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Pedal Kart

The creation and evaluation of a
cardiovascular exercise bike game

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Abstract

Lack of exercise is a serious issue in modern society, with video game players being especially at risk. Overweight and obesity is trending upwards, and sedentary lifestyles significantly contribute to this trend. Some games, known as exergames (exercise games), now involve physical exertion in their gameplay in order to provide exercise during a traditionally sedentary activity. However, most such games do not appeal to people who base their lifestyle around video games, but rather to more casual players. More work should therefore be put into exergames that are likely to appeal to this group of people. Given the length of gameplay sessions such gamers put in, exergames appealing to them have the potential to make more of a difference than exergames appealing to more casual audiences.

This report investigates what factors are key to creating an exergame that both provides useful exercise, and also keeps the player engaged for a long period of time. It does so by summarizing and building upon previous exergames, both academic and commercial, as well as existing research into exercise, exergames, and what makes games enjoyable.

Based on this research, the report outlines different elements and design principles that help make an exergame effective and enjoyable, as well as design constraints given the need for exercise as a component of gameplay. It further investigates the design considerations necessary when developing an exergame for an exercise bike.

Grounded in the research and the design principles outlined, a game design for a game called Pedal Kart was created based heavily on the commercially successful game Mario Kart. A prototype was then created based on the design, focusing on the functionality supporting short to mid-term enjoyment, while not including functionality likely to only affect long-term enjoyment.

The prototype was tested across three sessions on four test participants to determine whether Pedal Kart provides sufficient exercise, and is enjoyable in the short to mid-term. The results of the experiment were positive; the test subjects experienced a high degree of physical exertion, enjoyed the game, and claimed it made it easier for them to exercise than it otherwise would be. The limited scope of the experiment makes applying these results to a wide audience difficult, but do strongly support further investigation of the game in either a research setting or a commercial setting.

Sammendrag

Mangel på trening er et alvorlig problem i det moderne samfunn, og personer som spiller dataspill er særlig berørt. Overvekt og fedme er på vei opp, og livsstiler med lite fysisk aktivitet bidrar til denne trenden. Noen spill, kjent som exergames (exercise games), involverer mosjon som en spillmekanikk for å gi trening via en tradisjonelt stillesittende aktivitet. Dessverre appellerer de fleste exergames ikke til personer som bygger sin livsstil rundt dataspill, men heller til personer som kun spiller av og til. Det burde derfor skapes flere exergames som appellerer til de som spiller mye. Når slike spillere bruker så mye tid på dataspill, har exergames designet for å appellere til dem potensial til å gjøre en større forskjell enn exergames som appellerer til personer som spiller sjeldnere.

Denne rapporten utforsker hvilke faktorer som er viktige for å skape et exergame som både gir meningsfull trening og holder spilleren engasjert over lengre tid. Rapporten gjør dette ved å utforske og bygge videre på lærdom fra tidligere exergames (både akademiske og kommersielle), og ser også på eksisterende forskning på trening, exergames, og hva som gjør spill morsomme å spille.

Basert på denne forskningen identifiserer rapporten diverse elementer og designprinsipper som bidrar til å gjøre et exergame effektivt og morsomt, og diskuterer også designbegrensninger som oppstår av behovet for å integrere trening i et spill. Rapporten utforsker også hvordan valget av treningssykkel som plattform begrenser designet av et exergame.

Med denne forskningen og identifiserte designprinsipp som basis, ble et spilldesign for spillet Pedal Kart skapt. Dette spillet baserer seg i stor grad på det kommersielt vellykkede spillet Mario Kart. En prototype ble laget basert på designet, med fokus på funksjonalitet nødvendig for å gjøre spillet morsomt over et lavt antall sesjoner, mens funksjonalitet som trolig bare ville påvirket nytelse over lengre tid ble utelatt.

Prototypen ble testet i løpet av tre sesjoner på fire testpersoner, for å finne ut om Pedal Kart gir nok trening og er moro å spille over et slikt tidsrom. Resultatene fra eksperimentet var positive; testpersonene opplevde en høy grad av fysisk anstrengelse, likte spillet, og mente at Pedal Kart gjorde det lettere for dem å trene enn det ellers ville vært. Det begrensede omfanget av eksperimentet gjør det vanskeligere å ekstrapolere resultatene til et større publikum, men viser at videre utforskning av spillet av spillet bør gjennomføres. Slik utforskning kan gjøres enten akademisk eller kommersielt.

Acknowledgements

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Table of Contents

List of Figures

Part I

Introduction

This part will cover why this project was chosen, what questions it seeks to answer, and an outline of the whole report.

Chapter 1

Motivation

Playing video games is an increasingly popular pastime. As of 2017, two-thirds of all American households has at least one person who regularly plays games [1], while major European economies as of Q2 2017 have between 44% and 58% of their population playing video games [2]. At the same time, obesity rates have been increasing in the Western world [3], while exercise rates have decreased [4]. It is especially concerning that time spent playing video games correlates with obesity, and correlates negatively with time spent exercising [5]. While many gamers live a healthy lifestyle, there are also many who play games to the exclusion of exercise rather than in addition to exercise.

Obesity can lead to numerous health problems of varying severity, such as diabetes [6], increased wear and tear on joints, and cardiovascular disease. Overall, the life expectancy of an obese person is 3 to 7 years lower than that of someone in a normal weight range [7]. Physical activity can be an effective tool both for avoiding and combating obesity [8], reducing the occurrence of related health issues [9], and in improving overall health. The World Health Organization therefore recommend a minimum of 150 minutes per week of moderate-intensity exercise, or 75 minutes of vigorous-intensity exercise [10].

Exercise is most likely to succeed when the person exercising finds the act of exercise enjoyable [11]. Combined with the correlation between time spent on video games and obesity, it would make sense to target people who spend significant time on video games with games that are both enjoyable and provide exercise. By appealing to a core interest in these people's lives, it might be possible to motivate them to exercise more than they do today, thus improving the health of an especially vulnerable segment of the population. There have been a number of games that have managed to make exercise fun, known as "exergames". In recent years, the most notable example is Pokémon Go, which managed to motivate many to increase their level of activity.

I hope to create a game that can motivate people to exercise by making it an experience they enjoy rather than simply a chore they must go through to live a healthy life. Leveraging existing game mechanics should also help ensure a low barrier of entry for people already familiar with video games.

Chapter 2

Research Questions and Methods

The goal of this project is to get more people to exercise by creating an enjoyable exergame, and to add to the body of research on the topic of exergames so that future researchers can learn from what went well, and what did not, in this project. It will target the exercise bike platform first developed for the game Pedal Tanks; investigating what ideas may work on the platform. More specifically, the project will investigate what design principles are beneficial to exergames, with emphasis on the Pedal Tanks platform, as well as provide a design for a game for the platform with the potential for further development.

2.1 Research Method and Goal

The research method used for this project was based around the Goal, Question, Metric approach [12]. First a goal was defined, covering the conceptual level of the project. A set of research questions was created for the operational level. Finally, a set of metrics were devised to answer the research questions.

Research goal: Create a prototype for an exergame that will appeal to a subset of the group of people who currently do not exercise enough, thus helping them reach recommended levels of exercise.

2.2 Research Questions

To guide and evaluate the project, a handful of research questions have been articulated.

RQ1: What game design principles provide a good level of exercise?

What is fun and what is good exercise is not always related. While the game must be fun, it also has to provide sufficient exercise. This question will investigate what game design principles can help provide an acceptable level of exercise during gameplay. Such a level of exercise entails both that the exercise is intensive enough to replace traditional

exercise, yet not so intensive that the player gets exhausted too quickly to reap the benefits of the exercise.

RQ2: What design principles should be used to make an enjoyable exergame?

For the player to keep coming back to the game, the concept needs to provide lasting enjoyment. This question will explore what design principles are key to making an enjoyable exergame given the constraint of the user exercising at the same time.

RQ3: What limitations does the exercise bike platform impose on the design of an exergame?

The game will be developed for an exercise bike platform. This provides a highly limited set of inputs, which will constrain what is possible to include in a game design and still have it be enjoyable. This question will investigate what concepts have the potential to work well with the platform.

RQ4: Does the resulting game provide useful exercise?

A goal of the project is to create a game that encourages people to meet recommendations for weekly exercise. As such, the game needs to provide useful exercise. This question will attempt to identify whether the resulting game provides sufficient exercise to meet recommended weekly minimums.

RQ5: Does the resulting game provide enjoyable exercise?

The project seeks to make people exercise more by making it a more enjoyable activity. The resulting game therefore needs to be fun to play. This question will evaluate whether the resulting game provides significant enjoyment and might encourage parts of its potential audience to exercise more.

2.3 Research Process

In order to answer these questions, the first part of this report will be spent investigating prior art within the field of exergames to combine ideas presented there into a more cohesive whole. This will consist of a literature review of past exergames (both academic and commercial), what makes an enjoyable game, and what technology can be used to produce an exergame. The report will use past research to build a foundation upon which to build a game. The game design implications discovered based on the literature review will be examined in detail in a section of their own.

Based on these findings, a design for an exergame with the identified concepts will be created. This design will showcase the core mechanics and draw of the game, and illustrate how the game concept might make for an enjoyable exergame, as well as how the game can be developed further to make it suitable for a user study.

A prototype will be created based on the game design, implementing the core features necessary to conduct an experiment on members of the game's potential audience. A small-scale experiment will be conducted over three sessions to determine whether the

game design has the potential to provide useful and enjoyable exercise, and whether it would make sense to develop the game further into a complete product.

The experiment will make use of data triangulation [13] in order to ensure that issues with any single form of data collection cannot invalidate the results of the experiment. The results will be analyzed to determine if further development of the game would be warranted.

The project as a whole is divided into two parts: TDT4501 (Computer Science, Specialization Project, autumn 2017), and TDT4900 (Computer Science, Master's Thesis, spring 2018). This report includes both parts.

Chapter 3

Report Outline

This section provides an overview of what the report contains. The report is divided into seven main sections:

Part I - Introduction

This part gives a quick introduction to the project.

- Chapter 1 - Motivation: An introduction to the motivation behind this project and its primary goal.
- Chapter 2 - Research Questions and Methods: The questions the project is attempting to answer, and what methods will be used in the investigation.
- Chapter 3 - Report Outline: What you are reading right now.

Part II - Prestudy

In this part, the literary study conducted at the start of the project is covered.

- Chapter 4 - What are Exergames?: Covers what defines an exergame.
- Chapter 5 - Theories on Enjoyment: Covers several different theories on enjoyment and how they apply to games.
- Chapter 6 - Existing Exergames: Considers a selection of existing exergames to see what they did well and what they could have done better.
- Chapter 7 - Exercise: Discusses forms of exercise and weekly recommended exercise.
- Chapter 8 - Technology: A look into what forms of technology have been and can be used for exergames.
- Chapter 9 - Unity Game Engine: A brief overview of the Unity game engine, and what makes it suitable for a project like this.

- Chapter 10 - Evaluation of Exergames: Investigates how existing exergames have been evaluated by past researchers to uncover what techniques would be useful in this project.

Part III - Designing an Exergame
This part provides an overview of what elements were considered before the game itself was designed, and how such elements can help ensure a good exergame is created.

- Chapter 11 - Features and Genres: Qualitative analysis of what functionality works well for exergames, and which game genres might be a good fit.
- Chapter 12 - Multiplayer: A discussion of what multiplayer adds to exergames, and about the pros and cons of cooperative vs. competitive multiplayer.
- Chapter 13 - Replayability and progression: Analysis of what can be done to ensure that an exergame has lasting appeal.
- Chapter 14 - Exercise and Gaming: A discussion of what elements are important to ensure that an exergame provides sufficient exercise.
- Chapter 15 - Discarded Ideas: A look at what ideas for games were considered and eventually discarded.

Part IV - Game
In this part of the report the game that will later be created is presented.

- Chapter 16 - Inspiration: Lists what existing games were used as inspiration for the exergame, and especially which elements were considered.
- Chapter 17 - Core Mechanics: Details on the mechanics that underpin the gameplay, and how they interact to create a hopefully interesting game.
- Chapter 18 - Replayability and Rewards: Analysis of what mechanisms the game has to keep the player playing.
- Chapter 19 - Social Interaction: A description of how the game's functionality helps encourage social interaction during and after playing the game.
- Chapter 20 - Prototype: An overview of the prototype created of the game, and what functionality it possesses.

Part V - Experiment
This part of the report covers the experiment conducted in order to determine whether the prototype is a good exergame.

- Chapter 21 - Methodology: Describes the setup of the experiment and the methodology used to determine how the game is to be evaluated.
- Chapter 22 - Data Collection: Describes all forms of data to be collected during the experiment, and what the purpose of this data is.

- Chapter 23 - Test Subjects: Summary of the test subjects selected, and the method used for selecting them.

Part VI - Results
This part of the report summarizes and analyzes the results from the experiment.

- Chapter 24 - Physical Exertion: A summary of the data related to how much physical exertion the game provided
- Chapter 25 - Enjoyment: Summarizes of the data concerning how enjoyable the game was.
- Chapter 26 - Validity and Reliability: Information on various issues encountered during the course of the experiment, and discussion of how applicable the results are to the wider population.
- Chapter 27 - Discussion: A discussion of how the results answer the research questions.

Part VII - Conclusion
This part presents a conclusion to the research questions presented in Chapter 2, and evaluates to what extent these questions have been answered, and how useful those answers are.

- Chapter 28 - Conclusion: An evaluation of to what extent the request questions have been answered.
- Chapter 29 - Further Work: A discussion of how the prototype can be developed further, as well as possible related work.

Part II

Prestudy

To get an overview of what possibilities exist in the realm of exergames, a prestudy was conducted. This will build the foundation for the design of the exergame. This part will cover what an exergame is, several relevant already existing exergames, and what technology can be used for exergames. These parts will help inform what options there are when designing an exergame.

Furthermore, it will cover a few theories on enjoyment to help identify some elements important to making an enjoyable game. It will also cover evaluation methods used in past research on exergames, to help determine how to evaluate the result of this project. Finally, the Unity game engine, which will be used to create the exergame, will be briefly investigated.

Chapter 4

What are Exergames?

An exergame is a video game that requires physical exertion in order to play [14], thus combining the fun of games with the health benefits of exercise. To achieve this, physical exertion is used in some way an input to the game, combined with or replacing more traditional inputs like buttons and joysticks. To track such input, exergames generally use different controllers from more traditional games, such as cameras and acceleration sensors. By using one or more acts of physical exertion as part of the control scheme of a game, the user is forced to exercise in order to achieve success in the game. By combining a game with exercise, the user hopefully ends up with an experience that feels more rewarding and enjoyable than exercise for exercise's sake.

Exergames have existed for decades. Primitive exercise games first showed up in the 1980s [15]. Exergames can be considered a natural progression from physical games like sports and playground games; simply moving the idea of fun exercise into the virtual domain. With obesity being an increasingly common problem, and video games becoming increasingly popular, research into using games for exercise has increased significantly in recent years. Searching for '"exergame" OR "exercise game"' on Google Scholar reveals only 902 articles on exergaming before 2010, while the years since have produced 4880 articles. Exercise is far from the first area where games have been used to achieve something beyond simple enjoyment. Leveraging games for the good of society has seen success in a number of other areas, including education [16], military training [17], and medical research [18].

Chapter 5

Theories on Enjoyment

A theory on enjoyment is a framework identifying aspects of an activity that make it enjoyable to take part in. Both general and more specific theories on enjoyment exist; the more general theories can be applied to any activity, while more specific theories focus on some sub-set of all possible activities. In the case of exergames, what is especially useful is theories on enjoyment focusing on games in general, or exergames in particular. This section will cover a handful of theories on enjoyment.

5.1 Flow

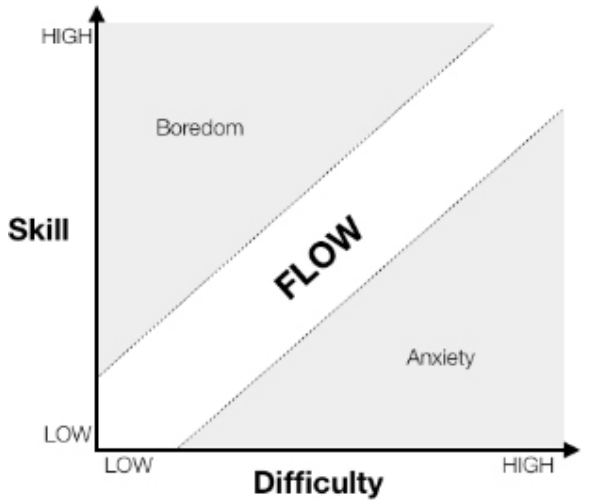

Figure 5.1: Balance between skill and difficulty described in flow

Flow is a mental state that can be achieved when a person is completely immersed in an

activity. The term was coined by Hungarian psychologist Mihály Csíkszentmihályi [19]. Colloquially, a state of flow is known as ”being in the zone”. While in a state of flow, a person will experience:

- Complete concentration on the current task
- Action and awareness combine; responses become spontaneous or automatic, and one loses awareness of the self being separate from the actions one is performing
- A sense of serenity; no concerns about one's self
- Sense of being in control without having to actively attempt to exert control
- Alteration of perception of time; slowing down or speeding up
- Experiencing the activity at hand as intrinsically rewarding

The concept of flow can be used both to guide game design, and to evaluate the experience of the players. It is especially applicable to exergames, where it is assumed that the act of exercise itself is not enjoyable for the player, and thus something they need to be distracted from, as otherwise they would not have a need for an exergame to get them to exercise.

