Master's thesis

NTNU
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Department of Computer Science

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WaveRider – A high-intensity interval training exergame for exercise bikes

Master's thesis in Computer Science
Supervisor: Alf Inge Wang
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IT3920 - TDT4900 - Master's Thesis

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Abstract

Statistics provided by the New England Journal of Medicine show that the Norwegian population has elevated levels of obesity compared to other European countries, and the highest values in Scandinavia. Studies show that we spend more time seated behind a screen than before, which together with a lack of exercise can have a negative impact on health. Exergames, video games where you use physical exercise as input to the game, provide a potential solution that does not require massive behavioral change.

The goal of this study was to develop an exergame achieving high-intensity interval training in a new, entertaining way that would increase motivation. The concept was built through a pre-study on the exergame market, game design- and exercise theory as well as gameplay features and genres. This identified functionality and frameworks that could provide entertainment and exercise and the concept of *WaveRider*, a bicycle rhythm game using cadence as input was created.

Using a research prototype developed based on the concept, a study with 14 participants was conducted. During this study users participated in four sessions, the three first focusing on different game configurations in order to compare engagement and a final session where participants had the option to choose the game configuration. The participants were monitored during the sessions by the authors and provided heart rate data through chest-wrapped sensors. This heart rate data was used to identify exercise quality and used together with observations and responses from questionnaires during and after the study to respond to research questions.

The study shows that the research prototype provided users with a highly engaging experience with an entertaining interval training option. Through feedback on the game configurations, the study showed a clear preference for competitive gameplay, which provided more motivation and challenge than collaborating or playing separately. After all four sessions, nearly all participants maintained or improved their motivation to continue playing. Together with the heart rate data indicating most users achieve high-intensity interval training these responses suggest the game can be used to provide an alternative to established high-intensity interval training activities.

Sammendrag

Statistikk levert av New England Journal of Medicine viser at den norske befolkningen har et høyere nivå av overvekt enn flere europeiske land og de høyeste verdiene i Skandinavia. Studier viser at vi bruker mer tid bak skjermen enn før, som sammen med mangel på fysisk aktivitet har en negativ innvirkning på helsen. Treningsspill, videospill der du bruker fysisk trening til kontroll i spillet gir en mulig løsning som ikke krever drastisk atferdsendring.

Målet med denne studien var å utvikle et treningsspill som oppnår høyintensiv intervalltrening på en ny og underholdende måte som kan øke motivasjonen til spillerne. Konseptet ble skapt gjennom en forhåndsstudie på treningsmarkedet, spilldesign- og treningsteori samt spillfunksjoner og sjangre. Forhåndsstudien identifiserte funksjonalitet og rammeverk som kunne hjelpe designe et spill som kan gi treningsutbytte og underholdning, og konseptet *WaveRider*, et sykkel-rytmespill som bruker pedalkadens som input ble opprettet.

Ved å bruke en forskningsprototype utviklet basert på konseptet ble det gjennomført en studie med 14 deltakere. I løpet av denne studien deltok brukerne i fire økter, hvor de tre første øktene fokuserte på forskjellige spillkonfigurasjoner for å sammenligne engasjement. På den siste økten hadde deltakerne muligheten til å velge spillkonfigurasjon selv. Deltakerne ble observert av forfatterne under øktene, og pulsdata ble samlet gjennom pulssensorer. Denne pulsdataen ble brukt til å identifisere treningskvalitet, og ble brukt sammen med observasjoner og spørreskjemaer tatt under og etter studien for å svare på forskningsspørsmål.

Studien viser at forskningsprototypen ga brukerne en meget engasjerende opplevelse som ga brukerne et underholdende alternativ til intervalltrening. Gjennom tilbakemelding på spillkonfigurasjonene viste studien at brukerne foretrakk å konkurrere mot hverandre, noe som ga dem mer motivasjon og utfordring enn å samarbeide eller spille hver for seg. Nærmest alle deltagerne beholdt eller forbedret motivasjonen til å spille spillet etter fire økter. Kombinert med pulsdataene som viste at de fleste brukerne oppnådde høyintensiv intervalltrening tyder dette på at spillet kan brukes til å gi et alternativ til etablerte høyintensitets-intervalltreningsmetoder.

Acknowledgement

We would like to thank everyone that participated in the user test. We know that it is not easy to set aside time for four sessions over a period of two weeks, and would like to express our greatest appreciation for the high level of completion, as almost all participants completed all sessions. We greatly benefited from their contribution of feedback and answers to our questions. This research could not have been completed without them.

We would also like to express our gratitude to our supervisor Professor Alf Inge Wang for giving us the opportunity to contribute to such an exciting project. Professor Wang's expertise helped us with both the preliminary report and this thesis. His guidance helped us through all parts of the research and writing of this thesis. Many thanks for the discussions and feedback that contributed to finalizing this report. Without his guidance, this thesis would not have been possible.

We would also like to thank NTNU Makerspace for permission to use their space to develop the research prototype and conduct testing.

Thanks to *PlayPulse* for permission to use their prototype bikes in this research.

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Part I

Introduction

This part goes into detail on what the project pertains to, what it plans to achieve, and the motivations behind it. It showcases the research goals and methods used to complete the project.

1 Motivation

Over the last 40 years, humanity has seen considerable growth in unhealthy overweight and obesity [1]. This data is based on the Body Mass Index model (BMI). BMI is a measurement of physical well-being based on height and weight. Norwegians have higher average BMI values than other Europeans, and Norway has the highest percentage of obesity in its population among the Scandinavian countries [2]. While the focus on physical and mental health has increased over the last decade, it is still essential to find new, innovative solutions to lowering the bar of entry for improving your stamina and fitness. Being overweight and obese have a significant impact on life quality, and can increase the chance of experiencing heart attacks or cancer.

Technology and games have a unique opportunity to improve public health (e.g., reducing obesity and improving fitness), as they provide new, entertaining ways to interact with the world. These products can promote physical activity for people who lack exercise. Data suggests that the average child or adolescent spends over 8 hours a day doing seated, stationary activities. Adults are also inactive, spending over 60% of waking hours stationary [3]. For a lot of children, part of this inactive period is spent playing video games. This means that with physically active video games, this period can be made into a period with activities that provide health benefits.

Our group consists of members with a background in Computer Science and Technology, with experience with programming software, game development, user experience, and product design. Both members consider physical exercise very important and understand how important it is for maintaining good health. As a result, we believe a well-executed combination of gaming and exercise can help contribute to decreasing obesity and overweight in the population. It does not need to only improve extreme health cases, as it could have a health benefit for people with a normal BMI as well.

2 Project and Context

The original task assignment was described as follows:

[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 by using her/his feet to move the pedals. The goal of the game is to both to have fun that can last over time as well as to get physical exercise. The game should be implemented in Unity using a provided API for the exercise bike controller.

The goals of this project are:

- *Research existing ExerGames and games that could fit this purpose.*
- *Design and implement a prototype game.*
- *Provide input on the API for the exergame framework used.*
- *Evaluate the game through user experiments.*

This master's thesis is a part of NTNU's ongoing efforts into researching exercise gaming and its potential uses. It is a continuation of the specialization project done by the authors during the autumn 2021 semester [4]. During the preliminary studies, the goal was to identify an exercise game concept using game design- and exercise theory. This thesis aims to implement that concept, and as such, most of the theory provided for this thesis is a result of the literary research carried out in the specialization project. The content of Section 1 & 3 in *Part I*, *Part II*, and most of Section 18 & 19 in *Part III* are reused from the specialization project [4].

This project goal and thesis are a part of NTNU's Game Technology For Health (GT4H) network, which is a community aiming to unify the resources in the field of ExerGames, share knowledge and research across branches of science, medicine, and companies, and to connect research to the game industry to provide serious gaming for health benefits [5].

3 Research Questions

To understand the task better and make it easier to steer the research in the right direction, the team started by transforming the task into a research goal. Afterward, the team broke down the research goal into seven research questions that clarified what the study should answer. This process was done by using the goal question metric (GQM) approach. The GQM approach is divided into three levels: Conceptual level, Operational level, and Quantitative level [6]. The *conceptual level* is the process where one finds the research goal for the project. The *operational level* is the process where the research goal is decomposed into research questions that need to be answered to reach the goal. The *Quantitative level* is the process where one explains which metrics are used, and how the research questions are answered. These categories were used to break down the goal into research questions.

Research goal: *The research goal of this project is to develop a new, entertaining exercise game for the PlayPulse platform to motivate users to obtain high-intensity exercise using gaming.*

The following research questions were established by decomposing the research goal. These research questions provide the observable requirements the study aims to resolve and the questions it aims to answer.

RQ1: *What is required in an exercise game to ensure high satisfaction and physical results?*

- *RQ1.1: How can you design a concept that provides both entertainment and physical workout?*
- *RQ1.2: Which intensity level and exercise amount per day balance health benefits and entertainment best?*

To provide health improvement, our game needs to offer users physical exercise while maintaining high levels of entertainment to keep users playing. This research question looks into what theoretical structures, principles, trends, and heuristics can be applied to exercise games to improve user experience.

The sub-questions add categories to the question: What gameplay elements provide an entertaining exercise game, and which amounts per day of these gameplay mechanics balance health benefits and entertainment best. Through literary review and design tools such as DualFlow, the goal is to identify the balance of intensity and enjoyment that gives users the strongest return on investment while maintaining motivation.

RQ2: *To what degree does our game provide high-intensity interval training?*
A key attribute of a good exercise game is to ensure that the user gets a progression in both health and fitness, in this case by completing high-intensity interval training. To ensure that the player improves, this research needs to find out to what degree our game manages to recreate the effects of high-intensity interval training. This can be gauged with feedback through forms with quantitative values, observations, and heart rate measurements.

RQ3: *How does our game affect the players' enjoyment?*
For players to stay motivated while playing the game, a key metric to observe is how much enjoyment a player gets out of the session. Identifying how the game affects players' moods and attitudes is key to ensuring a great experience.

RQ4: *What play configurations provide the most incentive and engagement?*
Games can be played in many different ways, alone or with people. The goal is to identify whether playing alone or with someone provides the most motivation and enjoyment of the game. Another

key aspect is to identify whether competition or collaboration provides the most encouragement to players.

RQ5: *Does our game provide a lower bar of entry to start training?*
To encourage exercise, our game aims to make it easier to get into working out. Exercise games have great potential to merge between user groups, and the goal here is to identify if our game can reduce this bar of entry for users who may play games but would prefer not to exercise. If the game achieves this, it could help improve public health for exposed users.

RQ6: *Does our game motivate players to train over a longer period of time?*
For exercise to have an effect you need long-term investment and repetition. An important question that needs to be answered is how we best make sure the user wants to play again at a different time, such as a day later. What rewards can be utilized in an exercise-driven system that would promote retention? The metric for checking retention would be the drop in activity in its users over time. Little drop-off shows signs of long-term motivation and high retention.

RQ7: *Does our game give players the opportunity to observe progress in stamina and skill?*
If the user uses our product over a long period of time they should see in-game and physical results of this commitment in the form of better results. What kind of activities and results are best used to display progress that accurately describes the users' physical state?

4 Research Method

The research questions in this thesis will be answered by following a research model from Briony J. Oates' *Researching Information Systems and Computing* [7]. Figure 1 highlights the parts used in this study. The aspects applied from the model are explained in this section.

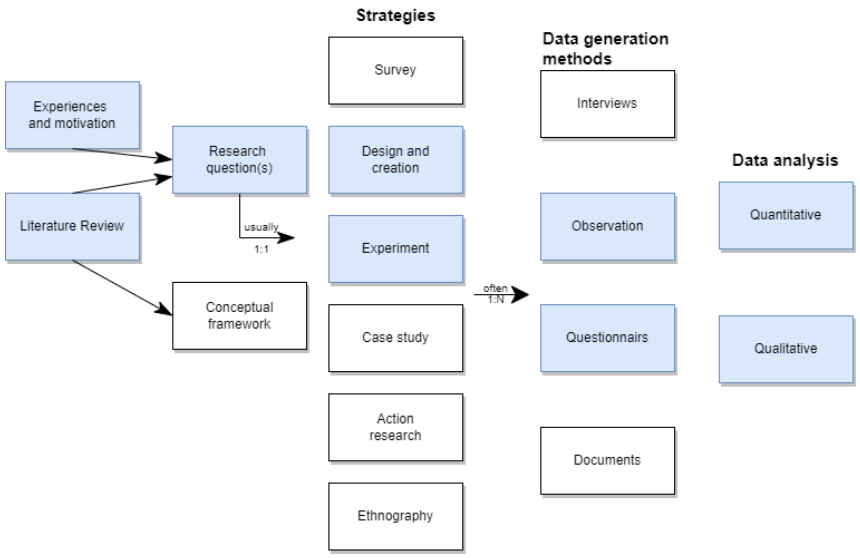


Figure 1: The model of Oates' research process [7]. Aspects applied to this study are coloured.

Experiences and motivation

The *experience and motivation* part of Oates Model is about finding the researcher's experience and motivation, the fundamental elements when selecting what to research. This phase will also help to find possible research questions, as shown in Figure 1.

This thesis is a continuation of the preliminary report. The authors started by defining their experience and motivation to do this research and identified which direction to take this study. This process helped to create research questions for this project.

Literature Review

The game concept from the preliminary project was based on a *literature review*. A literature review is a method of searching for and cataloging relevant research [8]. Properly executed, a literature review will grant the researcher a better understanding of the setting of the research space, granting a solid groundwork to build your hypothesis upon [7]. For this thesis, the literature review was conducted during the preparatory project. This literature review can be read in **Part II**.

Research Questions

Research Questions are a set of questions that contributes to answering the research goal. Oates mentions that one way to find research questions is to think about your motivation, what direction of research you want to do, and what you want to find out. Science literature can also be read to understand where more research is needed. The research questions can also be inspired by the parts *experiences and motivation* and *literature review* as seen in Figure 1.

The research goal for this thesis was created through discussion between the authors and the supervisor. Based on the project description this group decided upon the research goal described in Section 3. By using the authors' experience and the Goal-Question-Metric (GQM) approach, a set of relevant questions was uncovered. The research goal, research questions, and the GQM approach are described in more detail in Section 3.

Design and Creation

Design and Creation is one of the six strategies in Oates' model. A strategy is an overall way to find answers to the research questions. Design and Creation has its main focus on the development of new artifacts, which often is a computer-based system.

To answer the research questions in this thesis, developing a research prototype of the game concept was required. This concept was created during the preliminary project, based on the research goal and literature review. For a project to be a research experiment rather than an IT product, it needs to collect data and provide new knowledge. This was kept in mind while designing the game and during the experimentation process. The development process is covered in Section 22.

Experiment

Another strategy in Oates' model is *Experiment*. *Experiment* is in academic research defined as "a strategy that investigates cause and effect relationships, seeking to prove or disprove a casual link between a factor and an observed outcome" [7] [Chapter. 9, p.127]. An experiment starts with developing a theory within the topic. This theory leads to a statement that is possible to test empirically via an experiment.

To answer the research questions of this thesis, it was not enough to only develop a game prototype. Because of the fact that it was needed to test the prototype on users within the target group, a quasi-experiment was selected as the second strategy. Quasi-experiment is a type of experiment conducted in real-life setting instead of in a test laboratory. How this experiment was conducted can be read about in Section 23.

Data Generation Method

In this thesis, we use two different data generation methods: *Observation* and *Questionnaires*. Observation is a method where the user test participants are being observed and the testers take notes of what they observe. This method is used to find out what the testers do, and how they react to the different parts of the user test. Section 24 explains observation more in-depth.

One of the disadvantages of directly observing is that the observer must observe everything that happens, and it is possible to miss observations that are important for the research. Therefore, instead of observing directly, video-based observation was used. All user tests were recorded, and the videos were used to observe. The authors found this method better since it eliminates the possibility to miss any observations, especially when having multiple user tests in a row.

The second data generation method in this thesis is Questionnaire. Questionnaire is a set of questions defined in advance, that the tester should answer. The answers can then be used by the researcher to analyze and understand.

This research needed standardized data that is measurable to answer some of the research questions. Questionnaire was therefore used, to give the same questions with multiple select answers to all the participants. Questionnaire will be explained more in-depth in Section 23.

Quantitative and Qualitative data analysis

According to Oates it is mainly two data analyzing methods: *Quantitative* and *Qualitative*. *Quantitative data* is data based on numbers, which is often used in the strategies survey and experiment. The advantage of quantitative data is that it is easier to find patterns and draw conclusions. *Quantitative data analysis* was in this research used to analyze the data from the questionnaire as it mainly consisted of measurable answers.

Qualitative analysis on the other hand consists of all non-numeric data. The advantages of qualitative analysis are that it is more detailed and it is possible to get a better understanding of what the participants think. This research uses the qualitative analysis method to analyze the observations taken during the user tests.

The disadvantage with qualitative analysis is that it can contain of many different answers which makes it difficult to find patterns. On the other hand, only completing a quantitative analysis has the possibility to include misleading answers because of the predefined range of answers. Therefore, this research chose to include both quantitative and qualitative analysis to get better conclusions.

5 Report Outline

This report consists of five parts.

Part I - Introduction
This part has introduced the motivation for this project, the project and context itself, and research questions and methods. Parts of Section 1 & 3 are reused from the preliminary report.

Part II - Prestudy
As explained in Section 2, this part is reused from the preliminary report and shows the preparatory research done to create a concept. This part includes the definition of exergames, the theory needed to understand this report, and existing exergames and how they affect the users. It starts with an explanation of what an exergame is. Then it goes deeper into the theories about exercise, and enjoyment which include GameFlow, Malone's model, Dual Flow, and Rewards. Later it tells about PlayPulse, the Unity game engine, and existing exergames, as well as an evaluation of them. Finally, it delves into how different genres could be applied to PlayPulse exercise games, what features can provide implementations of theory, and potential concepts provided by the authors making use of these features.

Part III - Design & Implementation
This part covers the game concept used for the project's research prototype. It covers the features required for achieving the results to answer the research questions. This means covering how game features fit into the game design and exercise theory described in Part II. It also describes the development process, as well as the choices and planning made by the team to complete the game. Section 18 & 19 are reused from the preliminary report.

Part IV - The Study
This part explains the choices made to gather information to answer the research questions established in **Part I**. The section covers the choice of data collection methodology, why this methodology was chosen, as well as how the process went, and the validity of the result.

Part V - Result Analysis
The result analysis section looks at the data collected from the study in **Part IV** . It shows the data that came out of the study. The part provides data on the test population of the study, which describes the users that participated in the test. It then displays the result of the data gathering, such as questionnaires, heart rate data as well as observations done by the test facilitators during the study.

Part VI - Discussion
This section looks into the connection between the research questions from **Part I** and the results in **Part V**. The goal of this part is to identify whether the project achieves the goals set in **Part I** through comparison to the data collected. There is also an analysis of the validity of the responses to identify the accuracy of which we can draw a conclusion.

Part VII - Conclusion
The final part contains a reflection on the project and result, as well as identifying potential further investigation and work.

Part II

Pre-Study

The goal of this part is to define exergames, existing options, the technology used as well as theories on exercise, gaming, and enjoyment. This part is reused from the thesis' preliminary report.

6 What are Exergames?

An exergame is simply put, a concept where the player needs a form of exercise to play the game. The concept has existed for a long time, and we can find it back in 1980 where *Dance dance revolution*, a popular exergame, was launched. Many new exergames have been released since then, and this will be explored in Section 13.

The definition of exergame has changed, and many have different opinions on what the definition is. Some of the cited definitions from Oh & Yang [9] are:

- "Exergaming or exer-gaming (a portmanteau of "exercise" and "gaming") is a term used for video games that are also a form of exercise." (Wikipedia, 2010)
- "Promoting an active and healthy lifestyle by combining video games technologies and exercise" (Exergame Network)
- "Exergaming is the combination of exercise and video games" (Bogost, 2007)
- "New active video games combine body movement with gaming skills" (Lawrence 2005)
- "Video games that also provide exercise" (Wylie & Coulton 2008)
- "Tying play to physical activity" (Sall & Grinter 2007)

Oh & Yang looked through many of the exergame definitions and explained the patterns in their research [9]. They concluded with a suggestion of their own definition of both exergame and exergaming which are shown below.

Exergame: "A video game that promotes (either via using or requiring) player's physical movement (exertion) that is generally more than sedentary and includes strength, balance, and flexibility activities"

Exergaming: "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"

The most important difference between the definitions is that they either have focus on an exercise perspective or a game perspective. This project aims to have a main focus on the exercise perspective, and include multiple game design elements to engage and motivate the player to exercise. Therefore, this project uses Yang & Oh's definition of exergames.

7 Exercise Theory

Exercise is defined in the *Cambridge Dictionary* as "*physical activity that you do to make your body strong and healthy*" [10]. The goal of the exercise game is to make users physically active and to provide health benefits. To provide the highest possible return on benefits from the exercise the activity needs to meet certain criteria that have been scientifically proven to work. This varies based on what category of exercise you target. There are according to Harvard Medical School's public health education division, Harvard Health Publishing, four kinds of exercise: *aerobic exercise*, *strength training*, *stretching*, and *balance exercise* [11]. While strength training is possible on a technical level, this project uses bicycles that are meant for aerobic exercise.

Aerobic exercise is based on an increase in heart rate and breathing. This can be prompted through movement over some time. Examples of aerobic exercise are jogging, running, and cycling. A common trait in aerobic exercise is focusing on rapid movement without weighted resistance. The term *aerobic exercise* comes from Latin meaning *"with oxygen"*. This is because this exercise category forces blood to pump more oxygen to muscles in the body to continue, which requires a higher breath- and heart rate [11]. The health benefits of aerobic exercise include reduced blood pressure, decreased risk of heart disease, and better control over your blood sugar levels [12]. It also plays a big role in maintaining a healthy weight, as it helps to increase daily spent calories, which as mentioned in *Section 1* is one of the main goals of this project.

But how much does one need to exercise to get the most beneficial results? The Norwegian Institute of Public Health recommends for children and teenagers at least 60 minutes of moderate or intense exercise every day [13]. It is also recommended to do intense exercise at least three times a week. Moderate exercise would include activities such as fast walking, while intense exercise would include jogging and running [13]. For adults, it is recommended to get moderate exercise for 150 minutes a week, which would mean 30 minutes a day for five days. The recommendation can also be reduced to 75 minutes a week if the activity is an intense exercise.

One well-defined form of aerobic exercise is high-intensity interval training (HIIT). The goal here is to achieve short spurts of high intensity, with heart rate levels around 80% of the maximum heart rate. Heart rate is defined as heartbeats per minute. Maximum heart rate varies from person to person. There are different formulas made for calculating a person's maximum heart rate. Some may take into account different parameters such as activity level, gender, or weight. The one used for this project is written by Nes, B M et al. in the *Scandinavian journal of medicine & science in sport* [14]. Their formula is defined as *211 - 0.64 * age*. They found no correlation between the result and other factors. This formula is simple and has been proven to be very accurate. A 20-year-old person would have a maximum heart rate of 198 beats per minute according to the formula. This person would have to reach a heart rate of 160 for it to be 80% of maximum heart rate and to be considered HIIT. Calculations like these will be used on test users to deem whether or not the game can be used for high-intensity training. Figure 2 shows the optimal progression of heart rate in a session of HIIT. The user should have short bursts of high intensity with rest periods in-between with light exercise. An example would be the running exercise *4x4 interval training* where you run at near max heart rate for 4 minutes, rest by walking for 3 minutes, then repeat this three more times.

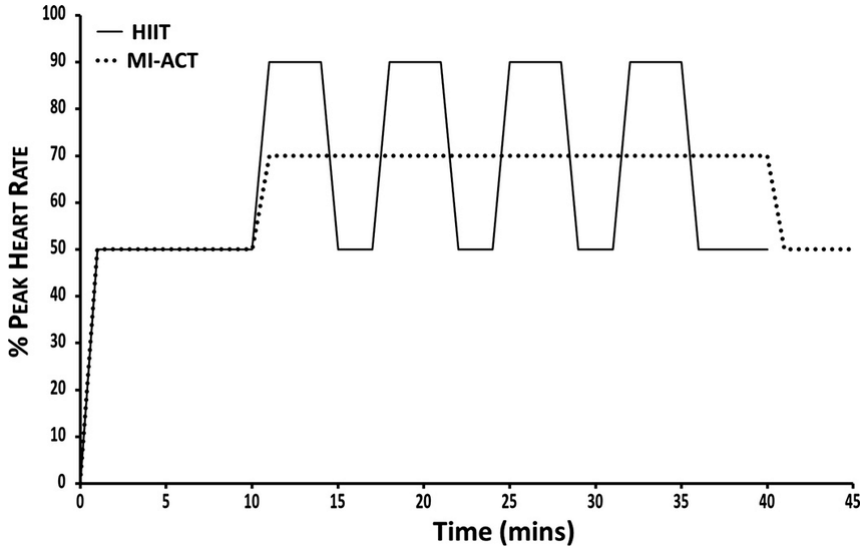


Figure 2: Representative heart rate responses during a single session of high-intensity interval training (HIIT) and moderate-intensity aerobic continuous training [15]

8 Game Design Theory

Designing a good game, in general, is a very complex task, and there are many parts to consider. Designing a game that also has to consider other aspects such as exercise in addition to enjoyment makes it more complex. The challenge is to design a game that is enjoyable over a long period and at the same time has health and activity benefits. Fortunately, there exist multiple researched models that can help.

This section will introduce different theories and models on enjoyment that are relevant for designing a good exergame. The first model, GameFlow, is a model used to evaluate player enjoyment in a game. Malone's model helps with guidelines for game designers with a focus on the three categories *Challenge*, *Fantasy*, and *Curiosity*.

8.1 Motivation

Motivation is defined as the drive, determination, and will an individual exerts in approaching or avoiding a behavior [16]. Research shows a connection between higher levels of motivation and greater results from physical exercise [17]. According to the *self-determination theory* (SDT) for motivational theory, there are different levels of motivation based on how well that behavior fulfills their individual psychological needs for autonomy, competence, and relatedness [18].

According to this theory, the highest level of motivation is considered to be *Intrinsic Motivation*, where the individual is motivated by the behavior itself. This would for example be the enjoyment of the behavior, mastery of the behavior, or the challenge of the behavior. The next level is *Self-Determined Extrinsic Motivation* where you value the result of the behavior, such as valuing health benefits, social aspects of the behavior, or relaxation. Thirdly, there is *Other-Determined Extrinsic Motivation*, where the individual is motivated by external means such as rewards, guilt, or coercion. Finally, the lowest level of motivation according to the self-determination theory is *Amotivation*, where there is no motivation for the behavior [18].

Research in an exercise context has shown that individuals with intrinsic motivation while exercising were more likely do regular exercise of sufficient intensity for health benefits [19]. This means that if we can design a game experience that triggers intrinsic motivation, it will have a positive effect on the results. Cognitive evaluation theory, a sub-theory of the self-determination theory, indicates that among other things, competition helps provide intrinsic motivation [20]. This is why game design is a very important aspect of this project.

8.2 GameFlow

Player enjoyment is one of the most important aspects of computer games [21]. Penelope Sweetser and Peta Wyeth therefore, created GameFlow, a model used to analyze and evaluate the degree of enjoyment. To understand this further, this section will first explain Flow, the model Gameflow is based on. Flow is an outcome of research about what makes experiences enjoyable, published by Csikszentmihalyi in 1990. The research continued for several years, with thousands of responses from people who used much time and effort on difficult tasks but did not get any external rewards for it [21]. As a result, Csikszentmihalyi created Flow which is divided into eight elements [22]:

1. A task that can be completed.
2. The ability to concentrate on the task.
3. That concentration is possible because the task has clear goals.
4. That concentration is possible because the task provides immediate feedback.
5. The ability to exercise a sense of control over actions

6. A deep but effortless involvement that remove awareness of the frustrations of everyday life.
7. Concern for self disappears, but sense of self emerges stronger afterwards.
8. The sense of the duration of time is altered.

The GameFlow model also consists of eight elements where each element is somehow related to the flow model. Sweeter and Wyeth also mapped the game literature elements to the elements for Flow, which can be found in Table 1 below [21].

Games Literature	Flow
The game	A task that can be completed
Concentration	Ability to concentrate on the task
Challenge Player Skills	Perceived skills should match challenges and both must exceed a certain threshold
Control	Allowed to exercise a sense of control over actions
Clear goals	The task has a clear goal
Feedback	The task provides immediate feedback
Immersion	Deep but effortless involvement, reduced concern for self and sense of time
Social Interaction	n/a

Table 1: Sweetser and Wyeth's mapping of Game literature elements to elements of Flow [21]

Social Interaction is not mappable to Flow but was included because it is an important aspect of games. Below follows a deeper explanation of the eight elements of Gameflow. The criteria for each element are taken directly from Sweetser and Wyeth's publication [21].

8.2.1 Concentration

The first element of the model GameFlow is *concentration*. According to Sweetser and Wyeth, a game requires concentration to be enjoyable. It will get more engaging if the player is more concentrated in terms of attention and workload. Therefore, the game should grab the player's attention at the beginning of the game and keep it until it ends.

Criteria

- Games should provide a lot of stimuli from different sources
- Games must provide stimuli that are worth attending to
- Games should quickly grab the players' attention and maintain their focus throughout the game
- Players shouldn't be burdened with tasks that don't feel important
- Games should have a high workload, while still being appropriate for the players' perceptual, cognitive, and memory limit
- Players should not be distracted from tasks that they want or need to concentrate on

8.2.2 Challenge

Challenge is the second element in GameFlow. Challenge is considered the most important aspect of good game design. Matching the challenge to the player's skill level increases the chances that the player continues to play the game. If the difficulty level is too high, the player may give up and consider quitting playing the game. At the same time, if a player feels like the game is too easy, it may get boring, and the player could quit playing the game. Among other things, satisfaction also increases by completing difficult tasks, challenging and being better than opponents, mastering useful skills, etc. [21] A popular way to solve this balance problem is by increasing the difficulty over time or as the player begins to get better at their skills.

Criteria

- Challenges in games must match the players' skill levels
- Games should provide different levels of challenge for different players
- The level of challenge should increase as the player progresses through the game and increases their skill level
- Games should provide new challenges at an appropriate pace

8.2.3 Player Skills

Another important aspect of GameFlow is the support for the development of player skills. Sweetser and Wyeth explain that it is important that the players enjoy learning the game as well as playing to have a good experience. This can be done by, for instance, forming the game such that the players will develop the needed skills while they play the game and accomplish something they want. *Reward* is an important part of learning, and it is an easy way to make learning enjoyable. The game should also be possible to play without reading the manual, and if the player is stuck at a place in the game, it should exist some sort of help as hints or online help.

Criteria

- Players should be able to start playing the game without reading the manual
- Learning the game should not be boring, but be part of the fun
- Games should include online help so players don't need to exit the game
- Players should be taught to play the game through tutorials or initial levels that feel like playing the game
- Games should increase the players' skills at an appropriate pace as they progress through the game
- Players should be rewarded appropriately for their effort and skill development
- Game interfaces and mechanics should be easy to learn and use

8.2.4 Control

Another way for a game to improve GameFlow is by giving the player a sense of control over their actions. The player should also feel a sense of control over their movements and have the possibility to explore. The game interface and game controls should be easy to learn quickly. It is also possible to increase the feeling of control by giving the player possibilities to start, pause, stop and save the game, help the player recover from errors, let the player play as they want, and also not force the player to do tasks that are not important [21].

Criteria

- Players should feel a sense of control over their characters or units and their movements and interactions in the game world
- Players should feel a sense of control over the game interface and input devices
- Players should feel a sense of control over the game shell (starting, stopping, saving, etc.)
- Players should not be able to make errors that are detrimental to the game and should be supported in recovering from errors
- Players should feel a sense of control and impact onto the game world (like their actions matter and they are shaping the game world)
- Players should feel a sense of control over the actions that they take and the strategies that they use and that they are free to play the game the way that they want (not simply discovering actions and strategies planned by the game developers)

8.2.5 Clear Goals

This element simply explains that goals should be clear for the player at all times. Over-riding goals should be presented at the beginning or early in the game. Each level should also have multiple goals that are presented to the player in an easy way [21].

Criteria

- Overriding goals should be clear and presented early
- Intermediate goals should be clear and presented at appropriate times

8.2.6 Feedback

Giving instant feedback when a player completes a task, will increase the player's concentration, which leads to better flow [21]. According to the authors of the model, a game should frequently give feedback at appropriate times, and players should get feedback on their progress, and if they are going in the right direction. Games should also use a scoring system so the player knows how well it goes, and it should give positive feedback when a player is mastering some task. The player's actions should also get feedback, and when progressing, the player should get a reward [21].

Criteria

- Players should receive feedback on progress toward their goals
- Players should receive immediate feedback on their actions
- Players should always know their status or score

8.2.7 Immersion

Immersion is the element of GameFlow that describes how involved a player becomes in a game at the same time as to how effortless it is. The result of this is that the player gets less aware of time, the real world, and everyday life. Most of the time people play games for fun, but some also play to relax after a hard day of work or to escape from reality. A way to increase immersion is by designing the game such that the player gets personally involved both emotionally and viscerally. This can be done by, for instance, the use of graphics, audio, and narrative.

Criteria

- Players should become less aware of their surroundings

- Players should become less self-aware and less worried about everyday life or self
- Players should experience an altered sense of time
- Players should feel emotionally involved in the game
- Players should feel viscerally involved in the game

8.2.8 Social Interaction

Social interaction is not one of the elements in the initial flow model. However, it is important within the enjoyment part of a game and, therefore, included in the GameFlow model. Many people choose to play a game whether they like it or not because of social interaction. The downside of including this element is the possibility of lack of immersion, as they focus on a connection to the real world. Ways to support social interaction in a game is by, for instance, creating opportunities for players to compete, cooperate, and connect both within and outside the game.

Criteria

- Games should support competition and cooperation between players
- Games should support social interaction between players (chat, etc.)
- Games should support social communities inside and outside the game

8.3 Malone's Model

Thomas W. Malone did research on what makes things fun to learn, and the result of this research was Malone's model, published in 1980 [23]. This research was mainly for educational games, but will also fit exergames. This is because, among other things, one of the main focuses of the article is on what makes a game fun. Malone organizes his theory into three parts: Challenge, Fantasy, Curiosity. These parts will be explained below.

8.3.1 Challenge

"In order for a computer game to be challenging, it must provide a goal whose attainment is uncertain" [23]. According to Malone, a computer game must provide goals to be challenging. If the game is simple, it should have a clear main goal. You can make goals clearer with visual effects or fantasy. If the game is more complex without any clear goals, it should be easy for the player to create their own goals for their difficulty level. Malone also states that goals based on fantasy are better than those where the goal is to use skills. Another important fact is that the player should know if they are on the right track and approaching the goal.

Uncertain outcome

If the player knows that they will win or lose the game at all times, the game may get boring. Malone, therefore, has four possible ways to make the game more uncertain.

Variable difficulty: A game should have different levels of difficulty. This can, for instance, be automatically done by the game, selected by the player, or selected by the skill level of the opponent.

Multiple level goals: A game should have multiple levels of goals. This can be implemented by having a meta goal, an overlying constant objective, in addition to a basic goal. A way to do this is *score-keeping*. By including a score, the meta goal is to get the highest score possible. It is also possible to have time as a meta goal. In other words, you have to complete a task as fast as possible or within the time limit.

Hidden information: Another way to increase uncertainty in a game is by hiding some of the information, and giving it to the player selectively. This has also the possibility to increase the curiosity of the player.

Randomness: An easy alternative to make a game uncertain is by adding randomness. This is used in most gambling games.

Self-esteem

As with success in most things, people also feel better and get increased self-esteem when they reach goals and complete challenges in games. Malone states that it is important that games have variable difficulty levels based on the player's skill level. If the player feels that the game is too hard, their self-esteem can decrease, which can lead to them stopping playing the game. On the other side, if the player gets the feeling that the game is too easy, they will probably get bored and stop playing the game. It is therefore important to have a balance where the challenge does not become discouraging.

8.3.2 Fantasy

A way to make games more interesting is by adding a fantasy. There exist two types of fantasies: Intrinsic fantasy, and extrinsic fantasy.

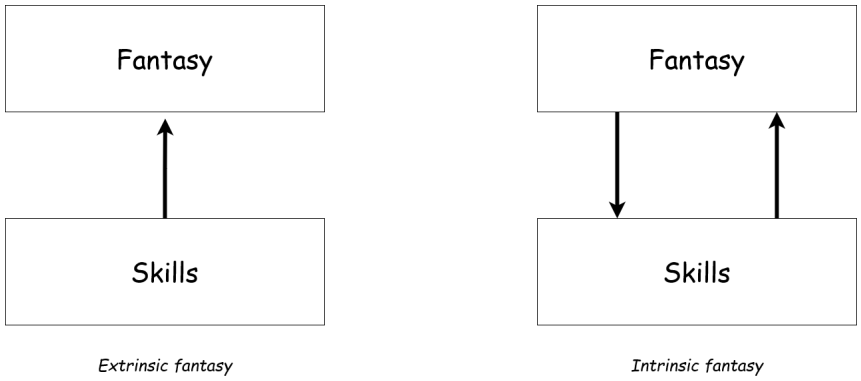


Figure 3: Malone's extrinsic and intrinsic fantasy [23]

As illustrated in Figure 3 above, extrinsic fantasy is where the fantasy depends on the skill. An example of this is a game where the goal is to get a spaceship to the moon. This is done by solving math problems, and for every right answer, the spaceship flies one step higher. The fantasy in this game is the spaceship traveling to the moon, which depends on the skill which is to solving math problems. This means that you do not have direct control over the spaceship, but make progress by solving problems that are indirectly linked to the story. Intrinsic fantasy, on the other hand, is where the fantasy depends on the skill, at the same time, the skill depends on the fantasy. If we consider the same goal as in the example before, the game would have intrinsic fantasy if you have control of the spaceship. This means that your actions and your skills are directly linked with the progress of the spaceship. Malone believes that intrinsic fantasies are more interesting and instructional than extrinsic fantasies.

8.3.3 Curiosity

Malone defines curiosity as "*the motivation to learn, independent of any goal-seeking or fantasy-fulfillment*" [23]. The game environment should not be too complicated in addition to not being too simple. Malone explains two types of curiosity: *Sensory curiosity* and *cognitive curiosity.*

Sensory Curiosity

Sensory curiosity is focusing on the curiosity where the player seeks excitement and new experiences. In computer games, this can be achieved by the use of audio and visual effects. Some examples of how to use audio and visual effects are as decoration, as a reward, as a representation system, or to enhance the game's fantasy.

Cognitive Curiosity

Cognitive curiosity is about that people like to know everything, and that people are eager to find out if there is anything they do not know. According to Malone, people achieve this by completeness, consistency, and parsimony. One way to increase the cognitive curiosity of a player is by using hidden information. Another way is *informative feedback*. Malone states that feedback should be surprising to engage a learner's curiosity, and randomness is an easy way to do that. Also, the feedback should be educational, such that the player gets feedback that will help them to change their knowledge.

