:40 13:20 15:00 16:40 18:20 20:00 21:40 23:20 25:00 26:40 28:20
Time
P9
P10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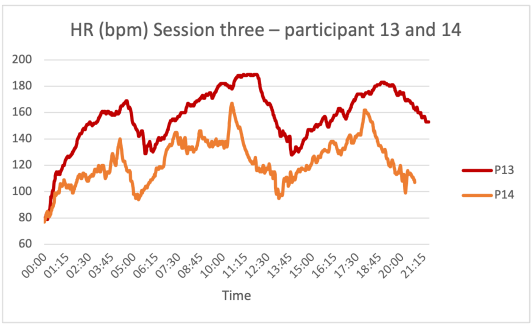
00:00 01:40 03:20 05:00 06:40 08:20 10:00 11:40 13:20 15:00 16:40 18:20 20:00 21:40 23:20 25:00 26:40 28:20
Time
P11
P12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180
160
140
120
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00:00 01:15 02:30 03:45 05:00 06:15 07:30 08:45 10:00 11:15 12:30 13:45 15:00 16:15 17:30 18:45 20:00 21:15
Time
P13
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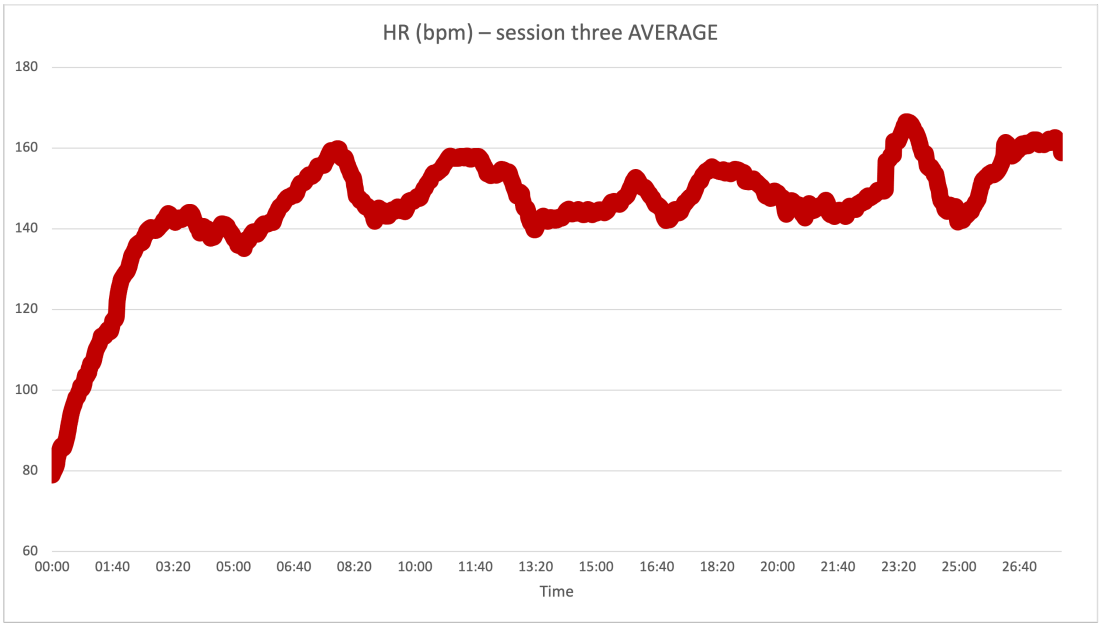
HR (bpm) – session three AVERAGE
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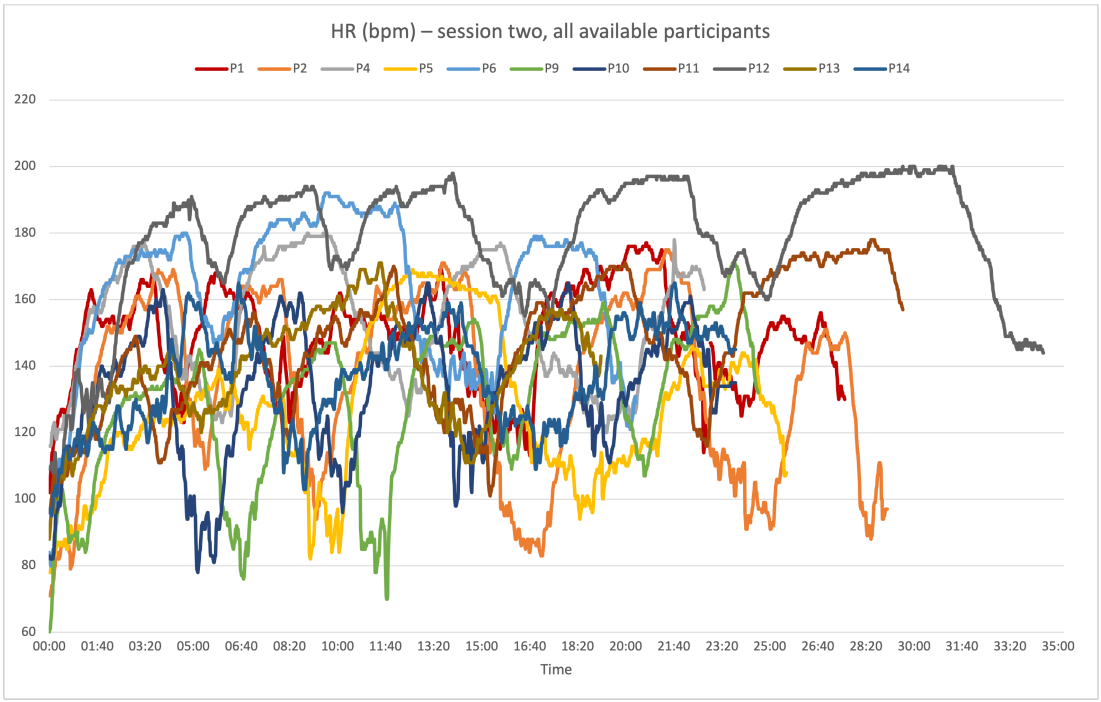
Time