For flow to be achieved, three conditions must be fulfilled:

- The activity must have clear goals and progression, so one knows what to do
- The task must provide immediate and clear feedback, so that one can improve one's performance
- Perceived skill and perceived challenge must be balanced; if the task is perceived as too difficult, the person will be frustrated. If too easy, the person will be bored. This is illustrated in Figure 5.1

A version of flow theory exists specifically for games, known as **GameFlow** [20]. It is intended to be ”a model for evaluating player enjoyment in games”. It outlines elements that a game should have in order for the player to enter a state of flow:

- The game should require and allow for concentration on the game
- The challenge level of the game must match the player's skill level
- The game must allow the player to become better at the game
- The player should feel that they are in control over their actions in the game
- The game should provide the player with clear goals
- The player must receive feedback on how they are doing in the game
- The player should feel immersed in the game
- The game should create opportunities for social interaction

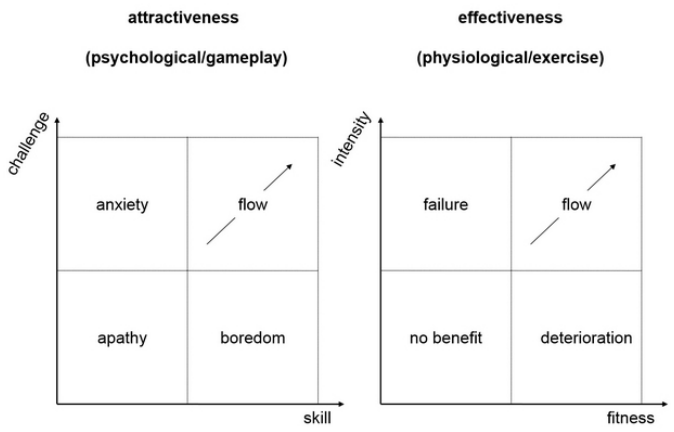

Figure 5.2: Illustration of dual flow

These for the most part map quite clearly to the criteria for flow, but restated in a way more directly applicable to games. This can be further refined for exergames with the idea of **Dual Flow** [21], which adds the dimension of exercise. Simply put, the game must balance the intensity of the exercise with the player's fitness. These two dimensions are illustrated in Figure 5.2.

Overall, for the purpose of exergames, flow theory entails that the game must have mechanisms for adapting its difficulty to the player's skill level, and for providing a level of exercise appropriate for the player's fitness. It may also mean that it is necessary to limit the target group to some extent, as even with mechanisms for adjusting the difficulty and intensity, most games fail to appeal to people at every single possible skill level.

5.2 Challenge, Fantasy, and Curiosity

Challenge, fantasy, and curiosity is a game-specific theory on enjoyment [22], which outlines those three elements as key to game enjoyment.

According to Malone, a game needs to be *challenging* if it is to provide long-term enjoyment, meaning that it must provide goals that are not guaranteed to be achieved. A good selection of goals is therefore key to providing a challenging game. In order for a goal to be good, it needs the following properties: the goal needs to be clear to the player; there must be a clear way of advancement. The goal must be of a level of difficulty matched with the player's skill. And finally, it must be clear to the player whether they are making progress towards their goal.

Furthermore, the outcome must be uncertain. Malone outlines four possible ways to achieve this. First, the game can provide variable difficulty levels, for example chosen by the player at the start, determined automatically based on how well they are doing, or in multiplayer by matching players with opponents of similar skill levels. Another possibility is having more than one level of goals. The game can have goals ranging from

easy to difficult, where while the player might easily achieve the easier goals, eventually they will meet a significant challenge. One example of this is providing a meta-goal, where it is not enough to just complete a level or objective; it can be done in a better or worse way. For instance, this could be tracking how long the player takes to complete a level, providing the player with the implicit goal of reducing the time taken. Another way to provide uncertainty is hidden information; by ensuring the player can't know all the information that influences the outcome of an action, the outcome will always inherently have some level uncertainty. Finally, the game can use randomness to make the outcome itself uncertain at all times.

By providing challenging goals that the player can achieve, Malone suggests that the game will engage the player's self-esteem. As achieving the goal is uncertain, upon completion the player will feel that they have achieved something of note. The inverse is also the case; failure can lower the player's self-esteem and hurt their enjoyment, making a careful balance between uncertainty and the player's chance of overcoming the challenges they face key. Games should also attempt to provide feedback on failure in a manner that minimizes the hit to the player's self-esteem.

Beyond being challenging, the game should appeal to the player's sense of *fantasy*. Games can present situations and courses of actions that the player will not or cannot experience in the real world, allowing for a form of escapism. Malone divides fantasy into two categories: intrinsic and extrinsic fantasies. The easiest form of fantasy to integrate into a game is extrinsic fantasy, where the fantasy is affected by the player's skill, but there is no clear connection between the skill used and the fantasy. If such a connection exists however, it is in the realm of intrinsic fantasy; the fantasy depends on the player's skill, and the player's skill also appears relevant to the fantasy.

By providing for fantasy, a game can appeal to the emotional needs of the player. Different players will find different fantasies enjoyable, and it is therefore important to match the fantasies evoked by a game with the user base the game targets.

Finally, games should evoke players' *curiosity*. The player should be motivated to learn. According to Malone the game's environments should have a complexity matching the player's existing knowledge; neither too simple nor to complex. The game should be novel, but not incomprehensible. Malone subdivides curiosity into two forms: sensory and cognitive.

Sensory curiosity is the curiosity evoked by the sensory input the game provides, primarily audio and visuals. The game's audio and visuals should be complex enough to be interesting, while not being so complex as to be overwhelming.

Cognitive curiosity is the curiosity evoked by the player seeking to understand the game. A game should try to ensure that there is always something more to learn just ahead, such as mastering when to use a given ability to a greater degree.

5.3 Summary

In summary, Malone's theory focuses on somewhat different aspects of game design than Flow theory, outlining three areas core to enjoying a game. By trying to appeal to these

three design principles a game is more likely to be enjoyable. In combination with Flow, this can be used to formulate specific mechanics a game can use to provide a long-lasting enjoyable experience.

Especially relevant to this project is the idea of Dual Flow, and the challenge of making a game that is sufficiently challenging as a game to get the user into a state of flow, without either overexerting the user or not exerting them enough. The designer has to tie the intensity of the exercise to the intensity of the gameplay, but not so tightly that if the user's level of fitness does not match their level of proficiency they end up either exhausted or barely exerted.

Chapter 6

Existing Exergames

A large number of exergames have been created over the years, both for research purposes, and by commercial actors. This section will cover a handful of each, introducing what has been achieved in the field. While some exergames have seen commercial success, most academic exergames have not been developed further and commercialized.

6.1 Dance Dance Revolution

Figure 6.1: Dance Dance Revolution

Released in 1998, Dance Dance Revolution (DDR) was one of the first exergames to see significant commercial success, having sold 6.5 million copies by 2009 [23], and having spawned an entire genre of games. The Just Dance series for instance had by 2012 sold over 25 million copies [24].

In DDR the player dances by hitting movement arrows with their feet. Which arrows to hit are indicated by the screen, with a rhythm matching the song being played. The game has a large number of different songs, each with several difficulty levels, ensuring that all players can tweak the difficulty based on their skill-level. Studies have shown that DDR can provide sufficient exercise to meet the weekly recommended minimum, showing that exergames can provide significant results. However, DDR will not appeal to all players, so exergames covering other niches of the video game market is necessary if exergaming is to have a truly significant effect on obesity in the Western world.

6.2 Wii Fit

Figure 6.2: Wii Fit U

The Wii Fit for Nintendo Wii [25] is an exercise platform consisting of a board with weight sensors, Wii Motion controllers, and a Wii game console. It comes with a large selection of mini-games. Some of these simply consist of on-screen instructions for more traditional exercise such as push-ups and yoga, with the Wii Fit board keeping track of the player's balance so as to help ensure the exercise is effective. Other games are intended to be more fun and incorporate somewhat more traditional gameplay. Examples include slalom and ski jumping games, where the player must lean to steer, avoiding obstacles on the way.

The Wii Fit saw significant commercial success, having sold over 22 million copies [26], and receiving mostly positive reviews [27]. The strength exercises of the Wii Fit function well as exercise, but make little use of game elements. The mini-games that do use traditional game elements have been tested in order to determine their exercise effect. While there was an effect, it did not reach the recommended intensity for daily exercise [28], and can therefore not be considered anything beyond merely supplemental exercise.

Figure 6.3: Holopoint

6.3 Holopoint

Utilizing virtual reality, Holopoint is an archery game where the player uses the controllers as if they were a bow and arrow [29]. The goal of the game is to make it through as many waves of targets as possible. At first, the targets are simply boxes hovering in the air, which when destroyed fire a slow-moving missile at the player, forcing the player to physically dodge. If the player is too slow to destroy the box, it will self-destruct, firing a much faster-moving missile. Eventually they are replaced by hostiles that have to be shot before they get to the player, giving the player more and more time pressure.

The combination of physical movement and inexorably ramping difficulty makes for an intense workout despite the relatively simple formula of the game, while ensuring that any player will get a challenging play experience.

While the player has to physically move, the amount of room needed is still low; a few square meters is sufficient, as the player just needs enough room to lean out of the way of incoming shots. The game requires an HTC Vive or Oculus Rift, and their associated motion controllers making the buy-in price high, but requires no special equipment beyond this.

6.4 Pokémon Go

Perhaps the most well-known exergame of all time, Pokémon Go released in the summer of 2016 [30]. By early 2017 it had hit 650 million downloads [31], and sits at 65 million monthly active users. However, despite its immense initial success, its peak has already passed, with most people who have tried the game having since quit playing [32]. Despite this, it is still one of the most played games of all time.

In Pokémon Go, the player captures Pokémon; monsters roaming the world. The player can find them by physically walking around with their phone, which will tell them where nearby they can find Pokémon to catch. The player can also acquire eggs, which hatch after the player has walked a certain distance ranging from 1 to 10 kilometers. To ensure the player is physically active, the game does not function if the player's speed is too high. In practice, this means the player is forced to play on foot or potentially a bike. The captured Pokémon can be used to conquer gyms, which are located near various landmarks. If successful, they get a variety of rewards, and until someone else takes over

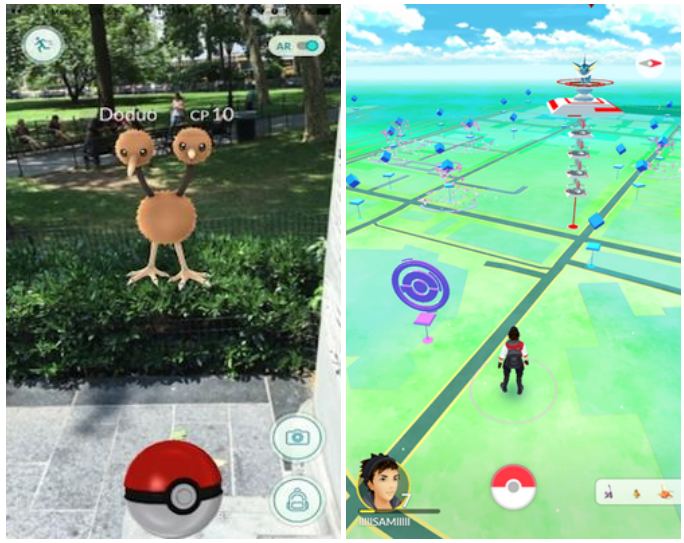

Figure 6.4: Pokémon Go

their username will be displayed on the gym.

Since walking at a moderate pace is considered sufficient to achieve the recommended weekly exercise, Pokémon Go can serve as a great incentive for increased physical activity. However, the drop-off rate might mean that for most it will be a short-lived incentive rather than a more permanent change to their lifestyle.

Pokémon Go is heavily based on the game Ingress [33] by the same company. Ingress in contrast achieved nowhere near the success [34] of Pokémon Go despite having nearly the same gameplay. This shows there are significant factors to success beyond the gameplay itself.

6.5 Brains & Brawn

Richards and Graham created the card-game Brains & Brawn to investigate how player agency can be achieved in repetitive-motion exergames [35]. The player controls a team of characters against an opposing AI-controlled team. Each turn, they get to play one card in order to attack the enemy team or provide healing to their team.

The core gameplay is similar to other combat card games, with one significant difference. Instead of the effects of cards being automatically applied, the player performs a set of exercises to apply the card's effect. How much of an effect the card has is determined by the quality of the player's exercise form; the better their form, the higher the effect. This repeated switch between exercise and rest maps to the standard pattern of repetitive-motion exercise, thus achieving meaningful gameplay while still incenting good exercise. The main tactical choices happen during the resting period, allowing the player to focus on the choices available without having to be concerned about exercise form, while during the execution of the card chosen, they can focus on their form without tactical concerns

Figure 6.5: Brains & Brawn

getting in the way.

The game presents the illusion of choice when it comes to what exercise is performed. Each card has an associated exercise, and the player gets to freely choose between the three cards currently on hand, but the order of exercise drawn from the deck is pre-determined to ensure a good exercise regimen. The player can vary the order of exercise some, but not the overall regimen.

6.6 Snowballz

Figure 6.6: Snowballz

In this virtual reality game, the goal of the player is to survive for as many rounds as possible by defeating all incoming enemies [36]. This is done by picking up snowballs from the ground and throwing them at the enemies. There are two forms of enemies; snowmen, and snowmen with cannons. The regular snowmen move towards the player, harming them if they reach them. The cannon snowmen fire large snowballs at the player,

which the player can either dodge or hit with a snowball of their own. The player creates snowballs by squatting down and reaching towards the ground.

The game scales the difficulty based on the player's performance in the game. It does this based on three factors: accuracy, snowballs created, and number of restarts. Each snowman hit gives the player an experience point (XP), while each miss reduces the XP level by one. Similarly, the difference between the number of snowballs created and number of snowmen in the current round is added to the XP level, while the number of times the player has had to restart due to death is removed. For every 10 points of experience the level intensity is increased. Increasing intensity makes the enemies move faster, and causes more of them to be spawned. This is applied at the start of the next round. The intensity ranges from 1 (very easy) to 5 (very hard).

The game ends once the player has exercised for a predetermined amount of time. The player is considered to be exercising whenever their heart rate is measured by the game to be above a certain percentage of their maximum heart rate. The adaptive difficulty is intended to ensure that the gameplay is neither too easy nor too difficult, thus hopefully avoiding both boredom and frustration.

6.7 Pedal Tanks

Figure 6.7: Pedal Tanks

Pedal Tanks The team-based shooter Pedal Tanks [37] is an arena shooter in which four players each control a tank using an exercise bike and a simple six-button controller attached to the bike's handlebars. Pedaling is used to control the speed of the tank, while the controller is used to turn the tank, fire its gun, reverse, and use two special abilities. The players are divided into two teams, with the goal being to capture the other team's flag. Once a team has scored at least one kill they can attempt to capture the other team's flag by driving onto it and then returning it to their own base. The enemy team can prevent the capture by killing the tank with the flag. Upon being killed, a tank will reappear back at its team's base a short time later. The round ends after three minutes, or after a successful flag capture. The overall winner is determined by the result of five rounds.

When tested on potential users, Pedal Tanks was shown to be significantly more intensive than walking, as well as subjectively enjoyable. The testers gave the game high ratings, but the authors emphasize that the long-term viability of the game cannot be determined from the testing conducted so far, as it was only tested across three sessions rather than through longitudinal testing.

The physical technology behind Pedal Tanks, which allows an exercise bike to be used as a game controller, is undergoing commercialization [38], and can also be used for other research projects such as this paper.

6.8 Exer Dungeon

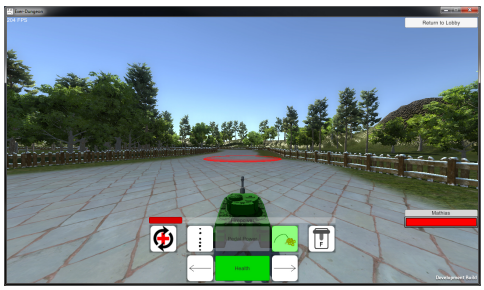

Figure 6.8: Exer Dungeon

Exer Dungeon This cooperative game [39] inspired by Pedal Tanks, World of Warcraft, and Alien Swarm puts four players on the same team facing AI opponents. It utilizes the same hardware platform as Pedal Tanks, with the pedals being used for both propulsion and for charging shots. Rather than instantly firing when the ”fire” button is pressed, the player pedals to determine how far the shot travels, releasing the button when they are satisfied with the distance in order to fire. In the game the players face a series of AI opponents with varying abilities and movement patterns, and must work together to defeat them. The players select from a selection of different abilities; some providing assistance to other players on the team, while some directly damaging the opponents.

Each level in the game is won once all enemies have been defeated. The game is lost if all players on the team are dead at the same time. The simple gameplay makes the game easy to pick up, and the testers found the core mechanics enjoyable, but the author noted a significant lack of replayability due to a lack of variation.

6.9 Exermon

Taking inspiration from the game Fitigochi, Exermon has the player do strength exercises to improve their exermon; a digital pet and fighter [40]. The player can use their exermon to fight other exermons, both randomly generated ones, exermons owned by other players, and especially strong boss exermons. The game uses exercise to improve the exermon,

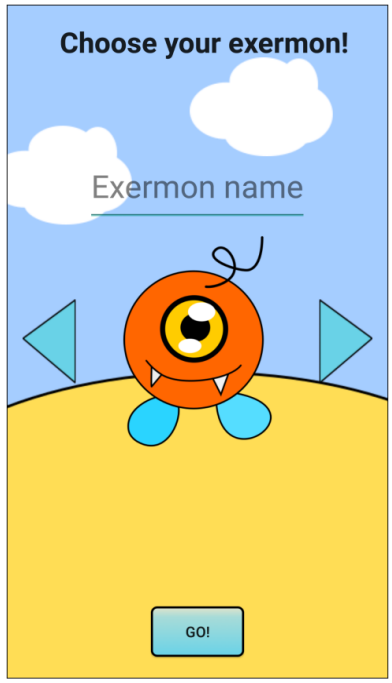

Figure 6.9: Exermon

while the more complex aspects of the game are undertaken via a smartphone. The fighting itself is done by swiping at the enemy exermon on the screen.

The game contains an in-game shop using currency earned in the game to buy stat boosts and boosts to their gain from exercise. The player's main goal is to improve their exermon and defeat other exermons. The player also gains badges showing what they have managed to achieve in the game. One badge for example is gained by doing 500 push-ups. This helps provide the player with both short-term and long-term goals.

6.10 Summary

This selection of exergames illustrates that there are many possible approaches to exergames, each with their unique advantages and disadvantages. It also shows that exergames have been successful both academically and commercially.

The selected exergames will be used to showcase the available exergame technology, what forms of exercise are well suited to exergame, and to guide the section on design principles relevant to exergames.

Chapter 7

Exercise

To be a good exergame, the game must provide safe and effective exercise. The National Institute of Aging, part of the U.S. Department of Health and Human Services, identifies four main forms of exercise [41]: endurance, strength, balance, and flexibility. Existing exergames exist for each form of exercise, with some games including more than one. The form(s) of exercise chosen for an exergame can have significant implications for the design of the game, as well as the choice of technology.