8.4 Dual Flow

Dual Flow is a framework for mental and physical experiences that facilitates creating a good exergame and focuses on both exercise and enjoyment [24]. The framework was developed by Jeff Sinclair, Philips Hingston, and Martin Masek with the definition of exergame as "*the merger of exercise and video games*" in mind. The model focuses on the combination between challenge and skills within attractiveness, and intensity and fitness within effectiveness.

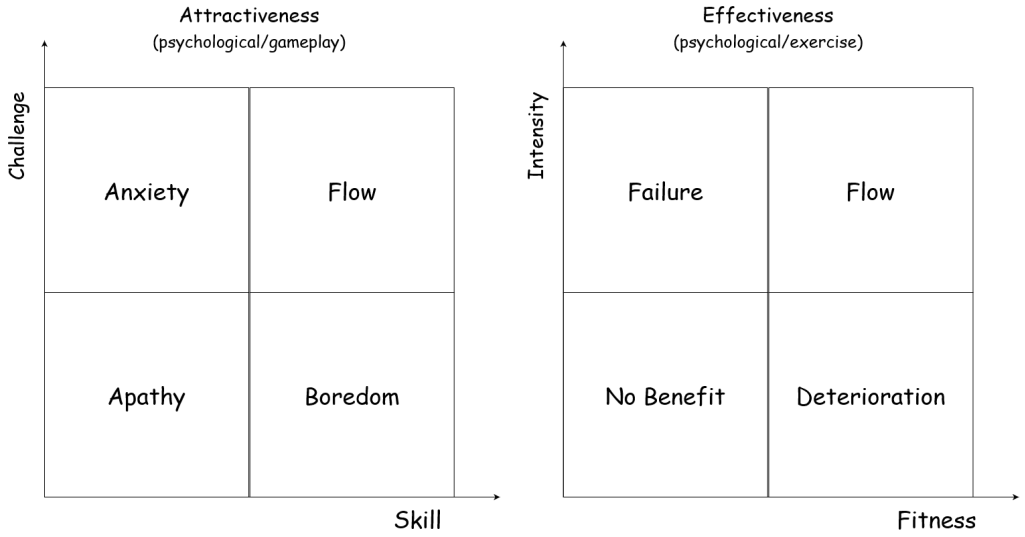


Figure 4: The Dual Flow Model [24]

Attractiveness

According to DualFlow [24], the attractiveness of a game is what makes the player motivated to play, and continue playing the game. One of the factors needed to create a successful exergame is that the game is fun. The attractiveness part of the dual flow model is based on the Flow and GameFlow models, and it is illustrated in the first quadrant of Figure 4. If the challenge is too hard compared to the skill of the player, he/she may feel anxious. On the other hand, if the player feels that the challenge is too easy, he/she can feel bored. A good balance between skill and challenge will therefore result in better games and good game flow.

Effectiveness

The other important aspect of exergames is that the outcome and result should be an achievement of health benefits. They further explain that the game should be designed considering the type of exercise and with a combination of duration, intensity, and frequency, to make sure that the

player gets health benefits from the game. Another important aspect to consider is that it should improve the players' physical condition over time. If the intensity is too high but fitness is low, it can end as a failure as shown in the second quadrant in Figure 4. On the other hand, if the fitness level is high while the level of intensity is low, it can end in deterioration. As with *attractiveness*, a good balance between the levels of intensity and fitness is what results in a good flow.

The article also suggests some general guidelines for aerobic exercise to maximize the health benefits. They are [25]:

1. Warm-up: A 5-10 minute period of low-intensity exercise.
2. Stimulus: Minimum 20 minutes at 70% to 90% of maximal heart rate.
3. Cool down: 5 minutes of low-intensity exercise to return heart rate to resting levels.
4. Three days per week.

8.5 Rewards

In 2012, Hao Wang and Chuen-TsaiSun at *National Chiao Tung University* released a research article on game reward systems [26]. In this article, they explain how reward systems work, discuss why it is important, give classifications for reward and reward characteristics, and also describe how the use of reward systems can change behavior in the psychical world. Reward systems can be thought of as the player's motivator. Examples of rewards are completing the XP bar and leveling up, being shown on the leaderboard, unlocking new features or items, etc. Rewards and reward systems are important because they can motivate the player to continue playing the game. Another interesting fact is that extrinsic rewards can provide a feeling of intrinsic reward. This can for instance be done by adding multi-level goals and motivating the player to learn new skills and making learning and progress more fun.

Wang and Sun divide rewards into eight forms: Score systems, experience point reward systems, item granting system rewards, resources, achievement systems, feedback messages, plot animation and pictures, and unlocking mechanisms.

The researchers also divided how players utilize rewards into four classifications as shown in Figure 5

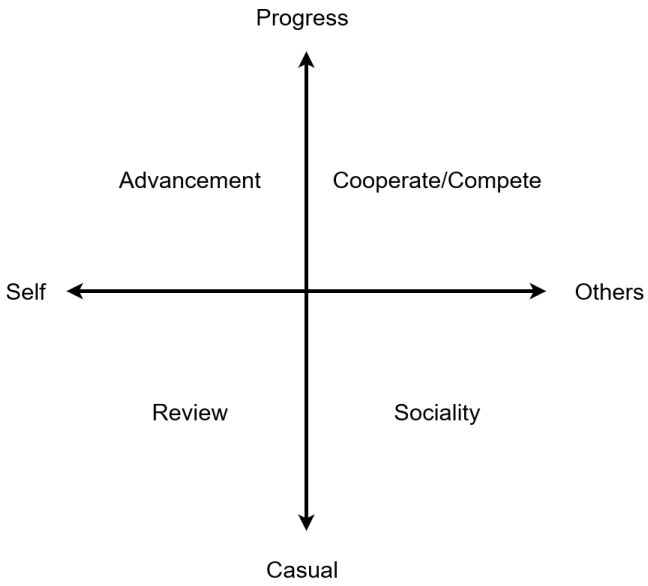


Figure 5: Classification of reward usage [26]

The Self-Others axis describes that the reward can be oriented towards the player him/herself or others. The Progress-Casual axis describes how seriously the player takes the game.

Advancement is where the player uses rewards to get progress in the game. This helps the player advance and gives the feel of more power. Another way players utilize rewards is *Review*. This is when the players check their collection of achievements and watch their avatars change and wear "better" items, etc. By reviewing rewards the player feels accomplishment and attaches a special memory to the various rewards. *Sociality* is when the player uses rewards as social tools, for instance, customizing their avatars, sharing information about how to get various rewards, and showing off their accomplishments. The last classification is *Cooperation/Compete*. This classification is about to encourage the players to interact and for instance exchange items. Many games are designed in a such way that you have to work together to get some achievements etc.

Wang and Sun conclude their research with some considerations to take in mind while designing reward systems. While designing one should create experiences that feel intrinsically rewarding. The player's time and effort spent should be balanced with the reward value. Adding uncertainty to rewards will be more fun for the player. Accumulated rewards such as, for instance, experience points show the player's progress. This can help the player get the feeling of long-term achievement. Another consideration is that rewards can be used for social purposes. For instance, by sharing and comparing with others.

8.6 Summary

After analyzing multiple definitions of exergame, this project has the main focus on the exercise perspective, at the same time as including game design elements. The project will focus on high-intensity interval training, as this is recommended, and require a shorter amount of time than other types of training, to reach the recommended amount of exercise. Including game design theory as GameFlow helps to create a game where the player reaches a state of flow. Using Malone's theory increases the chances of creating a concept that is fun to play. The DualFlow model helps us with balancing the exercise model, such that the concept fits more into the exergame category. In addition, including multiple types of rewards in the game can motivate and engage the player to continue playing the game for a long period.

9 PlayPulse

PlayPulse is a company that produces exercise bikes with a screen and controllers and a platform. The product started as a master's thesis where Stian Weie and Kristoffer Hagen made their prototype [27]. They later continued to work on the product and wanted to bring it to market. They have since run tests and implemented improvements based on results, and according to the official PlayPulse website [27] they have sold bicycles to the public since December 2021. Their mission is to "*turn exercise into a fun, virtual experience - giving people the joy and sense of mastery from working out by making it something you actually look forward to*" [27].

Figure 6: Their newest bike, Playpulse ONE

Their newest bike, Playpulse ONE, includes a controller and a screen where the software game runs. The pedals have millimeter precise sensors, that can be integrated into the player movements in the games on this platform. There is also haptic feedback, adjustable resistance, and a built-in screen. The bicycle is shown in Figure 6. Research and tests have proven the Playpulse platform to be a powerful contributor to exercise and can be an innovative way of exergaming. The results from these research papers will further be mentioned in Section 13.7, 13.8, and 13.9.

Our project will be used to develop an exergame concept for the Playpulse platform. The team did however not have the opportunity to get hold of the Playpulse ONE and therefore used a prototype with a pedal sensor and six buttons on the handlebars instead. This bike can be seen in Figure 7. This one does not have as many features as the Playpulse ONE production bicycle, and simply imitates a game controller using the buttons shown in Figure 7 and a sensor on the wheel. It does however work and gives accurate values.

Figure 7: The *PlayPulse* prototype bike used for this project.

For detecting the angular velocity from the pedals, the PlayPulse prototype (Figure 7) used for this project uses a light-sensor attached to the rim of the bicycle, and a circle split into equal pieces

of alternating black & white colors attached to the wheel (Figure 8). When the wheel spins the circle spins as well, and the light-sensor counts the number of times the color changes from white to black or vice-versa over a set refresh rate. This value is then used to emulate controller joystick input.

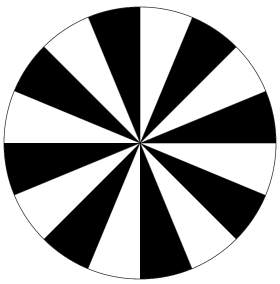


Figure 8: This pattern is placed on the prototype wheels to calculate velocity.

10 Alternatives to PlayPulse

This section goes through similar products to Playpulse, and how they work. While describing these alternatives, the differences between them and PlayPulse bicycles are also offered.

10.1 Zwift

Zwift is an application using sensors on spinning bikes to race against other players in an online multiplayer setting. Zwift is described in detail in Section 13.3. It is similar to Playpulse in its use of bicycles but focuses more on a realistic depiction of actual sports, such as cycling. Playpulse games have varied gameplay loops and settings that are not rooted in reality. Zwift aims to be a simulator of real sports.

10.2 Trickster VR

Trickster VR is an already existing spin cycle with road bike simulation games [28]. The bike can be seen in Figure 9.

Figure 9: *Trickster VR* spin cycle [28]

The bike consists of pedals, steering, and a screen. In addition, it consists of electronic controlled resistance which helps with a more realistic simulation of a road-style bike. This gives a more realistic feeling of going up and down hills, through sand traps, etc. It is also possible to connect with VR glasses and play both single-player mode, and multiplayer, where you compete with friends. The game consists of four different exercise modes and 114 unique exercises, which continually get updated. The usage of VR makes it very different from PlayPulse, which focuses only on an included screen.

10.3 Prop Cycle

Prop cycle, shown in Figure 10, is an arcade game produced by Namco in 1996 [29]. This fantasy adventure game is a race against time and requires the player to pedal the flying bicycle and pop balloons in the air to extend the time limit. The game has various difficulty levels and two play modes: Time Attack and Story mode. The goal in time attack is to pop as many balloons as possible, while in story mode, you have to learn difficult flight paths. Unlike PlayPulse, this is not a spinning exercise bicycle, but rather an arcade game requiring more setup.

Figure 10: *Prop cycle* arcade machine [30]

10.4 Body Max Game Rider

The Body Max Game Rider is a spinning bicycle with built-in sensors that use an included screen or connects to your television to turn your riding into gameplay. The Game Rider Pro is displayed in Figure 11. It is similar to Playpulse in the sense that it is a bicycle with an included computer that handles taking input and turning it into gameplay on a screen. It is however older than Playpulse. The bicycle is not connected to the internet and does not provide multiplayer options, unlike the Playpulse bicycle [31].

Figure 11: The *Body Max Game Rider Pro* bicycle mixes spinning bikes with gameplay, much like Playpulse [31]

10.5 Expresso

Expresso is a spinning bicycle with a built-in screen that lets players either ride long rides with varying resistance or play a HIIT-exercise game where you collect coins. The bicycle is shown in Figure 12. The key difference between Playpulse and Expresso is that Expresso focuses on road racing and realism while offering HIIT exercise as a side game. Playpulse provides very different

games with different focuses. Expresso also offers features meant for an exercise studio setting, unlike Playpulse [32].

Figure 12: *Expresso* is a spinning bike that provides players with both road-racing and HIIT-exercise game options [32]

10.6 Peloton

Peloton is a company with the main goal to use technology to help people to exercise more often, and get to the best version of themselves. They have several different technologies, among other things thread mills and spinning bikes with screens, similar to PlayPulse. The difference is that Peloton does not focus on games. With this product, the user can get help and encouragement from world-class instructors. It has multiple training programs and challenges, and real-time statistics of how the training goes. It is possible to ride live with other members who have this bike, which increases the motivation and engagement further. The Peloton bike is illustrated in Figure 13.

Figure 13: The *Peloton* spinning bicycle [33]

10.7 Summary

The concept of mixing video games and bicycles is not a new idea created by *PlayPulse*. Alternatives like *Prop Cycle* have already explored the exergame concept in an arcade setting. *Body Max Game Rider*, *Expresso*, and *Trickster VR* are more similar to *PlayPulse* in their usage of a spinning bicycle with a mounted display, and the release date of these systems varies. *PlayPulse* is the most recent addition to the series of exercise bicycle games and what makes it stand out from its alternatives is its usage of online play and alternative gameplay loops. Most of the established alternatives focus on games where you ride a bicycle, either in a race or collecting items. *PlayPulse*

games vary more to include things like Tanks, Bumper Cars, and more. Its usage of online play also provides more varying gameplay compared to some of the older alternatives.

11 Unity Game Engine

Unity is the world's leading 3D content creation platform, focusing on interactive, real-time 3D experiences. While it has expanded into the film and automotive industries, it is most known for being one of the most popular engines used in the video game industry today [34]. Unity offers support for both 2D and 3D environments, as well as systems for Augmented Reality and Virtual Reality experiences. Figure 14 shows the studio environment used for the development of games and experiences using Unity.

Figure 14: *Unity* offers users to create real-time 3D experiences.

Both of the students on our team have had some experience with *Unity*, and game engine architectures in general. This means the learning curve to work on a potential prototype should be lessened. If the team runs into issues, *Unity* has expansive documentation of its APIs, a highly active community forum, and thousands of free tutorials available. The platform also has an official asset store, the Unity Asset Store, that allows you to purchase or sell assets to use in your projects, such as materials, 3D models, and plug-ins. These can be used to quickly develop minimum viable products to check if the prototype will solve its goal.

Another useful feature of *Unity* is its customizability. It makes it very easy for third-party software to use its features, which is what allows tools such as *PlayPulse* and *Omni One*, a physical 360-degree treadmill, to feed physical data as input that can be used in experiences through the usage of SDKs, *Software Development Kits*.

12 Mapping Physical Input to Controls

Mapping the physical input to controls should be well thought out to create a good experience for the player. The mapping should be intuitive, and the design should be such that the player easily understands how the controls work. In addition, the activity should be physically satisfying when done correctly. The player should feel a form of happiness after completing a session within the game. The mapping should therefore support multiple levels of physical fitness, both people who have and have not worked out. A good example is the mapping between the game Ring Fit Adventure and the required accessories, shown in Figure 15. The game maps the player's real-world actions to movements in the game [35]. Ring Fit Adventure is explained in Section 13.1.

Figure 15: Ring-Con and Leg Strap, accessories created by Nintendo, used in Ring Fit Adventure [35]

It can be difficult to create a game concept different to the already existing exergames created for bikes. In most games, the pedal input has been used in a way to move the character forward. To make it easier to think otherwise, a list of possible ways to map the physical input to controls was created.

This list includes alternative ways followed by examples of how it can be used:

- *Up and down*: The pedal can be used to move the character upwards or down. An example can be the game Flappy bird. The input from the pedal can increase or decrease the elevation of the character.
- *Going from side to side*: The pedal input can be used to move an object from side to side. An example can be to move the character sideways between lanes.
- *Rotate*: The pedal input can be used to rotate something. For example, it can make the character rotate a wheel or gears. Another example is if the character sits on something that can rotate, such as a turret on a tank.
- *Lift up/Down*: The pedal input can be used to lift something up or down. The character can for instance steer a crane, where the pedal input is used to lift up the crane.
- *Intensity control*: The pedal input can be used as an intensity controller. An example is a shooting game, where how fast the player shoots is controlled by the pedals.
- *Loading bars, e.g. loading bar to throw something*: The pedal input can be used to load bars. For example an energy bar or power-ups.
- *Following line*: The pedal input can be used to follow a line, where the input is used to steer the character up/down or left/right.

- *Push/Pull*: The pedal input can be used to push or pull objects.
- *Digging*: The pedal input can be used to dig. For instance, dig up sand.
- *Making something bigger/smaller*: The pedal input can be used to make something bigger or smaller. For example, evolve the character.
- *Balance control*: The pedal input can be used as balance control, where the player has to hold the same pedal speed over some time to balance the character or item.

13 Existing Exergames

This section will go through several existing exergames, address the main concept of the game, and show how the games in question have provided physiological improvements based on related studies.

13.1 RingFit Adventure

RingFit Adventure is an exercise game developed and published by *Nintendo* for the *Nintendo Switch* console. The game was released on October 18th, 2019, and has as of June 2021 sold over 11 million copies [36]. The game uses the *Nintendo Switch JOY-CON* controllers for input together with a stretchable ring included with the game. Using this ring the player does different activities such as squats and stretches to exercise. To motivate players, these activities are used as controls in an Action *Role-Playing Game (RPG)* where you progress through a fantasy world and fight opponents using exercise movements. An example of gameplay of such a fight is shown in Figure 16, where a player is prompted to do a yoga exercise to progress. The game shows how to do the exercise required through both images and text, and once completed deals damage to opponents.

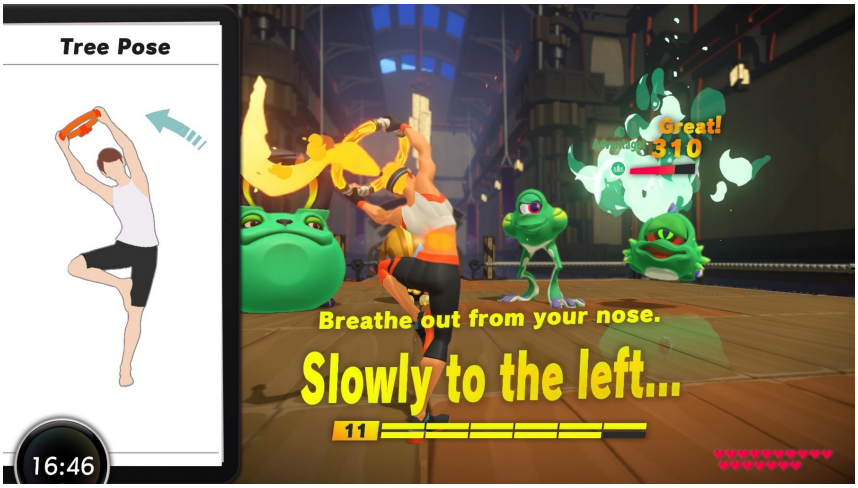


Figure 16: *RingFit Adventure* is an action RPG video game using exercise to fight monsters.

The activities promoted through the RingFit Adventure gameplay are known to provide health benefits such as muscle growth. Since its release, its potential use in physical therapy and training has been studied. In a 2021 research article by Takashi Sato et al. [37], the game was shown to provide physiological and psychological relief to patients with lower back pain. The study found that active use over eight weeks provided significant improvement in back pain and pain self-efficacy. A study from March 2022 by Yi-Syuan Wu et al. [38] suggests using RingFit Adventure as a tool to improve or maintain physical fitness for users involved in distance learning or those with a lack of exercise. In the study, the authors found that using RingFit Adventure over a period of four weeks improved its users' time on a 1600-meter run by an average of 19.79 seconds for women and 22.56 seconds for men. This shows the game's ability to provide tangible physical improvements given active use.

13.2 Beat Saber

Beat Saber is a Virtual Reality rhythm game developed by the Czech studio *Beat Games*. The game was released in early-access May 1st, 2018 on PC, and had its official release on the 21st of May 2019 on *Playstation 4* and *Windows*. Since its release, the game has been sold over 4 million times by February 2021 [39]. As shown in Figure 17, the gameplay revolves around cutting incoming

boxes to the beat of the music using in-game swords based on the VR system of choice's included hand-movement trackers. These boxes have an arrow on them that decides in which direction it needs to be cut, which forces the player to move in the desired way. Some boxes give a negative score meant as traps that the player needs to dodge, which forces the player to pay attention.

Figure 17: *Beat Saber* is an exercise game utilizing rhythm game mechanics.

Beat Saber has been used in different studies on exercise games and VR. A study on the motivational and physical effects of two VR Exergames [40] from Kivelä, Alavesa, Visuri, and Ojala published in 2019 showed a strong motivation to continue playing, and also found that after 10 minutes of play the users on average reached near 60% of maximum heart rate. The study recommends *Beat Saber* for aerobic exercise [40]. A study from the *Journal of NeuroEngineering and Rehabilitation* done by Erhardsson, Murphy & Sunnerhagen [41] used Beat Saber for rehabilitation and found that patients that invested more time in VR and Beat Saber, had achieved higher improvements in hand-eye coordination than patients with moderate or no use [41].

13.3 Zwift

Zwift is a mixed-reality game released in 2014 and used for workouts. It uses an Android and iOS application meant to connect to your exercise equipment such as a spinning bicycle or treadmill and uses the data from this equipment to move a character in the game that moves at the speed your equipment feeds it. It can also use speed sensors to estimate your power output if your equipment does not support exporting this data [42]. Figure 18 shows a user of a spinning bike with sensors that feed the video game. The game displays information such as how fast the player is going as well as their heart rate.

Figure 18: *Zwift* lets users ride a bicycle and race against other players.

With this, you can exercise on your own or compete in live races against other users. *Zwift* is one of the most popular bicycle exergame options on the market with hundreds of thousands of daily active users [43].

Several research papers have been written about *Zwift*'s usage of mixed reality for sports [44]. These articles focus on its application for exercise and mixed-reality sports. A qualitative study from May 2021 by D. Westmattelmann et al. at the University of Münster showed that *Zwift* was seen as a valuable and effective extension of and complement for training on a bike on the road. *Zwift* also provided more safety to its user than its analog counterpart, as traffic incidents and accidents such as losing traction and falling are impossible. The study shows that professional athletes appreciate the authenticity of some of the routes they ride, as it provides accurate practice before races [44]. This shows the potential to use games as a complement to sports that have a benefit for casual users as well as professional athletes in that field.

13.4 Wii Fit

Wii Fit is another exercise game produced and published by *Nintendo* released December 1st, 2007. This video game was developed for the *Nintendo Wii* console. Since its release, it has sold over 22 million copies making it the 6th most purchased *Nintendo Wii* game [45]. Similar to *RingFit Adventure* it includes a device to be used as a sensor for fitness activities. In this case, it is the *Nintendo Balance Board*, a balancing board users stand on that can sense weight and center of gravity. These functions are used for different activities such as yoga, balance training, strength training, and aerobics. The image shown in Figure 19 shows gameplay of how to use the *Wii Fit* platform to do exercises. The pressure plate is used in different ways to verify if users are doing the activity properly and increase the player's score based on that.

Figure 19: *Wii Fit* is an exergame where players use a balancing board to do different activities.

Wii Fit has been used for several research studies. One of its key potential uses is for the rehabilitation of balance. One study shows great responses to the use of Wii Fit for children with cerebral palsy, a non-progressive neurological condition that leads to motor impairments due to brain damage [46]. It has also been considered for its potential as a low-cost balance assessment tool, while it may not give as accurate results as professional equipment [47].

13.5 Pokémon Go

Pokémon Go is a mobile application developed by *Niantic Labs* and published by *Nintendo* and *Niantic Labs* on the 6th of June 2016 [48]. The game is an augmented reality video game where the in-game space is mapped to reality, so to move to a new place you must move there physically. It also uses your camera to artificially render Pokémon on-screen as if they were physically present. The goal is to walk around to locations where new pokemon are and capture them. The image shown in Figure 20 shows how the world is mapped using GPS data, showing real location data. There is also the aspect of reaching a pokemon and having to catch them using a Pokeball. These pokemon that get caught can also be leveled up and used to take control of "*gyms*", spots where the current controller is displayed to everyone in the vicinity as a token of skill. The game was a massive success, with over 1 billion downloads and 1.23 billion dollars in revenue after its release [49].

Figure 20: *Pokémon Go* is an exergame where you explore the world by moving around your local area and catching Pokémon.

There have since its release been done research studies on Pokémon Go and its effect on its users. A literature review by Alf Inge Wang (2021) has found 59 studies meeting review criteria that collectively suggest that Pokémon Go had an apparent positive effect on its users' physical and mental health [50]. This effect lasts as long as the user continues to play the game. The game makes its users commit to moderate exercise and users that play several times a week meet their recommended exercise quota given by the Norwegian Institute of Public Health as defined in Section 7. The reason users stop their activities with *Pokémon Go* is suggested to be due to slow progress and lack of variation and content [50].

A study by Wang from August 2021 shows the effects of Pokémon Go on various user groups [51]. Using 2191 valid responses, the study analyzed the physical activity level of users before and after playing the game. The study found that Pokémon Go drastically improved weekly exercise for users with low activity, where 63% of users went from having zero to three hours of exercise a week to at least four hours a week. The study also found that playing Pokémon Go improved its users' social activity. The game was shown the most substantial effect on male users who were unemployed and less physically active. This shows exergames' ability to provide positive change not only in physical exercise but in social activity as well. It managed to motivate groups who are hard to motivate to exercise and to be socially active.

13.6 Exermon

Exermon is a game developed by students at the Norwegian University of Science & Technology (NTNU) to create a new exercise game to increase strength. The name comes from the combination of the two words *exercise* and *monster*. The premise of the game is that the player chooses a monster to keep and level up through physical strength exercises. These are exercises such as push-ups, sit-ups, and squats, that are recognized using the mobile phone's proximity sensor and accelerometer. Based on the exercises and repetitions chosen the monster gains stats [52]. The game allows users to fight with these monsters against other players, where the users with the higher levels win.

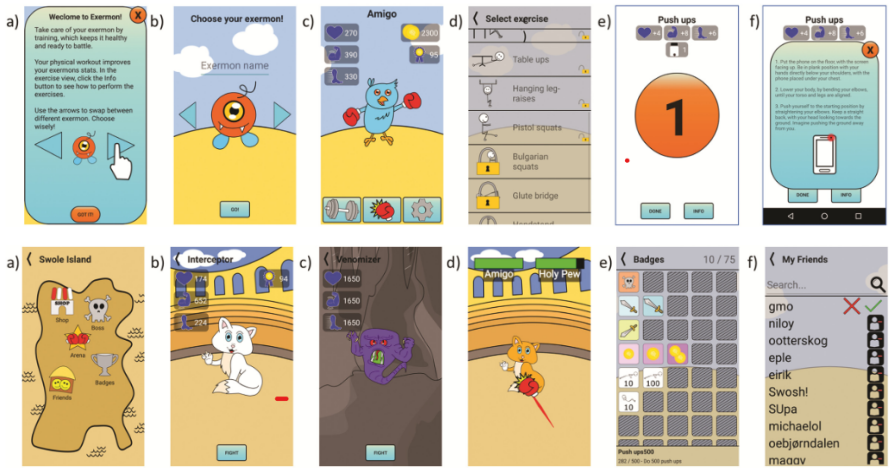


Figure 21: *Exermon* is a game where players raise a monster through exercise [52]

The result of a study on the *Exermon* game showed that entertainment and video games such as this can help increase motivation. The game was tested on 24 test subjects over two weeks, where the users responded to a questionnaire on the use of the game. The result indicated that while only some users saw physical improvements from the game, most found that it increased their motivation to work out [52]. Another interesting finding was that although the respondents who had a good exercise routine before did not increase the amount of exercise, the respondents who did not exercise before had an increase. Because of this observation, we can keep in mind how the difference in stamina and strength may impact how rewarding an exergame can be.

13.7 Pedal Tanks

Pedal tanks is an exergame made for the PlayPulse platform using the PlayPulse exercise bike. It was made as a master's thesis project by students at *NTNU* in 2015 aiming to create an exercise game with long-lasting entertainment and motivation value using gameplay mechanics from the mainstream gaming industry. The game lets you control a tank using the bicycle, and the gameplay loop is based on *Capture the Flag* (CTF). CTF is a game where two teams try to capture the other team's flag and bring it back to their base. In *Pedal Tanks* this is made possible by letting players control their tank's speed with the pedals and then shooting opponents [53]. Visuals of the gameplay are shown in Figure 22.

Figure 22: *PedalTanks* lets you fight against other players using tanks [53]

Pedal tanks aims to provide high-intensity interval training. To test whether their concept provided

HIIT, the students behind the game conducted a study and compared the results of their sessions with the heart rate curve of a high-intensity training session. What they found was that their results were similar to other high-intensity training exercises with the added benefit of gamification to increase motivation [54]. This meant that users that played *Pedal Tanks* actively over a longer period would achieve improved fitness.

Another study from July 2020 by B, Jonathan et al. had its main focus to find out if providing high-intensity exergame to sedentary adults would improve their cardiometabolic health [55]. A group of 52 inactive users participated in the study, where approximately half of them got free access to the PlayPulse exergaming platform within a period of six months. The rest was told to continue their normal routine. The results from this research show that there was no significant difference between the two groups, and the authors concluded that giving free access to the exergaming platform was not enough to improve cardiometabolic health. The authors of the article conducted another study in August 2020 [56]. The purpose of the study was to find the long-term effect on health when inactive adults got access to a high-intensity exergaming platform. This study also consisted of 52 inactive adults who were given access to the PlayPulse exergaming platform for six months, where the participants could choose how frequently they wanted to use the platform on their own. The results show that the participants enjoyed using the platform. However, the frequency of exergaming was low, and the participants were not motivated enough to continue playing regularly.

13.8 Pedal Kart

Pedal Kart is a master thesis project created by Magne Skjæran in 2018 [57]. The game uses the PlayPulse exercise bike and platform and aims for high levels of enjoyment and long-term motivation with a focus on utilizing game design elements from the mainstream gaming industry. The biggest inspiration for gameplay loop and design comes from *Nintendo*'s *Mario Kart*, in which players race around a map using collectible power-ups to gain an advantage over opponents. The game is illustrated in Figure 23.

To ensure that their research goal was met the team tested the game on a set of users to ensure that the gameplay loop gave tangible results in exercise as well as provided motivation to continue. A set of test users were asked to use the game over several sessions and the results that came from a questionnaire at the end of the period suggested that users found a higher level of motivation when the exercise was gamified. It also gave users the intended exercise. It is however hard to make conclusions, as there were only four test subjects, so more research would be required to increase the reliability of the data.

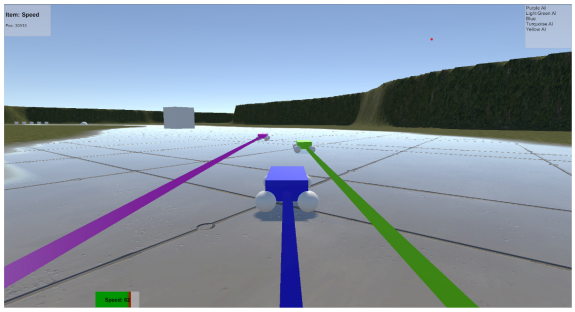


Figure 23: *PedalKart* lets you ride a kart against other players around a track [57]

13.9 Lane Rider

Lane Rider is an exercise game that was made by students at *NTNU* in 2020 by Emil Petter Schrøder & Øystein Hammersland for a master's thesis on the benefits of exergaming [58]. The game works similarly to mobile games such as *Temple Run* and *Subway Surfers* where you control a character and dodge obstacles in different lanes. An example of this is shown in Figure 24. The

less time the user takes to complete, the higher the score. This is mixed with multiplayer in which you race against other users, where the user who finishes first three times wins. To reduce the time it takes to finish the game, you can collect and use different power-ups.

Figure 24: In *LaneRider* the goal is to dodge incoming obstacles through activity [58]

The game was tested on 16 participants with various exercise backgrounds. The experiment tested its users over three sessions and collected results on motivation, enjoyment, and social interaction, as well as physical results using heart-rate monitors. The feedback on the questionnaire showed positive results in enjoyment and future motivation to continue exercising. For the exercise results, the data collected indicated that the exercise led to too low heart rates to be considered high intensity. Still, the team hypothesized that the equipment might have given lower values than reality. It did however result in moderate exercise for the test users.

13.10 Summary

After evaluating several different exergames it became clear that exergaming does not have many limits on what the concepts can be. Examples of adventure games like *RingFit Adventure* and rhythm games like *Beat Saber* provide exercise through very different game mechanics. These games do a good job of providing motivating factors to make up for the exhaustive nature of exercise gaming, such as audio through music and ambiance, and visual feedback like particle effects and physical mapping of activity. Concepts for *PlayPulse* however, often struggle with long-term motivation which will be important to be aware of while designing. Also, the effect of exercise only lasts as long as they play the game, as once they stop playing the game regularly they also stop exercising. The overall exercise motivation is connected to the motivation to play the game, which heightens the need to focus on retention.

Specific game elements and features from the different exergames mentioned in this section will be further analyzed in Section 14.

14 Evaluation of Existing Exergames

This section aims to identify positive and negative traits from games evaluated in Section 13. This will allow us to recognize features that may be worth considering adding to our project, as well as potential pitfalls that previous games have identified and perhaps solved. A key aspect of making an exergame like this is the fact that the motivational barrier is higher than usual as playing the game requires effort. Requiring effort is a prerequisite for it to give useful exercise, but also means the user needs to invest more into a session. Thus giving users a strong reason to play, especially once the novelty factor runs out is important.

A great example of long-term investment is how *RingFit Adventure* provides motivation. In *RingFit Adventure* they make use of RPG elements to give players an overarching storyline. Written well, this gives users interest in progressing in the story and unlocking new levels. Another interesting feature used in *RingFit Adventure* is how it represents the user's activity. The character in the game is animated to replicate the exercise movements the player has to perform. This makes it seem like fantasy is intrinsic, as your actions directly influence the controller as explained in Malone's model in Section 8.3. When you do an exercise, such as a squat, the character does a squat as well. To make it clear what muscle groups you activate the character in the game flames up in the muscle groups you are exercising. This is a very visual and dynamic way to display important information and can give players motivation to continue, as they know what muscle groups benefit from each action.

Beat Saber also does a good job of motivating users to continue. It also has an intrinsic fantasy where you swing your arms to control the swords in your hands to cut the blocks coming at you to the beat of the music. The game shows another interesting way to provide motivation: *Audio*. The game makes use of music to motivate players to play correctly, as the players feel satisfied when cutting the boxes to the beat. This is how most rhythm games motivate their users and translates well into exercise.

Games that are more applicable to our project are the games *Lane Rider*, *Pedal Kart*, and *Pedal Tanks* which are also made for the *PlayPulse* exercise bikes. All of them do a good job of providing exercise, where some target HIIT better than others. A key aspect to learn from is designing the gameplay to meet our specific exercise goals. If we wish to achieve high intensity, we need to find a gameplay loop that translates well into the same activity curve as for example running a 4x4 stamina exercise.

Something to note from many of these games is that one of the reasons users stop interacting with the game is due to a lack of long-term motivators. This can come as a consequence of lack of content, slow progress, or no incentive to keep playing. For exercise games, longevity is a very important trait to ensure physical results, so this is something to keep in mind.

15 Genres

When creating a video game, the genre of choice has a massive impact on what kind of game is made, which features are required, and which audience is targetted. This is why it is important to consider who the target player is for the exercise game. A sports game may be more appealing to already-exercising users that are interested in sports. For this project, the target audience is young adults that lack the motivation to exercise. This section will be looking at different genres that might appeal to this demographic and how to exercise gaming could be applied to the genre.

15.1 Sports

The sports genre includes games that simulate physical sports such as Basketball, Football, Swimming, Tennis, Boxing, Bowling, etc. Most games within this genre have been recreated from the original sport. Examples are *FIFA* (Football), *NBA 2K* (Basket), *PGA Tour 2K* (Golf), etc. A screenshot of the game *FIFA* is shown in Figure 25. Other games include *Rocket League* and *Tour de France 2021*.

Figure 25: *FIFA 2021*, a football simulation game [59]

Rocket League is a competitive and cooperative game where the players control cars in a football stadium. The goal is to work together with your team, get the ball forward and score. *Tour de France 2021* is a simulation sports game, where they recreated all the Tour de France stages, where the players have the possibility to be either the cyclist or the manager.

Both of these games can be recreated as exergames for the *PlayPulse* platform. Rocket league for instance can be transformed into an exergame by using the buttons on the steering to move and change direction, and the speed of the car can be changed based on how fast the player rides the bike. The downside of this concept is that it needs many players to generate a team if it does not include AI players, which is further mentioned in Section 16.2.2.

Tour de France, the game, can be recreated such that the speed of the bicycle in the simulation is based on the speed of the player while riding. A way to vary the game so that it produces a session of HIIT is by, for instance, having uphills and downhills, and sharp turns that force the player to break. It can also be designed to involve a career mode where they progress on their own and multiplayer modes, where the players compete with each other.

15.2 Racing

Racing games are video games where the player takes part in a racing competition. This type of game can be everything from real-world race to fantasy as long as it is a racing competition. Some examples are *Forza* illustrated in Figure 26, *Mario Kart*, and *Temple Run*.

Forza and *Mario Kart* type of games can be recreated as an exergame by using the pedals as accelerators. The same goes for Lane Rider type of games as *Temple Run* and typically racing games in general.

Figure 26: *Forza Horizon 4*, a racing game [60]

The main problem with typical racing games to fit into HIIT is that the goal is to be the fastest, which means that the players will give their all the whole time. One way to solve this is by adding an upper limit on either the speed or acceleration that will give a disadvantage when exceeded. These techniques can be found in games such as Wii Sports, where hitting a too powerful stroke in golf sends the ball flying a random direction. Another type of racing game is capture-the-flag. This concept is about two or more teams having a flag each, where the goal is to catch the other team's flag and get it safely back to your base. It is possible to match the HIIT graph by using the accelerometer and clever game flow design that promotes periods of rest and activity.

15.3 Board-Game

There is a genre of games that takes the popular board-game format and digitizes it. These games use a map made up of tiles that the player can traverse to reach a goal, and how many times a player can move at a time is decided by dice. Some of these games are direct digital translations of actual board games such as *Monopoly*, illustrated in Figure 27. In *Monopoly*, players move around a square and attempt to make other players go bankrupt by buying up property that players have to pay for landing on.