HR (bpm) – session two, all available participants
P1 P2 P4 P5 P6 P9 P10 P11 P12 P13 P14
220
200
180
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80
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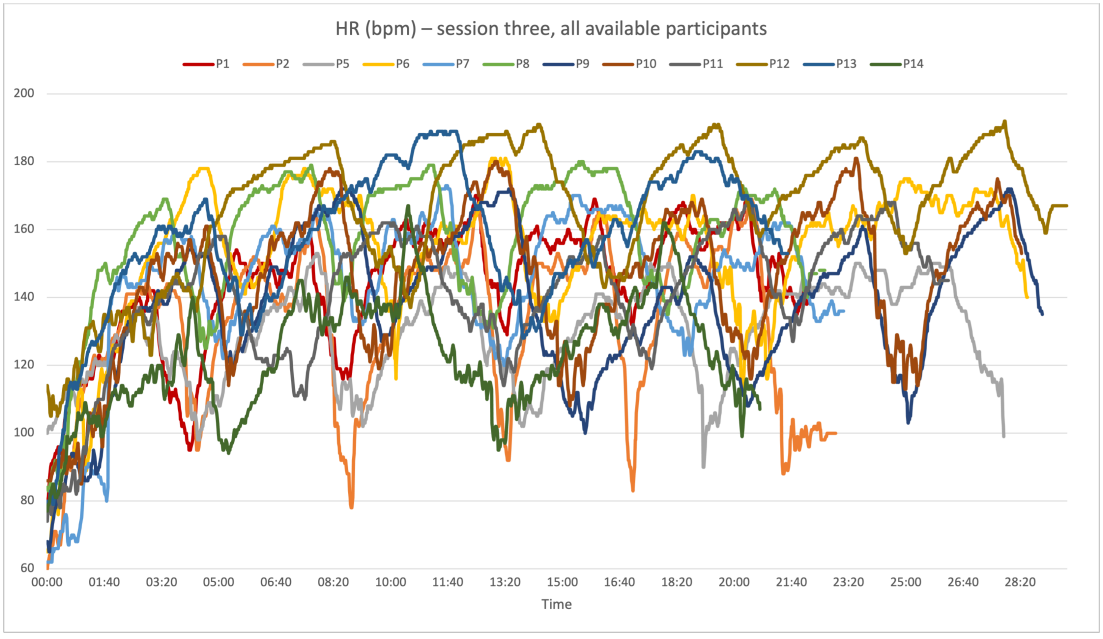
Time


HR (bpm) – session three, all available participants
P1 P2 P5 P6 P7 P8 P9 P10 P11 P12 P13 P14
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00:00 01:40 03:20 05:00 06:40 08:20 10:00 11:40 13:20 15:00 16:40 18:20 20:00 21:40 23:20 25:00 26:40 28:20
Time

D Observational form

The observational form used by the researchers during the experiment is attached on this page (only provided in Norwegian).

Observasjoner for deltaker

Hva	Antall ganger	Kommentarer
Uttrykker glede		
Uttrykker positiv overraskelse		
Frustrasjon om vanskelighetsgrad		
Frustrasjon om spill		
Frustrasjon om kontrollere		
Blir visuelt sliten		
Mestring av spillet		
Forvirret/roter rundt i spillet		
Kommer med tips til forbedringer		
Motivert til å prøve igjen		
Ikke Motivert til å prøve igjen		
Interagerer med den andre spilleren		

Hvor sliten er spilleren undervei

Deltaker-ID	Første 10 min	Andre 10 min	Siste 10 min

E NSD approval form

The user consent form signed by all participants before joining the experiment is attached in the following page (only provided in Norwegian).