Endurance Also known as aerobic exercise, the goal is to keep one's heart, lungs, and circulatory system health, as well as to improve one's endurance. It consists of activities that increases one's breathing and heart rate, such as jogging, biking, or dancing. In an exergame based around aerobic exercise, a major design challenge is ensuring the level of exertion is high enough to get the player winded, but not so high as to quickly exhaust them. Aerobic exercise has a variety of positive effects, including lowered blood pressure [42], reduced chance of heart disease [43], and improved cognitive function [44]. Pedal Tanks [37], Exer Dungeon [39], and Pokémon Go [30] are all examples of exergames centered around endurance training.

Strength This form of exercise is also known as repetitive motion or resistance exercise. The main goal is to maintain or increase one's muscle mass. Strength training typically consists of repeated sets of motions interrupted by regular breaks. An example would be lifting a set of weights 10 times, taking a short break, then doing so again. A significant challenge for exergames built around strength training is to provide player agency, as the nature of strength training requires that a relatively strict set of actions be performed, and requires slow and controlled motions [35]. If done improperly, a person can easily injure themselves. This makes it challenging to use the exercise itself to control a game, though games like Brains & Brawn and Exermon [40] show that it is possible. A number of minigames in Wii Fit [25] also base themselves around strength exercises, but they contain little to no gameplay, instead simply tracking the exercise. The positive effects of resistance exercise include building muscle mass [45], improving blood pressure [46], and stimulating bone growth [47].

Balance By performing activities that challenge one's sense of balance, it is possible to improve one's balance. Examples of such activities include standing on one foot and line walking. Balance exercises can work quite well for exergames as the activities involved can be highly varied without significant risk of getting hurt. Most of the minigames in Wii Fit base themselves around balance exercise, using the act of changing one's center of balance as the primary control for gameplay. Balance exercise is especially important as one gets older, as it can help one avoid potentially dangerous falls [48].

Flexibility Some exercises have as their goal to improve flexibility and avoid damage to muscles and tendons. Most exercise regimens include flexibility exercises to some extent in the way of stretching, while others focus primarily or entirely on flexibility, such as yoga. Like strength exercises, flexibility exercises are difficult to adapt to games due to the risk of hurting oneself if one is not careful. Some of the Wii Fit minigames incorporate flexibility, but much like the minigames that incorporate strength exercises, these minigames have very little actual gameplay. Performing flexibility exercises is important in order to avoid damage from other forms of exercise [49], and can help improve one's range of motion [50].

Recommended exercise level It is recommended by a large variety of government and health agencies that everyone exercise every week. The amount and form of exercise can vary from agency to agency. The most common recommendation is 150 minutes of moderate-intensity aerobic exercise a week, or 75 minutes of vigorous aerobic activity, on top of performing moderate to high-intensity strength exercise at least twice a week. This recommendation is backed by the American Heart Association [51], the UK National Health Service [52], the Center for Disease Control and Prevention [53], as well as the World Health Organization [10].

Despite these recommendations and associated health benefits, according to the CDC only 52% of American adults fulfill the recommendation for aerobic exercise, and only 22% both the aerobic recommendation and the strength exercise recommendation [54].

Summary Within these four forms of exercise a multitude of possibilities exist for exergames, with balance and endurance being the two forms of exercise most easily adapted to exergames. The potential health benefits are significant, yet most people do not meet the recommended amount of weekly exercise.

Chapter 8

Technology

To provide exercise, an exergame needs to make use of technology suitable to the form of exercise. While some exergames create their own hardware platform, there is also a large selection of existing platforms. This section will give an overview of some of the more notable platforms, investigating their upsides and downsides.

8.1 Virtual Reality

Figure 8.1: HTC Vive

The first consumer virtual reality headset, the Oculus Rift [55], was released on March 25, 2016, with the first prototype version having been released three years earlier. The consumer version of the competing HTC Vive [56] was released soon after. VR headsets provide the player with a 360-degree 3D virtual environment, in which the player's viewport matches the position of their head. While the first consumer version was intended for use while sitting mostly still, in 2016 the Oculus Touch motion controller was released, allowing the system to also track the position of the player's hands. This opened up for a far greater range of motion. The HTC Vive included motion controllers with its first

commercial release, and is intended for room-scale gameplay. The PlayStation VR [57] was also released in 2016. While not as advanced as the Oculus Rift or HTC Vive, it is currently beating them both in terms of market share [58] due to its lower price.

While VR headsets have largely been used for games where the main purpose is entertainment, many games involve significant movement. One example, Holopoint [29], is mentioned in the ”existing games” section of this report. There have also been a number of academic exergames made for VR, such as the Snowballz [36] game.

VR has the advantage of directly mapping physical movement to in-game movement, making it easy for players to immerse themselves in the game. This helps ensure the player ”forgets” they are exercising. The motion controllers also allow for a wide range of exercise. It is also possible to combine the VR headset itself with other forms of exercise, such as cycling simulators, where the player rides an exercise bike in a virtual world.

The most significant downside of current VR headsets is their price. The Oculus Rift currently has an MSRP of $399 for the headset and motion controllers [59], while the Vive retails at $599[60]. On top of the price of the headsets themselves, VR also requires a powerful computer as it is effectively rendering two monitors' worth of pixels at any given time [61]. The exception to this is the PlayStation VR. Like the Oculus Rift, it retails at $399 [62], but it only requires a PlayStation 4 retailing at $299 [63] rather than a powerful computer. This makes the PlayStation VR a significantly cheaper option, though it sacrifices some fidelity and performance in order to meet this lower price-point.

8.2 Kinect

Figure 8.2: XBox One Kinect

Kinect The Kinect [64] was released in November 2012 for the XBox 360. Two years later it was also released for Windows, and when the Xbox One was released in 2013, a new version of Kinect was included in the package. The Kinect uses a camera to track the player's movements, allowing gameplay via gestures and full-body movement. The full-body aspect makes the Kinect well suited to exergames. While the Kinect went out of production in late 2017, there are still millions of Kinects in circulation, having sold 35 million units during its lifetime [65].

One commercially successful exergame for Kinect is Dance Central [66], in which the player performs dance moves across a large number of different dance routines. The games

include a ”workout mode”, where the game approximately tracks the number of calories burned, and times how long the player has been exercising. Another exergame utilizing the Kinect is Brains & Brawn [35], though at the time of writing the game simply uses the camera to make the player believe the game itself is judging their exercise form while in reality they are being judged by another person.

Much like VR, the Kinect has the advantage of being able to directly map physical movement to in-game movement. However, it uses a regular TV or monitor as opposed to a VR headset, thus not achieving quite the same level of immersion. The Kinect is also able to track parts of the player's body beyond just their hands and head, though the tracking is not quite as precise as that of the Oculus Rift or Vive.

The Kinect while in production won out over VR headsets on price; an XBox One currently retails at $279 [67], while the Kinect itself retailed at $99 [68], and unlike a VR headset the player does not require an expensive computer for it to run, only a TV or monitor. This makes the barrier of entry far lower.

8.3 Smartphone

Figure 8.3: Smartphone displaying Pokémon Go

The smartphone is increasingly ubiquitous, with over 77% of U.S. adults owning one [69]. With such a great user-base, the potential for use in games is significant. Smartphones provide two tools that can be easily adapted to exergames: GPS, and motion detection. A number of exergames, most notably Pokémon Go [30], use GPS to track the player moving around, encouraging them to go on walks or runs. Similarly, a variety of applications intended for tracking bike trips, hiking trips, and so on exist, though these normally are not gamified.

The motion detection included in smartphones can also be used for exercise purposes [70], by tracking user movement on scales not detectable by GPS. This can for example be used to track repetitive-motion exercise.

Smartphones are sold at a great range of prices, but due to how common they are in modern society, and especially the younger generations [69], the target audience of an exergame can be assumed to already own one. However, the capabilities of smartphones when it comes to processing and graphics vary wildly, providing some limitations as to what can be achieved without significantly limiting one's audience.

8.4 Wii Balance Board

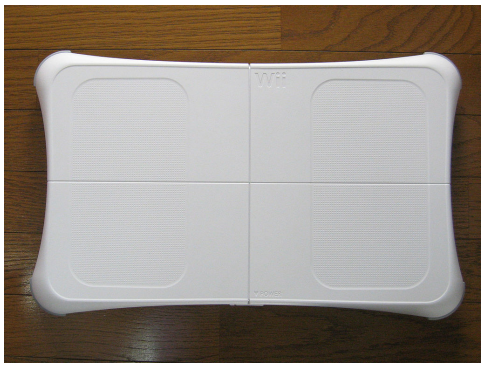

Figure 8.4: Wii Balance Board

The game Wii Fit [25], released in 2007, includes the Wii Balance Board as its primary controller. While its main purpose is the Wii Fit game itself, it can also be used by other games. The board contains four pressure sensors that combined measure the user's center of balance and force upon the board.

The ability to track the player's center of balance makes it useful for assessing the user's sense of balance [71] and thus assisting in efforts to improve the balance of groups such as the elderly [72] and people with Parkinson's disease [73].

Wii Fit U with the Wii Fit Balance Board sells for $90 [74], making it one of the cheaper exergaming options, but it also requires a Wii U game console, which retails for $300 [75].

8.5 Pedal Tanks Platform

In order to create the game Pedal Tanks [37], the authors also created a custom controller. The controller consists of an off the shelf exercise bike, sensors detecting RPM, and 6 buttons attached to the handlebars of the bike.

The RPM sensors allow using the speed of a bike as an input to the game. In the case of Pedal Tanks, it is used to propel the player's tank. The buttons on the handlebars allow easy input while using the bike, and provides enough buttons for a varied set of actions. In the case of Pedal Tanks, two buttons are used to steer the tank left and right, while the other four are used for shooting, special actions, and reversing.

For the purpose of exercise, a significant advantage of this platform is that the exercise itself is a direct input to the game; as long as the game manages to encourage the player to pedal enough, the player will be getting good cardiovascular exercise. The act of pedaling is also easy to map to propulsion, providing an intuitive way for the player to control the game.

The platform is not yet commercially available, but is made available for research at NTNU for free. The creators plan to eventually launch it in gyms and similar, where it

Figure 8.5: Early prototype of a Pedal Tanks bike

might serve as one more exercise device [38]. This differentiates it form the platforms above, which are primarily intended for individual use, but has the advantage of spreading the cost across far more people.

8.6 Game-specific Platforms

Some games, rather than use an existing platform, instead create their own specific to their game. Examples include Dance Dance Revolution's dance mats [76], a variety of other arcade games such as Prop Cycle [77], and the Pokéwalker [78].

The main advantage of a game-specific platform is that it can be tailored precisely to the gameplay of the game in question, which can in some cases make it more fun to play than if an existing platform was adapted instead. For example, the dance mat for Dance Dance Revolution change the game from simply being a rhythm game to also providing simple exertion; the rhythm aspect could easily have been achieved with a traditional console controller, but the exertion could not.

The downside of using a game-specific platform is that it increases the cost of the game itself. While for existing commercial platform an audience owning the necessary equipment will already exist, with a game-specific platform you have to create your own audience, making it more difficult to get end-users to buy the game. Most games with game-specific platforms have therefore targeted arcades rather than end users, since there the cost of the platform is split across all the users of the arcade, rather than being borne

Figure 8.6: Prop Cycle

by an individual. Cheap game-specific platforms like the Pokéwalker do not face this issue to any significant extent, as they are similar in price to traditional games.

8.7 Summary

There is a wide array of technology that can be used for exergames. The main concerns are price, existing user base, and what form of physical interaction they allow. The forms of interaction have major implications on exergame design.

Given the availability of the Pedal Tanks platform and the promising existing research for games built for the platform, it will be the platform used for this project.

Chapter 9

Unity Game Engine

The Unity game engine is a cross-platform tool for developing video games [79]. It provides functionality for 2D and 3D graphical rendering, drag and drop functionality, and a programming interface via C#. Unity is one of the most popular game engines on the market, in part due to its free version being usable even for commercial games up to an annual revenue cap of $100 000 [80], making it a great place for students and hobbyists to start.

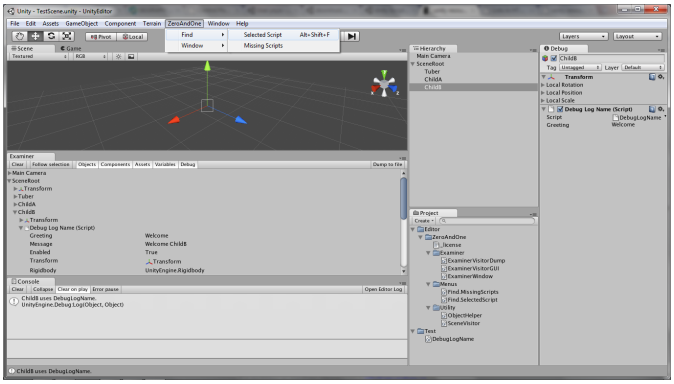

Figure 9.1: The Unity Editor

While being easy to use, the engine also has functionality sufficient for large-scale commercial games. Unity includes functionality for both single and multiplayer games, and its visual interface makes prototyping games simple.

Using a game engine allows a game developer to quickly start working on the game itself rather than the technology supporting it, and without having to re-invent fundamental principles like how to create a user interface, do 3D rendering, or support multiplayer connectivity.

Unity also has an Asset Store where developers can acquire the assets their game re-

quires, such as 3D models, animations, audio, and shaders [81]. While most assets cost money, there are also many assets provided for free, simplifying prototyping and the development of academic games where the gameplay is the core focus rather than the graphics and audio.

Summary The combination of the engine being free, easy to use, and having a large community providing free assets, tutorials, and other assistance, makes the Unity engine a great choice for an academic exergame.

Chapter 10

Evaluation of Exergames

Academic exergames generally have as a goal to improve the fitness or balance of some target group, and use a range of methods to evaluate the efficacy of the game, both when it comes to its exercise effect, and whether the players find it enjoyable.

When it comes to how effective the exercise is, several well-researched alternatives exist. Many exergames make use of heartbeat monitors, as heart rate is indicative of physical exertion and the necessary equipment is cheap and easy to acquire. Caloric expenditure can be estimated more directly using energy expenditure monitors such as SenseWear Armbands. While these have significant accuracy issues in practice [82], they can still be of use as a proxy for caloric expenditure. One of the most accurate methods for measuring caloric expenditure is indirect calorimetry [83], but the equipment required for it is costly enough that many researchers choose less accurate, but cheaper, methods. On top of direct measurement, most researchers also ask the test subjects about their subjective experience, for example by asking them to rate how tiring the exercise was on some scale.

Pedal Tanks [37] and Exer Dungeon [39] both made use of heart rate monitors and interviews to determine the effect of the exercise. Pedal Tanks additionally used SenseWear Armbands to have one more measure to indicate the exercise effect of their game. Brains & Brawn on the other hand used a trained kinesiologist who evaluated their exercise form over time. On top of testing their game, Pedal Tanks also had the test subjects go on moderately-paced walks to see if the exercise effect of their game could match or beat that of a recommended exercise activity. Similarly, Exermon [40] used interviews and observation to determine the subjective exercise effect.

On the side of evaluating how interesting the game is to play, and whether the participants will continue to play it in the future the primary method used is interviews. This method was used to evaluate all three games. While Pedal Tanks, Exermon, and Exer Dungeon's interviews focused on a set of questions based on the game flow theory, Brains & Brawn [35] used a Rhodes' affective attitude questionnaire [84] to determine if the test subjects would be likely to play a similar game in the future if given the option. All three also asked the participants to rate their enjoyment of the game, and let the participants talk about their experiences with the game. Pedal Tanks additionally compared the amount of

time the test subjects spent on the game compared to walking; the test subjects were given a minimum duration rather than a fixed duration. While they quit walking shortly after the minimum duration had elapsed, they kept playing the game well past the minimum duration, which the authors argued was indicative of the game being enjoyable. None of the studies attempted to determine long-term enjoyment of the game, largely due to the difficulty and time required to determine this. Long-term enjoyment is therefore largely unexplored in the realm of exergames.

Summary Overall combining a number of these methods can provide useful data on both the exercise effect of a game, and whether it is enjoyable in the short term. Determining long-term enjoyment is outside the scope of this work because of the time required.

Part III

Designing an Exergame

This part will cover elements and design philosophies that assist in making an effective exergame. It will cover features and genres applicable to exergames, how multiplayer can improve exergames, factors important for replayability, and design considerations for ensuring the game provides sufficient exercise.

The design principles outlined in this section will be used in the Game section to guide the design of the exergame itself.

Exergame ideas that were discarded rather than developed further will be briefly covered so as to provide some context as to why the final design was selected.

Chapter 11

Features and Genres

This chapter will examine the most common video game genres, analyzing which are suitable for exergames. It will also cover common features and functionality from some of the most popular video games on the market, and how applicable they are to exergames.

11.1 Genres

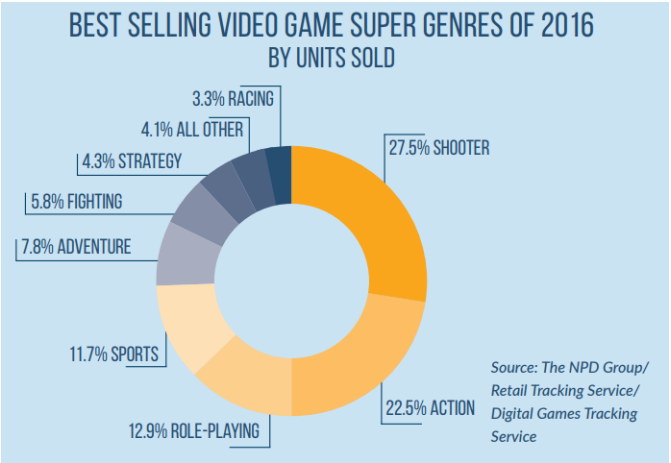

Figure 11.1: Popularity of game genres

Figure 11.1 shows the most popular video game genres in 2016 [85]. The eight genres as defined by the ESA cover 95% of the video game market. The extent to which they are applicable to video games varies.

Shooter Shooters come in two variants; first and third person. The player entirely or

primarily uses ranged weapons to defeat the game's obstacles. Most shooters rely heavily on fast-paced gameplay and reactions. This can work with some forms of exergame equipment; the game Holopoint [29] for example is an exergame first person shooter. This form of fast-paced gameplay is, however, less suited to platforms like the Pedal Tanks platform, as it lacks the ability to facilitate rapid yet precise movement. More slow-paced shooters like Pedal Tanks [37] itself can still work.