Figure 27: *Monopoly*, a popular board game [61]

Most of the video games of this genre are however unique to the digital platform. For these, there is often a minigame aspect on top of the tabletop game. After every player has thrown the dice in a round, the players play a minigame that affects the state of the game. This could be through giving rewards such as coins that could be spent to gain an advantage or remove lives from other players until they lose. Examples of games of this genre are *Mario Party* from Nintendo and *Pummel Party* by Rebuilt Games. These minigames are different short challenges that players play against each other. These are usually simple and easy to understand, and the win condition is clear from the beginning. Examples of these challenges can be climbing a tree by pressing a button the fastest or pushing other users off a cliff.

There are examples of these games being able to be used for exercise. *Mario Party* uses physical input using the *Wii remote* or the *Switch Joy-Cons*. The minigame activities force users to do a physical activity, and due to its short but competitive nature, it makes users put in a lot of effort and can raise the players' heart rate. If balanced correctly this can be used to achieve HIIT. By reducing the time in-between minigames and increasing the time rounds take, games like this can provide natural activity and rest periods.

15.4 Role-Playing Game

Role-playing games, often shortened as RPGs, are video games where the players take on characters, or roles, in a fantasy setting. These roles are acted out or controlled by the players and used to progress in a story. This is a well-known genre that allows a lot of creative freedom to the developers and players and includes titles such as *Bethesda*'s *The Elder Scrolls: Skyrim* shown in Figure 28, and *CD Projekt Red*'s *The Witcher* series. These are games where the player controls a character in a medieval setting, using abilities such as swordplay and magic to progress in a narrative. The games do however not have to be medieval, there are also modern and futuristic settings. The key aspect is the interactive playthrough of a narrative.

Figure 28: *Skyrim*, a popular RPG [62]

This can also be applied as a tool to motivate in an exercise game setting. This is exactly what Nintendo's *RingFit Adventure* does. As mentioned in Section 13.1, *RingFit Adventure* is an exercise video game for the Nintendo Switch using a ring as a controller. The player takes on the role of the Ring Fit Trainee, who along with the anthropomorphic controller named Ring to take down the dragon Dragaux. There is a work-out related storyline driving the progression of the exercise forward, introducing new exercises as abilities during the game. These kinds of narrative mechanics can be applied to other systems as well. Writing a setting that allows for high-intensity exercise using the *PlayPulse* bike as a narrative component could promote long-term motivation.

15.5 Survival Game

Survival games are an action-game sub-genre where the goal for the player is to survive as long as possible. In these games, the setting and world are against the player, and the player has to actively improve their situation to avoid dying. These games are often set in a post-apocalyptic setting, such as in games like *DayZ*, where the player has to manage his or her character's health by eating and drinking food but also surviving zombie attacks by running away or killing. A key aspect of these games is finite resources. There are not enough resources for all players to survive, so to win the player must collect more resources or eliminate other players. There are also survival games that focus more on fighting, such as *Battle Royale* games. In these games, players collect and improve their equipment and eliminate other players on an increasingly smaller map until there is one team or player left standing. Famous *Battle Royale* video games include *Fortnite* illustrated in Figure 29, and *Apex Legends*. There are also survival games based around surviving waves of opponents until you can no longer stay alive. This includes *Call of Duty: Zombies* and *Left 4 Dead*. In these games, the player is locked within a limited space and attempts to survive as many waves as possible while the opponents grow stronger and stronger, and unlock better equipment as the player gets further into the game.

Figure 29: *Fortnite*, a popular battle royale game [63]

There are not many games aimed at exercise that make use of the survival game genre. It could however be achieved by using the wave-based survival with exercise mechanics. The rounds of attacking opponents could be used for high-intensity exercise and periods between attacks used as rest. This would continue to escalate until the player's stamina could no longer keep up and the player dies. This would make for a natural way to promote exercise until failure.

15.6 Rhythm Game

Rhythm games are games with mostly music as the main topic and challenge the player's sense of rhythm. Normally the game is focused on either some kind of dance or simulated behavior where the player has to press some buttons that correspond to what was shown on the screen. The key feature of rhythm games is the focus on timing and, as the name suggests, rhythm.

The way users input and interact with the system varies from game to game. Some games attempt to replicate the feeling of using actual musical instruments, where you use a physical peripheral that may or may not be able to produce sound. Some games support using real musical instruments, while most create a replica that simplifies the input. These peripherals are used to give the game input to the beat of the music. Some examples of rhythm games using physical peripherals for input are *Rock Band* and *Guitar Hero*, shown in Figure 30. Both of these use replicas of guitars with buttons instead of strings that users use to play with.

Figure 30: *Guitar Hero*, a popular rhythm game [64]

Other games use keyboards, mice, or other computer input sources such as tablets to play. This includes games like *Osu!*, a game where you trace a pattern on screen using a computer mouse or tablet while pressing keyboard buttons to the beat of the song. This game uses user-generated tracks and has a community that creates intricate challenges to songs. Rhythm games do not however have to require complex input. This can be seen in for example mobile games. As of October 2021, there are two rhythm games among the top 25 most popular free games on the Android Play Store in Norway, *Beatstar - Beatstar - Touch Your Music* and *Magic Tiles 3*. In these games, players tap and swipe along lanes as boxes come down the screen. There are also other classic mobile rhythm games such as *Geometry Lite* that simply use tapping for jumping.

Finally, there are rhythm games that use physical movement for input. This means that the player needs to move in a certain way to the beat of the music. The game needs to have a way to recognize the player's movement and see if it fits the requirement. *Just Dance*, a rhythm game series from Ubisoft uses different inputs such as *Nintendo Wii* or *Playstation Move* controllers, and *Xbox Kinect* cameras to make players dance a specific dance move as requested, and gives a score based on the accuracy of the move. Another game, *Beat Saber*, as mentioned in Section 13.2, uses hand trackers and virtual reality to make the player cut boxes to the beat of a song. These games also work as exergames as they force the user to get aerobic exercise while playing.

15.7 Summary

This section goes into detail on how exercise games can be implemented in different genres to achieve different goals. The genre of a game plays a major role in which target audience will find the game interesting. Each genre has its own defining traits that require extra attention, such as rhythm game's focus on music and tempo, and role-playing games' focus on story and fantasy, but this does not mean that you cannot have exercise games in genres that do not typically seem targeted towards exercise. There are possibilities within any of them to create an entertaining gameplay loop using the *PlayPulse* exercise bike that provides high-intensity interval training, as shown by the abundance of different exercise games already on the market using vastly different genres.

16 Features

Features in a video game help shape what the game is about. A feature is a defining recognizable aspect or system in a game that provides something to the experience. Implementing certain features puts requirements on how the game should work in order to most effectively utilize those features. This section looks into what features games implement to apply theory for motivation, rewards, social interaction, and feedback.

16.1 Motivation

To get a player to invest a lot of time in a game, they need to have the motivation to continue. Not every second of every play session will be as enjoyable, especially for more difficult games. This is when motivational features help keep players interested.

16.1.1 Rewards

One way to motivate users is to offer them rewards. This means giving them items of value that improves their experience with the game. The promise of improvement motivates players to achieve the requirements. These rewards can be given at different times and rates based on what you wish to promote. *Daily Login Bonuses* is a reward system built around giving items to players that play the game at least once every day. Usually, these daily login bonus systems promote a streak of consecutive days played, where rewards increase in value based on how many consecutive days players play. These bonuses are meant to motivate players to play every day, without a requirement on the amount.

There are other bonus systems that reward time spent over consistency. These usually use leveling, a system where players rise in tiers based on collecting experience points in a video game. These experience points the players collect are usually based on time invested and quality of play. Once you reach a new tier you are given rewards, where rewards usually increase in quality the higher the level is. This system promotes the investment of time. Some games employ a *Battle Pass* system that builds upon this and adds a time-sensitive element. These systems have rewards only available for a set period of time, which means players have to invest a certain amount of time during this period to be able to unlock these rewards. After the period ends the player's progress is reset and new rewards are used for the next period. This promotes a shorter-term focus on involvement, but over and over again.

16.2 Social Aspect

The social aspect of a game is very important and has many benefits, and more and more games focus on this part. This helps the player connect with other players with similar interests, and to get to know new people. A game can also be a platform where friends and players can keep in touch. The social aspect can in addition increase the emotions and feelings of the player. This can, for instance, be done by including multiplayer features in the game.

16.2.1 Live Multiplayer

Within the game, it is also possible to add live multiplayer functionality. This can be in the form of either competition or cooperation or both. Competition between players and especially friends can contribute to an increased motivation to win, which again will result in more effort given to the game. Cooperation has the same effect, where the players can hype each other up because they have to work together to win.

16.2.2 Pseudo Multiplayer

In addition to live multiplayer possibilities, it is also possible to implement functionalities such as AI-players. AI can be used in many different ways. For instance, bots, who act similarly to other human opponents. AI players can also be neutral toward the players or act as the players' teammates. This feature is used in popular games like *Mario Kart Tour* and *Fortnite*. Mario Kart used AI players to race against you. *Fortnite* does the same and includes bots in their game. However, when checking out their names, it can seem like they are real people. For instance, *Fortnite* uses bots when playing for the first time. This is to help the player gain the experience and skills needed to start playing with real people.

It is also possible to record the gameplay a user does and save it to be used as a comparison against themselves or others. This feature often referred to as *ghosts*, lets players race against previous attempts, which gives the impression of multiplayer and challenge without the need for live competition. Often this is used to show the best result a player has done, and what to beat in order to achieve a new personal record.

16.2.3 Leaderboards

A leaderboard is a ranking system where your results in a game produce a score that is compared to other users, often all other players of the game. This means that you can see who has gotten the greatest result in the game. This promotes competition without having to directly play with others. It also has few restrictions on game design, as the only requirement is having a way to give results a score. Adding a leaderboard is an easy way to add a competitive element without requiring the game to be designed for multiplayer purposes.

16.3 Feedback

A key aspect of getting players invested in a game is having feedback. If a player does not get feedback on actions, it will feel like the action did not matter. If your actions do not matter, then there is no longer an incentive to play. Giving feedback on actions will make the player feel their actions have weight. Feedback can be given in several ways, including visual effects, haptic feedback, audio cues, and in-game actions.

Visual feedback is done through reactions such as particle effects or changes in the user interface. An example of this would be how *Ring Fit Adventure* gives feedback on your exercise movements. When you for example squat, the muscle groups that you activate light on fire on your character and show bright colors. This gives the player acknowledgment of which muscle groups you will improve from this activity, as well as maps the player's experience of strain on muscles to their character, which helps increase the immersion of the Ring Fit Trainee character you control. There are also particle effects such as gusts of wind when you do certain exercises, such as contracting the ring fit controller, that exaggerate the impact of the exercise and makes the action more satisfying to the player.

Haptic feedback is physical feedback through the controller. If you play a game on a modern console *(PS4, PS5, Xbox One, Xbox Series X)*, your controller has the ability to shake. Game developers use this to give feedback to the player. An example would be standing near an explosion in a shooting game. To give the player a sense of impact from the explosion, the camera in the game and controller would shake for a moment. This helps increase immersion as actions in the game have a physical impact on the player, reducing the divide between reality and play.

Audio responses are also an important tool to give users feedback. Audio cues can be used to increase the impact of actions, such as explosion sounds or bullet sounds when a gun is fired. In reality, there are very few actions that do not produce any sound, so to maintain immersion important actions should play a tune. This includes interaction with the user interface.

A very different kind of feedback that should be used in video games is information. Players invest

time and make choices when playing video games. This means these choices should have an impact on how well the player does in the game. The player should get feedback on whether or not they are fulfilling the requirements the game sets for the player's goals. This information needs to be tangible and comparable in order to be able to learn and improve.

16.4 Replayability and Progression

One of the more challenging parts of games is to get the players to play the game over a longer period of time. There exist multiple ways to increase the possibilities for replayability, and some of them are mentioned below.

A way to increase replayability is by including multiple ways to reach the overall goal. This way, the player has the possibility to choose the way they want to play. Multiplayer functionality can also increase replayability, among other things, because the players can play with friends or other real players, and the challenge will always be different. It is also possible to include different modes. For example:

- Single and multiplayer mode. Multiplayer mode can be divided into both collaboration and competition mode.
- A mode where the player has to try to get the highest score or clear the goals within a time amount.
- Play as long as you can in one round.

This way it can motivate the player to try out multiple modes, and continue playing the game. As mentioned in Section 8.3.1, hidden information is a strong way to keep the player playing. The curiosity will also increase and the player wants to know what happens next, which can increase the player's motivation to play further. In addition, including randomness can make the game more unpredictable for the player.

16.5 Summary

This section primarily focuses on which features will fit into this project, and alternative ways to implement them to design an exergame with good flow. Elements such as reward systems, leaderboards, and feedback are important elements to increase the motivation to play the game. In addition, focusing on the social aspect as including the possibility to play with your friends and other online players can increase the emotional involvement, and the level of challenge will get more unpredictable. As seen from the research results on the different exergames in Section 13, designing a game that will be played in the long-term is a big challenge. To make the game more replayable, this section also mentions different design methods that can help to decrease this challenge. Among other things, this can be done by including different modes, adding unpredictability, and designing the game such that it is possible to reach the goal in multiple ways.

17 Potential Concepts

While coming up with concepts that could be used to generate an enjoyable high-intensity interval training session, the main focus was evaluating these ideas through a set of requirements. These requirements are as follows:

- *Enjoyment:* How likely are players to enjoy playing this game?
- *Longevity:* How likely is the game to be able to motivate players over a longer period of time?
- *Complexity:* How difficult would it be to implement? Would the team have enough time to implement the game in a satisfactory manner?
- *Exercise Quality:* How much exercise will players get out of the experience?

Once a concept was created, the idea was evaluated against others based on these requirements, and the concept with the highest overall results was selected. This chapter discusses some of the alternative concepts that were considered but ended up not being chosen.

17.1 PlayPulse Party

This concept comes from the analysis of the board-game genre in Section 15.3. Inspired by games such as *Mario Party* and *Pummel Party*, it is based around progressing through a board game like a map using dice to roll for how many steps to progress towards the goal. In between rounds, players would compete in minigames using the *PlayPulse* bike as input for different kinds of minigames. Another source of inspiration for the minigames in particular was Nintendo's *Wario Ware* franchise. The minigames would give the players the high-intensity exercise required for HIIT, while the board-game section would serve as a resting period until the next minigame section. This would serve as a natural interval training session if the time spent in each aspect is balanced correctly.

Based on the criteria, this idea if implemented well would score high on enjoyment. There is natural progression due to the board-game aspect, and variety through different minigames. The minigames could be everyone competing, or players collaborating to meet a goal. This means each session would be completely different. The biggest issue with the concept was the complexity. It would require a lot of work to create a game with enough content to sustain longer periods of motivation, which the team does not have the resources to deliver on.

17.2 Bike Racer

Figure 31: *Bike Race*, a game where you control a motorbike through complex maps.

Another concept that could be proposed was a time-based race game inspired by the *iOS* and *Android* app *Bike Race*. In this game, the player would control a motorbike through complex maps using the pedals to control speed and other input to control rotation. Figure 31 shows gameplay of *Bike Race*. A key element of this game concept is that controlling your speed to make jumps is very important. This means that pedaling as fast as possible is not the solution, and instead, trial and error of figuring out the perfect speed to maneuver through the map is required.

Based on the criteria, it was assumed that enjoyment would score high, as it has a learning curve and precise control is required in order to complete the game. It would not be difficult to create, as once the bicycle controls work, all that is required is to make two-dimensional maps. The lack of variety does however indicate an issue with providing longevity, as it would be difficult to provide variety besides new maps and visual options.

17.3 Deadline

This concept is based on the racing genre in Section 15.2, and inspired by the movie *TRON Legacy* and a minigame called *Deadline* from *GTA V Online*, shown in Figure 32. The game concept can be explained as a multiplayer game, where each player gets one character that sits on a bike. They will be launched on a map, where the main goal is to kill the other players. This can be done by either pushing them off the ground and map or by having them hit your "laser". A "laser" is a temporary light trail that follows the player's bike for a limited distance. When a player makes contact with this trail they explode. The pedals are used for acceleration, and the buttons on the steering wheels turn left and right. To make sure players achieve HIIT, the game can be designed so that players explode if their speed drops below a set level. This forces the players to constantly stay active. This concept can either be played as a multiplayer competition game against friends or other online players, but also in a single-player mode against computer AI.

Figure 32: *Deadline*, a game where you control a motorbike and try to kill the others.

By an evaluation of the concept based on the criteria, it seems like the concept scores high on enjoyment. The complexity of the game is manageable, and the quality of the exercise could be good. However, the replayability of this game is uncertain. Different worlds, maps, unlocking new types of bikes and characters, and multiple levels of challenge, can help to increase replayability.

17.4 WaveRider

WaveRider is another proposed concept that fits into the rhythm genre. The game is similar to *Sing Star*, but instead of singing in the correct pitch, the player has to reach the different bars by using the pedal input on the *PlayPulse bike*. In addition, the player has to press different buttons on the steering in a given tempo, similar to the game *Guitar Hero*.

This concept appears to score high on enjoyment, and the complexity of the implementation is manageable. The game can lack replayability, but by including enough songs, creative animations,

and sound effects, it can be suited to play for a long period of time. It is possible to achieve high-intensity interval training by creating the songs in a way that each song will be a high-intensity interval, with a break in between the songs.

17.5 Evaluation

After completing an evaluation of each of the concepts, it seems like all of them get a high score on enjoyment. It is very likely that many players in the selected target group would play the game concepts.

Most of the games do also have the possibility to score high on the second criteria, longevity. However, PlayPulse Party requires a high variation of minigames to not get bored for the players. Bike Racer can get boring because it is difficult to implement variety. Deadline and WaveRider are also concepts where the player can get bored over time, but including a multiplayer mode can motivate the player to continue playing.

The complexity of the implementation of the concepts varies. Playpulse party needs a high variation of minigames which makes it complex to implement. Bike race, deadline, and WaveRider on the other hand are possible to implement, and the complexity is not very high.

The last criteria is exercise quality. All the games get an overall good score on this part because it is possible to design the game in a such way that it fits into high-intensity interval training.

The results of the analysis are shown in Table 2. The analysis of the concepts was used to generate comparative numbers on a scale of 1 - 5. All the games may be used to create games with, for example, strong longevity, however, the numbers are used to compare concepts against each other. This means a score of 1 does not mean that the concept is insufficient in this regard, but rather that it is severely lacking compared to other concepts in this requirement.

Concept Title	Enjoyment	Longevity	Complexity	Exercise Quality
PlayPulse Party	5	4	1	4
Bike Racer	4	2	5	3
Deadline	4	2	5	4
WaveRider	5	3	3	5

Table 2: A table comparing the results of the different concepts based on Enjoyment, Longevity, Complexity, and Exercise Quality on a scale of 1 - 5, the higher number the better.

Overall, the implementation time is crucial, and PlayPulse Party is therefore not an option. Of the other three concepts, *WaveRider* was the most appealing concept based on the results in Table 2 and was therefore chosen as the final concept.

Part III

Design and Implementation

This part describes the final game prototype. It explains the gameplay loop as well as the features used, the theory applied to make decisions, and a section on how the development process went.

18 Game Concept - WaveRider

The chosen concept can be summarized as a “rhythm game focusing on matching varying activity levels through pedaling to a beat”.

18.1 Gameplay

The core mechanics of the game provide the foundation for the experience that the players could get. The gameplay loop for this project is based on varying speed input using the *PlayPulse* bike. The game provides players with a set of songs and a set of difficulties within these songs. Based on experience and stamina level the player chooses an appropriate song and difficulty level. The player starts at level 1 and can grow this level through gameplay.

18.1.1 Match Cadence to Goal Activity Rate

Once a song starts, players play by matching the cadence, the pedal revolutions per minute, to a set level that changes throughout the song. The more accurate the player gets to the goal cadence, the higher the score gets. This means that the players have to pay attention to the flow of the song and what cadence rate the game wants the player to do next, then match it at the rate specified. If the player is cycling at a cadence different from the one the game wants, parts of the instruments fade out to indicate inaccurate play.

18.1.2 Quick-Time Events

While playing through a song and trying to match the activity rate the song aims for, prompts for other inputs appear on the screen. This means that players need to focus not only on matching the beat but also on what input is shown on-screen. This works similar to how some other games provide a boost if a second input is used, such as the whammy bar on the guitar in Guitar Hero. This can be done to give more variation to gameplay, adding different results in a song such as bonus score periods based on whether or not players manage to correctly hit the alternative input.

18.1.3 Result-Based Score

Once a song is complete, the player gets a score and can see how accurate their play has been. This score is used for a scoreboard where the player can see how their results rank among their own attempts. The player also receives experience points in order to level up, and when level ups are achieved, the player unlocks new songs. This provides the game with the pacing of content, allowing for users to have continuous progress while playing the game.

18.2 Inspiration

The game concept is designed with inspiration from multiple similar games, which will be explained further in this section.

18.2.1 Sing Star

SingStar is a karaoke game developed by *London Studio*, for the Sony PlayStation platform. The game includes a series of songs, where the goal is to sing the selected songs in the right pitch and tempo. The game helps the player to sing correctly by including bars that visualize the correct tune, as shown in Figure 33. In addition, it includes a reference on the tune of the player, and the combination can help the player to sing more correctly by adjusting their tune higher or lower.

The lyrics are also shown at the top of the screen. The research project uses the visualization of tone as vertical levels in SingStar, except in our game they represent activity levels achieved using the PlayPulse bike.

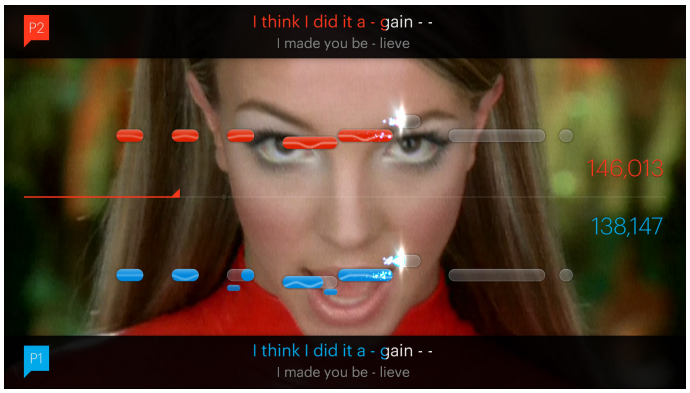


Figure 33: *Singstar*, The bars represent the right pitch, and the player has to aim as near this bar as possible [65]

18.2.2 Smule: Karaoke Singing App

Smule is also a karaoke game similar to Singstar, except only available on smartphones. This application includes features like singing karaoke, creating recordings and music videos, and also exclusive features such as the possibility to perform with popular music celebrities. It is possible to sing solo, in a duet, or in groups. An illustration of the karaoke page is shown below in Figure 34. Similar to Sing Star, it scores players based on the tune of singing and displays bars that show current and intended tone. As explained in Section 18.2.1, the bars are used to represent goal activity levels during the song, and visual effects like sparkles can be used to represent accurate play.

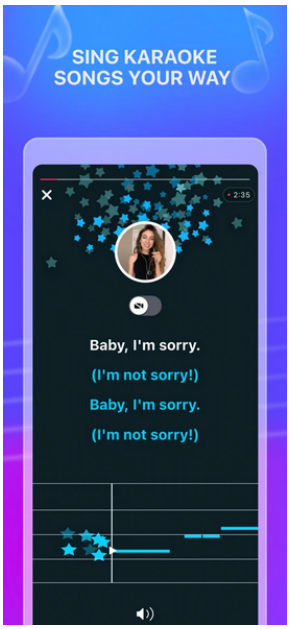


Figure 34: *Smule* [66]

18.2.3 Dance Dance Revolution

Dance Dance Revolution is a series of dance arcade games produced by *Konami*. The first model was released in Japan in 1998, then later in Europe and North America in 1999. Players press buttons on a dance platform to the beat of the music. These systems have been continuously improved upon, and the most recent version came out in 2020. The research prototype makes use of the difficulty system from the more recent editions of these games, where each song has several playable missions, with different difficulties. The difficulty is ranked from 1 being the easiest, then a gradual increase in difficulty with higher numbers.

18.2.4 Guitar Hero

Guitar Hero is a video game series developed by the studios *Harmonix* (2005-2007) and *Neversoft* (2007-2010). It lets the player use a controller shaped like a guitar and play to the beat of licensed music. The WaveRider prototype takes inspiration from the visual aesthetic of representing the game through a concert. Using a concert setting as a background of the game gives a stronger impression of the correlation between gameplay and music. Notes also are misplayed when the player misses the timing, which is another feature that is included, where playing inaccurately will worsen the song quality playing through changes in pitch or speed.

18.2.5 Rock Band

Rock Band is a video game series developed by *Harmonix*, the original studio behind *Guitar Hero*. Rock Band is a game where the player matches different input to songs by using physical controllers, however unlike *Guitar Hero* where the player plays on guitars, in *Rock Band* the player also has the option to play with drums or to sing. These can be combined so a group of players plays different instruments in the same song together. The prototype uses something similar, where players together control the power output, which means they have to cooperate to get the highest score possible.

18.3 Summary

WaveRider is a rhythm game using the pedal cadence of the bicycle as input. The player controls an icon moving up and down on the screen based on how fast the player is cycling. The songs provide indicators showing how fast players should be riding at specific times and the player is given a score based on their accuracy. The game takes inspiration from titles such as *Sing Star* and *Guitar Hero* and applies the game concept to exercise gaming. A video of the implemented game can be viewed on *YouTube* using this link: https://youtu.be/ZE00xiponFg.

19 Game Design & Prototype

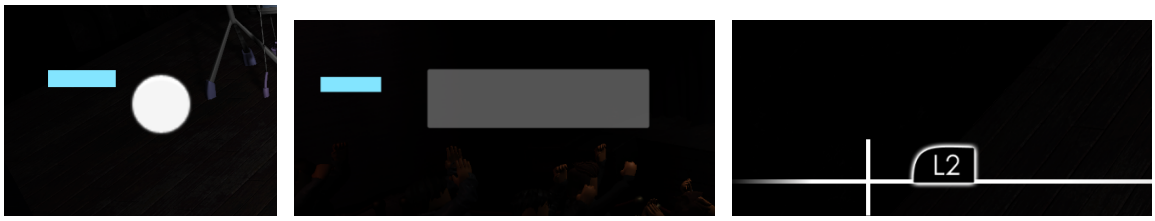
The core mechanics of the game provide the foundation for the experience that the players could get. The gameplay loop for the game is based on varying speed input using the *PlayPulse* bike. The game provides players with a set of songs and a set of difficulties within these songs. Based on experience and stamina level the player chooses an appropriate song and difficulty level. The player starts at level 1 and can grow this level through gameplay. This section will describe the gameplay features included in the research prototype, as well as show the final views of the different states of the game.

19.1 Core Gameplay

The gameplay is similar to other rhythm games like Guitar Hero and SingStar in its gameplay structure. The core of the gameplay experience is simple: The player controller, the UI icon representing the player, moves up on the screen when the player increases their cadence; the rate of spin on the pedals. If the player slows down, the in-game controller goes down. Meanwhile, the song is playing, and a canvas filled with different input notes move toward the controller. When a note on the canvas reaches the player controller's horizontal position, a score is calculated for that note based on how accurate the player was. The score calculation varies based on input note type.

19.1.1 Inputs

The game features three different types of notes that the player has to time correctly. These either behave differently or use different input methods. The UI used for these inputs is found in Figure 35.



(a) Single Point Input (b) Drag Input (c) Button Input

Figure 35: Three different types of input: *Single Point Input*, *Drag Input* & *Button Input*.

All of the input types have different ways of calculating scores but follow the same point structure. Each note can award a total of 100 points if they are achieved perfectly. The less accurate the player is the lower the points awarded are calculated. If the score equals the *"Fail"* point type, the awarded score is set to zero. Table 3 displays the range of point types and their required scores. Scores are clamped between zero and 100 to avoid potential negative scores.

Point Type	Score (>%)
Perfect	95
Great	80
Good	60
Ok	30
Fail	0

Table 3: The correlation between calculated scores and the awarded point types.

When a score is applied and a point type is calculated, the game shows a visualization of the point type in order to give feedback to the player on their accuracy. The images are shown in Figure 36.

Figure 36: Based on the accuracy calculated by notes, the player is awarded scores.

Single Point Input
Single point inputs are the simplest and most used input notes in the game. The user interface icon for this input is shown in Figure 35a. These are single points with a given timestamp and cadence rate. At the given timestamp, the game checks the player's cadence and compares it with the given value. The only factor used in calculating the score is the offset between the player's cadence and the input's cadence. The activation of the input happens automatically. The formula used for score calculation is as follows:

$$Score = 100 - |playerCadence - goalCadence|$$

Drag Input
The drag input type is based on average accuracy over time. These inputs define a start timestamp, an end timestamp, a start cadence value, and an end cadence value. When the start timestamp is reached in the song, the input starts calculating the offset from the expected cadence using linear interpolation from the start cadence value to the end cadence value based on progression through the note. At the end of the note, the average of the individual frame scores is calculated and submitted as the score of the note. The UI for the input is shown in Figure 35b. The formula for calculating the score is as follows:

$$pC = PlayerCadence, sC = StartGoalCadence, eC = EndGoalCadence$$

$$Score = \sum_{0}^{endTime-startTime} \Delta t * (100 - (|pC(t) - lerp(sC, eC, \frac{t}{endTime - startTime})|))$$

where lerp is a function for linear interpolation.

Button Input

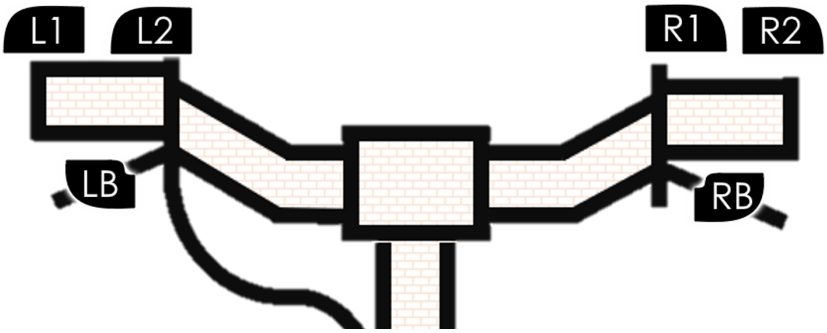


Figure 37: Button Input icons & where the correlated physical buttons are on the controller.

Button inputs provide an alternative way of interacting with the game. Unlike the other input types, it does not use the bicycle's cadence to calculate the score. These notes use the six buttons on the *PlayPulse* bike, using the mapping shown in Figure 37. When prompted, the player has to press the correct button at the right time. Pressing the wrong button or pressing too early or too late leads to a low score. Figure 35c shows a button input in the game. The white vertical line in the figure shows when to time the input click. If the correct button is clicked the score is calculated like this:

$$Score = 100 - |inputTimestamp - goalTimestamp| * 33$$

If the wrong button is clicked, the system considers it a fail and awards zero points.

19.2 Interface

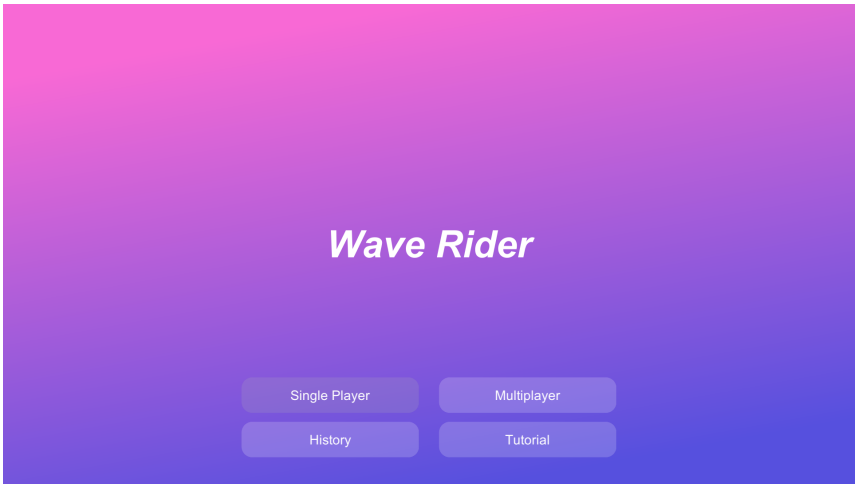


Figure 38: *WaveRider Home Screen.*

19.2.1 Song Selection

As a rhythm game, the game is made up of songs to play. These songs have been designed to be 4 minutes long to achieve the four minutes of high-intensity interval training that was sought for the game. Figure 39 shows the selection of songs available to the players. Songs are unlocked as the player increases their level, which is done through playing the game and achieving high scores.

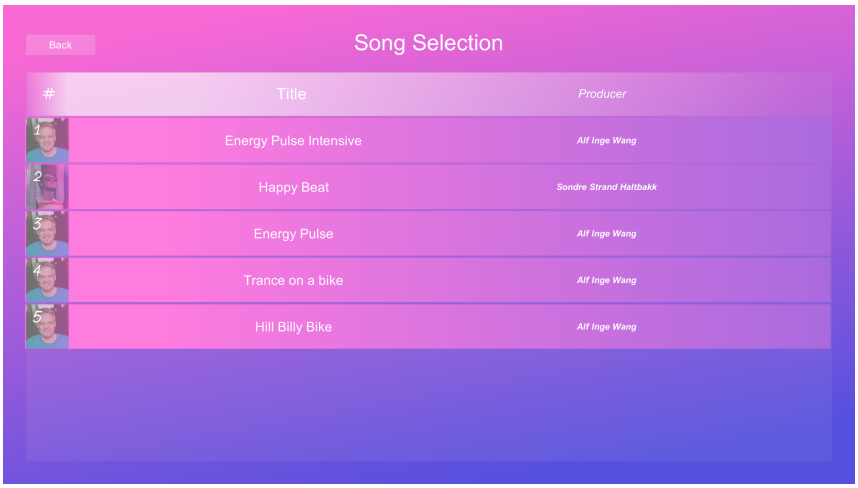


Figure 39: *The song selection in WaveRider.*

When a player has chosen the song they wish to play, they select the song and are taken to the difficulty selection screen shown in Figure 40. Each song has a set of difficulties. Only the simpler difficulties are available instantly. To unlock higher difficulties the player has to achieve a certain score in the difficulty below it. This gives players a gradual introduction to the difficulty of a song as they get more accustomed to it, but also increases the player's long-term investment in the game by rewarding them over time for their engagement.

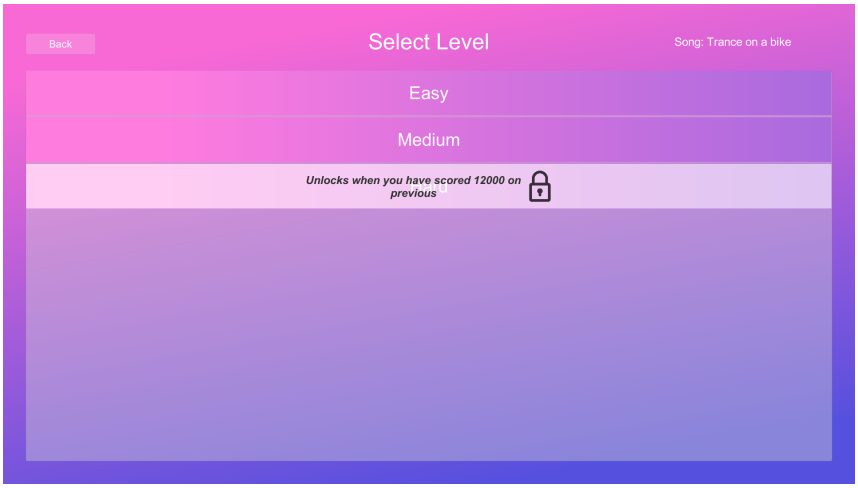
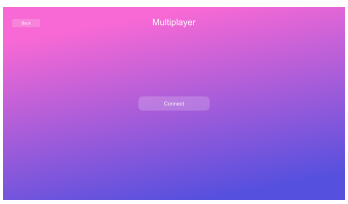


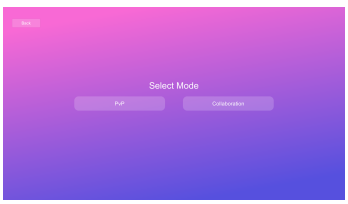
Figure 40: *Song difficulty selection in WaveRider.*

19.2.2 Match-making



(a) Multiplayer screen.

(b) Interface while in lobby.



(c) Multiplayer game-mode selection.

Figure 41: Multiplayer flow

In order to play with other players, the player needs to connect using the Multiplayer tab on the home screen shown in Figure 38. The user is prompted to "Connect" (see Figure 41a). Once the player clicks the "Connect" button, the server attempts to set up a connection. To do this, it looks for available open lobbies to connect to, and if none are found, the server creates a new lobby and makes the player the host. The game does not have matchmaking controls such as lobby lists and explicit lobby creation. When a player joins a lobby they are shown the players in the lobby (see Figure 41b), and once another player has joined they are given the option to start. When both players have joined a lobby, the icons on-screen have different colors. These colors show what color the player's controller will be to distinguish them from each other. Once the host decides to launch the game, the host is led to the page shown in Figure 41c, where they can select which multiplayer game mode they wish to play. The host has control over the choice of game mode, song, and difficulty. While the host selects song and difficulty, the non-host player will have a similar screen with an overlay explaining that the host is currently in the state of selecting. This view can be seen in Figure 42.

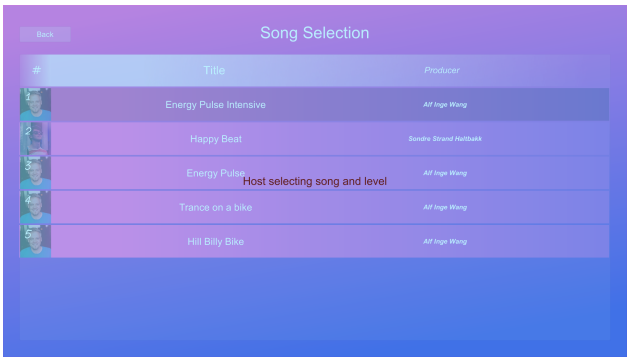


Figure 42: Song selection from the point of view of a non-host.

19.2.3 Game scene

When a song and difficulty are chosen, the game transitions into the game scene. The game loads in the notes and game inputs for the selected song and difficulty, and places them in the correct location on the canvas that is moved across the screen. The location is calculated based on the input's defined timestamp and the rate at which the canvas is dragged across the screen. After a countdown concludes, the canvas starts moving and game inputs are displayed on the screen. To gain the best possible score players have to time their speed and button clicks correctly. The types of inputs and how they work are found in Section 19.1.1. At the top of the screen, the player's score and progress into the song are displayed.