Vil du delta i forskningsprosjektet

Øke treningsmotivasjon ved bruk av spill til ergometersykkel ?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å teste om vårt spill til en ergometersykkel kan føre til økt treningsmotivasjon. Dette skrivet gir deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Dette studiet gjennomføres som en del av en Master-oppgave.

Målet med studiet er å komme frem til om man gjennom aktive spill (exergames), her spilt på en ergometersykkel, kan få økt motivasjon til fysisk aktivitet i hverdagen – hovedsakelig blant dem som har lav motivasjon til dette i utgangspunktet. Dette testes gjennom vårt selvutviklede spill som baserer seg på prinsipper fra tidligere forskning på området.

Gjennom forsøket ønsker vi å se på hvordan spillet påvirker spillerens glede, engasjement og motivasjon til å trene. Vi vil også se på om spillerens bakgrunn innen trening og dataspill har noe å si for hvordan spillet oppleves.

Hvem er ansvarlig for forskningsprosjektet?
Forsøket gjennomføres som del av en Master-oppgave ved Institutt for Datateknologi og Informatikk (IDI) hos NTNU. Veileder og hovedansvarlig for prosjektet er Alf Inge Wang. Forsøket vil bli gjennomført av studentene Magnus Rand og Sander Østvik.

Hvorfor får du spørsmål om å delta?
I studiet ønsker vi å se på en variert gruppe mennesker innen alderen 18–26 år bestående av folk med både høyt og lavt aktivitetsnivå. Denne gruppen er den vi ser som mest realistisk når det kommer til anvendelse av et slikt produkt.

Hva innebærer det for deg å delta?
Hvis du velger å delta i studiet innebærer det at du i tre omganger deltar i en observert spillsesjon, fyller ut et spørreskjema og gjennomfører et intervju. De tre omgangene vil finne sted på ulike dager og hver omgang vil ta ca. 60 minutter å gjennomføre. Spørreskjemaet inneholder spørsmål om dine spill- og treningsvaner, samt spørsmål om din opplevelse av spillet du spilte i spillsesjonen. Svarene vil bli registrert elektronisk. Under spillsesjonen vil det kunne bli tatt video og bilder, disse vil i så fall bli anonymisert; si fra hvis du ikke ønsker billedtakning under din sesjon. Pulsen din vil også bli målt under spillsesjonen. Dette for å få et inntrykk av hvor engasjert spilleren er underveis, samt for å måle eventuell helsegevinst av spillingen. Det vil bli tatt lydopptak og notater under intervjuet, som også vil handle om din opplevelse av spillet du spilte i spillsesjonen.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

Dataene vil bli lagret kryptert på NTNU sine servere og kun prosjektgruppen og veileder vil ha tilgang på dataene. Personopplysninger vil bli anonymisert ved at navn og kontaktopplysninger vil erstattes med en kode som lagres på en egen navneliste, adskilt fra øvrige data.

Det vil ikke være mulig å gjenkjenne deltakere i publikasjonen av Master-oppgaven. Kun gjennomsnitts- og behandlet anonymisert data, samt anonymiserte kommentarer fra spillsesjon og intervju vil bli oppgitt i publikasjonen.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Personopplysningene dine og eventuelle bilder, filmer og opptak vil bli slettet når prosjektet avsluttes og oppgaven er godkjent, noe som etter planen er 11. Juni 20201.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Norges teknisk-naturvitenskapelige universitet / Institutt for datateknologi og informatikk har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

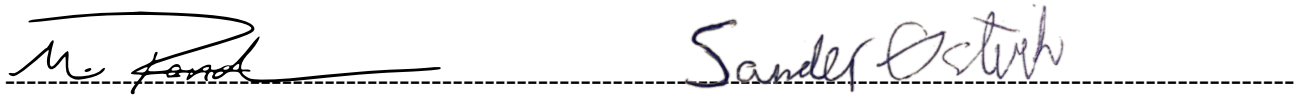
- Student: Magnus Rand, *christian.m.rand@ntnu.no*
- Student: Sander Østvik, *sanderos@stud.ntnu.no*
- Prosjektansvarlig: Alf Inge Wang, *alf.inge.wang@ntnu.no*
- Vårt personvernombud: Thomas Helgesen, *thomas.helgesen@ntnu.no* (tlf: 93079038)

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

(Magnus Rand, Student) (Sander Østvik, Student)



Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet «Øke treningsmotivasjon ved bruk av spill til ergometersykkel» og har fått anledning til å stille spørsmål. Jeg samtykker til:

- å delta i spillsesjonene
- å delta i spørreskjemaene
- å delta i intervjuene

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

---

(Fullt navn i blokkbokstaver)

(Signert av prosjektdeltaker, dato)

C. M. Rand, S. K. Østvik

2D Boss Fighter Exergame

NTNU
Norwegian University of
Science and Technology