Action The action game genre emphasizes hand-eye coordination and reaction time. It is an extremely broad genre, making it difficult to make any definite statements about whether it is a good fit for exergames, as that will largely depend on the sub-genre chosen. The core idea of hand-eye coordination and reaction time means it can be a good fit for exergame platforms supporting that form of gameplay, such as VR headsets.

Role-playing In a role-playing game the player takes on some form of role in the game world, improving their character over time and typically following some sort of overarching mission. This in intended to provide a lasting attachment to the player character and game. While most role-playing games are relatively slow-paced and thus lack the intensity required for exergames, there are many higher-paced games such as the hack & slash sub-genre. As the overall definition of the genre is very open, it should be entirely feasible to make a role-playing exergame.

Sports Sports games are simply a virtual representation of real-world sports. As such, the intensity-level is perfect for exergames as sports themselves are good exercise. The biggest difficulty is coming up with something more interesting than simply playing the sports for real, and making such a game work in the limited space available for a video game.

Adventure In adventure games, the player takes a role in an interactive story, exploring the setting and solving puzzles. The abstract nature of puzzle-solving and exploration is difficult to adopt to an exergame, as forcing the necessary intensity goes counter to the norm of puzzle-solving.

Fighting In fighting games the player engages other characters in close quarters combat. This generally takes place in some sort of area, usually across several rounds, and a wide array of characters to choose from with different characteristics and move sets. The high-intensity nature of fighting games is a good fit for exergames, with the round-based system forcing pauses at appropriate intervals.

Strategy Strategy games are centered around strategical or tactical challenges, and focus on skillful thinking and planning rather than reaction time. Despite this, reaction time plays a significant part in many strategy games; not all such games allow the player to interact with the game at their leisure. Even with a real-time strategy game, making it work well as an exergame is difficult as exergame controls are typically highly limited. Thus, only the subset of strategy games with very simple controls are likely to work, one example being the exergame Brains & Brawn [35].

Racing The goal in racing games is to race a vehicle against other vehicles, and getting to the goal first. While very much high-intensity, it is difficult to map racing games to exergames without the exercise mechanic becoming exhausting; most racing games have the player go at or near top speed the vast majority of the time, so mapping movement to exercise would quickly exhaust the player.

Summary To summarize, most genres can potentially be used for exergames, but some are easier to make fit than others. The genres easiest to adapt to the needs of an exergame are shooters, action games, role-playing games, and fighting games.

11.2 Features in Popular Games

Figure 11.2: Bestselling games on Steam in 2016

A wide variety of games see significant commercial success, across numerous genres, however, there are several features most of them share, indicative that these features can contribute significantly to a game's success. As a starting point, this section will analyze common features in the 12 best-selling games on the online video game retailer Steam in 2016 [86], shown in Figure 11.2.

The 12 games include 4 strategy games (Total War: Warhammer, XCOM 2, Dota 2, Civilization VI), 2 role-playing games (The Witcher 3, Fallout 4), 3 action games (Dark Souls III, Rocket League, No Man's Sky) and 3 shooters (Grand Theft Auto 5, Counter Strike: Global Offensive, and The Division).

Common features include multiplayer, progression systems, customization options for the player's character or team, and strategic depth:

Multiplayer Of the 12 games, 4 (Dota 2, Counter Strike, Rocket League, and The Division) are primarily multiplayer games where players fight other players. Only The Witcher 3, No Man's Sky, and Fallout 4 lack any form of multiplayer. With 75% of the top sellers having multiplayer in some form, it can be said to be a highly common feature. All 9 games that include multiplayer allow playing against other players, though most also include some form of team-based gameplay. Multiplayer can help prolong the longevity of

a game, as involving other humans necessarily increases the amount of variation encountered when playing a game. Competitive multiplayer also has the advantage of ensuring the player is sufficiently challenged; it is often easier to find another person of similar skill-level than to make gameplay systems that match the player's proficiency. Multiplayer will be covered further in Chapter 12.

Progression All 12 games have some form of progression, but the longevity of that progression varies wildly. Civilization VI for example has no progression outside individual relatively short-lived campaigns with the exception of purely cosmetic achievements, while the primarily multiplayer games all have some form of account progression. This form of progression varies however; the progression in Dota 2 for example has no actual gameplay effect, but instead allows the user to unlock cosmetic items and improve their ranking in the community. Games like Dark Souls 3 and Fallout 4 instead have the player's character gaining equipment and experience, increasing their strength and allowing them to customize their appearance. How progression can be used to keep the player coming back to the game will be explored in more depth in Chapter 13.

Customization Many games provide ways for the player to customize their look, their abilities, or both. This often ties in with progression, with more options unlocked over time. Dota 2 for instance allows the player to equip their various "heroes" with cosmetic equipment and skins, setting them apart visually from other players who play the same hero. In XCOM 2, the player can change both the look of their soldiers as well as their equipment and skill set, allowing them to fill a variety of roles. Cosmetic customization essentially lets the players express themselves, while role selection and other ability-based customization allows them to adopt whichever playstyle they prefer. This will be covered in more detail together with progression in Chapter 13.

Strategic depth Most of the games showcased provide many different approaches to any problem. The role-playing games for example allow numerous different forms of fighting, as well as diplomatic options. The strategy games are as their genre implies based heavily around strategic depth, providing the player with a large number of options to pick between at any given time. By providing the player with meaningful options, they both feel their choices are rewarded and keep coming back to try out other avenues to see what works best. Strategic depth will be covered further in Chapter 13.

Summary The four features above are extremely common in today's most popular games, indicating that emulating them might be a good idea for any game. They are not completely ubiquitous, so a game does not necessarily need all four to succeed. They will all be covered further in depth in the next two chapters.

Chapter 12

Multiplayer

As mentioned in the previous chapter, many popular games include multiplayer as a primary or secondary game mode. Multiplayer has several aspects which makes it appealing, including social interaction, easier balancing of difficulty, and increased gameplay variation.

Social interaction is a common reason for participating in exercise [87][88], making multiplayer especially relevant for exergames. By incorporating social interaction in the way of multiplayer, players might be encouraged to keep playing the game for longer than they otherwise would have [15]. Support for social interaction is also one of the elements required for the player to enter a state of flow according to the GameFlow theory [20]. While this does not necessitate multiplayer, as social interaction can be achieved in other ways such as discussion between friends outside the game itself, multiplayer makes it much simpler to ensure this element is fulfilled. Given the need for social interaction, simply silently playing with or against other players might not suffice; the game should encourage some form of interaction, though this can come in various forms. Coordinating with teammates is one way to achieve interaction. Another would be requiring the player to respond to the actions of hostile players. The amount of influence each player's actions has on the other players' actions should therefore be significant.

Cooperative Some games implement a cooperative form of multiplayer. Rather than fighting one another, the players work together to overcome some challenge. The exergame Exer Dungeon [39] is one example of a cooperative multiplayer game. A significant upside of cooperative games is that they encourage direct communication between players, thus providing the social interaction needed for a state of flow. Cooperative games might work especially well when the players already know one another, and already have experience working as a team. A good cooperative multiplayer game should ensure that the members of the team can directly influence one another in some manner, and that success in the game depends on coordination between the team's players, so as to make social interaction a requirement for doing well at the game. Ways to ensure this include

support abilities that boost or heal other players, as well as group-based attacks, or ”tank” mechanics where one role is to soak up damage to protect more vulnerable team mates.

Competitive The most common form of multiplayer is competitive multiplayer, where players try to do better than one another. Pedal Tanks [37] for example is a competitive multiplayer game. One big advantage of competitive multiplayer is the challenge it provides; it is often easier to ensure that player skill levels are reasonably matched than to create artificial intelligence (AI) that is challenging yet fair. For example, it is difficult to create AI for a first-person shooter that manages to coordinate well with other agents, but it is very easy to make an AI that will simply always hit the player. Despite being a significant challenge, such an AI would not be fun to play against, as it would be perceived as cheating. By having players fight one another this challenge is side-stepped entirely, though the issue of ensuring that players are of similar skill levels replaces it. Simplifying the process of matching challenge to skill level means that competitive multiplayer is especially well suited for ensuring that a state of flow is achieved.

In competitive multiplayer it is important to ensure that the competing players can affect one another, rather than simply playing in parallel. Olympic weightlifting for example is a competitive sport, yet the players cannot affect one another, thus providing no opportunity for social interaction as part of the gameplay. The most common way to ensure interaction happens is to make harming the other players part of how the game is won.

Team-based Cooperative and competitive multiplayer are however not mutually exclusive. Many games provide team-based multiplayer, thus including both cooperative and competitive elements. Pedal Tanks for instance pits players against one another in teams of two. Team-based multiplayer essentially tries to combine the best elements of both forms of multiplayer, thus encouraging both communication and competition.

Whether competitive or cooperative multiplayer works best for the purpose of exergames is difficult to determine, with there being studies providing results in either direction [89][90][91][92]. The two might simply appeal to different groups of people, making either a good option for an exergame. Some might prefer singleplayer games, but the research indicates that multiplayer is the most effective mode of play for most people. Providing the option of singleplayer might make sense if the budget of the game permits it, but for the purpose of exergames the emphasis should preferably be on multiplayer.

Summary In conclusion, inclusion of multiplayer is a significant assert for exergames, either in the form of cooperative or competitive multiplayer, or combining the two through team-based multiplayer. Offering a single-player mode in addition to multiplayer might make sense if the game’s budget is large enough.

Chapter 13

Replayability and Progression

Given that the goal of an exergame is to provide the player with a change in lifestyle, replayability is key. There has to be something that keeps bringing the player back to the game. Games employ a variety of different systems to encourage players to keep coming back, and this chapter will cover a number of such systems that can potentially be included in an exergame.

Strategic depth The core of a game is its gameplay; if the gameplay is not interesting, then there is little reason to play it more than once. One way to ensure interesting gameplay and provide a reason to come back to the game is the idea of strategic depth. Strategic depth means that the player must make meaningful choices with gameplay impact. For a choice to be meaningful, there has to be two or more potentially viable actions to take, rather than a single clearly superior option. As the player's situation changes, so does the optimal course of action, providing the player with the challenge of figuring out at any given time what the best thing to do is.

Strategic depth increases the replayability of a game as the player can, when faced with a similar situation, attempt a different course of action. Provided enough different situations and enough viable choices, strategic depth can massively increase the number of possible routes through a game, ensuring no two playthroughs are identical.

To create strategic depth the game must offer different tools to overcome the task at hand rather than telling the player what to do. In a fighting game for example, this is achieved by providing a large move set, where at any given time there are generally multiple moves that are likely to improve their situation. The player has to continually adapt to the choices of their opponent while making choices of their own, making no two fights quite the same. Allowing the player to figure out what to do on their own rather than forcing them down a specific path means that when they do succeed they feel like they accomplished something, and when they fail they can try to do better.

The main challenge when it comes to providing strategic depth is ensuring that the different tools the player can used are balanced against one another in such a manner that different tools are superior in different situations, and it is not always obvious which tool

is best in the given situation. If the choice is always obvious, even a massive set of options will be uninteresting, as the player will always simply choose the best one.

Tools that can be used in combination are especially well suited for providing strategic depth, as it then no longer becomes a choice between individual tools, but rather sets of tools, thus increasing the number of possibilities far beyond the number of tools in the tool set. A challenge with this approach is that it can often lead to unintended consequences; some combination of tools the designer did not think of might end up being far too powerful or otherwise frustrating, worsening the gameplay. Balancing over time based on how the players play the game can however generally address this issue.

Persistence To tie the player to a game over a long period of time, they might be encouraged or forced to make a game account. Such game accounts normally provide goals or rewards for the player outside the scope of individual matches. By providing some form of persistence between individual matches, the player is provided with overarching objectives to complete, meaning that even though they have finished an individual match, the game as a whole is left in an unfinished state. If implemented well, this will provide additional reason for the player to keep coming back.

Common goals and rewards provided via persistence includes cosmetics, achievements, ability unlocks, leveling systems, loot, and ranking systems. These will all be covered in further detail below. These systems can be divided into two broad categories: systems that change the gameplay itself in some manner, and meta-systems that provide the player something outside the gameplay itself (E.G., ranking systems).

Figure 13.1: Cosmetic items in Dota 2

Cosmetics Many games provide the player with ways to change the look of their character or other aspects associated with the player (E.G., the player's soldiers in XCOM 2). The idea is to allow the player to express themselves, as well as differentiate themselves from other players. Cosmetics are popular enough that some free to play games are funded entirely by purchases of cosmetic items, such as Dota 2.

By providing a large set of cosmetics and an unlock mechanism of some sort, a game provides one more draw to keep the player coming back: getting that fancy piece of equipment they really want. By carefully balancing the rarity of items, and potentially introducing more items over time, there will almost always be another item the player desires to gain.

Cosmetic items are commonly implemented as a form of persistence for multiplayer games, though many single-player games also offer cosmetic options. XCOM for example is primarily a singleplayer game, yet has extensive customization options for its soldiers. In XCOM's case it serves as a way for the player to establish a closer connection with their soldiers, thus making the gameplay feel more meaningful when those soldiers are involved in tense moments.

Capability improvements One of the most common forms of progression in games is improving the capabilities of the player, allowing them to overcome greater challenges. Common methods to improve the player's capabilities are equipment, ability unlocks, and "stat boosts" like increased health or damage. The latter two are often acquired via a leveling system; as the player completes missions and/or defeats enemies, they gain experience. Once enough experience has been amassed, they go up a level, and get to choose between various abilities and other improvements to their character. This helps the player feel they are progressing in the game, and works as a pacing mechanism to ensure the game's content is consumed at the desired pace. It can also be used to manage the complexity of the game so that it is easy to learn; many games will start the player off with only a small selection of abilities, gradually providing more as they level up. This way, the player gets time to fully understand their existing tool set before another tool is added to it, rather than being overwhelmed with a huge selection of abilities at the very start.

Many games instead or additionally allow the player to obtain equipment, typically providing bonuses such as increased damage output, reduced damage taken, and so on. Equipment is commonly acquired from defeated enemies, missions, and in-game shops. Equipment often also provides a way to change the appearance of the player, as mentioned in the Cosmetics section above. Much like leveling systems, this lets the player gradually increase their power to overcome ever bigger challenges. Between equipment and leveling system, the player can focus their in-game abilities on the playstyle they prefer, increasing the chance they find a way of playing that they enjoy.

Role selection Closely tied to capability improvements, many games have some form of role selection. In role-playing games, this normally comes in the form of classes, defining the player's capabilities in some manner. In other games, this might be a choice between various characters fulfilling different archetypes, between different tanks, or between different types of weapons. The role selected by the player normally also defines what sort of capability improvements they can obtain.

Role selection aids replayability both by allowing the player to select a role fitting their favored play-style, and by encouraging multiple playthroughs in a variety of different roles. In a role-playing game for example, the player might complete the campaign as a magic user, then decide to replay it as a melee focused player, redoing the same challenges with a different set of tools.

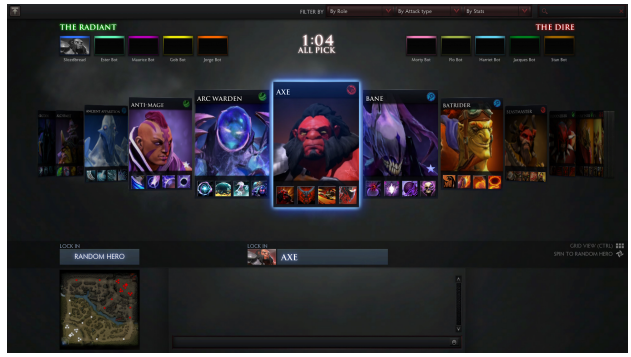

Figure 13.2: Hero selection in Dota 2

Increasing difficulty As outlined in flow theory [19] GameFlow [20], and by Malone [22], balancing the level of challenge to the player's skill level is critical for their enjoyment of a game. If the game is too easy, it will be boring. If it is too hard, it will be frustrating. One way to help match the player's skill level is to gradually increase the difficulty over the course of the game, the player's skill presumably improving from practice. This must be carefully balanced to not be too extreme so the player does not get stuck for an extended period. Other mechanisms can help counter the difficulty increase, such as the capability improvements mentioned earlier. Most games with capability improvements also provide increasingly capable opponents to defeat. If the game is currently too easy for the player, a well-balanced game will ensure the power of the opponents increases faster than the power of the player. Conversely, leveling systems generally mean that if the player is unable to overcome some challenge, they can spend some time on lesser opponents to gain more experience and power, letting them eventually overcome the greater challenge. Some games are balanced around the player eventually failing, most notably the roguelike sub-genre of role-playing games. This sub-genre provides replayability by challenging the player to do better and get further than they managed in their latest run.

Another option for difficulty is to allow the player to adjust the difficulty. Many games include difficulty levels of some sort, letting the player adjust the level of challenge to their liking. This too can provide improved replayability; after completing a game at a low difficulty level, the player might do another run at a higher one, putting their abilities to the test. Difficulty levels can be used in conjunction with increasing difficulty over the course of the game.

Achievements To provide the player with more specific goals to work towards, many games have achievement systems. Commonly this means that when the player completes a given goal in the game, they receive some sort of badge or similar outside the game, displaying their achievement to other players. This provides the player with a reward for their effort, and for achievements not normally achieved during a regular playthrough it encourages the player to play in an alternate manner, thus exploring other ways to play the game. Achievements can in this way encourage the player to keep playing, or replay, a game after the main storyline or campaign is complete. Achievements are thus essentially

Figure 13.3: Some of The Witcher 3's achievements

a way to make the variety a game offers more visible to the player, and make the player feel rewarded for playing the game.

Ranking systems Most multiplayer games provide some form of ranking system to indicate how good a player is at a game. These systems are used both for matchmaking to ensure that opponents are reasonably matched, and as a way to reward the player for playing the game. Their ranking in the game becomes a metric they can influence by getting better at the game. Combined with rank tiers (E.G., gold, silver, bronze), this can provide the player with concrete goals to work towards over a long period of time. Some games further emphasize this by having game seasons, where rankings are reset between each season, and players rewarded in some manner based on their placement in the season. This encourages the players to put more hours into the game to achieve a higher ranking in each season.

Ranking provides both a personal goal for players, and a way for them to display their proficiency to other players.

Randomization While many games are deterministic, having the same inputs always produce the same results, many instead use random elements to ensure that the exact result of player action has some element of uncertainty [22]. Examples include varying the amount of damage attacks do by some factor, having the AI pick semi-randomly between a set of possible actions, and randomizing the bonuses the player gets in the way of equipment and similar.