Figure 43: *Singleplayer* gameplay.

19.2.4 Competitive Play

When a player plays the competitive game-mode *PvP* against someone else the game screen changes up slightly, as shown in Figure 44. Another player controller icon appears on the left, and a set of vertical bars appear on the right side of the screen. The new speed input icon is transparent and represents your opponent's input. This icon has the same color as the icon from the match-making screen. This allows the player to compare how they are doing compared to their opponent. The two bars on the right side of the screen display in a visual manner the score of each player and the ratio between them. A taller bar means a higher score. This makes it easier for players to quickly identify how they are doing instead of having to read numbers while focusing during the match. The game works identically to when a player plays alone, except they now also see their opponent's input levels and score.

Figure 44: *PvP* lets the player challenge other available players live.

19.2.5 Collaborative Play

The game also features collaborative play that focuses on teamwork between the two players. In this game mode, instead of facing off against each other, the players work together to produce the best possible score. The game scene is shown in Figure 45. Instead of showing the two players' input as separate icons, the players now collectively control the same game input. The player's output from the bicycle is added together with the other player's input, then halved. This means that to reach what is equal to 50% output, both players must output 50%. This also means players can contribute with asymmetrical input, such as one person reaching cadence levels of 75% while the other reaches 25%. The two-colored bar on the left shows the collective input, as well as each player's contributions. Button input is alternated between the two players. The players also share one final score.

Figure 45: *Co-op* makes players team up to play together.

19.2.6 Result Page

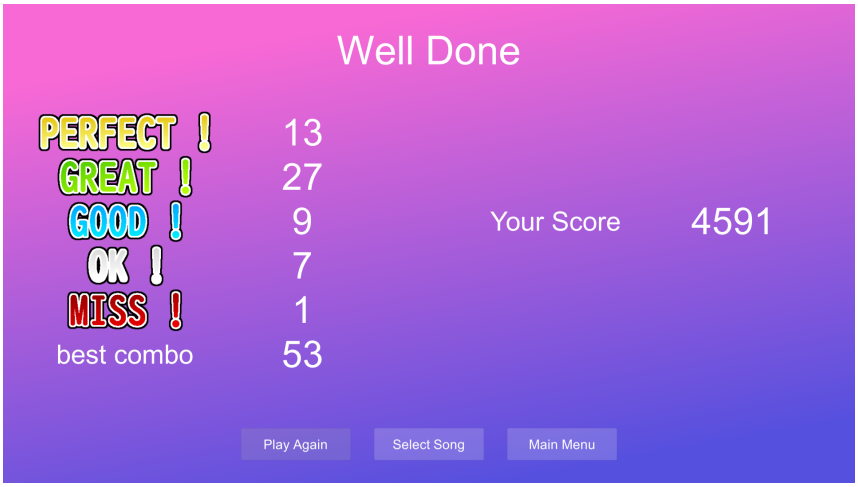


Figure 46: *Results screen.*

When a game has concluded the player is sent to the results page. This page displays statistics regarding the game that was just played. This includes showing the final score of the game, as well as how many of each point type the player achieved. This page can be seen in Figure 46. While on this screen, the game also applies the score as experience points. This is used for progression, where you level up and unlock new songs. At the bottom of the page are buttons allowing the player to maneuver the game. This includes playing the same song again, being sent to the song selection screen, and to go back to the main menu shown in Figure 38, where players can change game mode or look at their play history.

19.2.7 Scoreboard & History

Figure 47: *Scoreboard / History screen.*

The scoreboard/history page shows the player every session they have played, as well as statistics regarding these sessions. This allows the player to look back at previous runs, look at what songs they recently played, what their best scores are, and when these sessions were played. The page is shown in Figure 47. The entries in the list show the chosen song, their score, the other player's score if it is applicable, as well as their best combo and timestamp of which date it was played. Each entry in the list also features a button to play the song again if a player wants to beat the score. This launches the song in single-player mode.

19.3 Summary

This section has shown the features included in the game as well as how the different states look in the final research prototype. The game focuses on the ability to achieve specific a specific velocity using the *PlayPulse* bike. To provide variation, the game features three input types: *single time input* that scores players on their accuracy at the moment, *drag input* which scores the player based on accuracy over time, as well as *button input* that forces the players to pay attention to multiple aspects of the game. The game allows players to maneuver through various states, such as checking out their play history or playing different songs in different modes.

20 Application of Game Design theory

This section looks into how the game design theory established in Part II was used in the design of the game as described in Section 19. The goal is to show the game design and features' theoretical foundation.

20.1 GameFlow

GameFlow is a model used to design a game such that the player gets in a state of flow while playing. This is explained in-depth in Section 8.2.

Concentration

A game round includes many different sources of state, such as audio playing correct sound, visual activity bar matching the goal level, and VFX as accuracy feedback to provide stimuli. The game also grabs the players' attention quickly by forcing the players to pay attention to what the goal activity level is going to be so that they can quickly react and match it. In addition, the player is required to focus throughout the song to get the best possible score. If the player loses their concentration they may not react fast enough to match the goal rhythm.

Challenge

The challenge in this game increases as the players improve their skills. It starts with easy songs to introduce the mechanics with a lower risk of failure so that the player can learn the mechanics while playing the game. As they level up and increase their ability, they will be introduced to more challenging songs that match their skill level. Once they improve their skills further, they will be introduced to songs with more drastic rhythm changes, higher average activity levels, potential sudden full stops, and more challenging ways to use the secondary input using the buttons.

Player Skills

The game includes a simplistic mapping between the input and controls, which makes it easy for the player to start playing the game right away. The first time the player plays the game, it begins with tutorial levels and easy levels to get the player to learn by playing. When the players improve their skills, they will level up, and higher levels will include more difficult songs with an increase in rhythm changes. The player will also get better rewards the higher their score gets. Reaching certain scores on a song will unlock a more difficult level of the same song. This awards players for improving their game skills, by providing more challenges as they improve.

Controls

The controls in this game are very simple and consist of the pedal input and the buttons. The pedal input is used to move the player up or down to reach the bars. The buttons can be used as a secondary input prompt to match a tempo, in addition, to navigating the menu, pausing/continuing the game, etc.

Clear Goals

The visual bars combined with the location of the player pin within the game round, show that the player has to reach the bar. The game also clearly visualizes what activity level the player is at. This allows the player to quickly compare their speed and the goal input speed so that they may make up for the difference. The design of the songs can give an indication of when to be active and when to pause. Leveling up from scores gives an incentive to get better results. The progression of the player towards higher levels is shown after every song. The player can also see what he or she unlocks in the next level.

Feedback

Within a game round the score of how well the player is doing during the song will be represented and updated live. They will also get feedback on how accurate they hit the bars on five different

levels of accuracy: Fail, OK, Good, Great, and Perfect, which gives an accuracy percentage. The song progression will be displayed and updated at all times during a round, which helps the player to know exactly where in the song he/she is. The music will also change and play incorrect tunes when the player is inaccurate.

In cooperation and PvP modes the players can see the state of their teammate's or opponent's activity level and accuracy.

Immersion

One round in the game is designed in such a way that the player has to concentrate through the whole song to get a high score. The game also includes nice graphics, visual effects (VFX), sound effects (SFX), and music throughout the song. Also, including cooperation and PvP mode, can motivate the player and increase their emotional involvement in the game.

Social Interaction

The social aspect of a game is as important as the other elements in flow. This feature is included in the game in several ways. *History Leaderboard*: The history chart helps the player to compare their results to friends and other players. While it is not public, meaning you cannot directly read other players' history, it does provide the opportunity to verify a player's result when socializing about the game.

The game also includes two multiplayer modes: Cooperation mode and PvP mode.

Cooperation mode: In this mode, the players are forced to cooperate to create a good result, similar to Rock Band's cooperation mode.

PvP mode: In this mode, the player can challenge friends or other online players in a song to see who is better.

The original plan was to provide voice chat for the players to be able to quickly and intuitively communicate while collaborating. However, as the play sessions only occurred in person in groups, this was not necessary. For actual use, this would be a viable way to provide communication.

20.2 Malone's Model

Malone's model is a guide to build a game that is fun for the players. The theory is explained in Section 8.3. This section will explain how the three parts of the challenge, fantasy, and curiosity have been used in the game.

Challenge

The game includes a clear overall goal, which is to complete the song by following the bars by biking, at the same time being as accurate as possible. By including good graphics, visual effects, and fantasy, the goal gets more clear. The players can also set their own goals, and play as they want, at their own pace. The accuracy feedback also helps the player to know how well they do and how to improve within one game round.

The game also consists of variable difficulty on several levels. Within a song, the difficulty level increases as the player gets through the song. The same song also has different difficulty levels, which will be unlocked as the player improve their skills. The game consists of multiple songs in different difficulty levels, which will be unlocked as the players' skill level increases and they rank up. The player also has the possibility to select their own exercise level easy, medium, or hard, based on how intense of a workout they want to do.

Introducing multiple leveling goals also helps to motivate the player. This is done in the game by including different game modes, such as Player vs Player and Co-op mode. As the main goal is to complete the songs by following the bars by biking, meta goals can be to be as accurate as possible.

To make the game more unpredictable, only a few bars will be shown at the same time. The player will therefore not know where the incoming input may be, and which input buttons to press. This can make the player more motivated to keep the focus throughout the song.

The player's self-esteem can be improved by providing multiple difficulty levels in multiple areas such as within a song and between different songs. The player also has the possibility to select their own exercise level. The combination can help players set the challenge level they want to achieve. The players that feel like the challenge is too easy can challenge themselves with harder levels, and harder exercises.

Fantasy

Designing the fantasy in a game in a good way can improve the motivation to play the game. It is therefore important that the fantasy of the game and the skills of the player have a good connection. This is done in this game concept by creating a setting such as a concert. The player is linked to the artist on stage due to how the game handles audience cheering and how much of the audio tracks are played based on accuracy. If you play the game well, the audience cheers for the artists and the artists play the song well. This is built upon an extrinsic fantasy, where the fantasy of controlling the artist is done by activity-level based controls.

Curiosity

Several elements are added to the game to increase the curiosity of the players. Among other things, the player has a song and input to follow. The game includes visual effects such as accuracy indicators, to enhance the fantasy and provide visual variance. The game also has a concert setting, where the player's input and how well they play the game will change how the audience cheers. These are included to make the player more engrossed in the game.

The game also includes several songs and difficulty levels, which are not accessible before the player reaches a certain level or gets high scores. The wish to unlock everything and find out what content the game has to offer can help to increase cognitive curiosity and the motivation to play the game further.

20.3 Dual Flow

Dual Flow is a model based on Gameflow, with a focus on the exercise part. It is divided into *attractiveness* and *effectiveness*, where *attractiveness* focuses on the gameplay and *effectiveness* of the exercise. The theory is explained in Section 8.4.

Attractiveness

This part is approximately the same as the GameFlow model. The gameplay loop is designed to be satisfying, fun, and rewarding. In addition, the player should be put into a flow of matching the rhythm. The game also provides multiple levels of difficulty to allow varying skill levels to find engaging content. How the GameFlow model has been applied to the game can be read about in Section 20.1.

Effectiveness

The game focuses on the exercise part by including constant high activity over the course of songs that are approximately 3-4 minutes long. The song's activity level should be balanced correctly to get HIIT results, such that the players will achieve progress in fitness. Every session should start with a warm-up, and this can be done by the players playing easy songs for 5-10 minutes. The research project also includes shorter versions of songs to provide options for warming up. Improvement in the player's fitness due to playing allows the player to play more challenging songs, which makes the exercise a bit harder. To create a game considering HIIT, the players also need rest periods, and this is done by adding a break in between songs, such that the players can rest to reduce their heart rate out of high intensity.

20.4 Rewards

The theory of rewards is explained in Section 8.5. Rewards are applied in the game to among other things, increase the player's intrinsic motivation. The most applied use of rewards from Wang and Sun's rewards study is the *Advancement* classification. The game rewards activity through scores and achievements based on how the player performs. Leveling up or getting achievements unlocks new different items such as new difficulty levels, songs, and concert backgrounds. The game also offers advancement as the players improve their scores through more difficult songs. From the eight forms of rewards, the game uses score systems, experience point reward systems, and unlocking mechanisms.

20.5 Summary

In the process of implementing and designing the game, the use of game design theory and frameworks have made sure the game contains features that promote engagement and retention. *GameFlow* gives the game the tools to make players engaged and focused, and applying each aspect of the model has made the game immersive to optimize the chances of putting players into a flow state while playing. Malone's model provides aspects of game design that promote fun, where the challenge, fantasy, and curiosity aspects make the player entertained. Applying dual flow allows for scientific reasoning behind exercise-related choices in making the game, and rewards promote continued motivation. All these frameworks make sure the game design has statistical and scientific support before being developed and tested.

21 Exercise theory

The key goal of the game is to provide the players with meaningful exercise in a satisfying and motivating way. It does not matter that the players are motivated if the game concept does not provide a meaningful level of activity. Therefore, there is a need for assurance that the concept of matching the activity rate of songs can provide training.

Warm-up As explained in Section 8.4, it is recommended to have 5 to 10 minutes of warming up before doing moderate exercise. This is done to avoid injuries. In the game, this can be achieved by promoting lower-difficulty songs to players when they first launch the game. The player will have to make the choice to do lower difficulty songs themselves, but the game can promote songs and the reasoning why players need to warm up to increase the chance they will warm up properly.

Aerobic exercise Section 7 introduces aerobic exercise and what constitutes good aerobic exercise. The game concept created here aims for high-intensity interval training. This is provided through songs. Songs usually last roughly three to four minutes, fitting well with the 4x4 *HIIT* exercise pattern introduced in Section 7. To fit with the suggested heart rate, the game level system needs to recommend songs and difficulty levels that force the player to roughly 80% of maximum heart rate. The pause in between songs provides the rest required to reduce the player's heart rate. While players are intended to have the freedom, to take breaks between songs, it is possible to provide users with a set of songs in succession that have a forced interval. This forces players into an interval pattern without voluntary rest period lengths. To meet the weekly recommended activity level of 30 minutes a day for five days, the player needs to play roughly 8-10 songs of moderate exercise or four songs of intense exercise. This means there needs to be enough content to motivate users to play four songs every day. This can be simplified by making the aforementioned sets of songs contain four songs, so once players have played through a set they have met their daily required exercise goals.

Strength The game can also be used for strength training. The bicycles used make acceleration from low cadence heavier than with high cadence, which means that the game could promote strength training by making users drop to low cadence and then accelerate through the resistance to high cadence repeatedly. In our game, this would work by making the activity goal start at zero, quickly increase, and then drop back to zero in a loop. The rate of acceleration and de-acceleration needs to be tested and adjusted to ensure no risk of injury to the knees.

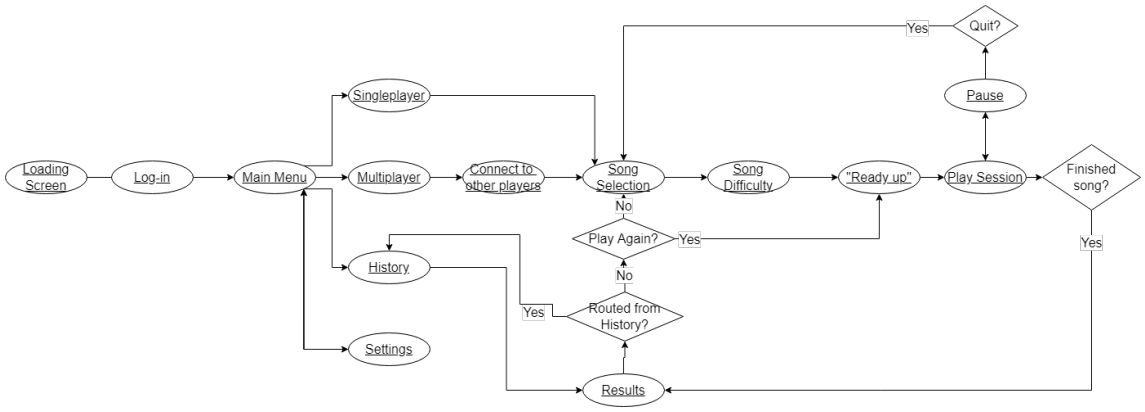
22 Development Process

This section covers the process of creating the game. It discusses the preliminary project process and how the concept from the preliminary project was conceptualized into actual features and then developed.

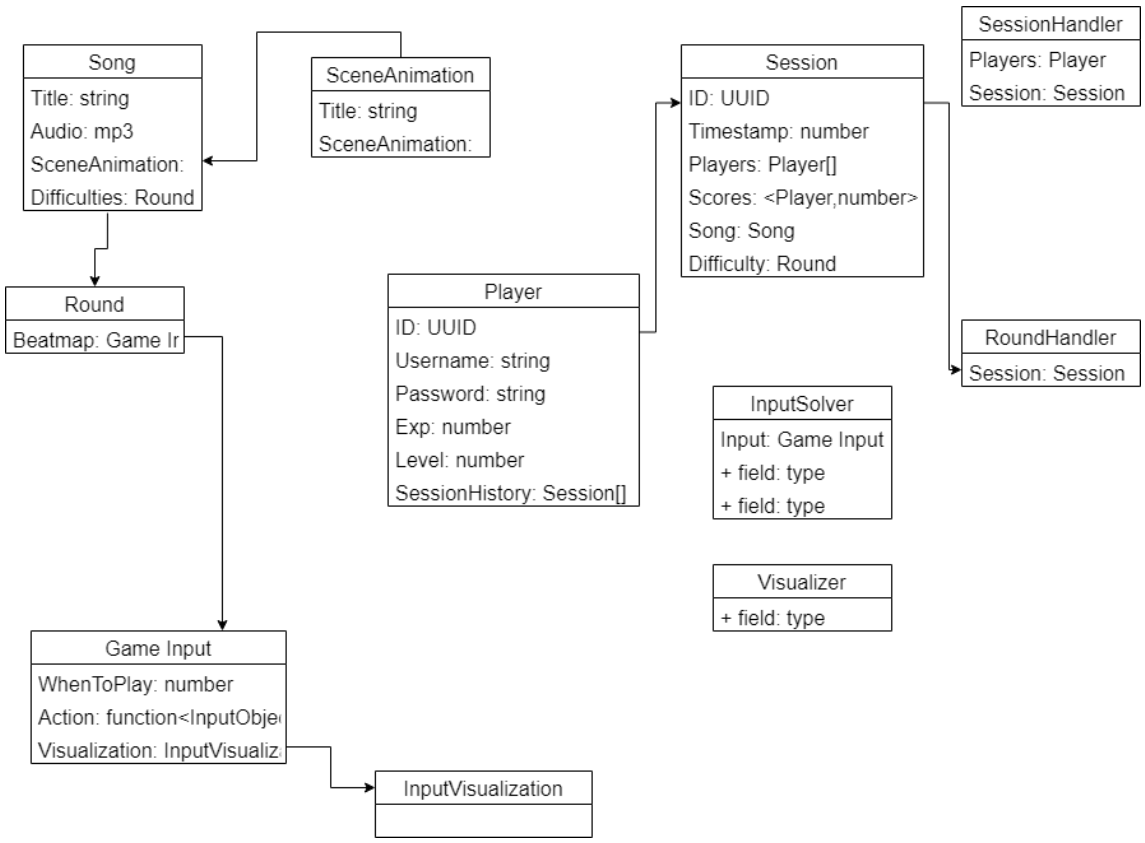
22.1 Development Process

The development of *WaveRider* started in January 2022. The concept had already been decided upon and the theoretical foundation had already been set during the preliminary project. The report conducts a literary analysis of the exercise game field and similar projects to identify a new way to approach exercise gaming using *PlayPulse* bicycles. Several sections of this thesis use this preliminary report as a basis, as it provides the theoretical basis of most of the design choices for the game. After this analysis, the final game concept was defined and selected.

22.1.1 Planning



(a) *WaveRider* game flow.



(b) Initial game software architecture.

Figure 48: The initial design diagrams used to create *WaveRider*.

To develop the game with structure and goals in mind, the team started with a planning meeting. During this meeting, the authors established the game flow and created a software architecture that would provide the gameplay loop from the game concept. These diagrams can be seen in Figure 48.

This allowed the team to quickly establish what features were required for the research prototype. The team also set up a timeline for when features were required to be complete to have enough time to properly collect and analyze data using the game.

In order to support the online features required to test the multiplayer game configurations, a backend architecture had to be set up. The multiplayer modes within the game need to support

players playing together with low latency with specific game data that needs to be replicated. The players also need to have their statistics and history saved into a database for long-term storage during the project. Two different networking architectures had to be put in place. There are several libraries meant for real-time data sharing between Unity clients. Due to previous exposure and experience with it, *Photon Cloud App* was chosen. This lightweight library allows for connections between clients through instantiating specific classes. This allows us to replicate the other player icon for *PvP* and receive their input to create the combined input bar in the collaborative game mode. For non-realtime data storage, *Google Firebase* was used. *Firebase* is a free, easy-to-set-up lightweight cloud storage platform that allows for quick data structure setup. This database allowed the game to provide progression and play history. *Firebase* does also provide real-time communication between clients, but as this project runs in *Unity*, a system that is built to use the Unity Engine's class system reduced overhead work in setup.

22.1.2 Game Development

After establishing the game flow and game requirements, the development focused around making the core gameplay loop work. The aim was to make a session of serving a set of notes to the player and applying joystick input to calculate a score work as fast as possible. Meanwhile, the core backend architecture was also set up. After three weeks of development, the core loop of playing a list of inputs and changing a score was set up. Figure 49 shows how the game looked at the time.

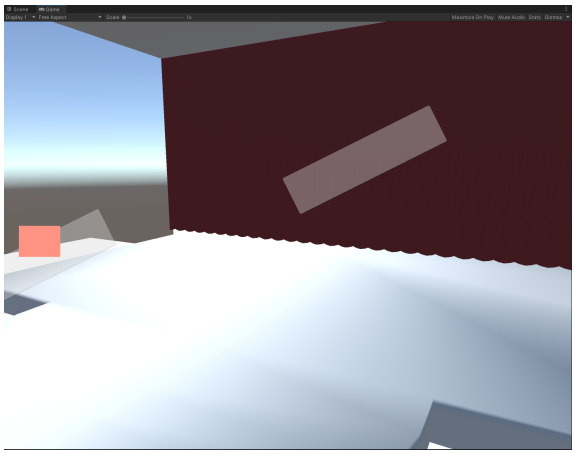


Figure 49: The state of the game 10th of February 2022.

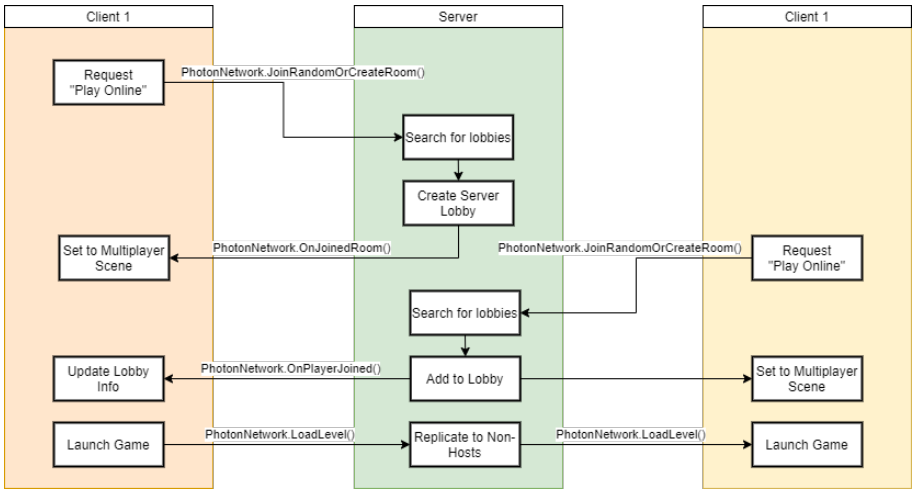
After setting up the core functionality, the development time was focused on expanding the game to answer the research questions. This meant developing the different game modes to compare game configurations and setting up progression and data tracking. The team had digital meetings every day where the members were available to each other to solve issues and discuss the game, using an agile work methodology. *GitHub* issues were drafted on a weekly basis and served as weekly sprint goals, and every morning the members would discuss what issues they were working on, and report to the other when an issue had been solved to allow for peer review.

During most of the development, input was replicated using a keyboard or an *Xbox* controller. The *PlayPulse* bicycle replicates controller input and thus designing the game for controller support would make it likely to play well on the bicycle. When testing with the bicycles commenced, the team discovered that the bikes were not responding fast enough for the gameplay loop to work. Section 9 describes the mechanics behind how the bicycles work. To fix this issue, the team had to edit and update the code running on the micro-controller handling the input. The input refresh interval was changed from 400ms to 40ms, making the input 10 times faster but also more sensitive. 40ms was identified to be the best possible balance between low latency and low levels of discrete jumps between cadence levels. This is because the shorter the interval, the fewer color changes the sensor can detect, which makes the jump between levels more distinct. A jump from 4 to 5 would entail a 20% input level change, while 49 to 50 would be 2%.

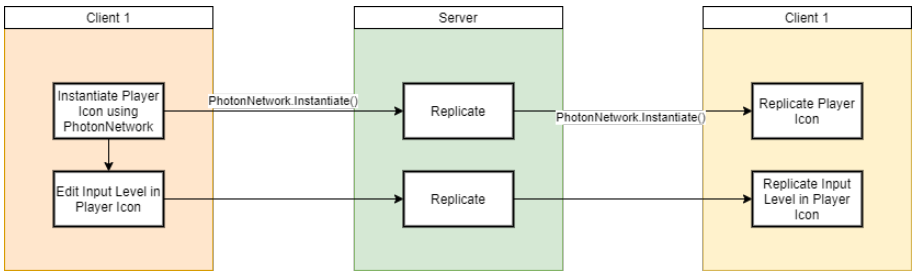
22.2 Software Architecture

This section goes into detail on how the software- and network architecture of the game is set up to achieve the gameplay goals. The focus is on the flow of data and how the implementations solve the feature requests they cover.

22.2.1 Network Architecture



(a) Process View creating a lobby.



(b) Process View replicating input data.

Figure 50: *Photon* network flow

As explained in Section 22.1.1, the game uses *Photon Network* for matchmaking in Unity and *Firebase* for long-term storage.

Photon serves as a matchmaking service and allows a simple way to create ”Rooms”, lobbies where players can join. Figure 50a shows the process view for setting up a ”Room”. The client asks for a lobby and the server returns any available lobby the player can join. If there is none available, the *Photon* server creates a new lobby and returns this. When another player does the same thing, the player is added to the available lobby and both clients are notified, including information on which is the *Master Client*, the session's host. When a host changes scenes and interacts with the game state, this automatically replicates to the other client. When the game starts, the clients create the input UI using *PhotonNetwork*. This allows for automatic replication to the other client when a field is updated, as shown in Figure 50b.

22.2.2 Software Architecture

The software architecture is based on the initial ideas from Figure 48b. The game needs the ability to play various songs with several difficulty levels to provide the variety and progression required

from a rhythm game. This meant the game had to be designed to easily allow the developers to create and edit songs. The logical view model of the software architecture is shown in Figure 51.

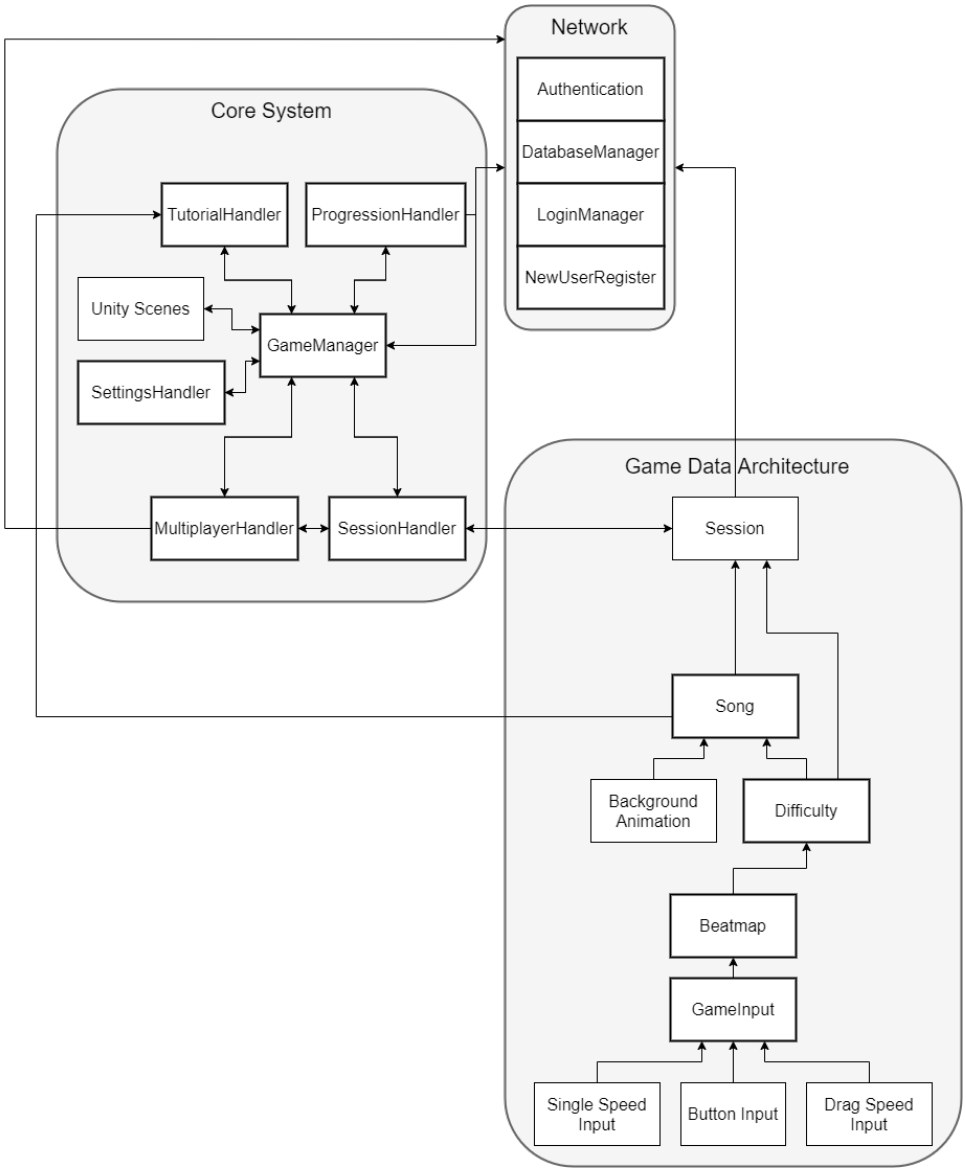


Figure 51: Logical view of the WaveRider software architecture.

The classes of the prototype are categorized into three types: *Core System*, *Game Data Architecture* & *Network*.

- *Core System:* For the overarching data flow in the game, the prototype uses Service architecture. The "Handler" classes are singletons that provide a specific self-contained set of features. This makes the software decoupled which means the code can be expanded upon for new features. **GameManager** is the core handler that controls the flow of the player through the game. It handles traversing the game state and makes sure the game sets up the correct prerequisites for the different game scenes.
  One "Round" of a song, the essential game mechanic, is called a *Session*. As such, the **SessionHandler** provides the control of playing the actual game. This service sets up the correct song & difficulty, builds the user interface required to play the game, and sets up and tracks the events required for gameplay. It also calculates the score based on results and generates a session object to save.

- *Core Data Architecture:* The core data architecture is what the team defines as the "gameplay logic". For the game to support easy modification and extension, the session has been structured in a very modifiable way. Every song has a *Background Animation*, such as a concert scene, and a set of difficulty levels. Each difficulty level has a *Beatmap*. These beatmaps are made up of a list of game inputs, including what time they are meant to be executed in the song and what input value they need to provide. The *Game Input* classes inherit from one core game input class and change how it behaves. This is visualized in Figure 51.
- *Network:* The network category contains the systems regarding communication with the third-party network services. These allow the player to create users, login, save their results from a game, and play with other players. These serve as wrapper classes around the *Firebase* and *Photon* APIs that the game uses. The core system services use these to fetch the data they need, or to send the data elsewhere such as to another client or to the database.

These features allowed the game to provide the gameplay loop that was used in the study. The final product contained all the required features that the team aimed to achieve.

22.3 Summary

This section described the game development process of the game. Building upon the game concept defined in the preliminary report, the team set up clearly defined goals for the research prototype. The game was designed to be easily modifiable in order to easily provide the progression and content required to maintain player motivation.

Part IV

The Study

This part describes the study approach used in the project. It covers the methodology and execution of the study as well as the data generation approaches used to respond to research questions. Finally, the reliability and validity of the results are reflected based on approach choices.

23 Methodology & Execution

This section discusses the structure of the study, and how it aims to collect research data. It covers how the experiment was conducted, information regarding sample selection, as well as what kind of data was collected in order to come up with conclusive responses to the research questions.

23.1 Covid-19 repercussions

Covid-19 has put serious restrictions on participation in research studies since 2020. Preventative measures such as distancing and disinfection have been required. During the development of the game for this study, most restrictions got removed. While it had an effect on participant gathering and the development process as meetings and development had to happen digitally, the study and experiment proceeded without national or regional restrictions. Equipment to clean and disinfect the bicycles was available and applied.

23.2 Execution

The research questions for this project aim to identify whether the game concept from Part III can provide an actual benefit to users. While theory can, and has been applied to the design to encourage behavior, these presumptions must be supported by quantitative data. A set of users were put through a four-session experiment to collect experiences and data for analysis.

Figure 52: Experiment setup

At campus Gløshaugen at NTNU, there are two PlayPulse prototype bicycles. These bicycles are shown in Figure 52 and their functionality and features are described in Section 9. During a period of 11 days, from March 28th to April 8th, participants were brought to the campus to play the game in a specific way based upon the high-intensity interval training regiment described in Section 7. Each session followed the same structure:

- *Warm-up:* Participants were given shorter songs to warm up to reintroduce them to the gameplay loop, get them experienced with the input levels required, and avoid injury.
- *4 minute high-intensity interval:* The game has a set of songs of around four minutes in length. The participants were prompted to play through these songs and aim for the highest possible score. The choice of song and difficulty level was up to the individual/group, however, they were encouraged to challenge themselves and to target the highest difficulty they could manage.
- *3 minute active break:* In-between intervals the participants were given three-minute active breaks in which they were encouraged to keep cycling at a slower pace. During this period

the players were given the opportunity to drink, and reflect on how they were feeling during the experiment.

To keep the experiment interesting for the participants, as well as to compare different configurations of cooperative and competitive play, each session had the participants play in a new way:

- *Session 1:* During the first session, the participants were introduced to the game and its mechanics. The participants played a built-in tutorial that taught them the controls, then played separately. The goal of this session was to teach them how to play, as well as to test their experience playing solo, without competing or collaborating with the other player.
- *Session 2:* For the second session the participants played the competitive multiplayer mode, as described in Section 19.2.4.
- *Session 3:* During the third session the participants were made to play cooperatively. The cooperative game mode is described in Section 19.2.5. During this session, the players shared songs and controls and were forced to communicate to achieve a good score. Most groups were balanced, where both players had similar physical skill levels. However, some had very different levels among the individual participants. This was intended, and allowed to experiment with asymmetric output, where one player "made up for the difference" between the two.
- *Session 4:* In the fourth and final session, the players were given the goal to achieve the highest possible score as well as the highest possible heart rate. The approach, such as game mode and difficulty, were freely up to the players. This was done to identify what game configuration the players themselves would choose if given the chance.

23.3 Participant Sample

The aim of the experiment, as explained in Section 23.2, is to verify that the game can provide a motivating alternative to exercise. The aim is not to replace established exercise theory and standards, but to provide a new alternative. The study used non-probabilistic selection, which means that the selection of participants has not been chosen based on accurately representing the target population [8].

Finding enough test users that play video games, lack the motivation to work out, yet wish to participate in the study was considered too resource-intensive to be beneficial. Thus convenience selection was employed, where participants were sought out and chosen based on interest in the project. This approach may introduce bias, as the authors' method of choice- and approval of participants means the sample members may share traits. This does not however mean the research questions and goal of the game were not regarded during the process. The target audience of the game fits well with the sample group, as both focuses on students. There are also variances within the sample that may provide comparative data. More information on the actual sample group can be found in Section 28.

23.4 Norsk Senter For Forskningsdata

The Norwegian Centre for Research Data (NSD) is the Norwegian national research data management organ. The goal of NSD is to facilitate research data storage and reusage [67]. It provides data collection guidance and ensures that the project's research data will be following international structure requirements and that it will be available for use for similar or derivative work. Our data gathering includes personal data, as it is used to contextualize the data. It is also used to calculate max heart rates, which is essential data to calculate exercise efficiency. As a result, the NSD has had to validate that our data collection is according to legal standards. The requirements are as follows:

- *Informed consent:* Participants need to know what data it is that is being collected on them, and to give explicit approval to collect this data. This consent may be revoked at any time. The form used to give consent for data collection and participation in the study can be found in Appendix A.
- *Data Insight:* Participating individuals should at any point be able to view all data collected on them. If a participant asks one of the authors or the supervisor for their data, they must comply.
- *Data encryption and storage:* The data collected on the participants needs to be encrypted. It must also be able to be removed completely once the project is over or a participant no longer wishes to give permission for use of their data. This means the data must be stored in a way it will not leave traces in 3rd-party data storage applications after removal. In the case of this project, the data was stored encrypted internally on university servers, with only the authors having access.
- *Anonymized data:* The data collected should be anonymous. The data should not be able to reveal individual personal information through irregularities in data. This includes being able to identify individuals from things such as combining unique age groups together with irregular heart rate data.

The data categories that this project has collected were submitted on December 15th, 2021, and considered to be following privacy regulations and approved on January 20th, 2022. The data generation methods used are defined in Section 24.

24 Data Generation

For the study to have any statistical value, the research questions defined in Section 3 need to be answered with data. The choice of data selection is essential to provide conclusive responses. As described in Section 4, the study was based on Oates' research process. A key aspect of the study is to verify the application of game design- and exercise theory. The data collection methods were then chosen to provide the option of both qualitative and quantitative data analysis. The chosen methods were *questionnaires*, *observation*, and *heart rate monitoring*.

24.1 Questionnaire

Questionnaires is a tool for researchers to obtain data for analysis. The questionnaire features a set of predefined questions meant to provide the researcher with information regarding the participants' experiences or preferences. Using standardized questions and responses from multiple participants, the researcher can identify patterns and make generalizations based on the feedback [8]. This is particularly useful for this study as we have a set of established goals and evaluation tools from game-design theory such as GameFlow. Using questionnaires, the specific evaluation criteria from theory can be applied as questions and the response can be used as the basis for reasoning around the success of the application.

The study made use of three questionnaires: Pre-form, Session form, and Post-form. Pre-form questions are labelled **AQ*n***, session form questions are labelled **BQ*n*** and post-session form questions are labeled **CQ*n***, where n represent the identification number.

24.1.1 Pre-form

Before participants began testing the game, they were sent the pre-form and told to fill it out. This pre-form, as shown in Appendix B, collects information such as age and workout/gaming experience. This information is used for categorization and data analysis based on user groups.

The questionnaire consists of two distinct parts. The first part is based on the participant's past experience. The values are objective, and not based on opinion. These are the questions:

- **AQ1:** What is your personal code? (Username)
- **AQ2:** What is your year of birth?
- **AQ3:** What is your gender? (E.g. Male, Female)
- **AQ4:** Approximately how many times do you exercise during a week (average)? (write with numbers)
- **AQ5:** How do you exercise? (No need to answer if you do not exercise)
- **AQ6:** Approximately how many hours a week do you spend on games (average)? (write with numbers)

The second part of the pre-form provides a Likert scale set of questions that provide the participants' opinions and preferences. Here the responses are subjective and reflect the participants' thoughts on subjects such as exercise and gaming. These are the Likert scale statements:

- **AQ7:** I consider myself fit
- **AQ8:** I really like to exercise
- **AQ9:** I really like to play video games
- **AQ10:** I like to compete against others

- **AQ11:** I like to collaborate with others

The participants were given a 5-step scale from “Strongly disagree” to “Strongly agree” for those statements.

24.1.2 Session form

After each session, the participants were given a form with questions regarding their experience with the session they had just gone through. This form asks questions regarding enjoyment and exercise. Having quantitative data for each session allows us to compare user experience between the different game configurations that each session is based around, as described in Section 23.2. Their experience is fresh in memory, allowing us to avoid the bias occurring where the sessions get harder to remember the longer time has passed. The session form is made up of a 5-step Likert scale ranging from “Strongly disagree” to “Strongly agree” with these statements:

- **BQ1:** This session was very entertaining
- **BQ2:** I found the session physically demanding
- **BQ3:** The session felt more like playing a game than exercising
- **BQ4:** I experienced getting exercise from the session
- **BQ5:** The game motivated me to complete the session

Each of the questions was chosen to provide feedback on the session and to provide data for discussion around the research questions in Section 3. The correlation between session form questions and research questions can be found in Table 4. The analysis of the responses and discussions regarding the responses in relation to these research questions are found in Part V and Part VI. The original questionnaire was provided in Norwegian and can be found in Appendix B.

Research Question	**Statement**
RQ2: *Does our game provide high-intensity interval training?*	BQ2, BQ3, BQ4
RQ3: *How does our game affect the players enjoyment?*	BQ1, BQ3
RQ4: *What play configurations provide the most incentive and engagement?*	BQ1, BQ2, BQ3
RQ6: *Does our game motivate players to train over a longer period of time?*	BQ5

Table 4: Shows the correlation between session form statements and research questions.

24.1.3 Post-form

After the last session, having responded to the session form, the participants were prompted to fill out one final questionnaire. This form aims to obtain responses regarding the exercise theory and game design evaluation tools explained in Section 8. The post form consists of three parts. The first part is a 5-point Likert scale with these statements:

- **CQ1:** It was easy to start playing the game
- **CQ2:** It is likely that I will continue to exercise without the game
- **CQ3:** It is likely that I would continue to exercise using the game given the opportunity

- **CQ4:** The game has made me more motivated to exercise
- **CQ5:** I experienced that I got better at the game
- **CQ6:** I felt that my stamina (endurance) improved after playing the game
- **CQ7:** I found the single player mode entertaining
- **CQ8:** I experienced the single player session more as a game than as exercise.
- **CQ9:** My motivation increased when I played with/against others
- **CQ10:** I found the PvP mode entertaining
- **CQ11:** Competing against each other greatly increased my motivation
- **CQ12:** I experienced the PvP session more as a game than as exercise.
- **CQ13:** I found the collaboration mode entertaining
- **CQ14:** Collaborating with others greatly increased my motivation
- **CQ15:** I experienced the Collaboration session more as a game than as exercise.
- **CQ16:** I was so involved in the game that it felt like time passed faster than otherwise
- **CQ17:** The last session was just as fun, if not more fun than the first session
- **CQ18:** Improving my score makes me want to play the game again
- **CQ19:** I felt that the controls made sense and that my actions did what I expected them to
- **CQ20:** I felt I was in control when I played the game
- **CQ21:** I found that my muscles made it difficult to complete the session
- **CQ22:** I found that my stamina made it difficult to complete the session
- **CQ23:** I quickly got used to the buttons
- **CQ24:** The game made interval training more enjoyable.
- **CQ25:** If the game was available to me, I would continue to play it actively

The form also asked participants to rate each game mode: single-player, collaborative play, and competitive play on a scale from 0 to 5 stars. After rating them, the participants have polled on which game mode they preferred. Finally, they had the option to leave extra thoughts not covered by the questions. The form provided to participants in Norwegian can be found in Appendix B.

The statements were designed to answer the research questions defined in Section 3. The research question categories are *Enjoyment*, *Motivation*, *Exercise*, *Progress* & *Lower bar of entry*.

24.1.3.1 Enjoyment

Research questions: **RQ3:** *How does our game affect the players' enjoyment?* & **RQ4:** *What play configurations provide the most incentive and engagement?*

To identify enjoyment in exercise games, the project used the *GameFlow* framework explained in Section 8.2. This is a framework featuring several identifying trends of an enjoyable exercise game. In order to analyze enjoyment in the study, the questionnaire featured questions that match observations from *GameFlow*. Positive feedback on these questions would suggest that the game has a high level of enjoyment.

The questions in the questionnaire related to *GameFlow* and enjoyment are: **CQ1**, **CQ5**, **CQ7**, **CQ8**, **CQ10**, **CQ12**, **CQ13**, **CQ15**, **CQ16**, **CQ19**, **CQ20**, **CQ23** & **CQ24**.

Motivation
Research question: **RQ6:** *Does our game motivate players to train over a longer period of time?*

One of the key aspects of making a game that could provide exercise benefits is ensuring that the player stays motivated. This would mean the participant wishes to continue even after the novelty effect of trying a new game runs out. The questions related to motivation on the questionnaire are: **CQ2**, **CQ3**, **CQ4**, **CQ17**, and **CQ25**. These include general motivation questions for the game in general, as well as specific questions regarding the specific game configurations such as multiplayer and game mode.

Exercise
Research question: **RQ2:** *Does our game provide high-intensity interval training?*

The ability of the game to provide high-intensity interval training is highly dependent on heart-rate data, which is described in Section 24.3. There are however questions related to exercise in order to get a better picture of the experienced gain from the participants. The questions in the form related to exercise and the game's ability to provide *HIIT* are the following: **CQ6**, **CQ21**, **CQ22**

Progress
Research question: **RQ5:** *Does our game provide a lower bar of entry to start training?*

The research goal of the project was to create an exercise game that motivates players. One of the research questions the study sought to answer was regarding the ability to motivate users who usually would not work out, meaning reducing the bar of entry to exercise. The questions regarding lowered bar of entry are: **CQ2**, **CQ3**, and **CQ24**.

24.2 Observation

Observation is used in research to study participant behavior rather than participant feedback. Questionnaires and other quantitative data analysis sources have the participant consciously giving their opinion. Observations, however, qualify as qualitative data. Through actions and expressions, subconscious opinions and experiences can be observed. This data may even conflict with the quantitatively collected data [8].

For the study, *overt observation* was used. Oates defines this as observation where the participant is aware of the fact and consents to the act of being watched. The participants were watched while performing their tasks, and particular observations regarding their approach and emotional state were written down. Sessions were also recorded with consent to provide observational analysis options after the sessions, and to catch details that may have gone unnoticed during the session. This style of observational research is what Oates refers to as *participant observation* [8], as the focus is on the participant. Between intervals, the participants were prompted to share their immediate thoughts, such as how they felt they were doing or how the bicycles felt like using.

24.3 Heart Rate Measurement - Polar H10

To generate quantitative data on exercise effect, heart rate monitoring was necessary. Heart rate monitoring is a key component of high-intensity interval training, as part of the HIIT approach is to target a certain percentage of max heart rate. This is information that is difficult to accurately depict through questionnaires, although the forms also feature questions regarding exercise efficiency to cross-compare with the heart rate data.

Figure 53: Polar H10 chest belt heart rate monitor [68]

For this study, the *Polar H10* was used. The *Polar H10* is a chest belt sensor using electrocardiography (ECG) technology to measure the heart rate of its user, as shown in Figure 53. Through comparison with medical-use Holter monitors, it has been confirmed to measure highly accurate heart rate data, with a signal quality above 99% [69]. It is also considered a lot more user-friendly, as it only requires the user to put on a chest strap as demonstrated in Figure 54. For the study two *Polar H10* belts were used, one for each participant at any given time. Once their last interval was complete, the data was tagged with a unique anonymous ID and session number.

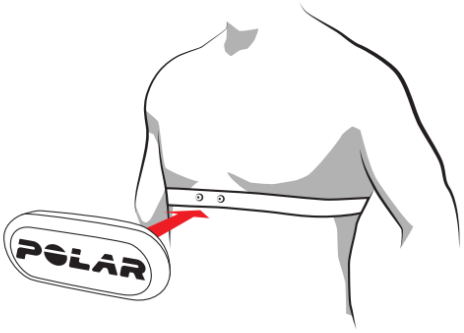


Figure 54: Application of Polar H10 monitor from Polar H10 User Manual [70]

25 Data Analysis

In order to put the raw qualitative and quantitative data into a relative scale, the use of central tendency is important. This means identifying a central value that reflects the center of the overall data distribution. Every participant has four heart-rate monitor data sets, as well as a questionnaire before and after the study unless they resigned before completing the full study. Every participant also has form responses from each session. This means analysis can be made using the pre-form, session form, post-form as well as heart rate data.

The pre-form contains data meant to classify user groups. These include comparing the amount of experience with gaming, as well as exercise levels. These groups are used to filter the post-form Likert scale responses, using *mean* and *median* values to calculate significance.

To compare the heart rate data for each participant, the maximum heart rate possible for the individual is used to calculate the exercise efficiency. The formula used to calculate max heart rate for this study, as previously stated in Section 7, is written by Nes, B M et al. in the *Scandinavian journal of medicine & science in sport* [14], and defined as *211 - 0.64 * age*.

26 Reliability and Validity of Approach

This section goes into detail about various sources of variances that may have affected the result of the study. This includes various equipment-related sources of inaccuracies, but also consequences of sample selection methods and sample size.

26.1 Heart Rate Monitor

The heart-rate monitor used in the study is the Polar H10. Section 24.3 goes into detail about its usage and qualifications. While it can be considered highly accurate when used correctly, the profile used to connect to the system is based on average male height. The profile used was not adjusted based on the participant, so variances in weight and height from the profile used in the app occurred. The impact this has on result accuracy is unknown.

26.2 Study Sample Size & Diversity

For the study, a selection of 14 people was chosen. For statistical analysis and significance calculations, researchers generally suggest a sample size of at least 30 [71]. This is because of the confidence interval generated from lower sample sizes. Within these 14 participants, there was a roughly equal spread of men and women and inclusion of diverse backgrounds. Most participants were however students around the age of 20-24, with few exceptions.

26.3 Familiarity Bias

This study made use of convenience selection of participant sample, so as a result all of the participants are from the social circles of the authors. As a result, this relationship may lead the participants to be biased in favor of the authors, in order for them to succeed. This would mean that participants may have responded with higher reviews than they honestly believe.

27 Summary

This part discussed the approach made to collect data for analysis. The study took place over two weeks featuring four sessions with different game configurations. Fourteen participants chosen by the authors through convenience selection participated and provided heart-rate data and feedback through questionnaires. During the session, the authors used overt observation to watch the participants and note particular expressions and signs of enjoyment or frustration. Due to the approach choices made, the reliability and validity of the data may be affected by familiarity bias and large variances due to the small sample size.

Part V

Results

This part goes through the results of the user test. It will present the results from the questionnaires, heart rate measurements, scores, and observations.

28 Test Population

The information and results shared in this section are collected from the questionnaire given to the participants before the user test. The questionnaires can be found in Section 24.1. Fourteen test subjects participated in the user test, where one participant quit after the second session, and another after completing the third session. The rest completed all four sessions. Both participants that quit were in the same group. The first participant that quit did not have any interest in playing games or doing physical activity. The participant found it difficult to withdraw from the user test and chose to postpone the third session instead. Due to this, the second group member could not complete the last session before he/she was taking the Easter holiday.

28.1 Age

The participants consisted of eight men and six women and were a collection of friends, acquaintances, and relatives. One of the conditions to participate was to be in groups of two where the participants knew each other. The reason for this condition was to simulate the game as it normally would be played (two-player game).

Age (AQ2)		
Gender	Age average	Age median
Men	27.75	24
Women	27.33	23.5

Table 5: Age in average and median categorized by gender.

Table 5 shows the age in both average and median categorized by gender. Most of the participants were in the age range between 20 and 27.

28.2 Time spent on gaming and training

The participants were divided into two groups: Non-gamers and gamers. In this thesis, the participants who do not play games at all (0 hours a week) are defined as non-gamers, and the rest are defined as gamers. As seen in Table 6, the participants consisted of ten gamers and four non-gamers, and the average hours of time spent on gaming in a week was 13 hours for men, and 2.33 hours for women. However, there were major variations in time spent gaming among gamer participants. Most of them were in a range between 3 to 10 hours a week, but one participant played 20 hours a week, and another 43 hours a week. These extreme values increase the average hours spent. The median was 9 hours for men, and 1.5 for women.

Time spent on gaming in a week (AQ6)			
Gender	Non-gamers	Gamers	Average hours in a week
Men	1	7	13 hours
Women	3	3	2.33 hours

Table 6: Number of participants playing games and average playtime per week.

Table 7 shows how many hours the participants spent on physical exercise in a week. The average number of hours in a week was 2.5 hours for men, and 2.67 hours for women. All participants except two men did exercise in some form. All but one gamer also exercised for 2-4 hours a week.

Time spent on physical exercise in a week (AQ4)						
	0 hours	1 hour	2 hours	3 hours	4 hours	**Average hours**
Men	2	-	-	4	2	**2.5**
Women	-	1	1	3	1	**2.67**

Table 7: Number of hours spent on physical exercise.

Table 8 shows what kind of physical activity the participants did. Most of them used the fitness center. Others played some kind of sport. This was a multi-select question, so the participants had the possibility to select multiple answers. Some of the participants did also exercise at home or outside in addition to either going to the fitness center or playing sports.

What kind of physical activity? (AQ5)				
	The Gym	Sport	At Home	Outside
Men	5	1	1	2
Women	4	1	2	2

Table 8: Types of physical activity the participants do.

The participants also got a question about how fit they perceive themselves. The results are shown in Table 9, and show that the answers are evenly distributed through the entire scale regardless of gender. Originally this was a 5-point Likert scale with the values strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree, but these were converted to three categories: disagree, neutral, and agree.

Statement: I consider myself well trained (AQ7)			
	Disagree	Neutral	Agree
Men	37.5%	25%	37,5%
Women	33.3%	33.3%	33.3%

Table 9: Results on statement: *I consider myself well trained.*

28.3 Motivation

This section will go through how the participants felt about their motivation to work out and play video games, in addition to how well they like to compete and collaborate. The statements in this section were originally 5-point Likert scales with the values strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree, but these were converted to three categories: disagree, neutral, and agree.

Information about the participants				
Statements	Gender	Disagree	Neutral	Agree
AQ8: I really like to exercise	Men	12.5%	25%	62.5%
	Women	16.7%	16.7%	66.7%
	Average	**14.6%**	**20.8%**	**64.6%**
AQ9: I really like to play video games	Men	-	12.5%	87.5%
	Women	66.7%	-	33.3%
	Average	**33.35%**	**6.25%**	**60.4%**
AQ10: I like to compete against others	Men	25%	12.5%	62.5%
	Women	33.3%	16.7%	50%
	Average	**29.15%**	**14.6%**	**56.25%**
AQ11: I enjoy collaborating with others	Men	12.5%	12.5%	75%
	Women	-	-	100%
	Average	**6.25%**	**6.25%**	**87.5%**

Table 10: Information about the participant

Table 10 represents the answers to the questions regarding the participant motivation. The results show that most of the participants had high motivation to train (**AQ8**) and that men to a much larger degree enjoy playing games than women (**AQ9**). **AQ10** shows that most of the participants enjoy competing against each other. Most men and all women also enjoy collaborating with others (**AQ11**).

29 Results from Questionnaires

This section will include the results from the questionnaires given to the participants after each section, and the questionnaire given at the end.

29.1 Session form

After each of the four sessions, the participants were instructed to fill out a questionnaire. The questionnaire can be found in Section 24.1.2. As the three first sessions included three different game modes, the statements in this questionnaire are mainly about finding out which of the modes were entertaining, included the most physical benefit, and was most motivational. The total number of participants was 14 in the first two sessions, 13 in the third session, and 12 in the last session. As one of the group members quit after session two, the other group member played with one of the researchers in the collaboration session to get the collaboration experience. This participant quit after the third session.

Each table below includes one of the statements given in the questionnaire with the answers from all sessions. Originally the answer options included a 5-point Likert scale, but these were converted to three categories: disagree, neutral, and agree.

BQ1: This session was very entertaining			
	Diagree	Neutral	Agree
Session 1: Single Player	7.15%	7.15%	85,7%
Session 2: PvP	7.1%	-	92.9%
Session 3: Collaboration	7.7%	-	92.3%
Session 4: Optional Mode	8.3%	-	91.7%
Average	**7.6%**	**1.8%**	**90.6%**

Table 11: Results on statement **BQ1** for each session.

Table 11 represents the answers for the statement *This session was very entertaining*. The results show that on average 91% of the participants felt the session was entertaining. Among the non-gamers, the first session was divided equally throughout the scale. In the last three sessions, all except one answered that they agreed with the statement.

The results are similar throughout the complete user test, which can be interpreted as that the game was entertaining over a longer period of time.

BQ4: I experienced getting exercise from the session			
	Diagree	Neutral	Agree
Session 1: Single Player	-	14.3%	85.7%
Session 2: PvP	7.15%	7.15%	85.7%
Session 3: Collaboration	-	-	100%
Session 4: Optional Mode	8.3%	-	91.7%
Average	**3.85%**	**5.35%**	**90.8%**

Table 12: Results on statement **BQ4** for each session.

Table 12 represents the answers to the statement *I experienced getting exercise from the session.* The result shows that on average in all of the sessions, 91% of the participants felt that they experienced exercise benefits. This can be interpreted as that all of the game modes have high exercise benefits. Also, three of four participants who exercised less than three hours a week did agree with the statement.

BQ3: The session felt more like playing a game than exercising			
	Diagree	Neutral	Agree
Session 1: Single Player	28.6%	14.3%	57.1%
Session 2: PvP	14.3%	21.4%	64.3%
Session 3: Collaboration	30.8%	7.7%	61.5%
Session 4: Optional Mode	33.3%	25%	41.7%
Average	**26.75%**	**17.1%**	**56.15%**

Table 13: Results on statement **BQ3** for each session.

Table 13 represents the answers to the statement *I experienced the session more as a game than as a training session.* The result shows that on average of all of the sessions, 56% agreed, 17% were neutral, and 27% disagreed. It is divided opinions on whether it felt like a game or a training session, and although more of the participants thought that it feels like a game, there is not such a clear difference to say anything other than that what they feel is different from person to person. One interesting finding was that, among the three participants who did work out less than three hours a week and played session three, all agreed that it felt more like a game than a training session.

BQ2: I found the session physically demanding			
	Diagree	Neutral	Agree
Session 1: Single Player	7.15%	7.15%	85.7%
Session 2: PvP	14.3%	21.4%	64.3%
Session 3: Collaboration	7.7%	7.7%	84.6%
Session 4: Optional Mode	8.3%	8.3%	83.3%
Average	**9.4%**	**11.1%**	**79.5%**

Table 14: Results on statement **BP2** for each session.

Table 14 represents the answers to the statement *I found the session physically demanding*. The result shows that on average of all sessions, 80% of the participants found the sessions physically demanding whereas 20% were either neutral or disagreed. This can be interpreted as that overall all game modes were physically demanding.

BQ5: The game motivated me to complete the session			
	Diagree	Neutral	Agree
Session 1: Single Player	-	14.3%	85.7%
Session 2: PvP	21.4%	7.2%	71.4%
Session 3: Collaboration	7.7%	-	92.3%
Session 4: Optional Mode	8.3%	8.3%	83.3%
Average	**9.35%**	**7.45%**	**83.2%**

Table 15: Results on statement **BQ5** for each session.

Table 15 represents the answers to the statement *The game motivated me to complete the session*. The result shows that on average, 83% of the participants felt that the game motivated the participant to complete the session, whereas 17% were either neutral or disagreed. This highly positive result can be interpreted as that all game modes contributed with motivation to complete the sessions.

29.2 Post-Project form

This section goes through the answers to the questionnaire given to the participants who completed the first three sessions. As one quit after the second session, this form was filled out by 13 of 14 participants. The results are divided into five tables, each representing one category of questions. The questionnaire can be found in Section 24.1.3.

High Intensity Interval Training			
	Diagree	Neutral	Agree
CQ6: I experienced that my stamina (endurance) improved after playing the game	7.7%	15.4%	76.9%
CQ21: I found that my muscles made it difficult to complete the session	23.1%	15.4%	61.5%
CQ22: I found that my stamina made it difficult to complete the session	53.8%	23.1%	23.1%

Table 16: Results on the statements relevant to the physical activity aspect.

Table 16 includes all the questions and answers relevant to the physical activity aspect of the game. **CQ6** shows that approximately 77% of the participants experienced an improvement in endurance when comparing before and after the four sessions. **CQ21** and **CQ22** were added as questions to find out what aspect made the game challenging to complete if it was their muscles or their stamina. Approximately 62% of the participants felt their muscles made it difficult to complete the game, whereas only 23% felt that their stamina made it difficult. This can be interpreted as that the bike resistance was too strong, which made it difficult to max out input. One interesting finding was that most of the participants who felt that their muscles made it difficult to complete, were participants who exercised 3-4 hours a week.

Single Player vs Multiplayer			
	Diagree	Neutral	Agree
CQ7: I found the single player mode entertaining	7.7%	7.7%	84.6%
CQ8: I experienced the single player session more as a game than as exercise	15.4%	15.4%	69.2%
CQ9: My motivation increased when I played with / against others	-	7.7%	92.3%
CQ10: I found the PvP mode entertaining	-	-	100%
CQ11: Competing against each other greatly increased my motivation	-	-	100%
CQ12: I experienced the PvP session more as a game than as exercise	23.1%	7.7%	69.2%
CQ13: I found the collaboration mode entertaining	15.4%	7.7%	76.9%
CQ14: Collaborating with others greatly increased my motivation	15.4%	15.4%	69.2%
CQ15: I experienced the collaboration session more as a game than as exercise	30.8%	15.4%	53.8%

Table 17: Results on the statements relevant to the different game modes.

Preferred Mode and Rating		
	Preffered (%)	Rating (0-5)
Mode: Single Player	23%	4.08
Mode: PvP	69%	4.38
Mode: Collaboration	8%	3.54

Table 18: Preferred mode in percentage and its average rating with a range of 0-5.

Table 17 and Table 18 include all the questions and answers relevant to the different game modes. With the results to **CQ10** and **CQ11**, where all of the participants answered that they agree, there is a strong impression that competing against each other is both highly entertaining and increases the motivation. By looking at **CQ7**, **CQ13**, and **CQ14**, it is possible to see that the two other modes also got positive answers. Many of the participants felt that collaborating with others made the game entertaining and increased their motivation. Multiple participants also found the single player mode entertaining (**Q7**). When asking if the mode felt more like a game than as exercise, there was a clear positive result for both Single Player mode and PvP mode (**CQ8, CQ12**). The collaboration session, on the other hand, did not get as positive results compared to the others. 30% of the participants felt this session was more like exercising than a game (**CQ15**).

The questionnaire that was given at the end also included a question where the participants selected their preferred mode and a question for each game mode so they could give a rating between 0-5 for each game mode. The results of these questions are represented in Table 18. PvP mode clearly is the most preferable mode among the participants with 69% of the votes. 23% preferred Single Player Mode, and only one person (8%) preferred the collaboration mode. The ratings were not far apart, with PvP mode getting 4.38, Single Player getting 4.08, and Collaboration mode getting 3.54.

CQ9 in Table 17 *My motivation increased when I played with/against others* got positive results where one of the participants was neutral, and all others agreed. The participant that was neutral to this also preferred Single Player Mode. This can be interpreted as that this participant did not like multiplayer.

Replayability			
	Diagree	Neutral	Agree
CQ2: It is likely that I will continue to exercise without the game	7.7%	7.7%	84.6%
CQ3: It is likely that I would continue to exercise using the game given the opportunity	15.4%	30.8%	53.8%
CQ4: The game has made me more motivated to exercise	15.4%	15.4%	69.2%
CQ16: I was so involved in the game that it felt like time passed faster than otherwise	-	7.7%	92.3%
CQ17: The last session was just as fun, if not more fun than the first session	7.7%	-	92.3%
CQ18: Improving my score makes me want to play the game again	7.7%	-	92.3%
CQ24: The game made interval training more enjoyable	-	-	100%
CQ25: If the game was available to me, I would continue to play it actively	46.15%	7.7%	46.15%

Table 19: Results on the statements relevant to replayability.

It is important to know for retention whether this is a game that the participants would have continued to play after the user test. Table 19 includes all the questions and answers relevant to replayability. **CQ18** got positive results with 12 of 13 participants agreeing, which can be interpreted as that the participants felt it was possible to improve and that the game was not too easy, nor too hard. This can help to increase the motivation to play further, which increases replayability. All except two participants agreed that it is likely that they will continue to exercise without the game (**CQ2**).

Over 50% felt that they could play this game again after the user test (**CQ3**). However, approximately 50% did not want to play the game actively (**CQ25**). Comparing **CQ3** and **CQ25**, the participants would like to play the game again, but half of them do not want to play it actively. One finding was that the participant that had no intentions to exercise without the game (**Q3**) had neutral feelings about continuing to play the game (**CQ3**), but would not play it actively (**CQ25**). On the other hand, the participant that was neutral to continue training without the game (**CQ2**) did strongly agree that he/she would both play the game and play it actively given the opportunity (**CQ3**, **CQ25**). All except one participant agreed that they had as much fun during the last session as during the first session (**CQ17**) and that they were so involved in the game that they experienced that time passed faster than otherwise (**CQ16**). These results are very positive and increase the chances for the game to be played over a longer period of time. One very positive result was that all the participants felt that the game made interval training more enjoyable (**CQ24**) regardless of their exercise and gaming background. Almost 70% also agreed that the game made them more motivated to train (**CQ4**), which is a good result.

Overall, the results of replayability seem positive, where most of the participants enjoyed playing the game and felt that they would have played it again. All the participants agreed that the game made interval training more enjoyable, which is a good result.

Controls and Progress in Stamina and Skills			
	Diagree	Neutral	Agree
CQ1: It was easy to start playing the game	-	7.7%	92.3%
CQ5: I experienced that I got better at the game	-	-	100%
CQ20: I felt I was in control when I played the game	7.7%	23.1%	69.2%
CQ23: I quickly got used to the buttons	-	15.4%	84.6%
CQ19: I felt that the controls made sense and that my actions did what I expected them to	23.1%	23.1%	53.8%

Table 20: Results on the statements relevant to controls and progress.

Table 20 includes all the questions and answers relevant to the controls in the game and the progress in stamina and skills. All except one participant that was neutral, agreed that it was easy to start playing the game (**CQ1**). Almost all participants quickly got used to the buttons **CQ23**, and most of them felt that the controls made sense and that their actions did what they expected them to (**CQ19**). The given answers to **CQ23** along with **CQ19** can be interpreted as the players feeling confused at the beginning, but they got used to it quickly. Most of the participants also felt that they had control when they played (**CQ20**). All the players experienced that they got better at the game as they played (**CQ5**), where two people agreed and 11 strongly agreed with the statement.

Overall, the results on controls and progress in stamina and skills were positive. The results show that the participants did not have any big issues with the controls, and all players experienced that they got better at the game.

30 Heart Rate

In addition to getting answers from questionnaires, this research needed to collect heart rates to confirm or deny that the players got the benefits of high-intensity interval training from the game. As mentioned earlier, high-intensity interval training is a type of aerobic exercise consisting of intense intervals and breaks in-between. The heart rate should be between 80% and 95% during the intervals. This can be read more about in Section 7.

In this user test, the participants used the Polar H10 heart rate belt, which is meant to be one of the most accurate heart rate belts on the market. This can be read more about in Section 24.3. All 14 participants used the belt during all of their sessions. The heart rate belt did perform well during most of the sessions, except for one session where it lost its connection multiple times. One of the other participants also got a very high pulse reaching 233 bpm, which is not caused by the game. Because of this, the authors decided that the participant had to skip the rest of the session for their own safety.

When completing a HIIT session, the heart rate graph should normally look like the graph in Figure 2. When testing out our game, most of the participants got similar graphs in all their sessions. Four graphs are shown below, each consisting of either our best or worst results. The rest of the graphs are similar and can be found in Appendix C. All graphs have multiple tops, where the last four tops in most cases are each of the four intervals. The time before is used for warm-up.

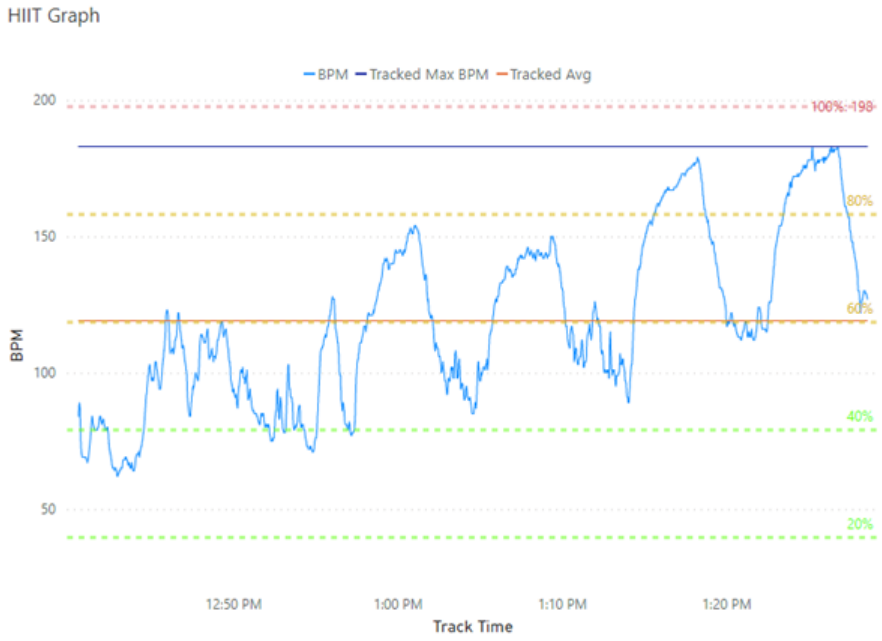


Figure 55: Heart Rate chart of Participant 4 Session 1

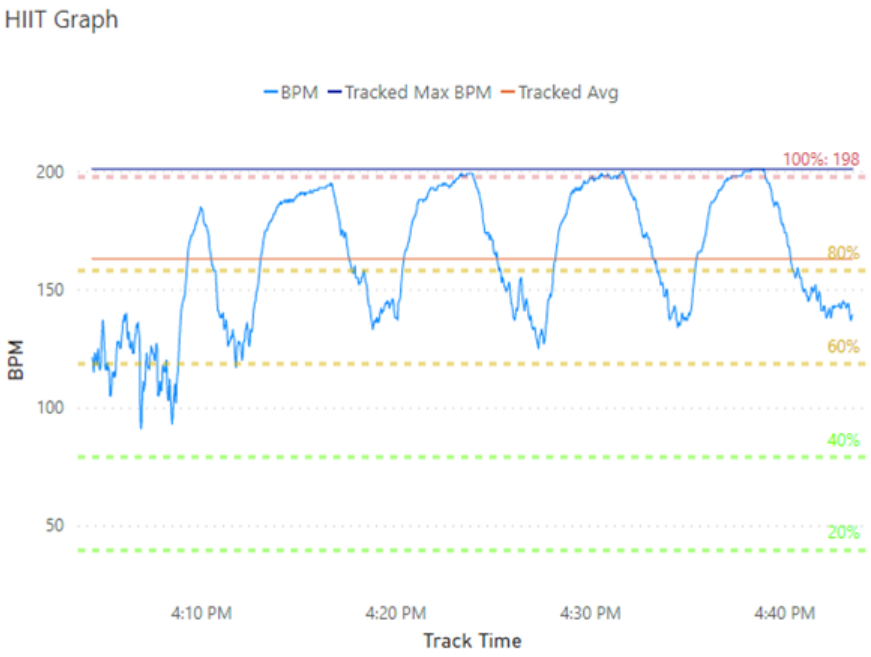


Figure 56: Heart Rate chart of Participant 1 Session 4

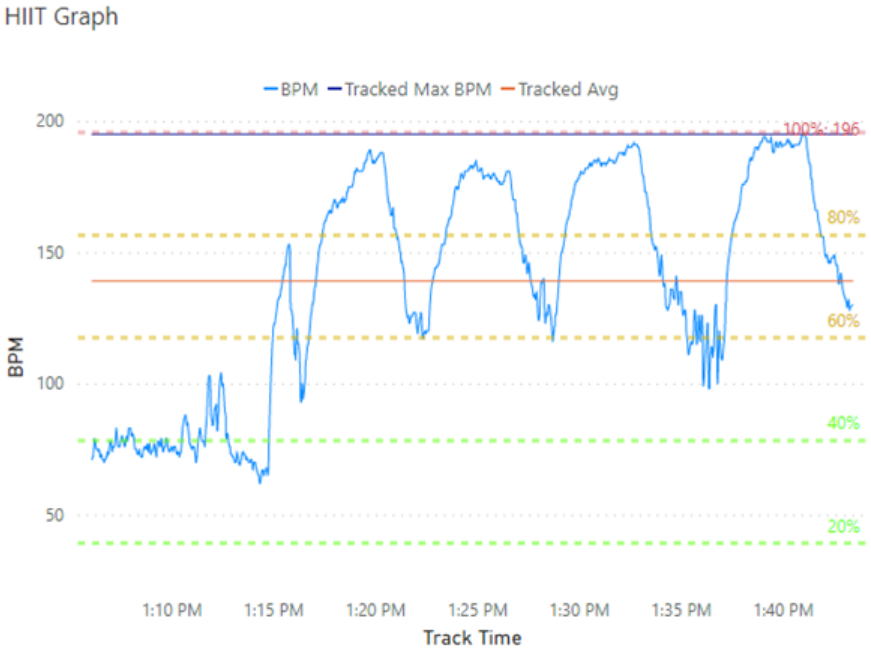


Figure 57: Heart Rate chart of Participant 2 Session 4

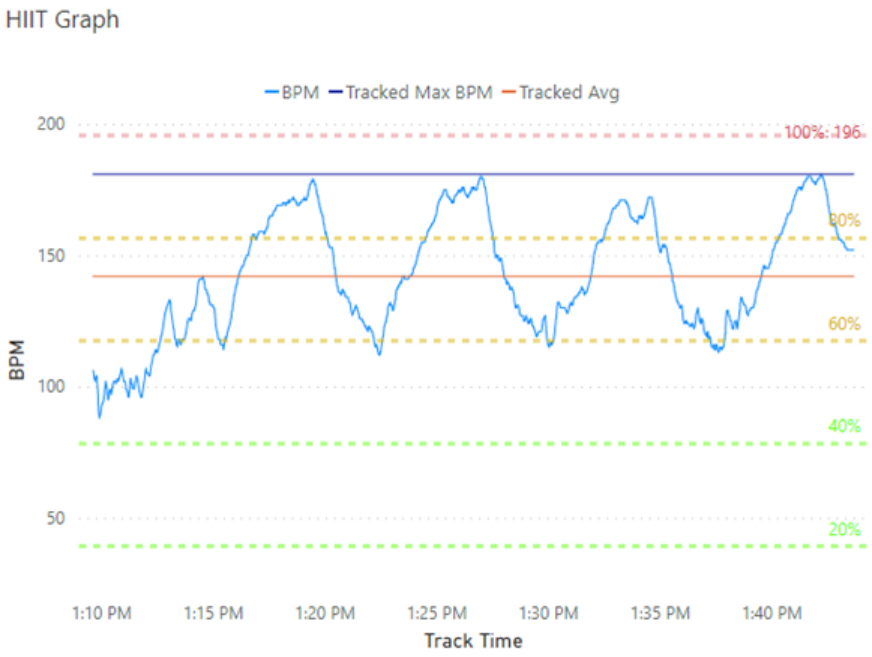


Figure 58: Heart Rate chart of Participant 3 Session 4

Figure 55 shows one of the graphs that are the least similar to the HIIT graph. This participant did have a heart rate under 80% during the first two of their intervals. As this is the first session it may be because they needed some time to get used to the game, as the heart rate increased a lot during the two last intervals. Figure 56, 57, and 58 shows on the other hand, the best results from the user tests. All of them are between 80% and 100% on every interval. Most of the other results are also similar to these figures, and this can be interpreted as that this game is suitable for HIIT. However, it should be possible to be more customizable, such that it will be more difficult for a well fit player, than a player that is not.

31 Scores

To find out if the participants increased in skills during the user test, the game tracked their scores of each song from each session. Dots represent individual score values, and lines show progress between scores of the same song and difficulty. No lines suggest that the selected song and difficulty was only played once, and cannot be used to show progress. The tables below illustrate how four of the participants progressed during the user test. The rest can be found in Appendix D.