By adding an element of uncertainty, it is more difficult for the player to determine the optimal strategy for a game. This means that more time can be spent investigation possible strategies, and can also help ensure that there are more viable strategies which aids the strategic depth of the game. Variance in results can make the gameplay more interesting by forcing the player to balance risk and reward; some strategies might have

Figure 13.4: Hit chance in XCOM 2. Randomization can sometimes lead to strange circumstances

few to no random elements, while strategies with more variance might have bigger payoffs if everything goes right. In the context of multiplayer games, this helps ensure that the result is not set in stone as quickly, as the underdog might get a lucky break letting them catch up with the player in the lead.

Randomization inherently increases the variability of the game itself, increasing the number of possible situations for the player. This helps ensure that no two playthroughs are ever quite the same, making it more likely the player will replay the game.

Procedural generation A particular form of randomization is the generation of content. For example, the statistics of equipment dropped by defeated enemies could have a significant random element, ensuring a huge variety of different pieces of equipment. More complex variations include the generation of maps, such as complex dungeon layouts, varying enemy placement, and varying locations for rewards and traps. Minecraft, one of the best selling games of all time [93], is one of the more prominent examples of procedural generation, with the entire map being a product of procedural generation with highly limited use of hand-crafted set-pieces.

Procedural generation can in many cases be cheaper than producing a similar amount of content by hand, allowing a far larger variety of content than possible through traditional means. A pitfall however is that in many cases procedurally generated content individually measures up poorly with handcrafted content. This was a challenge faced by No Man's Sky. The combination of handcrafted and generated content can in many cases help alleviate this. A dungeon crawler might for example have each individual room be handcrafted, while the procedural element affects the layout of the overall dungeon and minor elements within each room. This way, a game can increase its variety without losing the handcrafted feel.

Types of rewards Most of the concepts discussed above are ways to reward the player and incentivize them to keep playing the game. The collection of rewards causes the player's brain to release dopamine, creating a feeling of success [94]. Hallform and Hallford outline four main forms of rewards video games make use of in their 2001 book [95]: rewards of glory, sustenance, access, and facility. The concepts discussed above can be categorized within one or more of these categories.

Figure 13.5: Minecraft, a game where the entire map is procedurally generated

Rewards of glory are rewards that have no actual gameplay impact, but which the player values nonetheless. This might be through comparison to other players, or simply a sense of achievement. Cosmetics, achievements, and ranking systems fall into this category, having little to no gameplay impact but showing off the accomplishments of the player.

Rewards of sustenance on the other hand are rewards that allow them to continue playing the game. More clear-cut examples include bonuses like extra lives or countering a count-down timer before the game ends, but any reward that assists the player's survival fits this category. Capability improvements can be considered a reward of sustenance, as they provide the player with tools to help continue their survival.

Rewards of access are access grants to new content, such as level unlocks or the removal of barriers. Almost any story-based game will provide this form of reward in some manner, as more of the story is unlocked as the player progresses. Randomization and procedural generation fit this category to some extent, as continued play provides the players with different layouts, enemies, and so on. Increasing difficulty can also be considered an access reward, as the player gets new more difficult content over time.

Rewards of facilities allow the player to take new actions or improves what the player can already do. Capability improvements fall squarely into this category, as do role selection.

Ideally, a game should provide more than one category of rewards, though it is not necessary to provide all four for the game to be fun.

Summary All in all, replayability is core to an exergame as the goal is to encourage long-term healthy living. To encourage replayability a game needs to offer some form of progression so that the player feels incentivized to keep playing. Progression can be provided in a large number of different ways, as outlined above. Making use of several of these methods improves the chance that players will keep playing the game rather than quickly becoming tired of it. It is not necessary to include every single form of reward, not do most games attempt to. Instead a game should select a set of methods that tie together in a coherent fashion with the core mechanics of the game.

Chapter 14

Exercise and Gaming

The primary goal of an exergame is to provide long-term high-quality exercise. This has significant impact on the design of a game, as what works well mechanically and is fun in a regular game is not necessarily good exercise.

Earlier, four forms of exercise were identified: cardiovascular, strength, balance, and flexibility. By choosing one of these forms, the design of a game is constrained in unique ways.

Strength exercise For strength exercise, a major constraint is the requirement that the player's exercise form has to be good, or they risk harming themselves. The movements also have to be highly controlled and follow a strict regimen, leaving very little room for variation. This makes designing game mechanics around strength exercise difficult, so it does not lend itself very well to exergames. Making a strength-based exergame is despite this by no means impossible, as illustrated by Brains & Brawn [35] and Exermon [40], but it limits the designer's options to providing the illusion of player agency rather than making the exercise itself a core part of the game mechanics.

Balance exercise largely avoids this pitfall. While the player still has to be somewhat cautious to avoid falling and thus injuring themselves, balance exercise does not require a strict regimen of exercise, nor do the movements have to be anywhere near as controlled as for strength exercise. A simple way to work balance exercise into a game is to use the player's center of gravity as an input to the game, such as by having them lean to the side to steer, and forward to speed up. Combined with a controller, this provides for complex interaction with the game. An added advantage of balance exercise is that it is not as strenuous as strength or cardiovascular exercise, meaning that it is easier for the player to play the game for an extended period of time. On the other hand, the health benefits of balance exercise are not as extensive as those of strength and cardiovascular exercise.

Flexibility exercise falls into the same major trap as strength exercise. The movement needs to be controlled so as to avoid damage, significantly constraining the design possibilities surrounding it. Flexibility allows for significantly more variation than strength

exercise does, as the health benefits can largely be obtained even when not following a strict regimen. Much like balance exercise however, the health benefit is not as significant as that of cardiovascular and strength exercise. Overall, this makes flexibility difficult to adapt to exergames.

Cardiovascular exercise Finally, we have cardiovascular exercise. Here the goal of the exercise is for the player to maintain a significant level of exertion for an extended period of time. In accordance with the weekly recommended exercise mentioned in Chapter 7, the aim should be at minimum 150 minutes of exercise a week. Assuming up to five exercise sessions a week, this means that each individual play session needs to last a minimum of 30 minutes. This can be split up across several matches, and thus does not significantly constrain the design of a game. The major constraint of cardiovascular exercise is achieving a good intensity distribution. High-intensity interval-based exercise can be more enjoyable than continuous moderate-intensity exercise [96], and is also easier to adapt to games; a stable level of intensity provides no actual player agency in the form of exercise.

The main challenge thus becomes ensuring a high enough level of exertion to provide significant health benefits, while having it be moderate enough that the players do not quickly exhaust themselves. Additionally, it is important to ensure that the player feels they are deciding when to change the level of intensity rather than getting the impression that the game decides for them, otherwise the player will according to dual flow theory [21] quickly get bored with the game. The game mechanics themselves should encourage varying level of intensity in some manner. An example from Pedal Tanks [37] is the capture of the flag; once the player is in possession of the flag they will normally start pedaling at a much higher rate as they want to get away from danger and score a point for their team as fast as possible. While the mechanic essentially forces this as the optimal strategy, the player still feels like they are the one actively making the choice to do so.

A simple way to avoid the players exhausting themselves is to have each individual round of the game be short, several minutes long at most, with a short pause before the next round begins. This gives them a bit of time to cool down, and works well with the idea of interval exercise.

Technological platform The choice of technological platform imposes further constraints on game design. For example, the Dance Dance Revolution dance mat lends itself well to rhythm based games, but is not especially well suited for other forms of gameplay. This project will be using the Pedal Tanks platform, which has its own set of constraints.

One significant challenge is ensuring that the input maps well to its gameplay effect. This is important for the player's enjoyment of the game, as the mapping needs to be natural for the mechanic to provide intrinsic fantasy rather than extrinsic fantasy, as outlined by Malone [22]. Using the pedaling to propel the player's avatar forward for example is highly intuitive, but would mean that the design is limited purely to games in which movement is a major mechanic. Exer Dungeon [39] instead additionally mapped the pedaling to charging the player's shots. While not quite as clear of a mental link as mapping bike movement to in-game movement, the act of pedaling mapping to some form of charge is still intuitive enough for most players to quickly grasp. Other possibilities exist, but a clear

connection to the mechanics is key to ensure that the game is easy to learn and enjoyable to play.

The other main constraint of the platform is the limited number of inputs; seven in total. The player can pedal, providing an analog input, and has access to six buttons on the handlebars of the bikes. In a game with movement, this means that if two of these are used for steering, only four buttons remain for activating other mechanics. This significantly limits the number of actions available at any given time. By using one button as a modifier button, it is possible to provide six distinct actions rather than four, but this is still quite a low number compared to many games. This means that the gameplay must be relatively simple, though even games with simple inputs can still achieve significant strategic depth.

As the main input of the platform is that of pedaling the bike, the only feasible form of exercise is cardiovascular exercise. The constraints that imposes above apply in addition to those unique to the platform itself.

Summary In summary, the easiest form of exercise to adapt to exergames is cardiovascular exercise. With this form of exercise, ensuring player agency for the exercise input is key, as otherwise the player will quickly get bored. Ensuring varied intensity levels is important so that the player gets sufficient exercise without exhausting themselves prematurely. The Pedal Tanks platform further constrains design possibilities through its limited set of inputs, and requires a core mechanic that maps well to pedaling a bike.

Chapter 15

Discarded Ideas

Throughout the project, several possible game ideas were considered and eventually discarded. This chapter covers the most detailed of these ideas in order to provide the reader with an understanding of what the project might otherwise have produced.

Control scheme for existing game One idea early in the project was to not actually create a game at all, but instead provide an alternate control scheme for an existing commercially successful game. The most significant upside of this is that the game design would already be proven to be interesting enough to be commercially viable, thus eliminating one significant risk from the project. In practice, this could be done by using software to map the input from an exercise device to the inputs expected by the game. Assuming the Pedal Tanks platform [37] was used, one challenge would be mapping the continuous input from the pedaling to the binary input most computer games use for movement. It might therefore be necessary to adapt a console game rather than a computer game, as console games more commonly use analog movement.

The primary downside of adapting an existing game, and the reason why this approach was not chosen, is that without the ability to change the design of the game it is far more difficult to ensure that the level of exercise is appropriate. For example, if the game simply rarely or never provides natural breaks when it comes to movement, there is no good way to work it into the game when all that one can change is the control scheme. Creating a control scheme for an existing game is therefore highly limiting. Given the right choice of game it might still provide good results despite these limitations. In order to ensure a good level of exercise it might instead make more sense to make a game heavily based on an existing game. This eliminates the issue of not being able to adapt the design to exercise, while still getting most of the benefit of having a design that is already proven to be enjoyable.

Space cooperation In this game, four players would work together to control a spaceship and overcome increasingly challenging enemies. The game would be on the Pedal Tanks bicycle platform. Each player would control one aspect of the ship each. One

player would be the pilot, responsible for maneuvering the ship to avoid enemy fire. Another would control the shields to stop enemy fire from damaging the ship. A third player would control the weapons, firing at the enemy. The last would control the engines and repairs, keeping the ship moving and alive.

Each player would only be provided with information on how their station is doing. The player on the shields for example would not be able to personally see the incoming fire, but instead rely on the pilot informing them of when they need to increase power to the shields. By limiting the information available to each player, the players would be forced to communicate with one another to survive, thus ensuring a high level of social interaction.

The players would pedal to provide power to their station; pedaling slower in calm moments, and faster in response to danger. The player on the shields for example might pedal faster in response to the pilot informing them that there is a large amount of incoming fire. The players would use the buttons on the bicycle's handlebars to direct the efforts of their station. The player on the weapons would for example use the buttons to decide what to target, and which weapon to use.

The game would consist of a series of battles against other spaceships, with each battle lasting a few minutes, with a short break between each battle for the players to rest. Between each battle the roles would rotate so that all players get to experience all four roles. Defeating enemy ships would provide the players with currency and supplies, such as better weapons and other shield upgrades. The currency can be spent at stores; periodically between battles the players would get the option to buy equipment and other upgrades.

The game would gradually increase in difficulty battle by battle, ensuring that eventually the players would be defeated. This is intended to make the players wish to play again in order to do even better.

In the end, this idea was discarded due to other ideas being more compelling, as well as the difficulty of mapping the pedaling to the game mechanics and providing meaningful actions for each player role.

Mario Kart inspired arena battle In the racing game Mario Kart, there is also a battle mode where the players are put in an arena and have to fight one another. This seems like something that would work well as an exergame, given the highly varying movement speed and simple yet compelling gameplay.

The exergame adaptation for the Pedal Tanks platform would work as follows: Four players would fight one another in a small arena, with numerous obstacles so as to provide significant maneuvering opportunities. Scattered around the arena would be pickups. When picked up, the player would receive a random object that they can then use to attack other players. Examples include missiles, traps, temporary invincibility that also kills other players if one manages to physically run into them, and a speed boost that kills other players on touch. These items are single or limited-use, but the pickup location will after a short amount of time (10-15 seconds) generate a new pickup.

The battle would be timed, lasting two or three minutes. Every kill gives the player two points, while being killed removes one point. At the end of the battle, the players are ranked by points. A single game would consist of a series of four battles, with the players getting points based on their ranking in each battle, and whoever ends up with the most points winning the series.

The worse a player is doing compared to the rest, the better their odds of getting the best items when gaining a pickup would be. For example, they might be more likely to get a triple-use missile as oppose to a single-use missile. This helps ensure the game stays competitive even if some players are significantly better than others.

The controls of the game would be quite simple: the player would pedal to move forward, and use two buttons on the handlebars of the bicycle to steer left and right. One button would use an item, with another button causing it to be fired backwards rather than forwards if held. A third button would switch between the different items the player is holding, while the last button would cause the player to reverse.

This idea was discarded mainly due to sharing a lot of elements with Pedal Tanks; the project is intended to broaden the field of games for the Pedal Tanks platform and investigate alternative possibilities for exergames. However, many of the ideas from this design ended up in the design the project went forward with.

Summary These discarded ideas helped guide the chosen design. Each design could potentially produce a compelling and effective exergame, but this project only has time to focus on a single design. Other researchers are encouraged to develop these discarded designs further if they find them interesting.

Part IV

Game

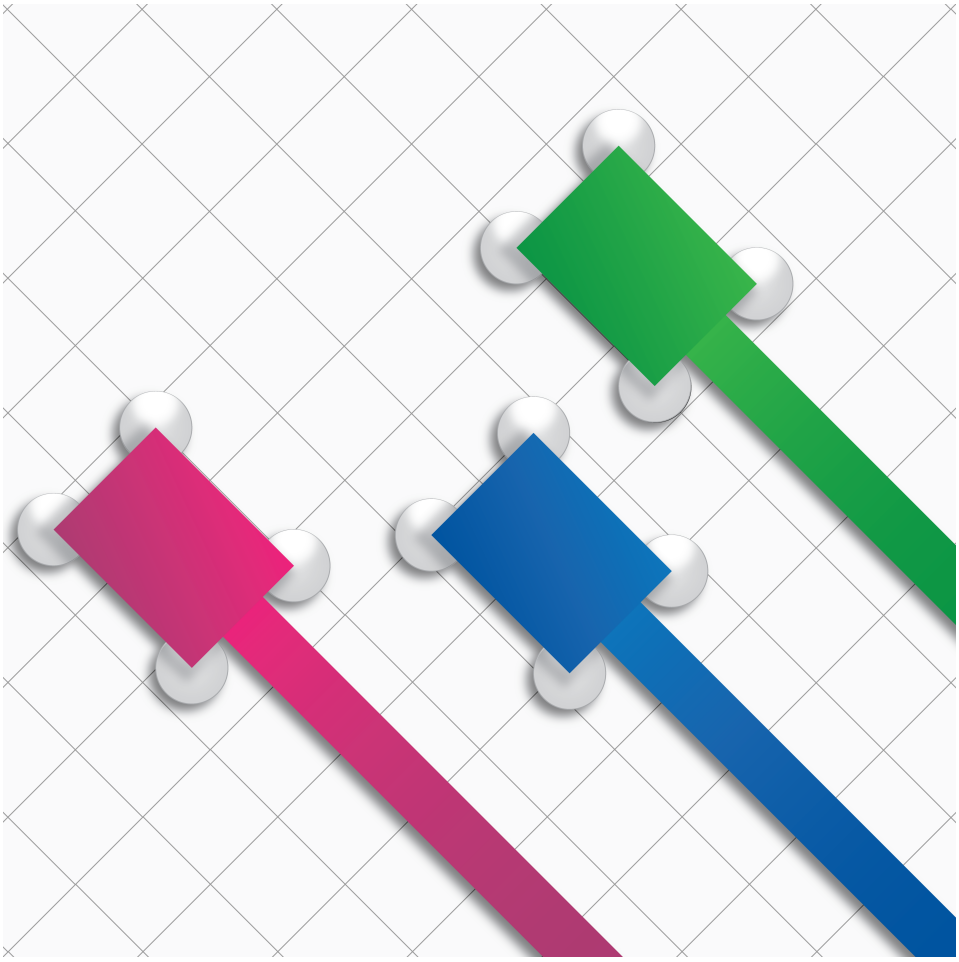

Figure 15.1: Concept art for Pedal Kart. Commissioned from Deric North

This part will cover the design of the exergame that will later be created. The game has a working title of ”Pedal Kart”. Concept art created at the end of the project can be seen in Figure 15.1. Included in the explanation of the design will be the sources of inspiration for the game, the core mechanics of the game, how the game supports replayability, and how it encourages social interaction.

This design will be used to create a prototype of the game suitable for empirical testing to determine whether it effectively supports exercise, and whether it has the potential to provide lasting enjoyment.

Chapter 16

Inspiration

Pedal Kart is heavily inspired by the game series Mario Kart by Nintendo. In Mario Kart, the players control characters from the Super Mario universe, racing around a large variety of tracks in vehicles reminiscent of go-karts known as a ”kart”. The main feature setting Mario Kart apart from most other racers is the pickups scattered around the track. When a racer runs into an item box they receive a random power-up item, which can be used to either improve their own position or harm other players. For example, the player might receive a red shell, which when fired homes onto the nearest player. When hit, the player is stopped and loses the ability to drive for a short period of time.

Figure 16.1: Mario Kart

Mario Kart includes several modes of play, but the one which Pedal Kart is based on is the ”Grand Prix” mode. In this mode, the players play a series of four races. At the end of each race, the racers receive points based on their position for that race. Whoever has the

most points at the end of the series wins the cup, with the top three players each receiving a trophy.