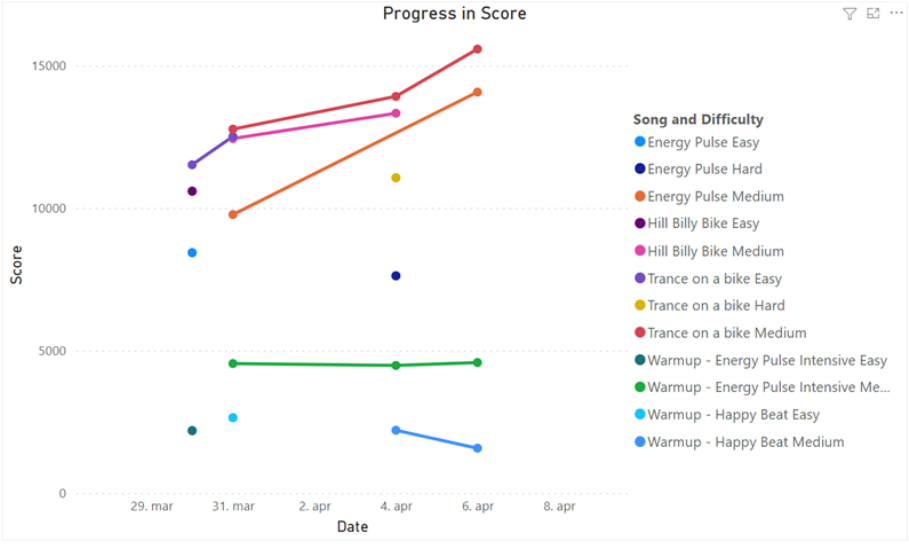


Figure 59: Progress in score of each song from first to the last session for one of the participants

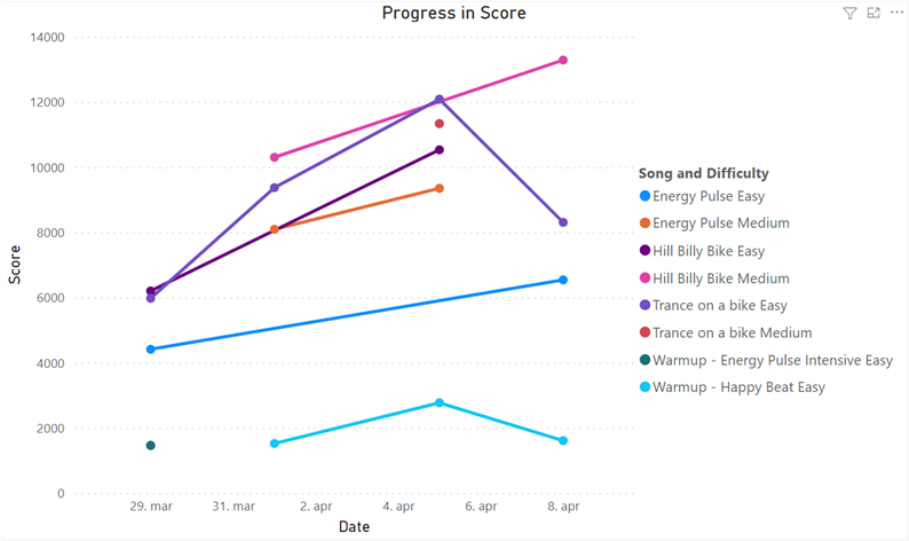


Figure 60: Progress in score of each song from first to the last session for one of the participants

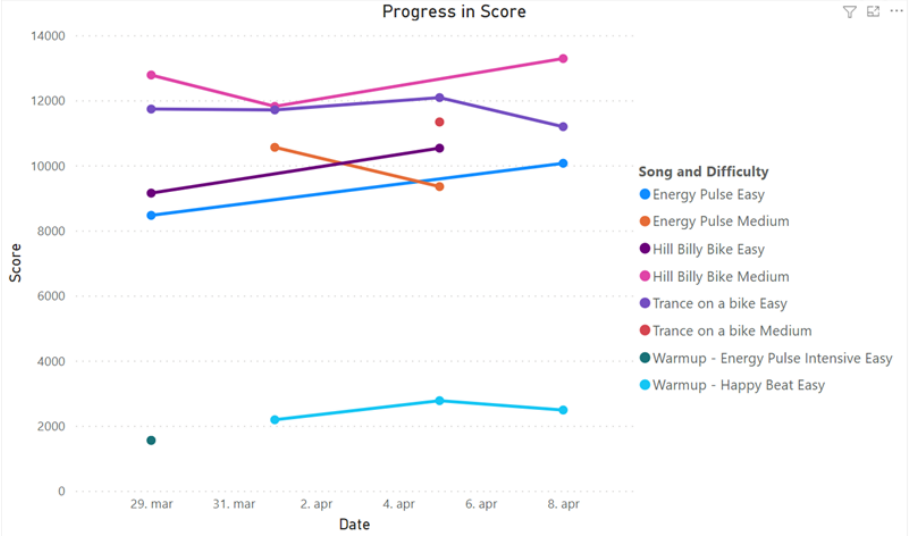


Figure 61: Progress in score of each song from first to the last session for one of the participants

Figure 62: Progress in score of each song from first to the last session for one of the participants

As we can see from Figure 59, 60, and 61, the participants improved their skills from the first to the last session. On the other hand, Figure 62 illustrates minor negative progress. The score results are not clear enough to conclude anything since there are many influencing factors, for example, whether the scoring system is accurate as a representation of progress. Also, a fault with one of the bikes made the scores less accurate which influenced the results. This is further discussed in Section 40.3.

32 Observations

This section goes through the observations found during the user test. The observations are divided into four categories: Exercise aspect, enjoyment, motivation, and social interaction. The observations are based on several things as the participants' face and body expressions, and what they said during the user test. The statements of the players were originally told in Norwegian but later translated to English by the researchers.

32.1 Exercise aspect and observed effort

The observations of the exercise aspect and the participants' efforts were very similar during all the sessions. After each interval in a session, most participants were tired and out of breath. All participants did sweat a lot, some had to wipe it off and fan themselves to reduce their body temperature. All of the participants got dehydrated and drank water at least once during a session, but most of them drank after each interval.

One player stated, "I thought this was going to be a game, but this is really high-intensity training". Another stated, "I planned to go to the gym after this session, but that is not going to happen now".

One observation on PvP mode was that the players did push themselves a bit extra because they wanted to beat the other group member. This was among other things, seen by how they tightened all their muscles at times to reach the different knobs in the game. On the other hand, multiple of the players did decrease the pedal resistance because they wanted to beat the other player. As the researchers monitored their heart rate, they told them to increase the pedal resistance if they felt that it was too low.

One finding in Collaboration mode was that in most groups, one player worked harder than the other. They needed to collaborate, but the game was too fast and it was difficult to both communicate and focus on the game at the same time. However, during the breaks in-between each interval, the players discussed how they should communicate. Multiple groups also felt like the collaboration mode was the hardest mode of the three. One player stated, "Collaboration had high and intensive tempo the whole way". This can also be because they in session three had unlocked more difficult levels than they had in the first two sessions.

32.2 Enjoyment

The observations on enjoyment were found by looking at the participants and noting particular facial expressions such as smiling and laughing. It was not much that separated the different modes. All the players laughed at some point. All but one player laughed multiple times during the intervals and the breaks in-between. Almost all of the players felt that the songs were fun and catchy.

In PvP mode, the players laughed less during the game due to focusing on the game but laughed more during the breaks. Also, most of the players did smile when they took the lead. One participant got tired and felt that the game was too difficult. This particular participant has almost never played any games in their life and does not enjoy playing any types of video games, which may be the reason for the lack of enjoyment. This participant did also quit the user test after the second session. Otherwise, it seemed like all the participants enjoyed the game. Multiple participants stated that the game made the intervals of four minutes feel much shorter and that they forgot that it is exercise. These statements were told by the participants who both did and did not play video games.

In collaboration mode, multiple participants also laughed when they missed the knobs in the game, because of that they both gave too much or too less power. Most of the users did also unlock harder levels in this session, and they smiled while playing because of the challenge of the levels.

32.3 Motivation

Observations on motivation are mainly found through what the participants said, and their actions. Almost all the participants were highly motivated to unlock all the levels, and also beat their own and others' high scores. Multiple of the participants had particular facial expressions when they missed during the game. Many forgot to blink while playing because they concentrated and focused so much on the screen. Some participants looked multiple times at the other player's screen during a song to check how they stand compared to themselves. One participant stated, "Time just flies, it does not feel like 4 minutes at all". Another stated, "this game suits everyone". This can be interpreted as the participants enjoying the game and were very motivated while playing. Multiple participants discussed the game in their own free time outside of the user test. For instance, they talked about different strategies, and how to play as best as possible. In addition, four groups asked if they could play more after the session was completed. These groups also asked if they could create and play tournaments with other friends, but due to lack of time, this was not carried out. One group also wanted the bike and the game to be placed missed, so they could play it in their free time.

In the PvP session, multiple of the players turned down the knob that controls the pedaling resistance. This was because they wanted to get higher scores and beat the opponent. As a result, it may have had a negative impact on the exercise aspect, but by monitoring their heart rate, the researchers told them to increase their pedal resistance if they felt that it was too low.

In collaboration mode, the players were fully concentrated on the game while playing. A few times, the players got a bit upset with each other since they could not collaborate well enough to reach the different knobs because of differences in skills.

It is hard to conclude that the players were motivated to play the game by only the observations. This is because everyone reacts differently, but overall it seemed like almost all players were motivated during all the sessions.

32.4 Social Interaction

Observations on social interaction are collected by looking at the communication and actions between the players. During all the sessions, every participant communicated with each other during the breaks in-between the intervals. Multiple players told that the songs were catchy during one of the sessions. Otherwise, there was not much in common between the different game modes.

During the single player session (first session), the players' shared their knowledge with each other and discussed how to play to get the highest scores possible. They helped each other to understand parts of the game, and gave tips and strategies on the things that the other player felt were difficult. They also compared scores after each interval by looking at each other's screens even though it was meant to be an individual session. To improve the user tests and separate the game modes even more, it should have been a wall between the participants during the single player session.

In PvP mode, there was less talk during the intervals, but more during the breaks. This was because the players were fully focused on their screen to beat the opponent. During the breaks, however, the participants talked about different things, for instance, exercise in general, how fun the game was, and how different parts of the song came as a shock. They also discussed strategies to do their parts better. Otherwise, most of the participants were very competitive and told each other that they were going to beat each other in the next rounds. Multiple participants also discussed high scores and best combos. Since this was the first session the buttons were introduced in the game, three groups talked about how it was more difficult to concentrate on both the buttons and the rest of the game at the same time.

There was a bit more interaction between the players during the game in collaboration mode, as most groups had to communicate to get the highest score possible. For instance, the players told each other to not relax when one of the players contributed a lot more than the other. They also

planned which songs to do first and which to do later, to get the best scores. The groups had different strategies, where most of them just told each other that they should give more or less power to the different parts of the song. One group had another strategy where they discussed that they should shout ”I’ve got a button”, and when they got a button, the other player could do most of the work with the pedals.

32.5 Other comments by the participants

During the user test, multiple participants made comments regarding the game. Among other things, multiple participants meant that the button controls were confusing when comparing them to a PS controller. However, all of these participants learned the controls quickly. One participant commented that a countdown should be shown at the end of each song to motivate the players even more to give a little extra. Multiple participants commented that they did not understand the difference between the score group *Perfect* and *Great* because there was little accuracy that separated the two.

33 Summary

This part stated the results of the user test. Fourteen subjects with a variety in how much they exercised and played games, participated in the user test. The results from questionnaires, observations, and heart rate measurements combined provide a strong basis to discuss and make conclusions regarding the research questions.

Part VI

Discussion

The goal of this part is to discuss the observations and results from Part V in light of the research questions to identify notable traits regarding the fulfillment of the research questions of the thesis. The part will discuss comparisons between user groups and look into how results reflect the research questions regarding exercise, enjoyment, and engagement. This discussion covers reflections regarding theory, choices made by the team in the study, and the implications these choices may have on the results.

During the discussion of research questions, the user groups established based on the questionnaire from Section 24.1 will be used to identify variances between user groups, and how different groups may experience the research prototype. This includes discovering how well the prototype fulfills the research questions for different user groups. The user groups used for the discussion are:

- *Men* vs *Women*
- *Gamers* (1+ hours of gaming a week) vs *Non-Gamers* (0 hours of gaming a week)
- *Active* (3+ hours of exercise a week) vs *Non-Active* (Less than 3 hours of exercise a week)

These groups are defined in Section 28.

34 Evaluation of the degree of physical benefits

RQ2: *To what degree does our game provide high-intensity interval training?*

This section will discuss and evaluate if playing the game has any physical benefits for the player, and to what degree the game provides high-intensity interval training (**RQ2**). As mentioned in Section 7, the players have to get at least 75 minutes of high-intensity interval training in a week to reach the recommended amount of physical activity. In addition, the players have to stay between a heart rate of 80% and 95% of their maximum heart rate during each interval to be considered as HIIT.

To evaluate the physical benefits of the game, this section will look at the players' own thoughts given through the questionnaires, and the observations of the researchers. The most important statistic will however be the heart rate measured during the sessions. The combination of subjective and objective data will help to give a more accurate evaluation.

34.1 Questionnaires

In the questionnaires, the players answered very positively when it comes to the benefits of the game. On average, 91% of the participants agreed that they experienced getting exercise from the sessions (Table 12). Also, 80% of the participants found the sessions physically demanding (Table 14). Most of the players also felt that their endurance improved after playing the four sessions (Table 16). These answers contribute in a positive way to the evaluation of the physical benefits. There was no significant difference between the different user groups.

When asking about if it was their stamina or their muscles that made it difficult to complete, most of the participants found their muscles most challenging. As the game had a manual pedal resistance knob, the participants were told that they could tweak it as they want during the game, just not too low. However, tweaking the resistance lower will make it unpleasant to bike, as it feels like you do not have any control of the pedals. This could have made the sessions too difficult for some players. As this limit was caused by the bike itself, the researchers could not solve it in any way, but the newer *PlayPulse One* bikes do have the possibility to tweak the resistance automatically, even by the game itself. This could solve the problem, by automatically adjusting the resistance depending on the players' heart rates or based on in-game difficulty.

34.2 Observations

The observations showed that the players got tired during the sessions (Section 32.1). Most of the participants breathed heavily, drank water, and wiped off sweat. They pushed themselves and it was possible to see that they tightened all their muscles at points, and made different facial expressions. The players got tired during and after the sessions, and this can be interpreted as that the players got a heavy exercise. These results match the results of the questionnaires.

Another disadvantage with the manual adjustment of the pedal resistance is that the players started to decrease the resistance to reach the higher parts of the game easier so they could get higher scores. This removed some parts of the exercise aspect, but as the researchers monitored their HR, and told them to increase their resistance this got solved during the user tests. However, in a real-life scenario, this would not be a solution. As mentioned earlier, automatically adjusting the resistance on the newer *PlayPulse* bikes will solve this problem as well.

34.3 Heart Rate Graphs

Heart rate graphs will be the main source of data to validate if the players got high-intensity interval training. As these graphs are both objective and based on numbers, they provide a direct way to validate the success of the study regarding physical benefits. To reach HIIT it is required

that the players are between 80% and 95% of their maximum heart rate during each interval. *As seen in Appendix C, most of the participants reached these results.* Most of the cases where players did not reach over 80% of their max heart rate were measured in the first session. This can be because the players wanted to learn how to play the game. Another reason could be that the game was too difficult for their muscles, which resulted in them not reaching their maximum heart rate.

Many of the participants also reached 100% of their heart rate during many of the intervals. When taking into consideration that most of the participants felt that their stamina was not an issue from the results in the questionnaire, this was a bit strange. One possible answer to this may be that the formula used to calculate the players' maximum heart rate is inaccurate. Another can be that the Polar H10 HR belt is inaccurate. A third option is that the question from the questionnaire was formulated in a difficult way which may have led to misunderstandings. The max heart rate can also vary from person to person, which could be the cause for these participants, and the reason for them reaching 100% of their heart rate. If this is not the case, the game clearly indicates that the game gives physical benefits to a high degree.

34.4 Evaluation

Overall, combining the results from the questionnaires, observations, and heart rate graphs, give positive results. *The participants felt as if they got the physical benefits from the game.* Many of the participants that already had done interval training mentioned that doing it through a game like this made it much more fun and that the game gave physical benefits. Also, all except for one of the non-gamers mentioned that they got physical benefits from the game. *The HR graphs validate and indicate that most of the players reached HIIT, which is a great result.* As mentioned in the Dual Flow theory (see Section 8.4), the balance between Game Flow and the training aspect is important for delivering a good game. *As most of the participants felt like they enjoyed the game, and also got physical benefits, it is possible to conclude that the game has a good balance.*

The only disadvantage was the manual control of the pedal resistance and the bike itself. The manual control of the pedal resistance tempted multiple players to decrease the resistance to get better scores. This will be solved by programmatically adjusting the pedal resistance, which is a possibility with the new *PlayPulse* bike. Another problem is the weight of the wheel on the spinning bike. If the weight is not adjusted to the player's weight and fitness level, the players do not have the same starting point, which will cause a difference in the physical benefits for the players.

35 Evaluation of participants' enjoyment of the game

RQ3: *How does our game affect the players' enjoyment?*

This section will discuss the research project's ability to provide enjoyment to the users of the game. It will compare collected data to established game design theories applying enjoyment to verify the project's ability to give players a satisfying experience. User enjoyment is not an objective data source. Enjoyment means different things in different contexts. In Section 8.2, the concept of *GameFlow* is introduced. *GameFlow* introduces a list of elements and their criteria. This model, along with other models for exercise games and enjoyment such as *Malone's model* and *Dual Flow* will be applied to the data collection and observations done in the study to identify the research project's effect on enjoyment.

35.1 Questionnaires

In order to identify whether or not the research project fulfills these criteria, questions were included in the session forms and the post-session form described in Section 24.1.2 & Section 24.1.3. The results of these questionnaires are found in Section 29.1 & 29.2 respectively. The questions from the post-session form related to *GameFlow* are the following:

- Control
  - **CQ19:** I felt that the controls made sense and that my actions did what I expected them to.
  - **CQ20:** I felt I was in control when I played the game.
- Immersion
  - **CQ16:** I was so involved in the game that it felt like time passed faster than otherwise.
- Player Skills
  - **CQ1:** It was easy to start playing the game.
  - **CQ5:** I experienced that I got better at the game.
  - **CQ23:** I quickly got used to the buttons.

There are also direct questions regarding enjoyment included in the questionnaire, unrelated to GameFlow. These questions focus on specific comparisons between game modes and entertainment. These questions are the following:

- **CQ7:** I found the single player mode entertaining.
- **CQ8:** I experienced the single player session more as a game than as exercise.
- **CQ10:** I found the PvP mode entertaining
- **CQ12:** I experienced the PvP session more as a game than as exercise.
- **CQ13:** I found the collaboration mode entertaining.
- **CQ15:** I experienced the Collaboration session more as a game than as exercise.
- **CQ24:** The game made interval training more enjoyable.

35.2 Observations

Section 32.2 discusses the observations regarding enjoyment during the experiment. The participants are shown to have been positive. *While being focused during gameplay, the participants would smile or laugh after the high-intensity interval.* There were signs of friction and frustration during the tutorial for the game mechanics. This was due to how progression through the tutorial worked, which turned out to be unintuitive and difficult for many participants. The tutorial required you to stop, then reach a certain level of cadence to progress. Players however believed they had stopped when they had not, which lead to a gap between expected behavior and the intended approach. This could have been avoided if the game had used normal button input for progression. Players did however have a clear understanding of cadence input levels once the actual game started as a result.

35.3 Evaluation

The results shown in Section 29.2 show that there is a high degree of user satisfaction with the game. For the *GameFlow*-related questionnaire statements, there was a broad consensus that the game was enjoyable. On average, 82% of the users responded "Agreed" or "Highly agreed" on the statements regarding *GameFlow*. Everyone agreed that they experienced progression, however, the biggest disparity was regarding **CQ19**. *Only 53% agreed that their actions did as they expected them to.* This can be due to game design issues such as unintuitive mapping of controls or poor tutorials. It could also be related to an issue that came up during the study experiment, where one of the bicycles had slightly inaccurate speed readings, most likely due to a misplaced movement reference image used by the sensor for speed detection. The system that handles speed detection on the *PlayPulse* bikes is explained in Section 9. The bicycle had a difficult time maintaining constant output even though users experienced riding at the same speed. This led to users having to compensate for the drops in speed, which may have been experienced as strange and unintuitive. This would not be a flaw in the game design and rather in the physical execution. This could have been avoided had the researchers identified the problem beforehand as a flaw, not as a skill issue.

As discussed in Section 34, the participants felt they got physical exercise from the study, and the collected heart rate data support the claim. Applying the *Dual Flow* model, see Section 8.4 this means both the requirements for attractiveness and effectiveness are met. *The game seems to provide enough challenge to keep the player focused, as well as enough skill and control given to the player that provides what the model describes as flow.* For effectiveness, the pulse data suggests the research prototype does provide the intensity required to provide benefits. The fact that almost all the participants finished all four sets in every session suggests that the game is also balanced to the point where players can continue to play in order to improve their fitness. This means *Flow* is applied in both exercise and gameplay, which may explain the participants' high level of enjoyment.

36 Evaluation of game configurations

RQ4: *What play configurations provide the most incentive and engagement?*

This section will discuss the different game configurations the research project explored and how they have affected the participants' engagement and motivation. The different game configurations include playing alone, playing collaboratively, and playing competitively. This section will discuss how the feedback from participants may identify features that motivate participants to play more and to improve, which may be used in order to improve an exergame's engagement.

36.1 Questionnaires

All of the questionnaires provide some data used for the assertion of which game configurations provide the highest engagement. As explained in Section 23.2 the study consisted of four sessions. For the first three sessions, the participants tried different game configurations. In the last session, the participants were allowed to freely choose their approach. After each session, the users responded with their opinions regarding that session. This means each session form is mapped to a game configuration.

The post-form also features questions regarding the user's preferences in-game configurations. Table 17 and Table 18 from Section 29.2 show the statements that may be used for discussion regarding game modes. Table 17 contains statements regarding game modes as well as whether users like to collaborate or compete in general. Participants were asked to give ratings to each game configuration they tried and to pick one preferred mode. This information is shown in the aforementioned Table 18. This table shows that 69% of participants preferred playing against each other, 23% preferred playing separately, and 8% preferred playing collaboratively.

36.2 Observations

While observing the users during the different sessions as pointed out in Section 32.1, the users generally put a bit more active effort into doing their best when the players competed against each other. Doing better than the other player proved to be a strong motivator. This could also be seen by how users laughed less during PvP as they were focusing. Participants were also focused during the collaborative game mode, but some showed signs of frustration as different levels of effort were put in, where one had to "pick up the slack" from the other user.

36.3 Evaluation

All of the game configurations received positive feedback. The configuration that participants preferred the most was playing competitively against other users. Playing alone or collaboratively had some users find the experience to have less enjoyment, while all of the participants agreed that playing against each other was entertaining. This seems to fit well with the social aspect of *GameFlow*. While not one of the initial *Flow* elements, it is considered an important part of the model. Malone's model, see Section 8.3, also provides insight into why the players found PvP more fun. According to Malone, *Challenge*, *Fantasy*, and *Curiosity* make learning more fun. This has also been applied to exergames. The most relevant aspect is *Challenge*. Playing against other users provides an uncertain outcome as a person's success is pitted against their opponent's. This means that there is a variable difficulty as the success requirements depend on the skill of the other player. This skill is hidden information, which gives the sense of slight randomness from the player's point of view.

Playing collaboratively also provides challenges but in a different way. When playing collaboratively, your outcome depends on the other player which introduces another set of challenges. Unlike

the other game modes, you do not have full control of the input. This does provide an uncertain outcome. This lack of control does however go against *GameFlow*'s element of control, which may have influenced the rating.

Overall the rating and preferences were similar to the expected results. *Competition increases the odds that the player will experience intrinsic motivation [20] and provides new variable difficulty and uncertain results that may provide more excitement to the player.* The fact that the collaborative game mode was the least enjoyed was surprising, but can be attributed to the lack of control and frustration caused by inequality of effort.

37 Evaluation of the game's ability to lower bar-of-entry to exercise

RQ5: *Does our game provide a lower bar of entry to start training?*

This section will discuss the effect the game has on motivation to exercise. Specifically, this section looks into the bar of entry to play the game and compares it to high-intensity interval training such as 4x4 to identify whether the game makes it easier to start exercising.

37.1 Questionnaires

The questionnaires identified user groups based on activity levels. Two groups were recognized in Section 28.2, where four participants had two or fewer hours of exercise during a normal week while ten participants had three or more. One of these participants did not complete the study and as such did not complete the final questionnaire. The post-study form featured several statements aimed at identifying how well the research prototype gamified exercise:

- **CQ8:** I experienced the single player session more as a game than as exercise.
- **CQ12:** I experienced the PvP session more as a game than as exercise.
- **CQ15:** I experienced the Collaboration session more as a game than as exercise.

The full list of questions related to motivation and enjoyment and their results are shown in Table 17.

Playing along and against each other received the same results from the questionnaire: 69% of participants experienced the session more as a game than an exercise session. For the collaborative play that value was a bit lower, at 54%. For PvP and single-player in particular, this result suggests players can get interested based on the merits of the gameplay. After each session the participants filled in a form, where two of the questions were applicable:

- **BQ1:** This session was very entertaining
- **BQ3:** The session felt more like playing a game than exercising

Looking at the result from the first session, an estimation of first impressions can be created. After the first session, 86% of participants responded they enjoyed the session, and 57% responded they experienced the session more as a game than as an exercise. This suggests a strong first impression.

37.2 Evaluation

The applicable information from these questions is the degree to which the games provide intrinsic motivation. To lower the bar of entry to exercise, the game needs to provide motivation driven by more than just the external benefits. This would be extrinsic motivation, and as explained in Section 8.1, intrinsic motivation is considered to provide better results and is easier to sustain than extrinsic motivation. The way the game can provide intrinsic motivation is through enjoyment, where the player wants to play because the game is fun, not its benefits. This is especially the case for high-intensity interval training, as it requires pushing your heart rate to its max, which may be uncomfortable and unappealing for inactive people. As discussed in Section 35, the study suggests that the enjoyment level of the game is high. *For lowering the bar of entry to exercise, the statements regarding experiencing the project as a game rather than an exercise are extra useful.* This is because these questions suggest players focus on the gameplay rather than the exercise, which would increase the chance for someone inactive to continue playing. *While the average among*

users who experienced the prototype as a game after the first session was 57%, among the users considered non-gamers this value was 25%. While this value has a low representative value as the population is only four, it does suggest that the game may have difficulty applying the gamified appeal to non-gamers. *In comparison, the value for gamers is 70%, which suggests a strong gamified appeal to people with experience with games.* For inactive participants, this value is 50%, while for active participants this value is 60%. Again, the confidence in these results is low because of the small population, and there is some overlap between the inactive and non-gamer user groups. The non-gamer user group's low result may be due to little exposure to gaming, or little interest in gaming in general which may lead to focusing on the exercise aspect. The result from the inactive group suggests that the game manages to gamify the high-intensity training well, as they both responded relatively high on experiencing it as a game, as well as high enjoyment. *This means the game has some ground to stand on to claim that it reduces the bar of entry into intensive exercise.* This does however assume there is a connection between experiencing the prototype as a game and interest for gamers. This may not necessarily be the case, which means drawing conclusions is difficult. It would be useful to look more into the concept's appeal to inactive people who have not tried the game in order to identify if more of them would play the game than would participate in traditional exercise, meaning the bar of entry would be lower.

38 Evaluation of the motivation to train over a longer period of time

RQ6: *Does our game motivate players to train over a longer period of time?*

If this exergame is played for exercise purposes, it only has exercise benefits if played over a longer period of time. Therefore, it is important to evaluate if the players are motivated enough to continue to play the game after the user test. This is evaluated by analyzing the results of the questionnaires and looking at the observations. This section will also evaluate how the game suits gamers, non-gamers, the ones that are physically active beforehand, and the ones that are not.

38.1 Questionnaires

The questionnaires consisted of questions that among other things asked about the players' motivation and the game's replayability. On average 83% of the players felt that the game motivated them to complete the session (Table 15). Almost everyone felt they wanted to play the game again to improve their results (Table 19). Also, they felt that they were so involved in the game that they experienced that time passed faster than otherwise.

Most of the participants wanted to play the game if the opportunity was given, but only half would play it actively. The players that did not want to play actively were the players that played games 7+ hours a week. This may be due to different reasons, such as HIIT being a bit challenging or that the game got less fun after a while because it only consisted of three songs and one type of background animation. However, since all the participants felt that the game made interval training more enjoyable and almost all felt that they had as much or more fun during the fourth session as during the first, the latter would make less sense. As mentioned in Section 37, high-intensity interval training is a challenging exercise for someone that does not like physical activity, which can result in a further lack of motivation. However, mostly all participants responded that the game made them more motivated to exercise which is a good result. This can strengthen the fact that exergames can help with motivation to do physical activity.

38.2 Observations

The observations matched very well with the answers on the questionnaires. Almost all the participants were motivated to unlock all songs and levels and beat their own and others' scores. This shows that including theory on rewards such as unlocking mechanisms and score lists really improved the game. The GameFlow theory mentions that it is important that the players do not get distracted while playing the game. Multiple of the participants told that they forgot to blink because they needed to focus, which can be interpreted as that this part of the GameFlow theory is implemented well into the game.

38.3 Evaluation

As this research also evaluated that the exergame has high training benefits (Section 34), it is possible to conclude that the application of dual flow theory in our research prototype is well balanced between the GameFlow and the training aspect. *Since everyone agreed that this game made high-intensity interval training more enjoyable, it can be concluded that this game at least has possibilities to be played by people who want to start or do interval training.* Even though the results in this research show that most of the participants would have played the game again, these results are based on players' thoughts after playing the game four times within two weeks. It is difficult to predict if the game is re-playable for a longer period of time, and further experiments that take place over a longer period of time are needed to conclude this. However, based on this research it seems like the exergame is enjoyable over time. Adding more songs, levels, and a variety

to the background animations, for instance, including concert arenas and animations that match the game, will improve the game further.

39 Evaluation of progression from the prototype

RQ7: *Does our game give players the opportunity to observe progress in stamina and skill?*

This section looks into how the game handles progression. This means both in the game as well as on a personal fitness level. Using the results from the questionnaire as well as observations, this section will look into the research prototype's implementation of progression and retention features, the effect these have had, as well as the experienced progression among participants.

39.1 Questionnaires

Progression is usually an objective metric of change. The questionnaire however provides feedback on the subjective experience of the participants regarding progression. The questionnaire had several questions where the aim was to identify whether or not the user felt they had improved, both in the game as well as in fitness:

- **CQ5:** I experienced that I got better at the game.
- **CQ6:** I felt that my stamina (endurance) improved after playing the game

The questionnaire statement regarding endurance improvement had a level of agreement of 76.9%. This means that most of the participants themselves felt their endurance improve. This could also be reflected in the in-game score result, as their improved endurance would make it easier to stay focused and do well during the game.

39.2 Evaluation

The game was designed to include specific progression aspects such as a leveling system that unlocks new songs, as well as new difficulties being locked behind score requirements. The decision to include these tactics was based on theory from Section 16.4 and apply the concept of hidden information to provide retention. It also provides progression, as players observe they have more options than in the beginning. Being able to look at play history also provides a sense of progression, as players can compare their scores. *Regarding improvement in the game, all of the participants responded they experienced growth.* Examples of how each participant scored in the game can be found in Section 31. The examples show that most users experienced positive development during the course of the study. As mentioned in that section, there is not enough data to be able to conclude that playing the game makes players improve. However, the questionnaire suggests the participants believe so themselves. This improvement most likely comes from a better understanding of the controls, such as how best to adjust cadence as well as from knowing how much input maps to the different levels in the game. *When it comes to fitness progress, four sessions is not enough time to accurately gauge improvement in oxygen intake.* The heart rate data from Section 30, as well as the discussion from Section 34 suggests that most users achieve HIIT. This should over time provide progress in physical fitness if players maintain the effort of playing. Given that the game has enough songs and difficulty options, as well as a balanced unlock rate, the game can provide a lot of progression to the player if they keep playing, both in the game and physically.

40 Validity and Reliability

Two important facts to discuss in all research are validity and reliability. It is important because the results should be replicable, and high validity and reliability will increase the quality of the research. In this research, there exist multiple facts that can have an impact on the final result and conclusion, that need to be mentioned.

40.1 Sample

Due to conducting a large user test within a two-week time span, it was crucial to find people that could participate four times during this period. Due to the strict time limit, it was easier to plan and carry out the user test by asking acquaintances. Thereby, this research used convenience sampling, a non-probability sampling. Even though it was easier to get a sample, one big disadvantage is that it is not possible to know if it represented the entire population.

Another disadvantage of selecting acquaintances is that it may result in inaccurate answers because the researchers are familiar with them. However, the participants consisted of both acquaintances and their friends who did not know the researchers. Also, the participants were informed that they should answer as honestly as possible to get more accurate research. Since most of the participants were university students and had some knowledge of how research works, and since the answers on the questionnaires, observations, scores, and HR graphs match, it is a high probability that the answers are accurate.

In total, 14 participants were a part of the study experiment. As mentioned in Section 26.2, in order for statistical analysis to have representative significance researchers suggest a sample size of at least 30. This means the result of the study results may have variances in the population.

40.2 Representative Value

The results found in this study represent the response from the *WaveRider* research prototype. While it is natural that the data can be applied to analyze the effect of the prototype, applying the same data for a more general issue may provide uncertainties. The research prototype is an exercise game, but there are variances between gameplay mechanics, genres, and intended markets between games that can affect how an exercise game may perform. As such, using the study as a representation of exergames may prove inaccurate. The positive responses in the study do provide some indication that there is potential for exercise games to provide high entertainment and motivation, and in this case, specifically in the rhythm game genre.

40.3 User Test

One limitation with the user test was that the test room was too small, and had few poor ventilation options. Since many of the user tests were right after another, it sometimes smelled of sweat, which may have affected the impression. More importantly, the warm climate could have affected the heart rate, which could result in a less accurate heart rate measurement. It was planned to move all the equipment to another larger room with better ventilation options before the user tests, but could not be done in time. To make the best of it, the researchers put a table fan on the table to get some air.

One thing that multiple of the participants felt was that one of the bikes had some faults. While the correct bike did make the character in the game go smooth, the faulty bike did make the character go a bit up and down. When inspecting this further, the researchers found the movement reference image used by the sensor for speed detection to be slightly misplaced. As this was found after some of the sessions, the researchers concluded to not do anything about it to get as similar tests as possible for the participants. This could have an impact on what the participants felt and answered

on the questionnaires. Also, this makes the score results less accurate, which is one of the reasons that it was not prioritized as one of the main resources of data.

Another fact that could have resulted in less accurate results is that the game was played in groups of two. Communication between the group members during the sessions could have affected their opinions. However, this also goes the other way, where the participants may get a clearer picture of their opinions based on the other's point of view.

The user test only consisted of three songs. As it may be enough for most of the participants for playing only four sessions, it can have affected some participants that get bored easily.

Some of the participants could also have misunderstood the questions in the questionnaires which would make an impact on the final results. To solve this, some of the questions were asked several times worded in different ways. This research also took advantage of the triangulation method, with multiple kinds of data generation methods such as questionnaires, observations, score data, and heart rate measurements. This increases the validity of the collected data.

Part VII

Conclusion and Further Work

This part summarizes the research goal and research questions, and how the study and report answer these goals and questions. It also provides its scientific contribution and suggests further work to advance the field of exercise games.

41 Conclusion

The goal of this study was to develop a new, entertaining exercise game for the Playpulse platform to motivate users to obtain high-intensity exercise using gaming. The result was the creation of *WaveRider*, an exercise rhythm game where the goal is to match cadence values that varies based on the song. These songs were designed to provide four minutes of high-intensity interval training, where the gameplay loop would naturally replicate the heart rate progression of traditional HIIT. The game utilized game design and exercise theory to optimize the user experience. This section will look into the research goals from Section 3 and draw conclusions based on the study and results from this report.

RQ1: *What is required in an exercise game to ensure high satisfaction and physical results?*

Exercise games aim to contribute to exercise in a way that motivates users differently from traditional exercise means. The field of exercise and games has been explored, and useful models for design have been created. Models such as *Dual Flow*, *Malone's theory*, and *GameFlow* provide important aspects to consider as well as tools for the development of exercise games. These laid the foundation that our game design rests upon. Our research shows that focus on challenge, progression, and variety provides users with an intrinsic motivation that drives players to do their best and feel satisfied. Balancing the game difficulty proves essential to provide physical benefits, so knowledge of exercise theory as well as testing and feedback is required.

RQ2: *Does our game provide high-intensity interval training?*

WaveRider was designed to provide high-intensity interval training. The gameplay flow intends to replicate the flow of the traditional 4-minutes-of-running-3-minutes-of-rest exercise. Based on responses from questionnaires as well as heart rate data collected using H10 heart rate sensors show that the game provides most users with HIIT. Heart rate data match very well with the requirements, having almost all users reach above 80% max heart rate during the intervals. Paying attention to incoming input draws the user's focus away from exhaustion which leads to users finishing the sets. As long as difficulty is balanced, the game is shown to provide high levels of intensive exercise.

RQ3: *How does our game affect the players' enjoyment?*

For a game aiming to provide intensive exercise, enjoyment is a key aspect to maintain the motivation required to continue the training regimen. By applying game design theory and focusing on visual and audio feedback to users, the game has shown through questionnaire responses to reach high levels of enjoyment. Several participants commented that the exercise aspect was forgotten as they were too engaged in the game. The game provides a gameplay loop that forces users to stay attentive, as the time from new input levels are introduced to when they need to meet it is short. This means some level of reflex is involved, providing variation and unpredictability. Responses show that the prototype was very entertaining and kept players engaged through all sessions.

RQ4: *What play configurations provide the most incentive and engagement?*

To achieve the highest level of engagement possible, the prototype was designed to provide several approaches to play. The game lets players play by themselves, play against other players, or collaborate to exercise. Including various game modes provide the game with variation, but the main focus was to identify which configurations players matched HIIT most accurately as well as what

they wanted to play the most. The results show that competitive play was the most entertaining way to play, where challenging each other provided extra motivation to do better. Playing cooperatively was the least engaging, as it provided areas of conflict due to lack of communication. The results of this study can be kept in mind for future exercise game design, as competition provides extra motivation which is essential for games with physical strain where ease of use is low compared to traditional video games.

RQ5: *Does our game provide a lower bar of entry to start training?*

Exercise requires physical effort, which means motivating users to play exercise games requires more motivation to start than non-exercise video games. *WaveRider* aims to reduce the bar of entry to exercise for people who lack the motivation required for traditional exercise. The game attempts to do this by focusing on interesting gameplay and visual and audio fidelity. The game was designed to look nice which may entice players to try it. Using gamification as a metric for identifying how well the game disguises exercise allowed the study to get data used as a heuristic for the bar of entry for exercise games. The response from participants showed that the prototype provided an experience more akin to gaming than exercise. Assuming the individual has a lower threshold to play games than exercise, this can be promising results for lowering the bar of entry to exercise for inactive people with an interest in games.

RQ6: *Does our game motivate players to train over a longer period of time?*

For exercise to provide a significant lifestyle impact, it requires long-term investment and repetition. For the game to motivate players to keep up with activity using the game, the prototype needed content and replayability features. The inclusion of leveling systems, different unlocking methods, and multiple songs with several difficulties aimed to provide participants with new experiences over time. The prototype also provides players with different ways to play. Thanks to these variations and gradual introduction of content the participants responded with high enjoyment for all of the study sessions without a drop-off of interest. Approximately 92% of the participants responded that their last session was equally as fun as their first. This level of long-term interest shows that given enough content the game can become routine for players.

RQ7: *Does our game give players the opportunity to observe progress in stamina and skill?*

Assuming exercise theory for HIIT applies as well as the heart rate data collected is accurate, the participants would see significant improvement in stamina after continued repetition. All requirements for HIIT were met as almost all players reached 80-95% max heart rate, some even up to 100% of calculated max heart rate. For progress in skill, the scores are a valid representation. Looking at how participants scored over time during the study, most of them experienced positive development. Questionnaire responses also suggest players experienced skill development during the study. As the gameplay loop is simple with few concurrent factors, it is unlikely it would take very long to reach a skill ceiling with limited content. To prolong skill progression, new factors would need to be introduced. Stamina improvement would improve focus during the game, so players would see some skill improvement over time.

41.1 Summary

The *WaveRider* prototype manages to provide players with an exercise game experience where high-intensity interval training is achieved while enjoyment and motivation are kept high. The study shows that the project was successful in creating a new, entertaining exercise game for the *PlayPulse* exercise bikes. The game manages to focus its players on the gamified goals, and

competition was shown to provide extra intrinsic motivation to perform. Players were motivated over several sessions with no drop in interest and experienced improvement in stamina and skill.

42 Further Work

This section suggests ways to continue this project further. It will describe different solutions for improvements to the game, new concepts to consider, and further experimentation for more reliable research.

42.1 Improvements

As mentioned in Section 9, *PlayPulse* has produced *PlayPulse One*, their newest spinning bike. The first step in improvements will be to adapt the game to this bike. Since there is little that separates this bike from the prototype when it comes to the platform, this will not be very difficult. The big advantages of this bike are the in-built heart rate measurement system and automatic pedal resistance that can be controlled by the game. One of the problems within this research was that the participants lowered the pedal resistance to get better scores in the game. With the technology on the new bike, it is possible to, for instance, change the resistance based on the player's heart rate to obtain HIIT benefits.

Many of the participants asked about the highest scores on the different songs and levels and telling them motivated them further to beat these scores. As a leaderboard had not been implemented due to lack of time, this was told manually by the researchers. Implementation of a leaderboard system would improve the game further and could potentially motivate more players. In addition, new songs must be added for the players to not get bored over time. Alf Inge Wang, the supervisor for this thesis, and one of the researchers contributed with songs for the user test. To make this game even more popular, a solution may be to collaborate with artists or to buy licenses to use popular songs as similar rhythm games have done. New levels should also be implemented. In this user test, many of the levels were manually created by finding timestamps in the songs. A simple level creator was implemented, but with a limit of only putting input to the beat of the song. One possible solution to create levels easier would be to implement a more advanced level creator platform.

For enjoyment purposes, it is also important to vary the visual graphics. A solution would be to create multiple 3D concert arenas and animations that match the songs. For instance, adding a character that plays banjo if the song includes the instrument, or including a beach concert arena if the song has a summer atmosphere.

Something that was frequently asked by the participants was what the highest score possible was on the different songs. Each level was different so the scores varied, and the researchers were unable to provide the theoretical max scores. One possible solution is to have the scores consistent and include a concrete maximum score on each of the difficulty levels and divide the score by the number of input tiles instead. For instance, all easy levels have a maximum score of 100,000 and all medium levels have a maximum score of 150,000. Another thing that was commented on a lot was the score alternatives for each tile. In the user test it was possible to get five different options: *Fail*, *Ok*, *Good*, *Great*, *Perfect*. The participants did among other things not understand the difference between great and perfect, as it was difficult to identify the difference in input required to get a perfect score. A solution to improve this is to have three different options instead of five: *Fail*, *Good*, *Perfect*.

For the players with their main focus on the exercise aspect rather than the game, or for the players that want to get more advanced results about how they performed, it may be a solution to implement statistics into the game. For instance, the distance ridden, the number of calories burned, and heart rate. This will be easier to implement for *PlayPulse One* since the heart rate monitor is already built into the bike.

42.2 New Concepts

The results from this research show that the rhythm genre works well for spinning bikes and should be explored further. Also, it seems like most people prefer some kind of socialization while playing. This can be implemented by creating multiplayer modes.

The research prototype was suitable for high-intensity interval training but the game does not need to be limited to only this type of exercise. The players that lack the motivation to begin to exercise, would probably not be happy to start with an exercise in high intensity. One possible solution is to find new concepts where the exercise level is closer to moderate intensity.

With *Playpulse One* which includes the possibility to adjust the pedal resistance automatically through the game itself, it is possible to change the exercise concept from HIIT to other exercise types such as strength training. Also, the game does not need to be limited to a spinning bike. Some work should be put into discovering the possibilities to use the game with other exercise machines. It may, for instance, have the potential to be played on a rowing machine or other exercise machines meant for consistent effort.

42.3 Further Experimentation

The conclusions in this research are based on a user test where 14 participants tested the game four times over two weeks. Even though the results from this research sound promising and show that it is on the right track, factors such as a lack of songs and levels in the game, one faulty bike, and a short test period make it hard to conclude long-term engagement. Also, the selection of participants is a limited group of people. Conducting a larger experiment over a longer period of time with participants that better represent the population, can lead to new interesting findings. Among other things, this can discover how well the game works with people of different ages and different physical fitness.

Getting people to be more physically active is one of the reasons to create exergames. Therefore, it is also crucial to find out how long-term usage of the game will affect the health and fitness of the player.

42.4 Summary

The researchers of this study believe that *WaveRider* is a game with potential and should be improved and explored further. They believe that implementing the requested features, adapting the game to *PlayPulse One*, exploring the potential for other exercise machines, and including less challenging levels of exercise in addition to HIIT, will be the next step. Further, an extended study on both the game and health benefits of long-term use should be conducted with a group of participants that represents the population.

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Appendix

A Consent Form

Vil du delta i forskningsprosjektet

Wave Rider

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å måle nytteverdien av treningsspillet Wave Rider. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Formålet med prosjektet er å finne nye konsepter for å promotere trening gjennom spill. Vi har gjennom litteraturstudie identifisert et konsept som kan oppnå treningsgevinst og ønsker å verifisere at brukere oppfatter nytte fra konseptet.

Det vi ønsker å identifisere er i hvor stor grad brukere forbedrer sin fysiske form gjennom spillteorien tatt i bruk for designet av spillkonseptet. Derfor ser vi på treningsmengde og motivasjon hos brukerne, samt oppfattet gevinst.

Dette er en masteroppgave for studenter på Informatikk- og Datateknologi-studiet.

Hvem er ansvarlig for forskningsprosjektet?

NTNU - Fakultetet for informasjonsteknologi og elektronikk (IE) / Institutt for datateknologi og informatikk er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?

Du har blitt valgt til undersøkelsen ved utvalg fra prosjektets forfatteres kontakter. Målgruppen for denne forskningen er personer mellom 18-30 år. Det er totalt 10 personer i denne målgruppen som deltar som testkandidat ii prosjektet.

Hva innebærer det for deg å delta?

Hvis du velger å delta i prosjektet, innebærer det at du samtykker til å være testkandidat hvor det under brukertesten vil bli tatt video- og lydopptak og samling av pulsdata. I tillegg innebærer det at du fyller ut spørreskjemaer. Testen vil foregå gjennom 1-2 uker med oppmøte 2 ganger i uken. Video- og lydopptak vil bli brukt til å analysere brukertesten ytterligere. Spørreskjemaet inneholder spørsmål om opplevelsen av trening og spill. Dine svar fra spørreskjemaet blir registrert elektronisk.

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. Kun forfatterne av oppgaven samt veileder har tilgang til testbrukeres tilbakemeldinger og data.

Du vil per e-post motta det elektroniske spørreskjemaet og en personlig kode. Den personlige koden MÅ fylles ut på spørreskjemaet. Denne koden erstatter e-postadressen din som sammen lagres på egen liste adskilt fra øvrige data. Spørreskjema blir delt gjennom NTNUs Microsoft Forms som holder data lagret internt i våre nettverk.

Deltakerne vil ikke kunne gjenkjennes i publikasjon.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?

Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 15. juni 2022. Da fjernes all personlig informasjon og datasett som er blitt samlet inn slettes.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke.

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

Dine rettigheter

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

- innsyn i hvilke opplysninger vi behandler om deg, og å få utlevert en kopi av opplysningene
- å få rettet opplysninger om deg som er feil eller misvisende
- å få slettet personopplysninger om deg
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

Hvis du har spørsmål til studien, eller ønsker å vite mer om eller benytte deg av dine rettigheter, ta kontakt med:

Alf Inge Wang

Institutt for datateknologi og informatikk

alf.inge.wang@ntnu.no

73594485

Vårt personvernombud:

Thomas Helgesen

thomas.helgesen@ntnu.no

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: 53 21 15 00.

Med vennlig hilsen

Alf Inge Wang	*Sondre Strand Haltbakk*	*Aschmirthan Sivaranjan*
(Forsker/veileder)	Masterstudent	Masterstudent

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *Wave Rider*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ¨ å delta i brukertesting av spillet
- ¨ at video- og lydopptak tas av spillopplevelsen
- ¨ at pulsdata blir samlet inn under øktene
- ¨ å delta i spørreskjema om opplevelsen av spillet

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

---

(Signert av prosjektdeltaker, dato)

B Questionnaires

Pre-Session form

WaveRider - Forskjema

Dette prosjektet er en masteroppgave ved NTNU Trondheim, Fakultet for informasjonsteknologi og
elektroteknikk, Institutt for datateknologi og informatikk.
Målet med prosjektet er å gjennomføre en undersøkelse på nye treningsspillkonsepter skapt ved bruk av treningslære og spilldesign, som tar i bruk treningssykler. Spillkonseptet blir utviklet av forfatterne og testes for å verifisere hvorvidt spillet oppnår treningsmålene satt med høy motivasjon.
Derfor benyttes brukertesting med spørreundersøkelser for å samle data for konklusjonen. Gi derfor din ærlige tilbakemelding på disse spørsmålene.
Det er alltid mulig å trekke seg og å få fjernet sin tilbakemelding. Dette gjøres ved å sende epost til oss på sondsh@stud.ntnu.no eller aschmirs@stud.ntnu.no. Vi samler også inn din epost slik at vi kan ta kontakt. All personlig informasjon slettes ved slutten av prosjektet.

* Obligatorisk

1. Hva er din personlige kode ? (brukernavn) *

2. Hva er ditt fødselsår ? *

3. Hva er ditt kjønn? (Eks. Mann, Kvinne) *

4. Ca. hvor mange ganger trener du i løpet av en uke (gj.snitt)? (skriv med tall) *

5. Hvordan trener du ? (Trenger ikke svare om du ikke trener)

- [ ] Treningssenter
- [ ] Sport
- [ ] Hjemme
- [ ] Ute
- [ ] Annet

6. Ca. hvor mange timer i uka bruker du på spill (gj.snitt)? (skriv med tall) *

Svar basert på hvor enig du er i påstandene:

7. *

	Helt uenig	Litt uenig	Nøytral	Litt enig	Helt enig
Jeg oppfatter meg selv som godt trent	◯	◯	◯	◯	◯
Jeg er veldig glad i å trene	◯	◯	◯	◯	◯

Jeg er veldig glad i å spille videospill	◯	◯	◯	◯	◯
Jeg liker å konkurrere med andre	◯	◯	◯	◯	◯
Jeg liker å samarbeide med andre for å løse problemer	◯	◯	◯	◯	◯

WaveRider - Testskjema

Dette prosjektet er en masteroppgave ved NTNU Trondheim, Fakultet for informasjonsteknologi og
elektroteknikk, Institutt for datateknologi og informatikk.
Målet med prosjektet er å gjennomføre en undersøkelse på nye treningsspillkonsepter skapt ved bruk av treningslære og spilldesign, som tar i bruk treningssykler. Spillkonseptet blir utviklet av forfatterne og testes for å verifisere hvorvidt spillet oppnår treningsmålene satt med høy motivasjon.
Derfor benyttes brukertesting med spørreundersøkelser for å samle data for konklusjonen. Gi derfor din ærlige tilbakemelding på disse spørsmålene.
Det er alltid mulig å trekke seg og å få fjernet sin tilbakemelding. Dette gjøres ved å sende epost til oss på sondsh@stud.ntnu.no eller aschmirs@stud.ntnu.no. Vi samler også inn din epost slik at vi kan ta kontakt. All personlig informasjon slettes ved slutten av prosjektet.

* Obligatorisk

1. Hva er din personlige kode ? (brukernavn) *

2. Hvilken økt er dette ? (skriv tall) *

Svar basert på hvor enig du er i påstandene:

3. *

	Helt uenig	Litt uenig	Nøytral	Litt enig	Helt enig
Denne økten var veldig underholdende	◯	◯	◯	◯	◯
Spillet motiverte meg til å gjennomføre økten	◯	◯	◯	◯	◯
Jeg opplevde økten mer som spill enn som trening	◯	◯	◯	◯	◯
Jeg opplevde å få treningsutbytte fra økten	◯	◯	◯	◯	◯
Jeg opplevde økten som fysisk krevende	◯	◯	◯	◯	◯

WaveRider - Etterskjema

Dette prosjektet er en masteroppgave ved NTNU Trondheim, Fakultet for informasjonsteknologi og
elektroteknikk, Institutt for datateknologi og informatikk.
Målet med prosjektet er å gjennomføre en undersøkelse på nye treningsspillkonsepter skapt ved bruk av treningslære og spilldesign, som tar i bruk treningssykler. Spillkonseptet blir utviklet av forfatterne og testes for å verifisere hvorvidt spillet oppnår treningsmålene satt med høy motivasjon.
Derfor benyttes brukertesting med spørreundersøkelser for å samle data for konklusjonen. Gi derfor din ærlige tilbakemelding på disse spørsmålene.
Det er alltid mulig å trekke seg og å få fjernet sin tilbakemelding. Dette gjøres ved å sende epost til oss på sondsh@stud.ntnu.no eller aschmirs@stud.ntnu.no. Vi samler også inn din epost slik at vi kan ta kontakt. All personlig informasjon slettes ved slutten av prosjektet.

* Obligatorisk

1. Hva er din personlige kode ? (brukernavn) *

Svar basert på hvor enig du er i påstandene:

2. *

	Helt uenig	Litt uenig	Nøytral	Litt enig	Helt enig
Det var lett å	◯	◯	◯	◯	◯

begynne å spille spillet	◯	◯	◯	◯	◯
Det er sannsynlig at jeg vil fortsette å trene uten spillet	◯	◯	◯	◯	◯
Det er sannsynlig at jeg vil fortsette å trene med spillet gitt muligheten	◯	◯	◯	◯	◯
Spillet har gjort meg mer motivert til å trene	◯	◯	◯	◯	◯
Jeg opplevde at jeg ble bedre på spillet	◯	◯	◯	◯	◯
Jeg opplevde at formen min (utholdenhet) ble bedre etter å ha spilt spillet	◯	◯	◯	◯	◯
Jeg synes singleplayer-modus var underholden de	◯	◯	◯	◯	◯
Jeg opplevde singleplayer øktene mer som et spill enn en treningsøkt.	◯	◯	◯	◯	◯
Min motivasjon økte i stor grad når jeg	◯	◯	◯	◯	◯

spilte med/mot andre					
Jeg synes PvP-modus var underholden de	○	○	○	○	○
Å spille/konkurr ere mot hverandre øker motivasjonen min i stor grad	○	○	○	○	○
Jeg opplevde PvP-modusøkten mer som et spill enn en treningsøkt.	○	○	○	○	○
Jeg synes Collaboration -modus var underholden de	○	○	○	○	○
Å samarbeide/s pille med hverandre øker motivasjonen min i stor grad	○	○	○	○	○
Jeg opplevde Collaboration -modus økten mer som et spill enn en treningsøkt.	○	○	○	○	○
Jeg var så engasjert i spillet at jeg opplevde at	○	○	○	○	○

tiden gikk fortere enn ellers					
Jeg hadde det like moro eller mer moro under siste økt som under den første	○	○	○	○	○
Å forbedre resultatet mitt gjør at jeg har lyst til å spille spillet igjen	○	○	○	○	○
Jeg følte at kontrollene ga mening og at handlingene mine gjorde det jeg forventet	○	○	○	○	○
Jeg følte jeg hadde kontroll når jeg spilte	○	○	○	○	○

3. *

	Helt uenig	Litt uenig	Nøytral	Litt enig	Helt enig
Jeg opplevde at musklene mine gjorde det vanskelig å fullføre	○	○	○	○	○
Jeg opplevde at oksygenopptaket mitt gjorde det	○	○	○	○	○

vanskelig å fullføre					
Jeg ble fort vant til knappene	◯	◯	◯	◯	◯
Spillet gjorde at intervalltrening ble mer underholdende for meg	◯	◯	◯	◯	◯
Hvis spillet var tilgjengelig for meg, ville jeg spilt det aktivt videre	◯	◯	◯	◯	◯

Spillmodus

4. Hvor godt likte du Single player?

5. Hvor godt likte du PvP modus?

6. Hvor godt likte du Collaboration modus?

7. Hvilken modus av spillet foretrekker du mest? *

- ◯ Single player
- ◯ PvP
- ◯ Collaboration

8. Noe annet dere vil legge til?

C Heart Rate Graphs

This appendix section includes the heart rate graphs of each participant. The sudden drops to 0 is when the heart rate monitor looses its connection.

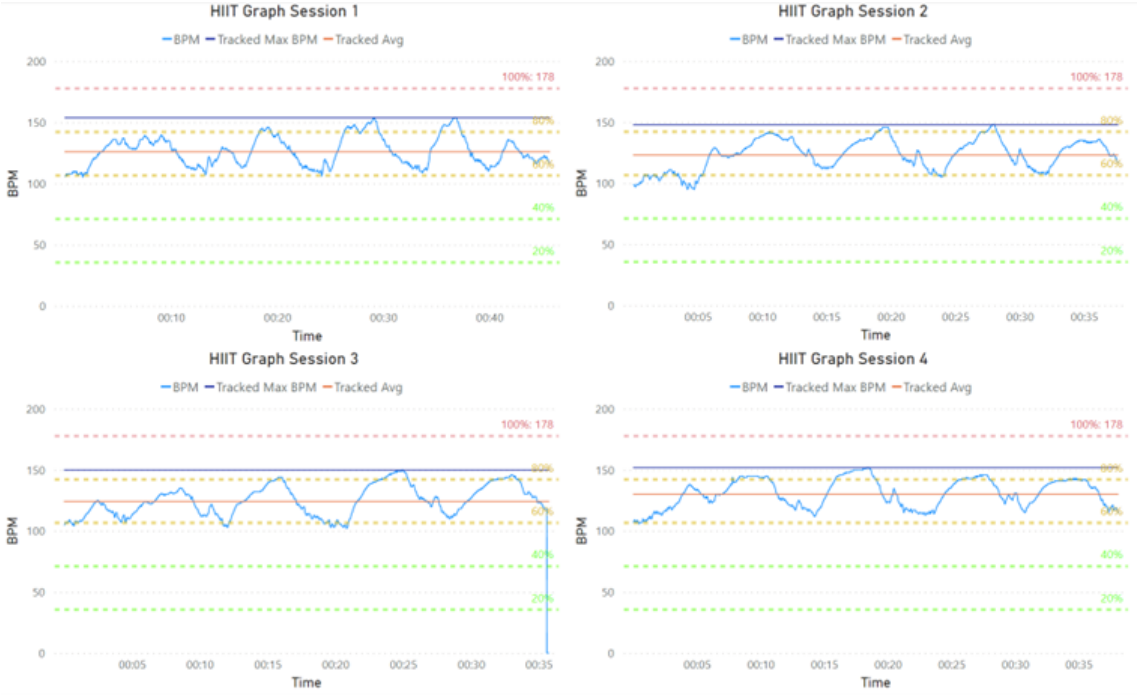


Figure 63: Heart rate Participant 1

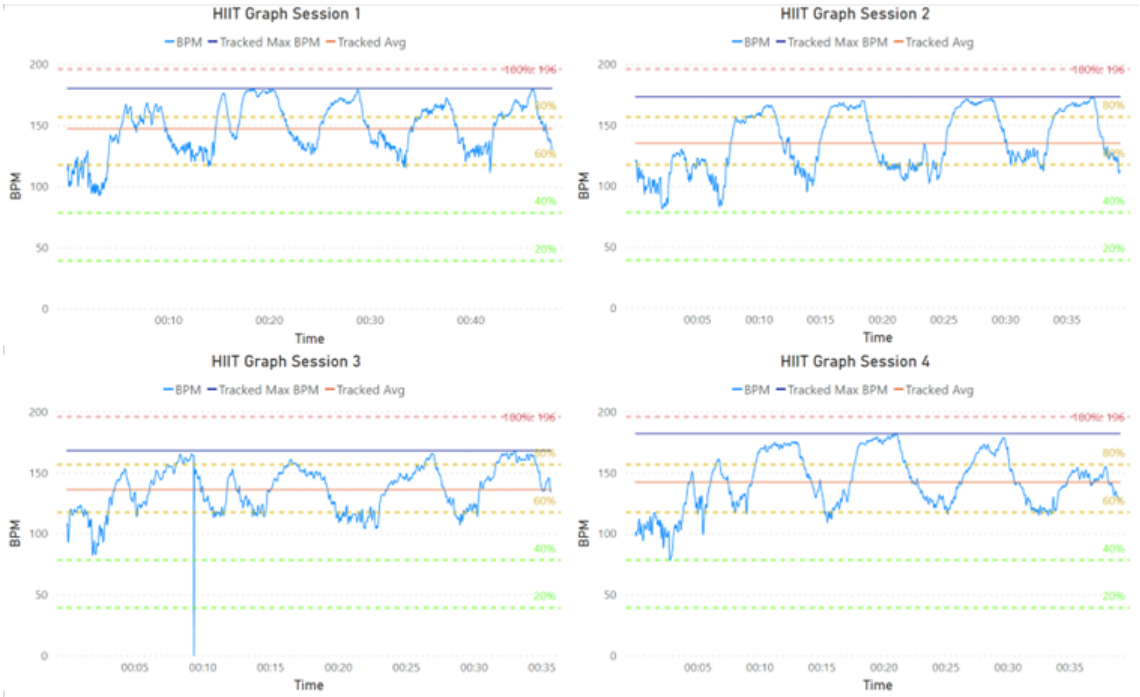


Figure 64: Heart rate Participant 2

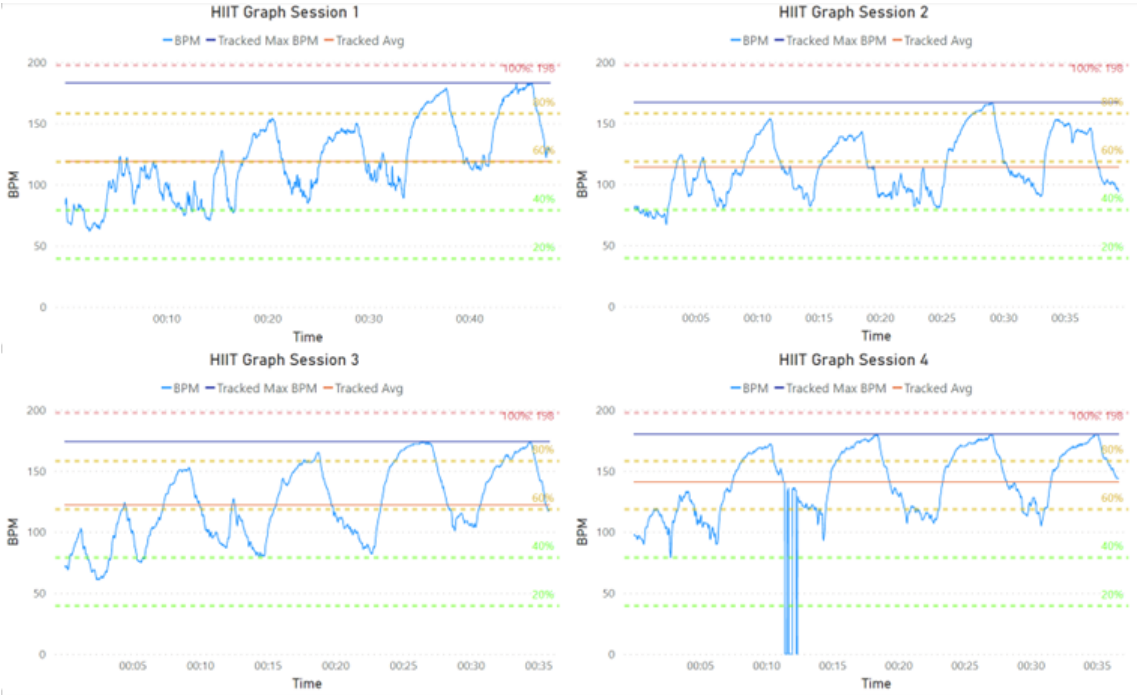


Figure 65: Heart rate Participant 3

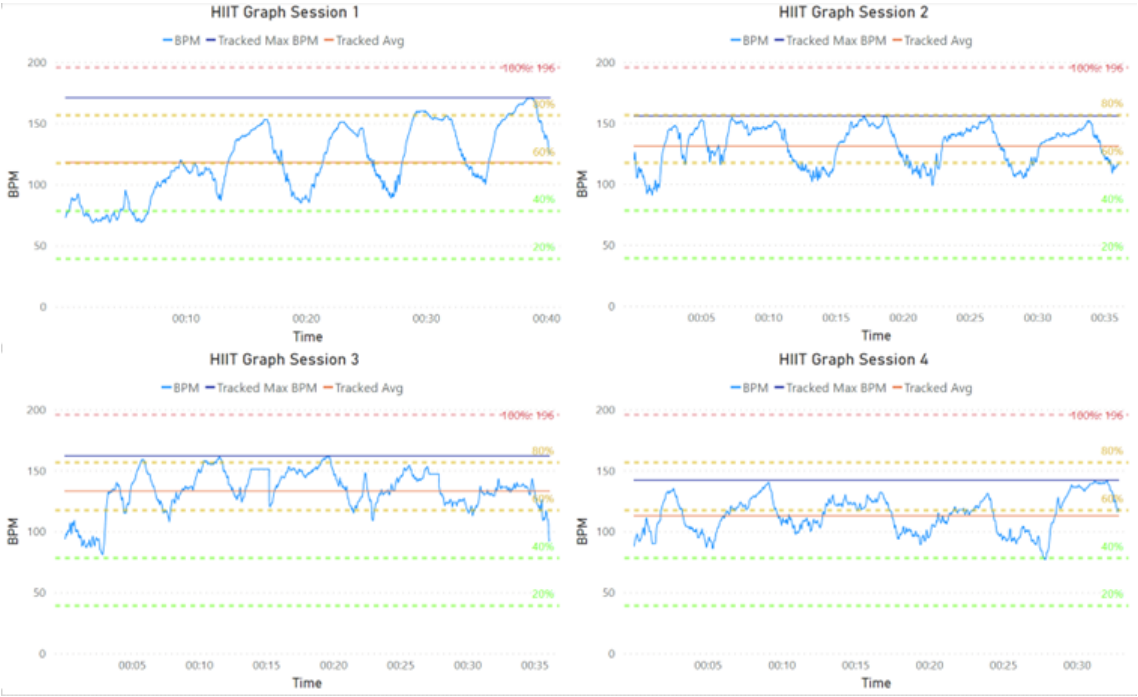


Figure 66: Heart rate Participant 4

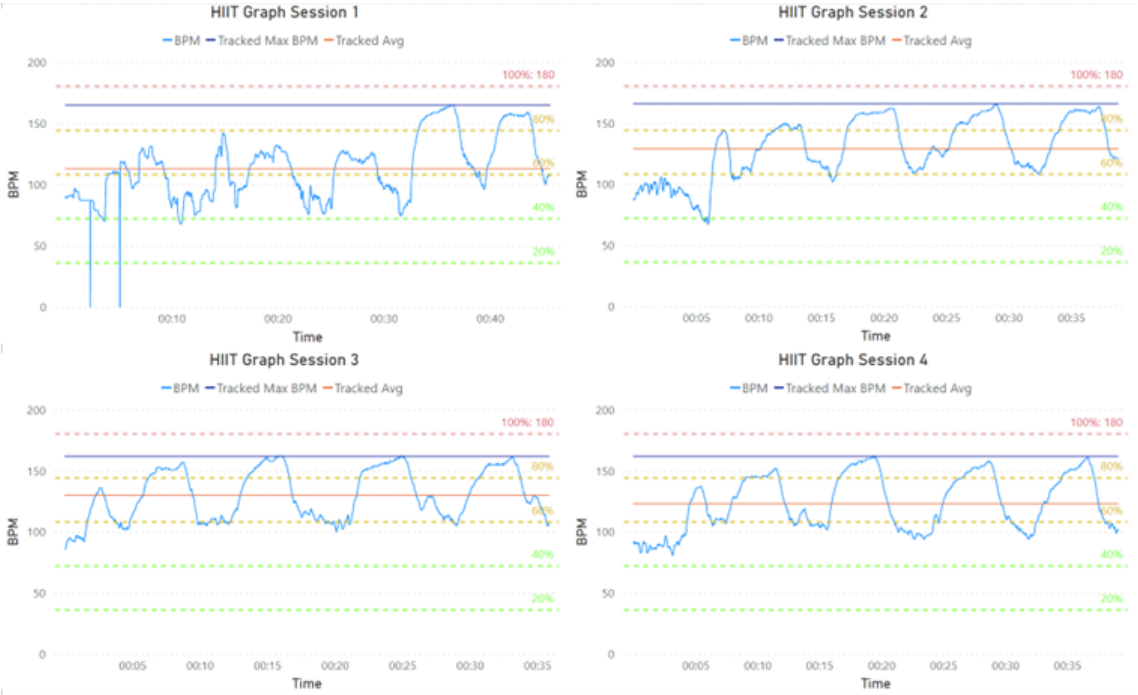


Figure 67: Heart rate Participant 5

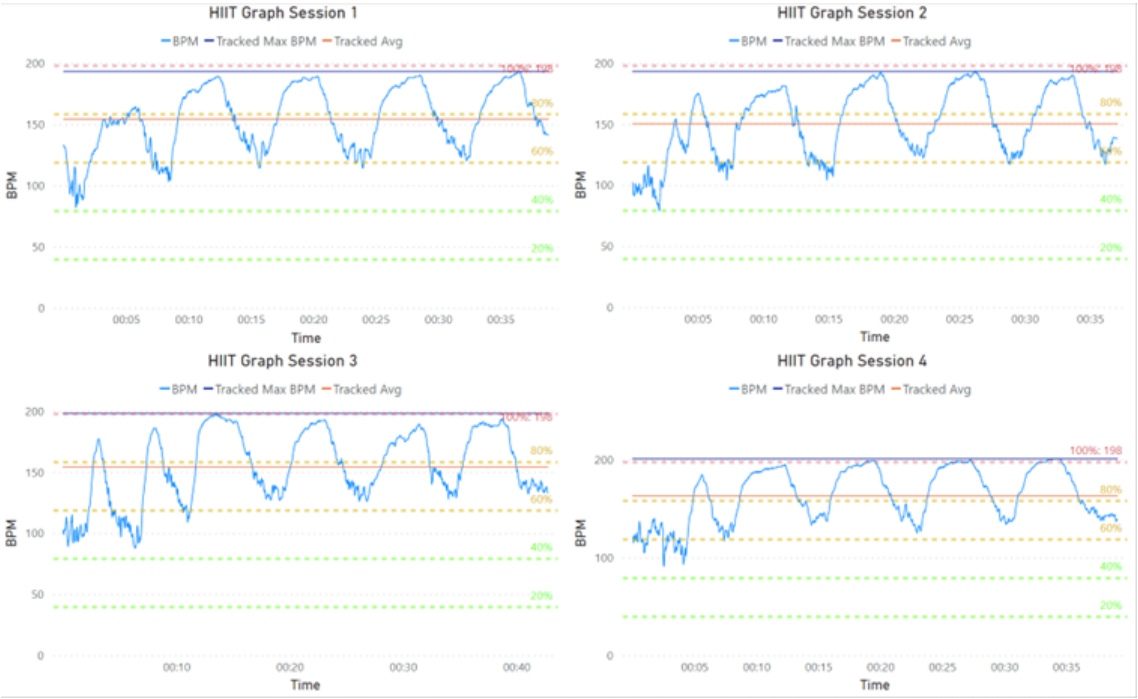


Figure 68: Heart rate Participant 6

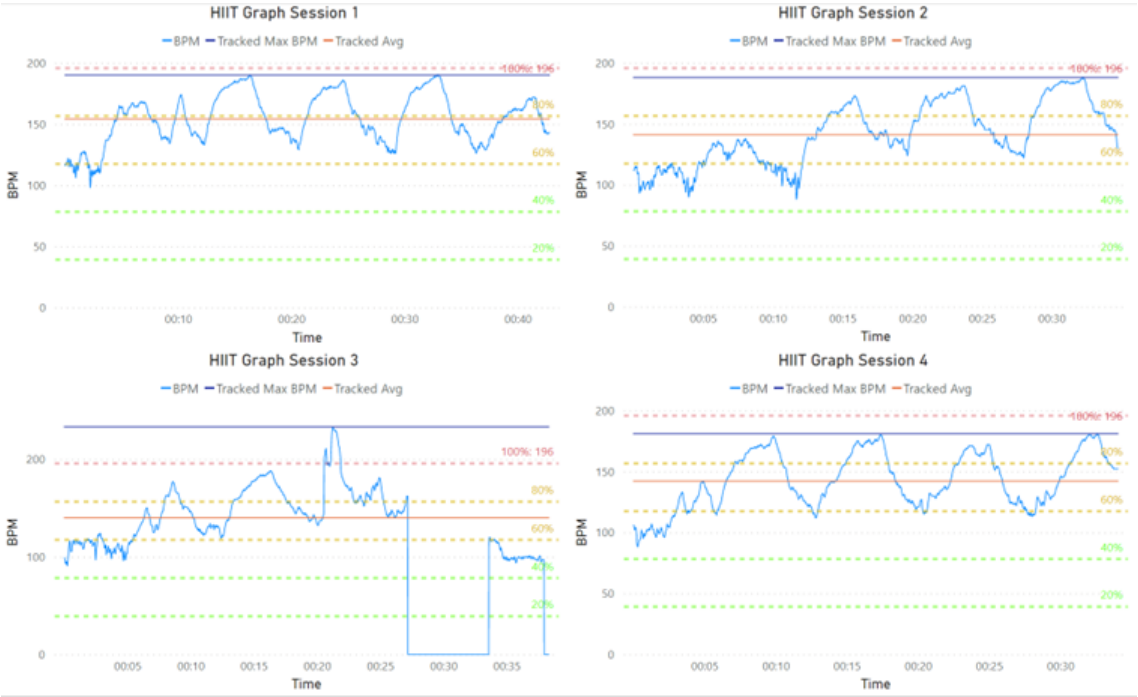


Figure 69: Heart rate Participant 7. This participant got a sudden increase in heart rate in session three, and the researchers concluded that the this participant should skip the rest of this session.

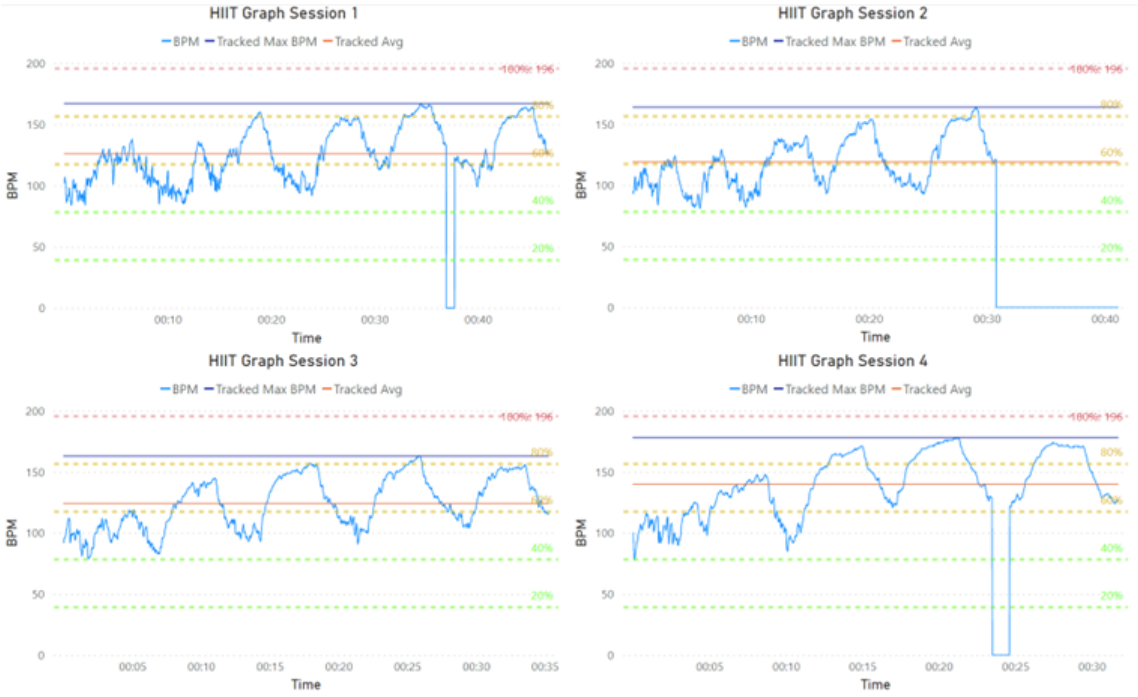


Figure 70: Heart rate Participant 8

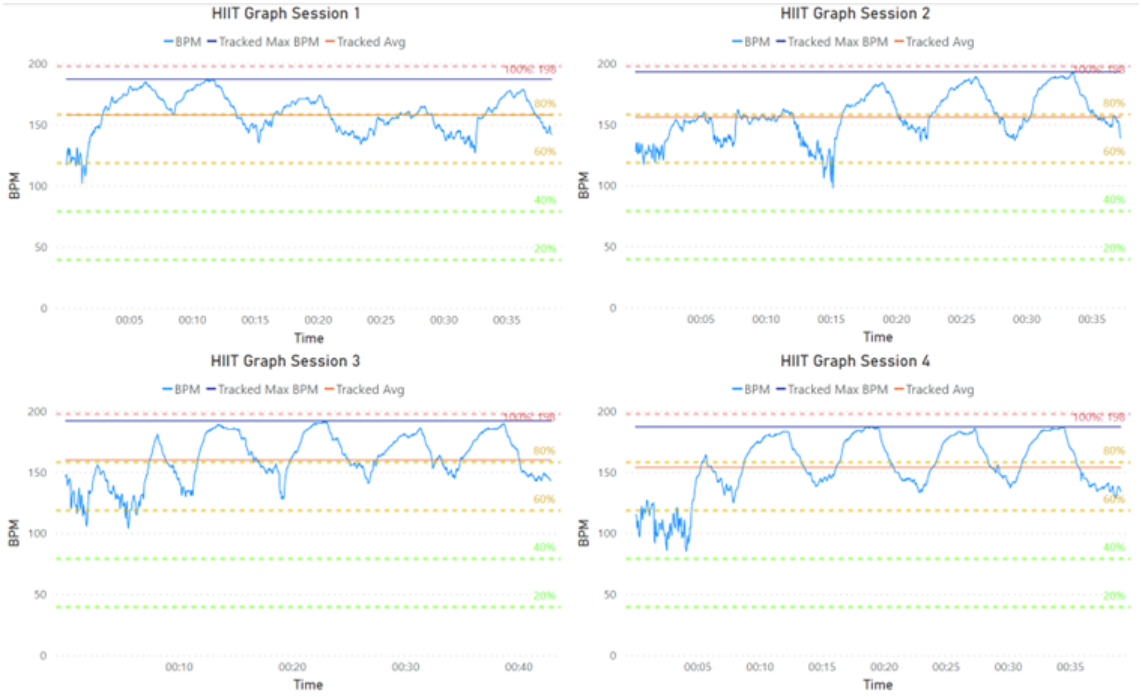


Figure 71: Heart rate Participant 9

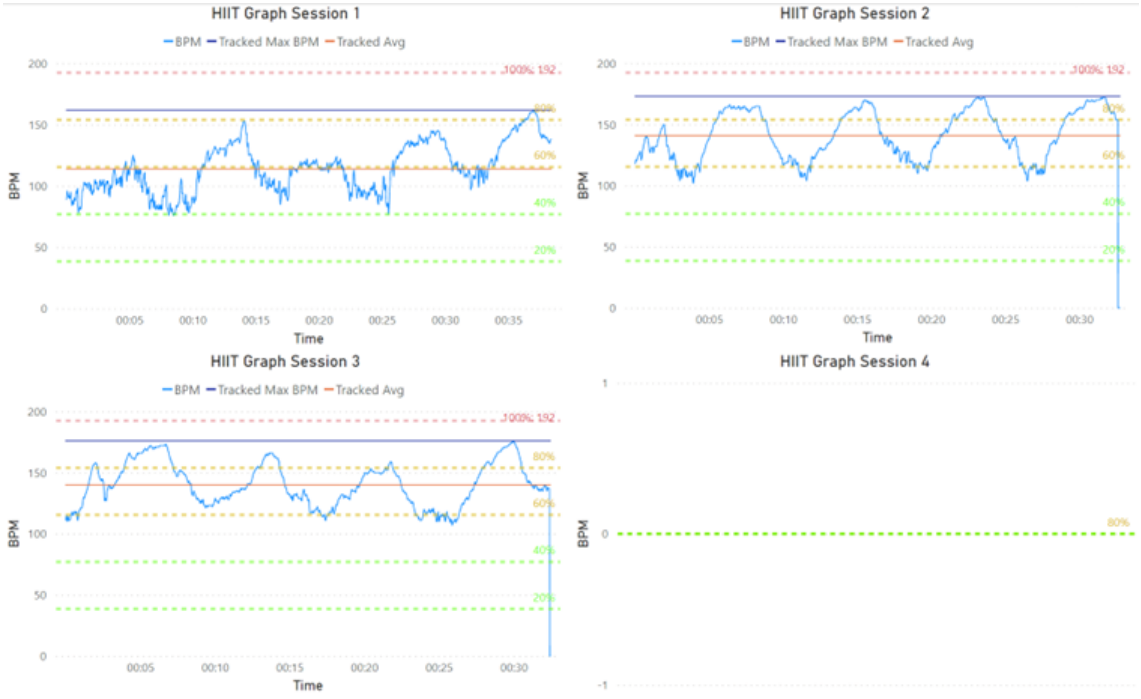


Figure 72: Heart rate Participant 10. This participant only participated on the first three sessions.