Pedal Kart will make use of the core mechanics of Mario Kart and the Grand Prix mode, while varying the formula some via the choice of items, the incorporation of exercise as a mechanic, and the addition of progression mechanics to improve the long-term replayability of the game.

Chapter 17

Core Mechanics

This chapter will outline the mechanics that create the core game loop of Pedal Kart, and how they are intended to support a suitable level of exercise.

Core concept At its core, Pedal Kart is a multiplayer item-based racing game. In the game, four players compete against one another as well as computer opponents to reach the finishing line of each track. Each player chooses a character from a roster, each character having somewhat different values when it comes to their racing characteristics. Scattered around the tracks are pick-up items that can be used to improve the player's standing in the race, or hamper their opponents.

Figure 17.1: Item boxes in Mario Kart

Item mechanic The key mechanic that sets Mario Kart and Pedal Kart apart from most other racing games, is how central items are to the game. Each track will have numerous locations where pick-ups periodically spawn, as shown in Figure 17.1. When someone

drives into the pick-up, they receive a random item. Some items can be used to help themselves, while others can be used to harm other racers. At any given time the player can hold up to three such items, saving them up to be used at an appropriate time.

As a balancing mechanism, the item odds are based partially on the player's standing in the race, with players further behind in the race on average receiving better items. For example, they might have a better chance of receiving a triple-use version of a normally single-use item. This helps ensure the race remains competitive even when some players are better at the game than others as with a mix of luck and good use of the items provided, a player who has lagged behind can catch up even when the gap is significant. This balancing mechanic helps ensure the player is sufficiently challenged, facilitating a state of flow [19].

Selection of items The game will have a large selection of items to keep it varied, and make a variety of tactics possible. The item selection includes:

- Basic missile - Fires a missile that travels in a straight line, making it easy to dodge by other players. On hit the player is stopped in their tracks, and stunned for a few seconds. Also comes in a triple-use variety. This is the most common item drop
- Homing missile - Fires a missile that locks onto the nearest opponent, turning slowly in their direction, making it very difficult to dodge. Does not attempt to avoid hitting obstacles, making turning a tight corner or interposing an obstacle the main way to avoiding it. Also comes in a triple-use variety, which can only be received by players far behind in the race standings
- First player missile - Fires a missile that flies off into the air, then lands on the player in first place. Cannot be avoided. Rare, and only available to players in the bottom half of the rankings
- Mine - Drops a mine behind the player, which is indicated on the ground by a small antenna. If a player (including the person who dropped it) runs over it, they are stopped in their tracks, and stunned for a few seconds. Also comes in triple-use variety
- Fake item box - Drops a mine disguised as an item box. Players will have to distinguish them from real boxes by memorization of spawn locations, or based on their slightly different design from real item boxes
- Oil slick - Sprays a pool of oil behind the player. Players who drive into the oil slick will lose control over their steering, continuing in the direction of travel, as well as suffer reduced speed. Especially effective when used in a sharp turn to cause players to run into walls. The pool dissipates after three players have run into it
- Speed boost - Temporarily uncaps the player's speed, and makes their pedaling 50% more efficient. Also comes in triple-use variety
- Invulnerability - Temporarily makes the player invincible and moderately boosts their top speed. Other players will be stunned if touched while the invulnerability is active

- Lightning - When used, all other players are hit by lightning. This stuns them for a moment, and makes them drop their items
- Mystery item - Provides one of the above effects, but which is unknown until the player actually uses it

Any item that stuns a player will confer them with a few seconds of invulnerability upon recovery to avoid frustrating players by continually being stunned.

Item combos The player may combine two items in order to cause a more unique effect. The possible combinations are as follows:

- Basic/homing missile + mine - The missile will drop up to three mines as it travels. For the first few seconds of their existence, these mines cannot be triggered by the player who fired them
- Mine + fake item box - Drops a fake item box. When someone runs into it, four mines will be thrown a few meters from the box in addition to the box' regular effect
- Oil slick + fake item box - Drops a fake item box. When run into, an oil slick will spawn where the box was, in addition to the box' regular effect
- Basic/homing missile + fake item box - Works like missile + mine, except dropping fake item boxes
- Mine + oil slick - Works like oil slick + fake item box, except with the effect of a mine rather than fake item box
- Basic/homing missile + oil slick - Spawns an oil slick on impact, in addition to the regular effect of the missile
- Lightning + basic/homing missile - Fires lightning-infused missiles at all other players, stunning them for longer. Like the lightning, cannot miss, even if a basic missile is used
- Lighting + mine/fake item box/oil slick - When hit by the lightning, a mine/fake item box/oil slick also spawns just behind the player
- Invulnerability + basic/homing missile - While invulnerable, the player periodically fires a missile; a total of three combined
- Invulnerability + mine/fake item box/oil slick - While invulnerable, the player periodically drops a mine/fake item box/oil slick; a total of three combined

Racing mechanics Given that Pedal Kart is a racing game, it is important for the racing mechanics to be engaging. In Pedal Kart, the player will spend less of their time at or near top speed than in most other racing games. Instead, the emphasis is on maneuvering and the tactical use of items. To successfully hit other players with the items the player has to carefully time their use of the item. This is especially pronounced when it comes to the

most common item, the basic missile. This item is fired in a straight line, meaning the player has to use it in a situation where either the target cannot dodge or where dodging significantly hampers them.

To further emphasize maneuvering as key to the game, the player's turn radius degrades the faster they are going, forcing them to either slow down in turns or take a wider, more predictable turn than they otherwise would have. Given that other players might choose this moment to fire a weapon at them, predictability can be a major misstep.

Each race will consist of two to four laps, giving the players a chance to learn the layout of the track, and making the persistent items (mines, fake item boxes, and oil slicks) more likely to impact the race. The race concludes when all human-controlled racers have finished all laps. After each lap, the lap times for each racer compared to first place is shown as they cross the goal line.

The track itself provides high traction and speed, but is surrounded by sand or grass. The player can drive outside the track itself if they so desire, but this significantly reduces their traction and speed. It may in some cases still be worth it in order to cut corners, but the loss of speed makes them easy targets for opponents' items.

The player's kart has significant inertia, meaning it takes a few seconds to get up to top speed or to come to a complete halt.

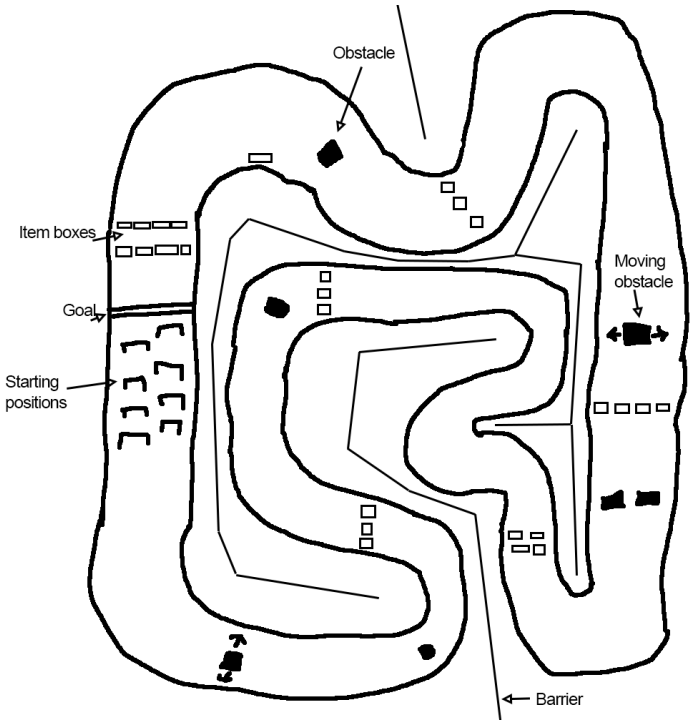

Figure 17.2: Sketch of a Pedal Kart race track

Level design The level design of the game is intended to bring the importance of items

and maneuvering to the forefront. Race tracks will contain numerous obstacles, some of which move, as well as having many twists and turns. The obstacles ensure the players cannot simply drive in straight lines, while also providing chances to dodge out of the way of enemy fire. The twists and turns ensure the players must frequently slow down, and balance the risk of maintaining speed and traveling in a predictable path, and slowing down and thus maintaining better control over where they are going.

Figure 17.2 shows a sketch of a race track in Pedal Kart. Item boxes are scattered liberally throughout the track, and the player is often forced to maneuver to avoid obstacles and round corners. Barriers ensure that players cannot bypass most of the track entirely, but they can still cut many corners by traveling outside the track itself.

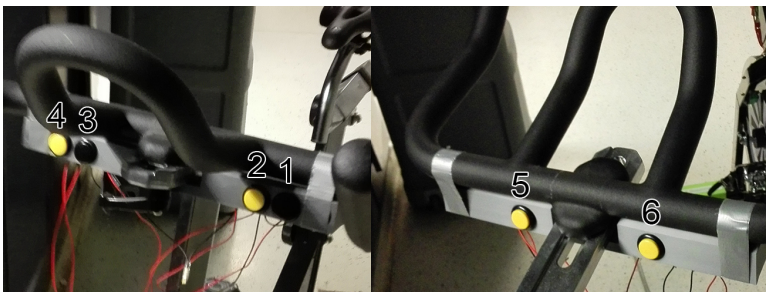

Figure 17.3: The buttons on a prototype of the Pedal Tanks bicycle platform

Controls and exercise Given that Pedal Kart is an exergame, providing sufficient exercise without driving the player to exhaustion is key. Several modifications are therefore made to the Mario Kart formula in order to better support exercise. The game also needs an intuitive set of controls that are possible to use with the limited inputs the Pedal Tanks platform provides. The buttons provided are shown and numbered in Figure 17.3.

The controls mapping is kept simple to make the game intuitive and easy to learn. The pedaling maps to the speed of the player; the faster the player pedals, the faster they will move in-game. This will provide the brunt of the cardiovascular exercise the game is meant to encourage. The player can steer left and right using the two directional buttons on the handlebar (numbered 5 and 6).

If the player has more than one item picked up, they can press the third of the back-facing buttons to switch which item is currently selected. This allows them to use whichever item makes the most tactical sense, rather than being forced to use the items in acquisition order. When an item is selected, any item that can be combined with it will be highlighted. Figure 17.4 shows how this highlighting might be shown in-game. In the figure the ”missile” item is currently selected, and it can be combined with the ”lightning” item the player also holds.

When the player has picked up an item, they can hold down the first back-facing button. A portion of their pedaling will then be used to ”unlock” the item, making it possible to use. The faster they pedal, the faster the item will become available, but this comes at the cost of some kart speed. Figure 17.4 shows how the unlock progress might be shown in-game.

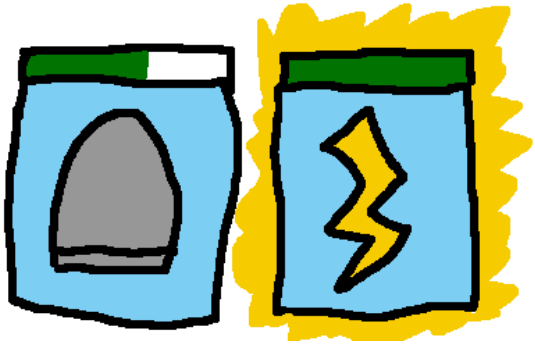

Figure 17.4: Item interface in Pedal Kart

Once the item has been unlocked, the second back-facing button can be used to activate its effect. If another equipped item that has a combo with the item is also unlocked, it will also be used. Unless the item is multi-use, activation will immediately remove it from the player's inventory.

The fourth and last back-facing button can be held down to reverse. This can also be used as an especially effective way to slow down, since the reverse acceleration will combine with the natural deceleration of the kart.

By tying the act of pedaling to movement, the game will provide an intuitive mapping between the exercise and the in-game effect. However, without further restrictions the winning strategy would be to pedal at top speed at nearly all times, quickly exhausting the user. To prevent this the game has a soft speed cap which is achieved when pedaling at a moderate rate. Beyond this cap the game provides significantly diminishing returns for pedaling faster, making players unlikely to do so except when close to the finish line or in an attempt to dodge an incoming missile.

The sense of control this control scheme gives should help ensure a state of flow [19] as outlined by GameFlow [20].

If the soft speed cap has the intended effect, most of the time they will simply pedal at cruising speed. They will likely pedal slower during turns in order to improve their turn radius, and at a higher rate after the turn to quickly get back up to the soft cap. Additionally, the players are intended to pedal faster after acquiring an item to unlock its use. The game should therefore provide natural variation in pace, thus emulating interval exercise. On top of this, there will be natural breaks in the action due to the brief stun when hit by an item, as well as breaks between each race.

Figure 17.5 shows the whole user interface for Pedal Kart. In the lower-left, the player can see their currently held items. At the bottom is their current speed. When going past the soft-cap (the end of the bar) the fill will continue in red to the right of the bar itself to illustrate that while they are going faster it is not especially effective. In the bottom right is their current ranking, while the top left tells the player what lap they are on. The top right provides a mini-map showing the location of all players as colored dots. The player's kart is visible near the bottom of the screen, with the track up ahead visible in front of them. All in all, this simple interface should ensure that the player has all the information they

Figure 17.5: User interface in Pedal Kart

need available, with the exception of what exactly each item and combo does. This they should be able to learn via experimentation. The interface ensures that the player knows what to do and how well they are doing, assisting them in achieving a state of flow [19] as outlined by GameFlow [20].

Race series As each individual race only lasts a few minutes, the races are organized into series. A race series consists of five races, totaling 10 to 20 minutes of playtime combined. At the end of each race each participant receives points based on their position in the race. First place receives 10 points, second place 8, third place 6, dropping by one point per rank after that. After each race, there is a short break of around 15 seconds in which the race times for the race are shown as well as the ranking for the series so far.

Each track in a series will be different, providing the players with significant variety. At the end of the series the winners are crowned; the top three players each get a trophy ranging from gold to bronze. After this the players get the option to play another series. If they choose to do so, five tracks will then be picked at random for them to race through.

Summary The above mechanics form the core game loop for Pedal Kart. They should provide varied cardiovascular exercise, emulating that of interval exercise. The soft cap on speed should ensure players do not feel incentivized to drive themselves to exhaustion, while still providing significant exercise. The competitive nature of the game and the mayhem provided by the items should ensure the game loop is compelling.

Chapter 18

Replayability and Rewards

Pedal Kart is intended to get players to exercise, and keep exercising. It is therefore important for it to provide a high degree of replayability, and provide the player with rewards of a caliber that encourages them to keep coming back and pushing themselves to do better.

Strategic depth One of the more important aspects of replayability is strategic depth. Pedal Kart provides strategic depth based around balancing risk and reward in races, predicting what opponents will do, and the tactical use of items. While the game is intended to be easy to learn, the player is left with significant room to improve their tactics. For example, how to best avoid incoming fire has no easy answers. Maneuver too wildly, and too much speed is lost. Maneuver too little, and you are too easy to hit. The player must combine both predicting when the opponent will fire, and keeping their opponent from predicting where they will be. When using items, the dynamic is inverted, providing variety in the tactical considerations the player has to make. This will help the player get into a state of flow [19], as the strategic depth assists in several of the criteria outlined in GameFlow [20]. The depth encourages concentration, it provides a mechanism for the player to improve, and it provides clear goals and feedback.

Role selection The strategic depth in the game is further boosted by role selection. At the start of each series each player selects between many different karts, each with different characteristics. Some are heavier, moving more slowly but being more difficult to push out of the way and easily pushing away lighter opponents. Some are lighter and more maneuverable. Others are slightly faster. Some get better items on average. Some have better grip and are less affected by bad terrain. The selection means that players can change their characteristics to better match their favored play style, and provides variety as each series might have a different set of karts in play. A mock-up of the selection user interface is shown in Figure 18.1.

Short and mid-term rewards The game provides short-term rewards in the form of items, race positioning, and winning individual races. On top of this, between each round in a series offer the player a choice of three randomized boosts. The player might for

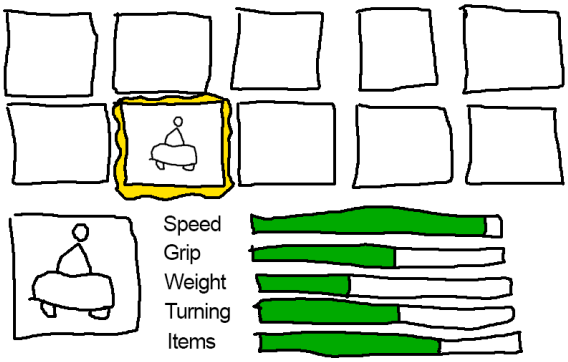

Figure 18.1: Role selection in Pedal Kart

example get the option to move 5% faster for the rest of the race, turn faster, or get better items on average. This system both adds to the strategic depth by letting the players adjust their characteristics during the race series to counter the other players, as well as providing the player with a rewarding experience.

To further encourage the player to keep coming back, after each series the player gets to choose a boost, much like after each race. However, unlike the boost between races, this lasts for the next three race series. The player thus gets the opportunity to try out a variety of play styles, as the exact boost they want will not always be available, forcing them to adapt based on the choices they are provided with. This is also intended to encourage the player to keep playing to see what they can achieve with the boost they just received.

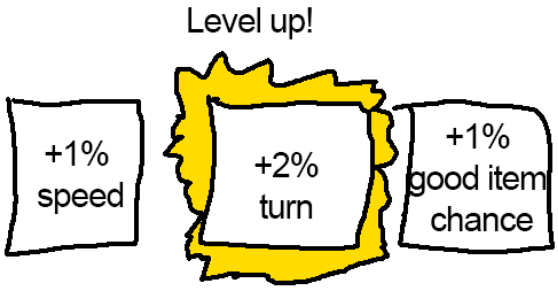

Figure 18.2: Level up in Pedal Kart

Long-term rewards Pedal Kart requires long-term replayability, and will therefore also provide more long-term rewards. The game will have a simple level system, where after the player has played a sufficient amount since their last level, they get to choose a small permanent boost. Initially, the player will level up after each race, but as they progress the time between levels will gradually increase. This ensures the player always has another milestone to obtain, and a reason to keep coming back. Figure 18.2 illustrates how the level up system will function.