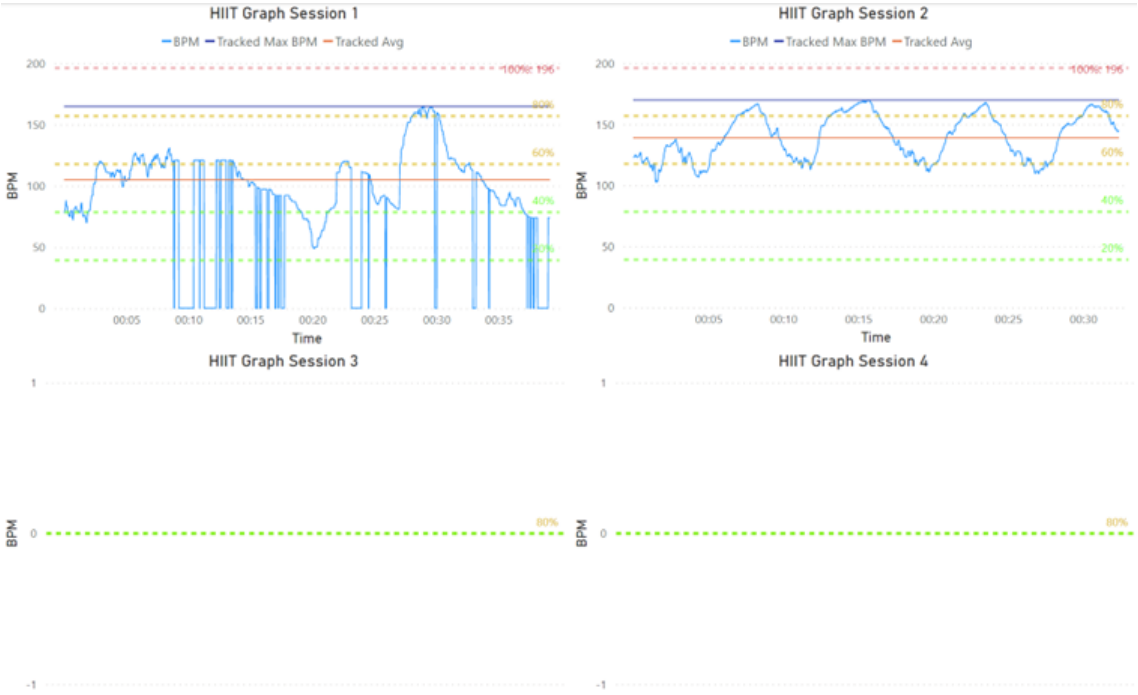


Figure 73: Heart rate Participant 11. This participant only participated on the first two sessions.

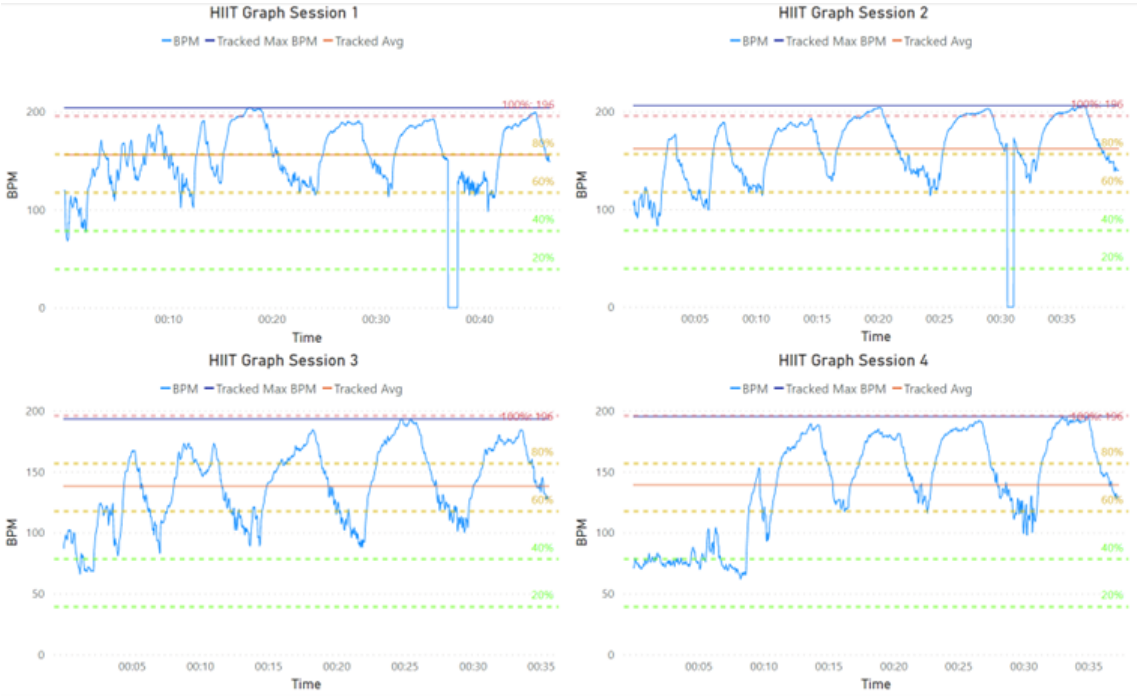


Figure 74: Heart rate Participant 12

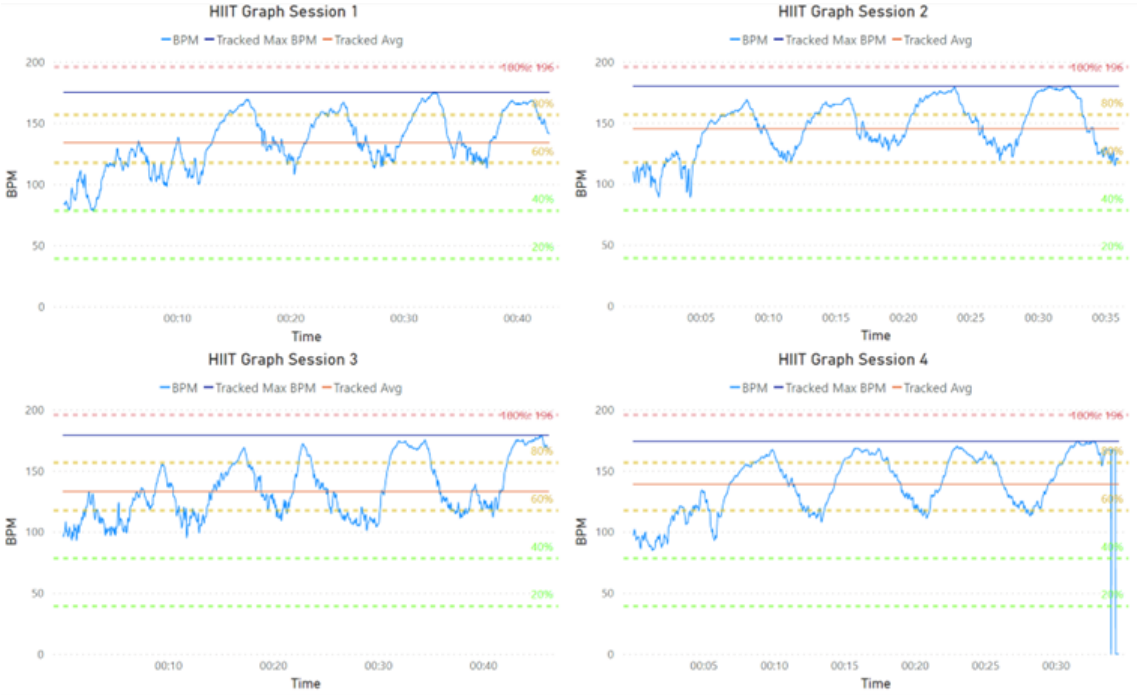


Figure 75: Heart rate Participant 13

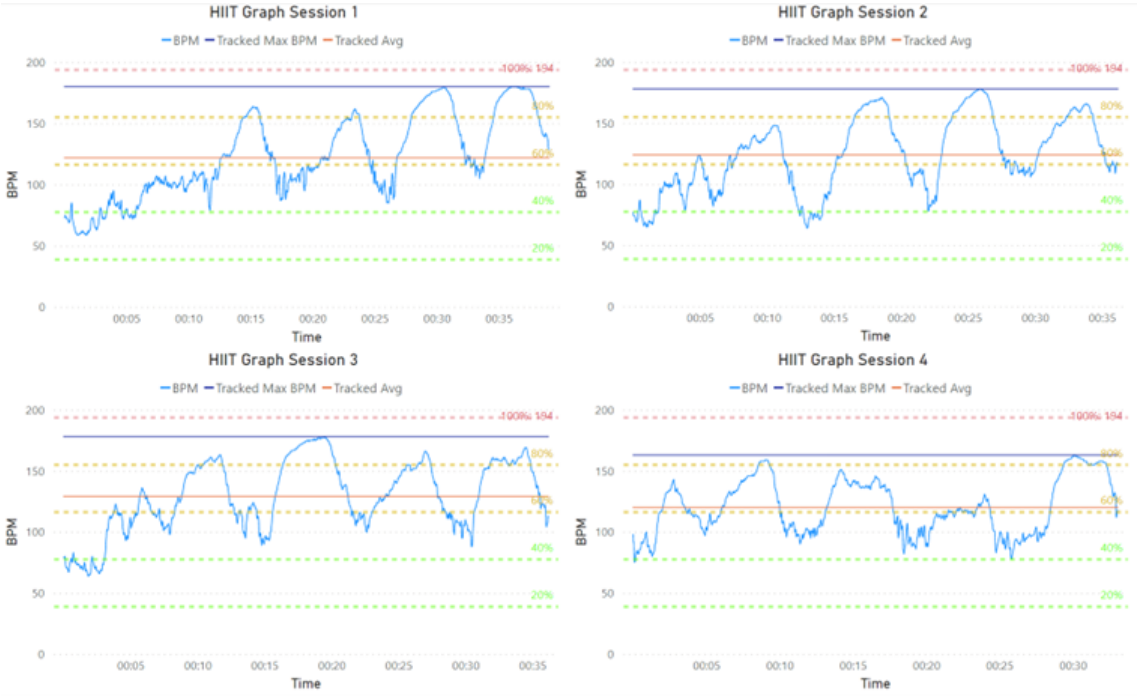


Figure 76: Heart rate Participant 14

D Scores

Figure 77: Progress Participant 1

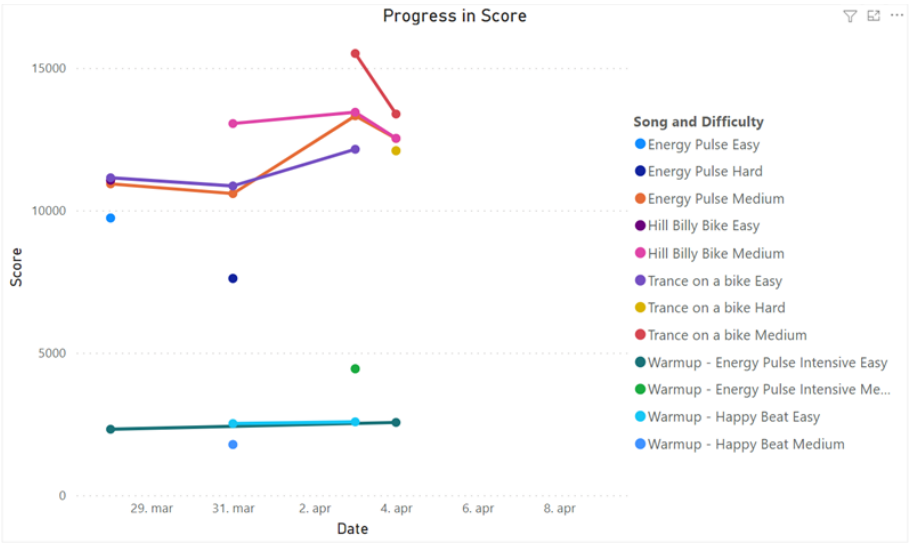


Figure 78: Progress Participant 2

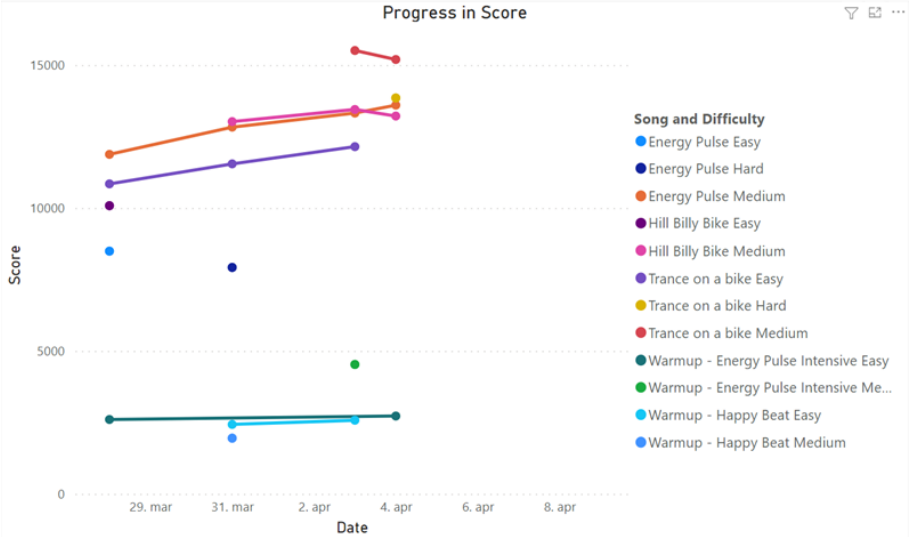


Figure 79: Progress Participant 3

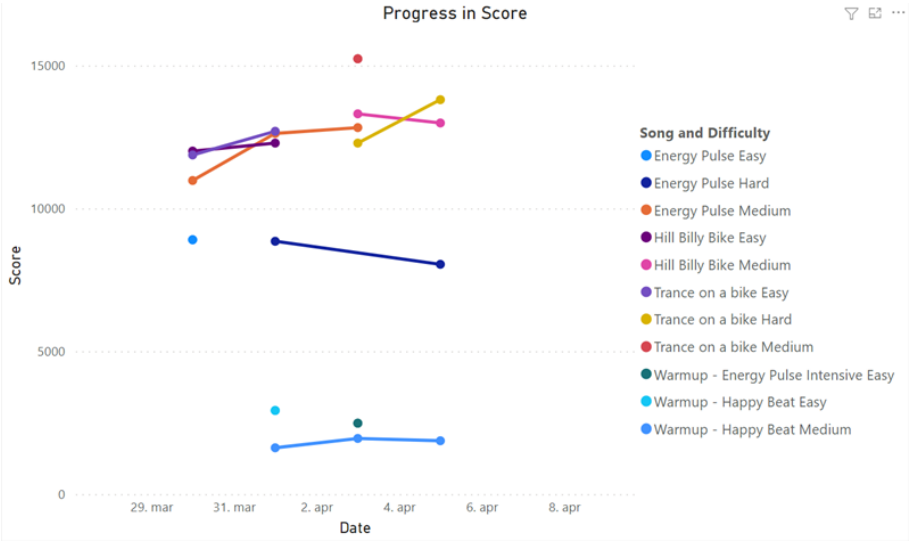


Figure 80: Progress Participant 4

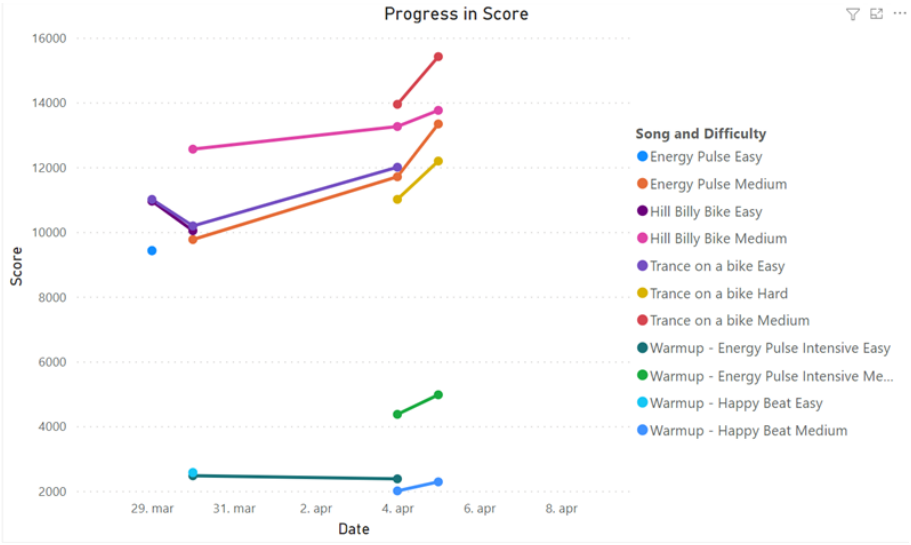


Figure 81: Progress Participant 5

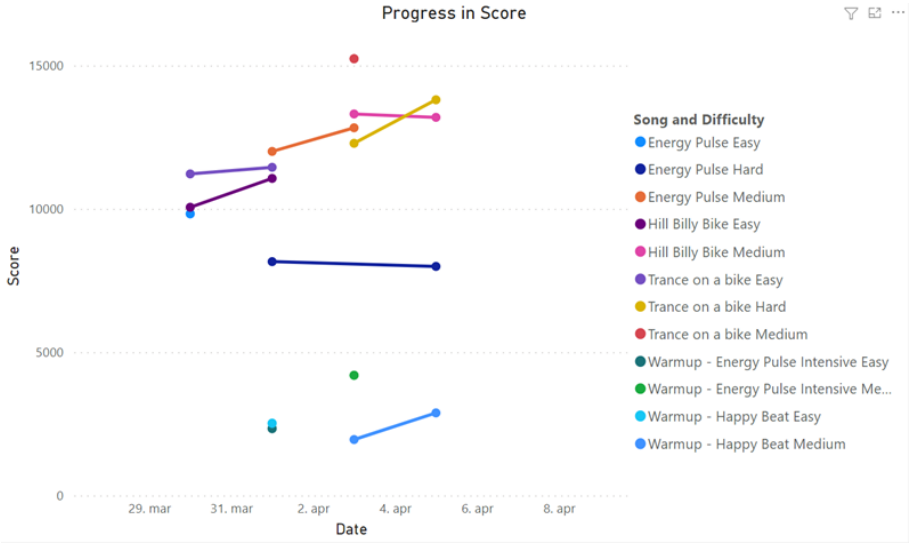


Figure 82: Progress Participant 6

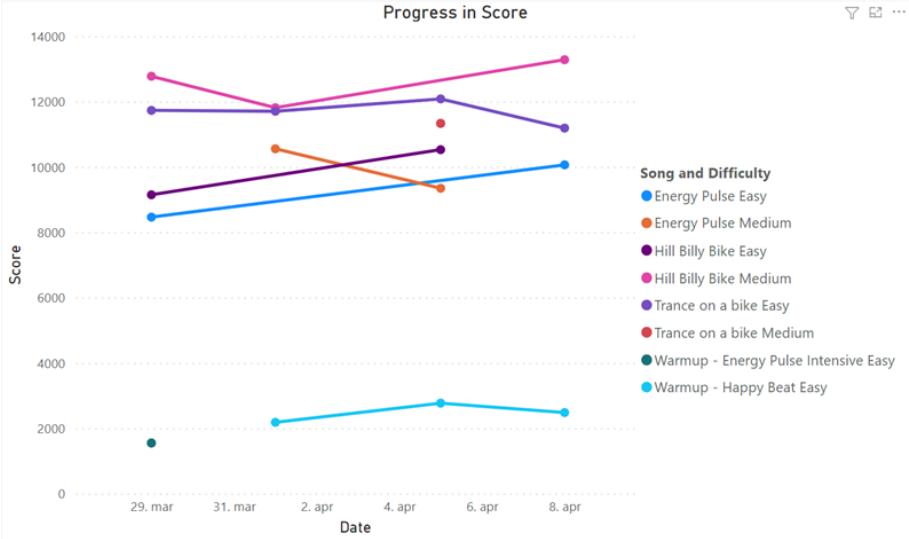


Figure 83: Progress Participant 7

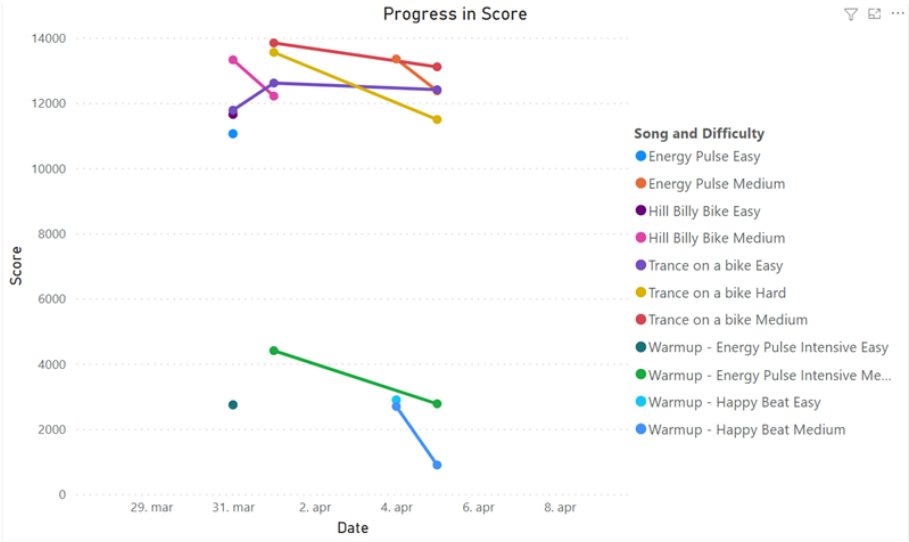


Figure 84: Progress Participant 8

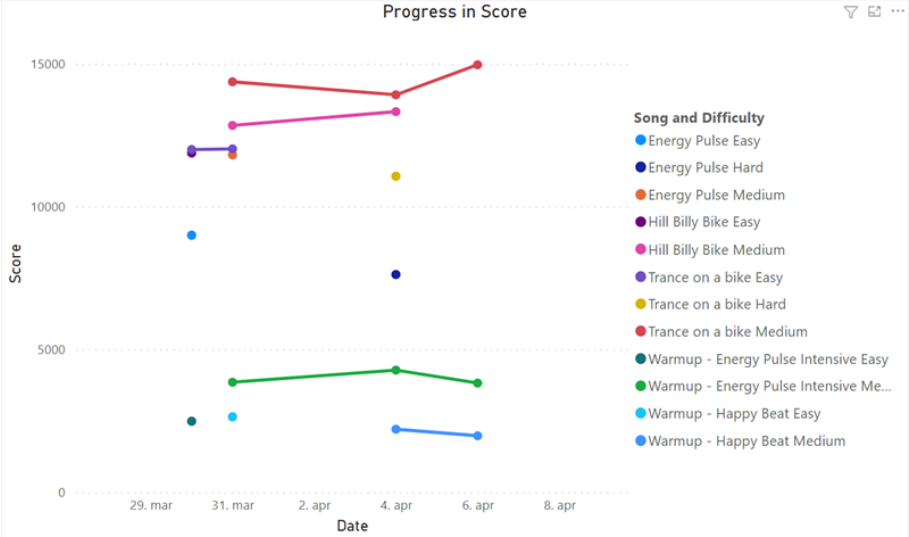


Figure 85: Progress Participant 9

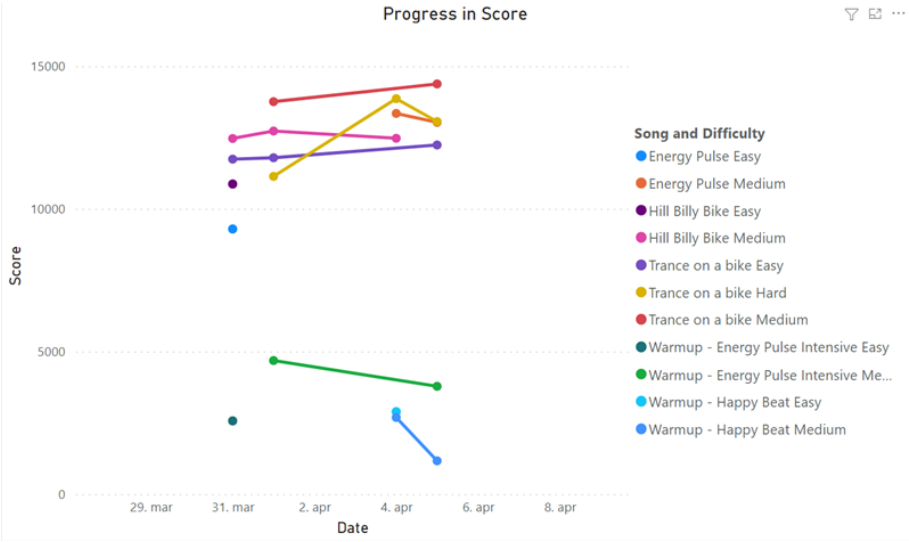


Figure 86: Progress Participant 10

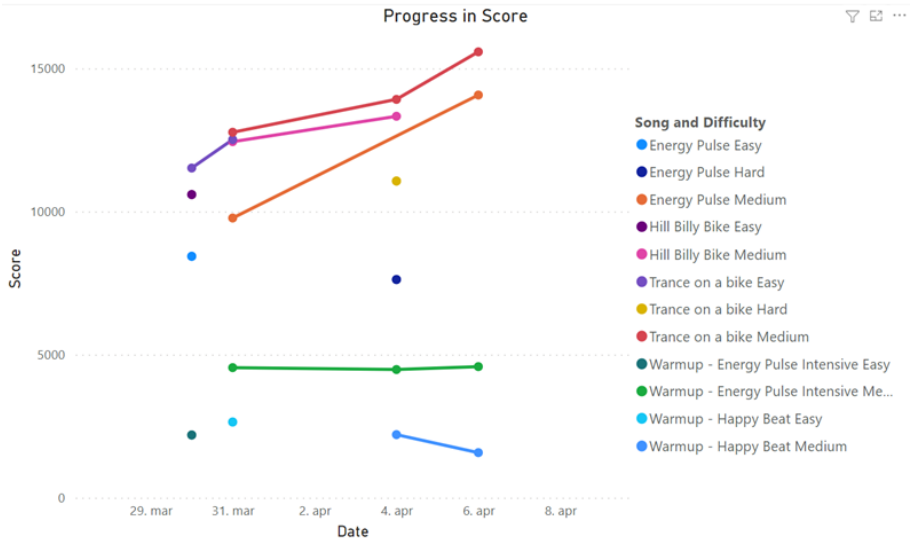


Figure 87: Progress Participant 11

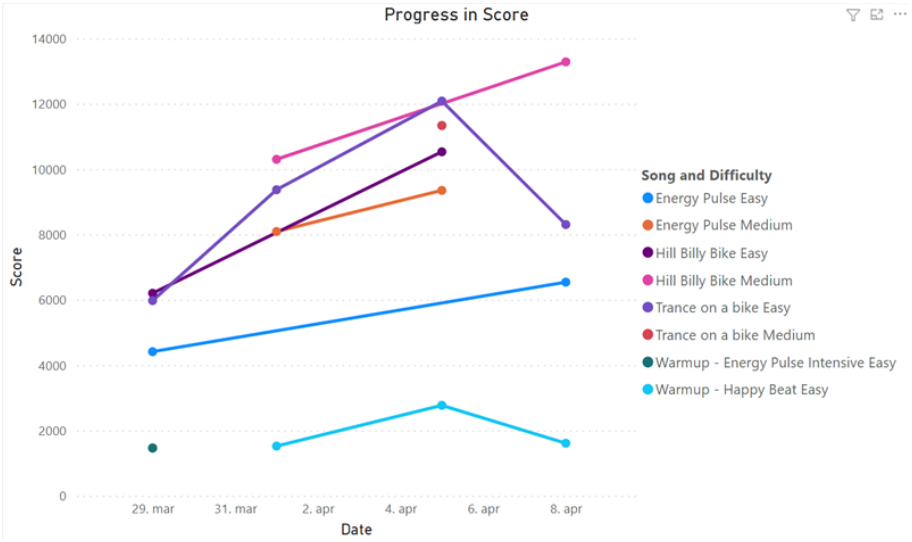


Figure 88: Progress Participant 12

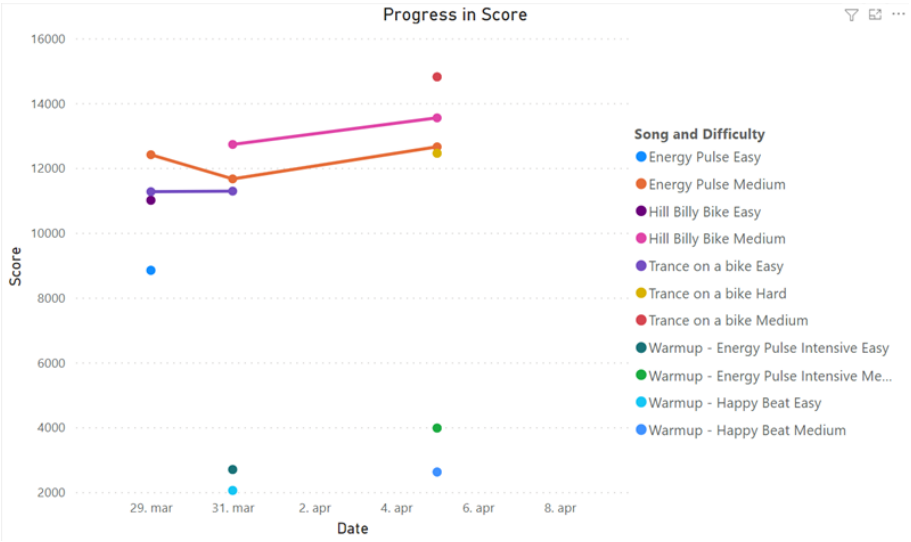


Figure 89: Progress Participant 13

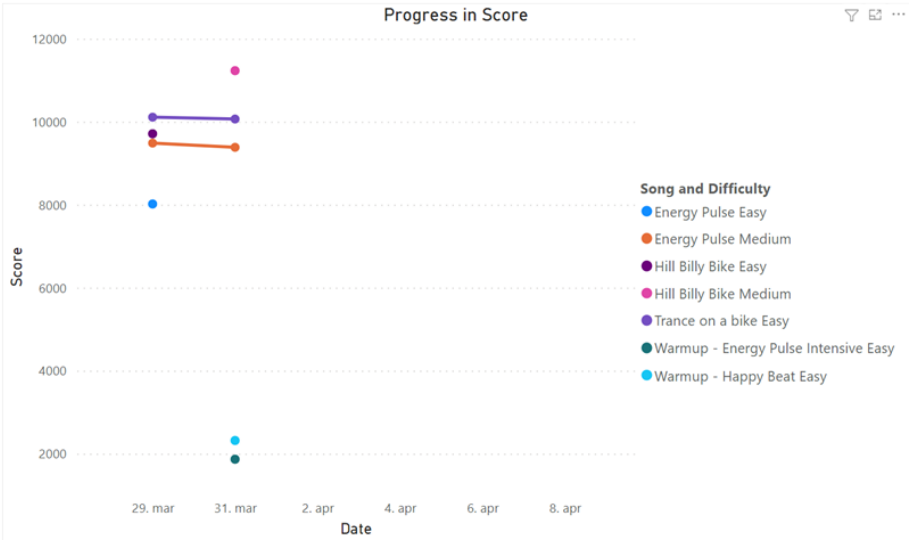
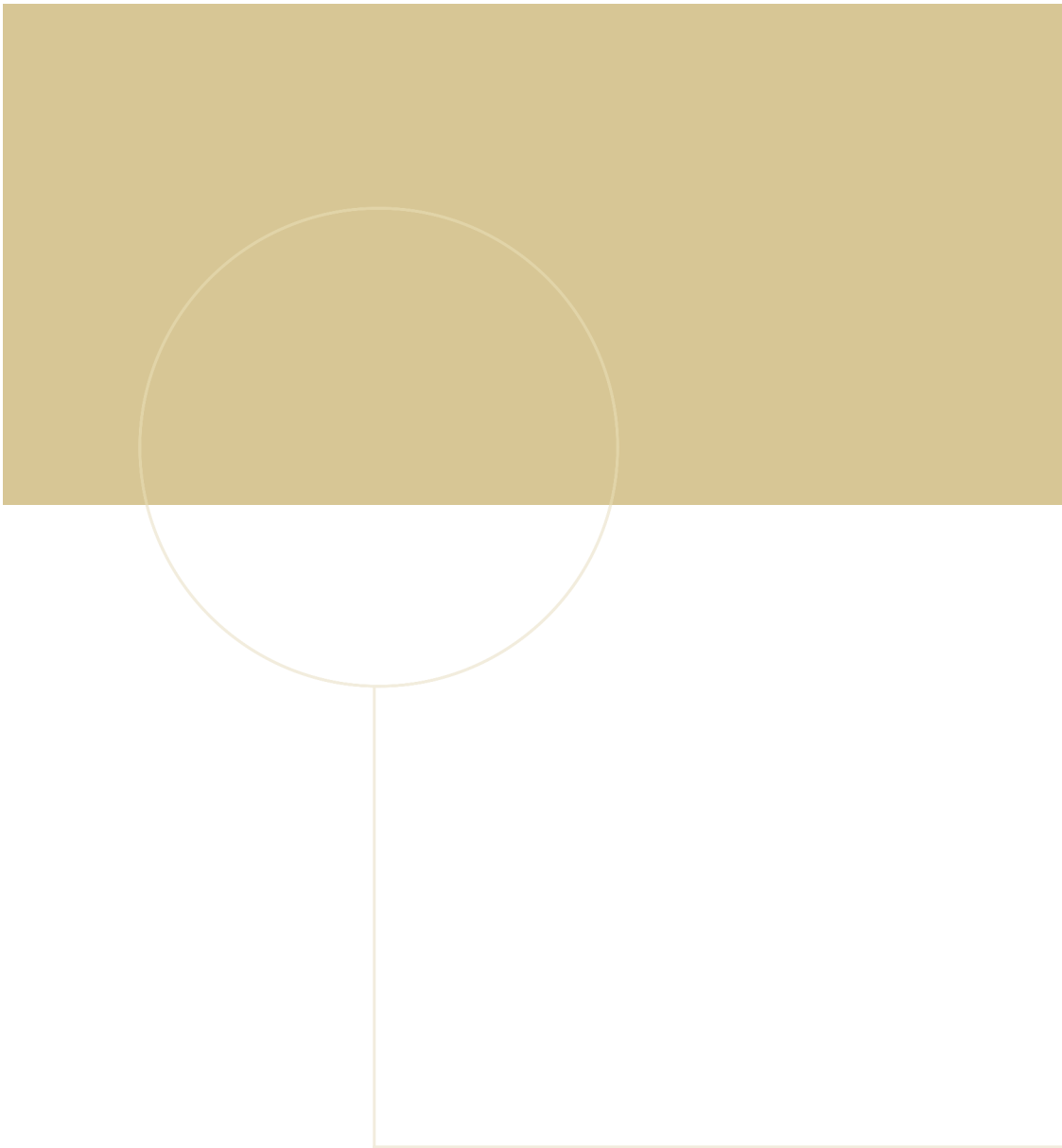


Figure 90: Progress Participant 14



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