Persistence Beyond improving their avatar, the game will offer several other forms of persistence. Like many games, it will offer achievements, ranging from simple ones like ”win a race”, ”win a series”, and ”place in the top three five races in a row” to more difficult or long-term ones like ”win a hundred races” and ”place first three series in a row”. This provides the players with tangible goals they can attempt to achieve, and provides a sense of progression and accomplishment.

The game will also provide statistics on the player's gameplay. This is a simple addition, but one which will add to the enjoyment of a segment of the user base. Included will be statistics like the number of races the player has participated in, how many items they have used, what their average position has been, how many kilometers they have driven, and so on. At little cost the player is provided with numbers they can easily see their influence on.

Finally, the player will be able to customize their avatar, making it more distinct from other players. They might for example color their car bright red, or put ornaments on it. Cosmetic items are provided at random as the player plays the game. This will allow players to express themselves, and gives them another way to show their accomplishments in the game.

Multiplayer Multiplayer is one of the main balancing mechanics of the game, ensuring a fitting level of challenge as outlined in flow [19] and by Malone [22]. The mix of multiplayer and catch-up mechanics should ensure that the player can never take victory for granted, and always feels they have a chance at doing well in a race. Multiplayer also encourages variety in gameplay, as players will adapt to the strategies and tactics of other players, ensuring no two matches are quite the same.

Randomization Further improving the variety in the game is the heavy use of randomization when it comes to item pickups. The player cannot know ahead of time what they will receive, and therefore has to adapt on the fly based on what they get. On top of that the item pickup odds are stacked in the favor of the players doing worse, serving as a balancing mechanic. Doing better will provide players with an advantage, but it is still feasible to catch up after initial missteps. The random nature of item pickups is intended to evoke the player's curiosity, as outlined by Malone [22].

Summary The game will have a large number of mechanisms that encourage the player to keep playing the game. The game is designed to provide a challenging experience regardless of the player's skill and exercise level, and it provides periodic rewards to incentivize continued play. It attempts to encourage the player to get into a state of flow [19] so that they will want to return to the game so as to obtain that experience once more.

Chapter 19

Social Interaction

Pedal Kart is a multiplayer game, which makes social interaction key. Social interaction is conducive to exercise [87][88], so it is especially important for the game to get it right. The game provides interactions between characters in a number of ways. The game is intended to be played by four players all together in the same room, allowing for real world interaction between the players during and after the game.

Destructive actions The most obvious way players will affect one another in the game is by targeting one another with items. This allows them to hamper each other's standing in the race, providing a direct and significant method of interaction. What other players decide to do can decide whether or not a player wins the race, but the actions of other players are never totally out of their control. Most items they can dodge or avoid, while the rest they can minimize the risk or effects of. For example, the player can avoid the risk of being hit by the first player missile by tactically staying just out of first place until the very end of the race. The players can also hurt one another by physically crashing their kart into the other player, causing them to be knocked off the track or into a wall. Some karts are especially suited to this as they are heavier than others.

While the other players' actions can hurt the player, the way item pickups are determined gives them added opportunity to respond in kind. The further behind they are in the race, the better their items will be on average, making revenge a simple matter. This form of destructive interference is intended to appeal to the players' competitive instincts, and give them something to react to during the match and discuss after it.

Non-destructive actions The players also interact more indirectly by jockeying for position in the race. While one player using a speed boost does not hurt other players, it is still opens for interaction by improving their position in the race, potentially passing other players. Points are given based on position at the end of the race, so one player doing better effectively means any player they pass is doing worse. Players can thus indirectly influence one another even when there is no direct interaction.

Lack of predictability Unforeseen actions on the part of other players helps make the

social aspect of the game more interesting. If in any given situation it was obvious what the other player would do, there would be little to react to or discuss. Instead, the game encourages the element of surprise by randomizing item drops, and providing a variety of tactics in any situation. Using for example the first player missile at a well-timed moment, thus causing the person in first to lose the race, is sure to entice a reaction.

Post-game interaction With the variety of possible tactics and actions resulting from the item and racing mechanics, there should be plenty for players to discuss with one another after a match. They might reminisce about a perfectly timed use of an item, or how things went wrong. Over the course of a race series, there should be plenty of unexpected moments to think back on later.

Summary The direct and indirect interaction between player avatars in Pedal Kart should provide significant opportunities for social interaction, making the experience more enjoyable, and giving the players a reason to keep exercising. The gameplay does not outright force social interaction given that communication is not necessary to succeed, but it is still designed to make verbal reactions to others' actions likely.

Chapter 20

The Prototype

A prototype was created based on the game design outlined in the previous chapters. The purpose of this prototype was to evaluate whether the outlined design has the potential to be an effective exergame and should be developed further.

Figure 20.1: One of the maps in the Pedal Kart prototype

20.1 Implementation Process

The prototype was developed over a period of four months. During the implementation the core of the design was implemented. This process involved the author learning to use the Unity engine and editor, and creating the game itself.

At the start of implementation, the focus was on the movement of a single car. A few weeks were spent tweaking the movement mechanics until they felt right on a keyboard.

Due to lack of access to an exercise bike, early movement was purely binary based on keyboard input.

As the movement system progressed, the first map of the game was implemented so that the movement mechanics could be tested in practice. The final version of the map can be seen in Figure 20.1. In particular, this allowed for iterating upon how the turn rate maps to movement speed, forcing the player to slow down to make sharp turns. As part of adding the map, off-road terrain was implemented, incenting the player to stay on the track.

Once the movement felt natural, the item pickup mechanic was implemented. Item pickup boxes were scattered across the map, letting the player boost their speed or fire shots off into the distance. Soon after, artificial intelligence was implemented. This consisted of the AI having an ordered list of points on the map to traverse, and simply turning to ensure it would hit the next point. When close enough to the point, it would start turning towards the next point in the list. This worked much better in practice than the author had hoped, with early versions of the AI being able to complete the track faster than the player.

With the AI implemented, the game was now ready to test on an exercise bike. With some remapping of movement, this worked quite well, and was iterated upon further until the acceleration curve, braking, and turning all felt natural.

To finish up the prototype, a lap system was implemented, as well as time ranking, map changes, and more maps. In total four maps were implemented; two of them being reversed versions of the other two maps. Finally, multiplayer functionality was added, allowing up to four people to connect at once and race against one another. This was implemented using the Unity Multiplayer service, allowing one person to host a server and three others to join. Car positions, colors, names, items, and so on were synchronized between the host and clients numerous times a second, ensuring the state remained similar enough on all machines for the players to interact with one another.

20.2 Alterations from Design

Due to time constraints many parts of the original design were left out. Which elements were left out was largely based on which were believed to have the greatest impact on short to mid-term enjoyment, as the experiment itself would not be able to sufficiently investigate long-term enjoyment.

Cut Functionality Numerous pieces of functionality were eliminated or reduced as compared to the original design. The core of the play experience was preserved, but many pieces of supporting functionality were not implemented. Below is a list of features in the design that did not make it into the prototype:

- The original design included so-called item combos; the player would be able to combine two or more pick-ups to create a stronger, more unique effect. For example, combining a mine with a missile would create a mine that fired a number of missiles when a car runs into it. While a significant deviation from the Mario Kart formula, the sheer amount of time to make this system work smoothly was considered too significant for inclusion in the prototype

- In the design, a total of 10 usable items were outlined. Only four (missiles, homing missiles, speed boosts, and mines) were implemented, with six (first player missiles, fake item boxes, oil slicks, invulnerability, lightning, and mystery items) left out
- In order to help ensure that less skilled players still had some chance of victory, the design stated that stronger items would be more likely to drop for players further behind in the rankings. In the end this system was cut for time, but a rubber-banding system was implemented instead (see "New Functionality" below)
- Originally it was supposed to be possible to have more than one item picked up at a time. With the combo system cut, there was not much of a purpose to this system
- The original control scheme included a button to accelerate backwards instead of forwards. During prototyping, it quickly became apparent that reversing instead of simply turning around did not map well to using an exercise bike
- The design specified that past a certain point, pedaling harder would only give diminishing returns when it comes to increasing max velocity; a so-called soft-cap on speed. A hard cap was implemented instead, with pedaling at a rate of 75% of the maximum recognized by the system allowing the player to maintain max speed. A system of diminishing returns for acceleration compared to current velocity was still implemented; the faster the player was going, the lower their acceleration. While pedaling beyond 75% did not increase max velocity, it did reduce the amount of time it took to reach max velocity
- The UI mock-up included a mini-map to show the player's current position, as well as those of the other cars. Emphasis on the core experience resulted in there not being time to implement a mini-map
- The design included a variety of forms of persistence between individual races. In the end, these were all cut. As the experiment would only be able to test the short to mid-term enjoyment of the game, persistence was cut as it largely affects long-term enjoyment. This includes rankings, statistics, the level-up mechanic, and so on
- The player was intended to be able to pick from a large selection of different cars, each providing different attributes such as speed and acceleration. Given only three play sessions, role selection was believed to have little effect on the game compared to the amount of time required to make it work

New Functionality During prototyping and pre-experiment testing of the game, a few features not in the original design were added to address situations not originally planned for. Below is a list of these added features:

- A **rubber-banding system** was added. To ensure that players less skilled at the game would not fall too far behind, a rubber-banding system was added. Players and AIs not in first place get a passive boost slowly building up over time, capped by how far behind first they are. This boost increases the car's top speed, acceleration, and turn rate. As a result the car travels faster without significantly changing the difficulty of maneuvering

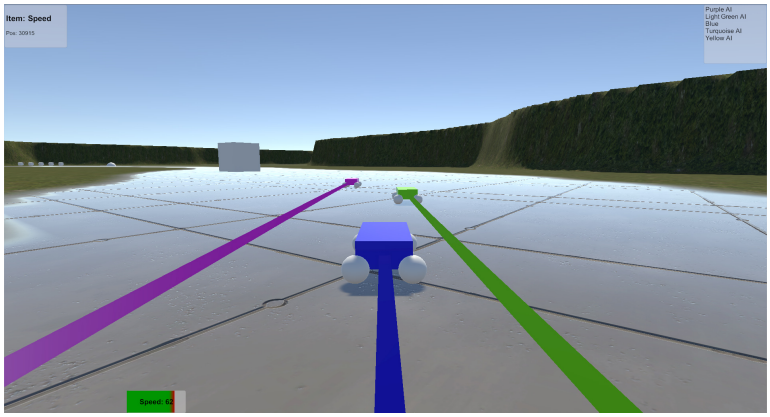

Figure 20.2: A player close behind two AI cars

- **Differing AI speed**: After the first session of the experiment it was clear the AI cars performed too similarly, almost always placing either dead last, or between the last and second last player. To combat this and help ensure all players get to see other participants, the four AI cars had their base speed set to four different levels
- **High speed camera effect**: In order to make the cars feel faster, the camera was made to zoom in and hover closer to the ground the higher the player's velocity. This subtle effect made the top speed feel much higher
- **Car trails**: During prototyping, trails behind cars were initially added to make it easier for the programmer to see the AI cars from the Unity editor. The trail was simply a line showing the path each car had travelled for the last handful of seconds. These were turned into a feature, and changed to have the same color as the car. They helped ensure the players could see if there was another player or AI up ahead even if they were outside line of sight, making it easier to maintain motivation when trailing another car. These trails can be seen in Figure 20.2

Part V

Experiment

This part will talk about the planning of the experiment

It will cover the design of the experiment; what the experiment would consist of in practice. Further, it will list all forms of data to be collected by the experiment. Finally, the method of selecting test participants will be covered.

Chapter 21

Methodology

To evaluate Pedal Kart, data on two aspects is needed: the physical aspect of the game, and the psychological aspect of the game.

The physical aspect of the game boils down to whether the game provides sufficient exercise. Pedal Kart is intended to supplement or replace traditional exercise, and therefore needs to be intense enough that the player reaps the health benefits of exercise. The level of activity therefore needs to be of at least moderate intensity.

The psychological aspect of the game is whether it provides enjoyment. Especially important is the potential for long-term enjoyment, though the extent to which this can be investigated is significantly limited by time constraints.

Figure 21.1: The test setup for the experiment, consisting of four exercise bikes each with a monitor attached

The Experiment In order to get some understanding of the long-term enjoyment of the game, the experiment was divided across three sessions, each lasting around an hour.

These three sessions were split across a period of three weeks, with one session occurring each week. The time gap between each session was intended to eliminate as much of the novelty effect as possible for the latter two sessions. During the first session the test subjects were given a short introduction to how the tests would be conducted, and to the game itself. They were informed that after 30 minutes of play they could cease playing, but that they could keep playing after that if they so desired. If still playing after 60 minutes, they would be asked to stop. Due to technical issues (see Section 26), two of the three testing sessions went past this 60-minute limit.

After the end of each play session, the test subjects were asked to fill out a questionnaire establishing their flow state. These questions will be covered in more detail in Section 22.1. The test subjects' comments before, during, and after each play session were observed and noted down where relevant.

During the play session and the questionnaire, the test subjects wore heartbeat monitors so as to establish their level of exertion.

The experiment was conducted in two locations, both in professional gyms. The test subjects were provided with water to drink during all phases of the experiment. The test setup can be seen in Figure 21.1.

Chapter 22

Data Collection

Data was collected in several different manners to give a detailed view of the test subjects objective and subjective experiences with the game.

22.1 Questionnaire

A questionnaire was prepared before the experiment to gather information on the test subjects' subjective experience of the game. The full questionnaire can be seen in Appendix A. At the end of each of the three test sessions, the users filled out the questionnaire. For the second and third session they were instructed to disregard how they had filled out the questionnaire in previous sessions.

The questions were divided into several different categories, each intended to provide insight into some aspect of their experience with the game. Most of the questions used a 5-point Likert Scale [97]. The categories were as follows:

Personal Background: First the questionnaire asked the participants to fill out background information about themselves; their age, height, weight, and gender, as well as how often they exercise and how many hours a week they spend playing video games.

Flow State: Next, they were presented with 26 statements to rate on a scale from 1 to 5, where 1 was labeled "Strongly Disagree", 3 was labeled "Neither Agree nor Disagree", and 5 was labeled "Strongly Agree". Each of these statements related directly to some aspect of Flow [19]. The mapping can be seen in Table 22.1. This questionnaire was based on a similar questionnaire used to evaluate Pedal Tanks [37], with some adaptions to make it more suited for Pedal Kart. Pedal Tanks' questionnaire was in turn based on work by Jackson and Marsh [98]. The statements were presented in a randomized order (different for each person and each session) so as to minimize risk of priming.

Perceived Enjoyment and Exertion: The questionnaire asked the test subjects to rate their enjoyment of the game, the level of challenge, and the physical intensity of the game

Table 22.1: Mapping of questions and flow state elements

Flow element	Question number
Challenge-skill balance	1, 14, 21
Action-awareness merging	2, 15, 22
Clear goals	3, 23
Unambiguous feedback	4, 10, 16
Concentration on task at hand	5, 11, 17
Paradox of control	6, 12, 24
Loss of self-consciousness	7, 13, 18
Transformation of time	8, 20, 25
Autotelic experience	9, 21, 26

from a scale from 1 to 10. Diverging from the rest of the questionnaire, a 10-point scale was used rather than a 5-point Likert Scale, with the hope of lowering the bar for test subjects changing their answer between sessions to get a clearer view of to what extent these three factors drop off as the initial first impression of the game wears off.

Other Aspects: Furthermore, the questionnaire posed several more statements about the game, which the test subjects had to rate using the 5-point Likert Scale. These statements attempt to determine if the game and its social aspects lower the bar to exercise and make users exercise longer and/or harder than they otherwise would.

Open-ended Questions: Finally, the users were asked four open-ended questions about the game. First, how Pedal Kart compares to using an exercise bike with no associated gameplay. The remaining three questions asked what they liked the most and least about the game, and what they would like to see changed or improved in the future.

22.2 Heart Rate Monitoring

To help determine their level of physical exertion, each test subject was made to wear a Fitbit Charge 2 wristband to record their heart rate during the course of each session. These were put on a few minutes before the gameplay began, and worn until the play session was complete and the users had all filled out the questionnaire. There were significant issues with the accuracy of this data, which will be discussed in more detail in Section 26.1.

22.3 Observation and Small Talk

During the play sessions notes were made of the test subjects' play-style, visible physical exertion, exclamations, and so on. The author would occasionally ask test subjects about their thoughts on the game, both in general terms and based on what was currently happening in-game.

How long the test subjects were motivated to play the game was also recorded. They had been told at the start of the experiment that they only needed to play the game for 30

minutes and that any time spent beyond that point was purely voluntary. Playtime beyond the minimum can therefore be interpreted as a result of engagement with the game and/or the social setting it creates.

Chapter 23

Test Subjects

In order to complete the experiment, four test subjects were recruited.

23.1 Sampling

The sampling technique used was non-probability convenience sampling [99]. Sampling technique is the method used for selecting members of the population to include in the study. This has a major impact on the extent to which any results from a study can be assumed to apply to the wider population. Being applicable to the wider population is not necessarily important for all studies. In the case of this experiment, low applicability is considered acceptable as the core goal is to determine whether the design is worth developing further, for which even a limited ability to generalize the results should suffice.

In order to decide on the form of sampling, the following were determined:

1. The target population
2. The sampling frame
3. The sampling method

This project aims to improve the level of exercise among those who do not currently meet the weekly recommended minimums. This population however is far too heterogeneous; that a single exergame might be applicable to the whole of this population seems unlikely. The target population was therefore restricted further to the sub-set of this population between 21 and 35 years old, as this is the single largest age group among so-called ”core” gamers; gamers who consider gaming an important part of their life, spend a significant time playing games, and enjoy playing with or against others [100]. Enjoying playing with or against other is especially applicable to this project, since multiplayer and the social interaction resulting from it is core to the design of Pedal Kart.

The sampling frame defines which members of the population the sample can be drawn from. With significant time constraints, and the equipment necessary to conduct the test

being in Trondheim, Norway, a natural sampling frame was students within the age group studying at the Norwegian University of Science and Technology.

The sampling method defines how test subjects are selected within the sampling frame. Time and financial limitations have a significant impact on what methods are feasible. Sampling bias and the ability to generalize based on the experiment will be significantly affected by the method chosen. The implementation and experimentation phase of the project, plus the finalization of this report based on the results, spanned merely 20 weeks. Much of this time was dedicated to the implementation of the game and writing the thesis, making only limited testing possible. Four weeks were set aside to ensure that three sessions of testing could be completed, with one extra week in case of scheduling conflicts or other delays. It was therefore necessary to find four people that would all be able to play the game at the same time across three sessions. For this to be feasible, convenience sampling appeared the most practical approach.

Convenience sampling draws test subjects from the population based on convenience rather than randomization. It is therefore highly vulnerable to sampling bias, as the test subjects are unlikely to be representative of the entire population. This limits the extent to which the results can be generalized. For this project, this means that it is not possible to draw conclusions such as ”most people will find this exergame enjoyable, and it will provide them useful exercise”, but it might be possible to conclude ”the test subjects all enjoyed the game, and were provided with useful exercise”. While not as useful, this would still be sufficient to motivate further investigation that might be able to assert a more general conclusion.

23.2 The Participants

Four test subjects were found by the author asking acquaintances if they would like to participate. The four test subjects all live in the same student house as the author, independently renting rooms from a 3rd party. The participants are all students at the Norwegian University of Science and Technology. Their personal data is summarized in the following table.

ID	Gender	Age	Height (cm)	Weight (kg)	Exercise frequency (sessions per week)	Gaming frequency (hours per week)
1	M	22	183	66	1	0
2	M	22	183	62	2	2
3	F	24	160	42	0	3
4	M	22	176	71	4	4

As can be seen from the table, the test subjects are relatively homogeneous. All in a similar age range, and with relatively low gaming frequency. They do however vary significantly in how often they exercise, providing a wide range of physical fitness.

The participants were offered no incentive prior to them verbally agreeing to participate, though between their original agreement and the commencement of the experiment, the author promised to buy them all lunch after the first session of the experiment. The cost of this lunch amounted to 200 NOK per test subject.

Part VI

Results

This final part will outline the data collected as part of the experiment, both when it comes to physical exertion and enjoyment. The reliability and applicability of the data will then be discussed, which will include covering issues encountered during the experiment that may impact the quality of the data. What this data indicates about Pedal Kart will then be discussed.

Chapter 24

Physical Exertion

During the experiment, three forms of data related to physical exertion were gathered. Each test subject had their heart rate measured during the experiment, were asked to rate their physical exertion in a questionnaire after each session, and notes were taken on their visible physical exertion during each session.

24.1 Pulse

During the experiment, each participant wore a Fitbit Charge 2, which measured their pulse. This included measurement during active gameplay, between rounds, and for a short while before and after each session. There were major issues with the heartbeat data, which will be discussed in Section 26.1.

Figure 24.1 shows heartbeat data from one participant during the second session of the experiment. Data for all participants across all three sessions can be seen in Appendix B. A cyclical nature to the participant's pulse can clearly be seen, with peaks corresponding to each round of Pedal Kart, with lowered pulse between each round. Most of the data sets showed this spiking behavior, indicating that the test participants were physically exerted, but due to the low quality of the data, the extent to which the testers were exerted cannot be determined from the heartbeat data alone.

24.2 Perceived Exertion

The questionnaire included a question asking the test participants how physically intense the game was on a scale from 1 to 10, with 1 labeled ”not at all intense”, and 10 labeled ”extremely intense. The test participants consistently gave the game high marks on physical intensity, with none ever putting a number below 8. The average score was 8.6. It saw very little change between sessions, averaging 8.8, 8.5, and 8.5 respectively. The full questionnaire results can be seen in Appendix C.

Figure 24.1: Heartbeat of one participant during the second test session. The start and end of gameplay is indicated

Figure 24.2: Test participants about to start a new round, having just finished a drinking break

24.3 Observations

During the test notes were taken on visible signs of physical exertion. During the first session, after four rounds sweat was visibly pooling on the skin of two test participants, while the other two were glistening from sweat. Similar occurred during each session; within a few rounds of the game all participants would be visibly sweating, and breathing heavily.

Occasionally between rounds some participants would sit down or lie on the floor to recover. Most participants were also observed refilling their water bottles between rounds, having drunk it all. Figure 24.2 shows that only a few rounds into the first session, the test subjects had already drunk a significant portion of their water. At the end of the first session, one participant expressed regret that their clothes weren't great for exercise, given how physically intense and sweaty the session had been.

Without fail, all participants were visibly sweaty and out of breath by the end of each session. When the users asked to stop at the end of each session, the claimed reason was being too tired to play another round, rather than boredom.

Chapter 25

Enjoyment

Four forms of data were collected related to enjoyment. In the questionnaire, the test subjects rated their perceived enjoyment. They also answered a series of questions intended to establish whether they entered a state of flow. How long they played compared to the minimum they were instructed to play was noted down, and observations were made during the experiment of any visible signs of enjoyment or lack thereof.

25.1 Perceived Enjoyment

The participants answered a number of questions related to perceived enjoyment. These can be seen in Table 25.1, and will be discussed in more detail in this section. The full questionnaire results can be seen in Appendix C.

Each session the participants rated their enjoyment on a scale from 1 to 10, with 1 labeled ”not at all fun”, and 10 labeled ”extremely fun”. The game scored highly here with no scores below 7, and an average score of 8.4. The first and last sessions both averaged 8.8, while the second session averaged 7.8. This drop was largely due to one participant giving it 10 points in the first and last session, but only 7 in the second session.

The participants also rated the level of challenge from 1 (not at all challenging) to 10 (extremely challenging). Only once did the scores here drop below 7, with one rating of 6. The average score was 7.8, indicating a high level of challenge. For each session it averaged 8.0, 7.5, and 8.0 respectively. The drop in the second session was largely attributable to the same person who reduced their rating of the level of fun in the previous question.

Given that the goal of the project is to encourage more people to exercise, the participants were asked each session whether the game made it easier for them to exercise. The scale ranged from 1 (strongly disagree) to 5 (strongly agree), with 3 as a neutral response. The average score was 3.6, but varied significantly between sessions, at 4.0, 3.5, and 3.3 respectively. Of the 12 responses, 8 were 4 or higher, indicating at least some positive influence. Only two responses were below 3, with one participant twice putting a score of 1.

Table 25.1: Questions related to perceived enjoyment

Statement	Scale	Session 1	Session 2	Session 3	Average
The game was fun	1-10	8.8	7.8	8.8	8.4
The game was challenging	1-10	8.0	7.5	8.0	7.8
The game made it easier for me to exercise than it otherwise would be	1-5	4.0	3.5	3.3	3.6
The social aspect made it more fun	1-5	5.0	5.0	5.0	5.0
The social aspect made me push myself harder	1-5	4.8	5.0	4.8	4.8
If this game was available at a gym near me, I would exercise more	1-5	2.3	2.0	2.0	2.1

It was theorized that multiplayer would have significant impact on the game experience. The participants were therefore asked if they agreed that the social aspect made the game more fun. All twelve responses were ”strongly agree”, indicating that the multiplayer had a clear positive effect on the game. Similarly, they were asked if the social aspect made them push themselves harder. This was nearly unanimous, with ten responses of ”strongly agree” and two answers of 4 (unlabeled, so may have been interpreted as ”agree” or ”partially agree”).

They were also asked if the game was available at a gym near them, that they would exercise more. Here the responses were neutral to negative, with no response above 3. The average response was 2.1. It is clear the participants did not believe the existence of the game would cause them to exercise more often.

The questionnaire also included open-ended questions about what the players liked and didn't like, and what they would like to see improved. Almost every participant mentioned either the competitive aspect or the social aspect, indicating that these contribute significantly to the enjoyment of the game. A few also mentioned the respawn system and the rubberbanding, both of which were tweaked based on feedback in the first two sessions. Test participants did highlight that the crash physics could have been better, and that occasional wonkiness led to crashes feeling overly punishing at times. A couple of testers also mentioned that it was difficult to keep track of one's position in the race due to a lack of a minimap or similar mechanism.

The test participants who have previously used an exercise bike were also asked how Pedal Kart compared. Of the three who had used one, two found Pedal Kart more enjoyable than using an exercise bike with no gameplay, though one raised the concern that Pedal Kart is less relaxing.

25.2 Flow

Included in the questionnaire was 26 questions related to flow, distributed across 26 categories. Given the sheer number of questions, this section will only summarize them on a category basis, as well as individual questions with answers that differ greatly from the rest. The average score for each category per session and overall is shown in Table 25.2.

Table 25.2: Mapping of questions and flow state elements

Flow element	Session 1	Session 2	Session 3	Average
Challenge-skill balance	4.3	4.4	4.6	4.4
Action-awareness merging	3.2	3.7	3.7	3.5
Clear goals	4.3	4.5	4.6	4.4
Unambiguous feedback	4.3	4.3	4.5	4.3
Concentration on task at hand	4.5	4.5	4.6	4.5
Paradox of control	4.0	4.4	4.6	4.3
Loss of self-consciousness	3.5	4.0	4.2	3.9
Transformation of time	4.2	4.1	4.2	4.1
Autotelic experience	4.8	4.4	4.7	4.6
Total	4.1	4.3	4.5	4.3

All but two categories averaged a score above 4, showing that these aspects of flow state were likely achieved. The two categories that scored below 4 are action-awareness merging, and loss of self-consciousness. For action-awareness merging, the question ”I made the correct movements without thinking about trying to do so” got especially low scores, averaging only 2.8. This might indicate that the control scheme was not intuitive enough, though the score did improve from 2.5 in the first session to 3.3 in the last. For loss of self-consciousness, two of the three questions were consistently rated highly, but ”I was not worried about my performance during the game” dragged the average down, averaging only 2.8. The low score here might indicate either lacking feedback about how well the player is doing (such as difficulty telling what position one is in, as mentioned in the previous section), that players felt they could have done better, or a mix of the two.

Overall, the score was 4.3, increasing from 4.1 in the first session to 4.5 in the last session. This appears to indicate that the players had little trouble entering a state of flow, and that it got easier for them as they got more used to the game. The changes made to the game between sessions may also have contributed to this.

25.3 Playtime

The testers were told they were only required to play the game for thirty minutes, and that any play beyond that point would be completely voluntary. How long they decided to actually play therefore serves as a proxy for enjoyment.

The first session had significant technical issues (see Section 26), making it somewhat difficult to determine how long the testers truly played, as the two first rounds got interrupted after a minute or so. If one counts the start of the first fully completed round as the starting point, the testers played for a total of 55 minutes spread across 7 rounds, each round lasting 3-4 minutes with breaks interspersed between them.

The second session lasted 76 minutes spread across 11 rounds, though technical issues forced a 10-minute break at one point. The final session lasted 62 minutes across 10 rounds, this time with essentially no time lost to technical issues.

All told the gameplay each session ranged from 55 to 76 minutes across 7 to 11 rounds,

as compared to the minimum of 30 minutes. The main barrier to continuing appeared to be exhaustion rather than boredom.

Figure 25.1: A test subject satisfied with winning a round of Pedal Kart

25.4 Observations

During the course of the experiment the test subjects displayed a variety of signs of both enjoyment and frustration. During the first test, cheering when winning a race was a common occurrence. A couple of test subjects were at times frustrated at coming very close to victory, pushing themselves harder in subsequent rounds. Figure 25.1 shows a satisfied participant resting just after winning a round.

Players were at times frustrated when not managing to nail a turn, ending up on the grass, but generally blamed themselves rather than the game. At times, the players would engage in good-natured trash talk when winning a race.

Some of the participants stated that their motivation often took a hit when they were in the lead due to it being impossible to tell how much of a lead they had, and a lack of direct interaction with other cars while in the lead.

After the first test, a group from PlayPulse tried out the game and expressed their enjoyment of it. Similarly, after the second test friends of one of the test participants asked to try the game and found it enjoyable, though a bit exhausting. A recurring trend is that the first time someone plays the game, they push themselves to near exhaustion, but in subsequent rounds take a more measured approach.

After the first session, the test subjects were largely left to their own devices; beyond being told when technical issues and similar had been resolved, they would start new

rounds of the game on their own initiative rather than being prompted to do so.

At several points, test subjects commented that the resistance of the bike constrained their play-style. The bikes had adjustable resistance, but if tuned too low braking became difficult (due to the momentum of the wheel itself), while if tuned too high, accelerating was a chore. As a result. the resistance had to be set within a relatively narrow band to be comfortable, especially for the less physically fit test subjects; for them the range between the momentum of the wheel being too high, and pedaling requiring too much exertion was narrow.

Chapter 26

Validity and Reliability

Due to the limited scope of the experiment and a number of issues encountered during it, the results are of limited wider applicability.

26.1 Data Collection Issues

The biggest issue faced was the quality of the heartbeat data. During all three sessions the Fitbit Charge 2s appeared to almost always under-report the actual heartbeat of the test participants. At times, the clocks would even claim the participant had no heartbeat whatsoever. At one point test subjects had sweat visibly pooling on their skin, yet the reported pulse indicated only moderate exertion.

Whether other people had experienced issues with the Fitbit Charge 2 was investigated, and several online discussions on the quality of its heartbeat data was found, with most participants agreeing that the clock often under-reports their heartbeat. Some had gone as far as comparing with heartbeat data from chest strap heart rate monitors. Some users concluded that the lack of accuracy was likely due to the clock using optical measurements [101].

As a result, the heart rate data collected during this experiment should not be given much weight. It can to some extent show an interval-exercise effect, but fails to establish that a high level of exercise was occurring.

Given these issues, future researchers should refrain from using the Fitbit Charge 2. A chest strap device as used by Pedal Tanks [37] will provide significantly more reliable data.

26.2 Technical Issues

Given the prototype nature of the game, technical issues were expected. A variety of technical issues caused a number of delays during the experiment. Most of these were due to issues in the game, but a few were caused by factors other than the game itself.

The start of the first session was delayed by about 15 minutes due to issues synchronizing the Fitbit Charge 2s with the author's smartphone. This was eventually resolved by syncing them to another phone instead.

The first three rounds during the first session ended after merely a minute due to the multiplayer server suddenly disconnecting all the users. These rounds were therefore not considered for the purpose of the experiment. The issue was solved within about half an hour of discovery; it turned out the position synchronization in the game was overloading Unity's multiplayer service. By reducing the frequency of position updates the issue was eliminated. All told, the full start of the first session ended up delayed by 50 minutes due to the combination of the disconnection issue and the delay caused by the Fitbit Charge 2 synchronization issue.

After the completion of the first map in the second session a new map would not load. This turned out to be due to a build issue with the game executable; the map was not correctly included. It was connected by building a new executable, forcing a 10-minute break.

The second session ran into players getting disconnected twice, though this only occurred at the end of rounds rather than during active gameplay and therefore only caused minimal disruption.

The start of the third session got delayed by about 20 minutes due to issues with the internet connection. This was caused by misconfiguration of the computers rather than by the game itself.

Twice during the third session the game had to be rebooted due to the AI getting stuck, preventing the game from continuing onto the next map. This only added a few minutes to breaks that would likely have occurred regardless.

Beyond interruptions in gameplay, there were also a number of reoccurring bugs. The AI would sometimes fire multiple missiles rather than only one. At times missiles that appeared to hit on one user's monitor would have no effect due to being in a different position on the computer of the person they were trying to hit, leading to some frustration.

During the first session, the color of cars was not synchronized between machines, making it difficult for the players to know which car was which. This issue was resolved between the first and second sessions.

All in all, technical issues caused delays at the start of two of the three sessions, as well as several interruptions during each session. Most of these interruptions were however shorter than most of the breaks the test subjects took between rounds when unaffected by technical issues, so should not have a significant impact on the results.

26.3 Modifications During Experiment

A number of changes were made to the prototype during the course of the experiment itself. Between the first and second session, a number of bugs and balance issues were fixed. This included making the rubber-banding effect of the game stronger, as well as a couple of changes to make it easier to tell which car is which player. The four AI participants were also made to travel at varying speed, and two new maps were added.

Between the second and third session, fewer changes occurred. The biggest change was reworking the respawn mechanic (invoked when a car ends up flipped or crashing into

a wall) to put the car back on the track rather than simply ensuring it has the right side up. This eliminated a common source of frustration.

These modifications mean that some of the changes in the data between sessions might be a result of changed gameplay, obscuring effects such as the novelty effect.

26.4 Potential Ethical Issues

It is important that test participants understand what the data they generate will be used for. The participants were told their data would be anonymous. They were informed that all information they entered in the questionnaire might be used in the resulting master's thesis. They were also told they would be under observation during the experiment, and that any observations might be incorporated in the thesis in an anonymized form.

In some cases it might be necessary to apply for permission from a government agency or similar in order to conduct an experiment. In Norway the relevant agencies are the Norwegian Social Science Data Services (NSD) and the Regional Committees for Medical and Health Research Ethics (REC). It was determined that for this experiment permission from either agency was not necessary.

NSD has a test for when they need to be notified about an experiment [102], outlining five circumstances in which notification is necessary. For this experiment none of these circumstances applied as no directly or indirectly identifiable personal data was collected. Weight, height, and gender was collected, but should not on their own be enough to identify any individual. IP addresses are considered personal data which would have been a concern for the questionnaire the users filled out, but as the questionnaire was filled out on the author's computer rather than on the test subjects' computer, the IP addresses collected cannot be connected to the test subjects.

The REC requires approvals for some forms of medical and health research. However, research that only makes use of anonymous information does not require approval [103]. As such, no approval was necessary since none of the data collected during the course of this experiment is personally identifiable.

26.5 Applicability to Wider Population

Given the data collection issues for the heartbeat data, and the convenience sampling used, the applicability of the results from this experiment to the wider population is limited.

This does not pose a significant problem, as this experiment was intended to show the game design is worth developing further, rather than make significant conclusions about the wider population. It is sufficient that it be likely that the game will be appealing to, and providing useful exercise to, some subset of the wider population if it were developed further. Providing entertainment and useful exercise to the population at large is not necessary for further development to be warranted.

Chapter 27

Discussion

Based on the data resulting from the experiment, it is now possible to discuss to what extent the research questions have been answered, and what those answers are. RQ4 and RQ5 will be discussed first, as determining whether the resulting game is enjoyable and provides useful is necessary in order to be able to make conclusions about design principles and similar.

RQ4: Does the resulting game provide useful exercise?

The experiment provided three forms of data on physical exertion. Objective data on heartbeat, subjective data on the level of exertion perceived by the test subjects, and subjective observations of visible signs of physical exertion.

The heartbeat data has significant limitations due to the quality issues discussed in Section 26.1. Despite this, the data does show clear intervals of increased pulse during active gameplay, establishing that the game does provide some level of physical exertion. Given the quality issues however, on its own this is not enough to establish that the game provides enough exercise to meet weekly recommendations.

The test participants reported a very high level of perceived exertion, averaging 8.6 on a 10-point scale. However, the test participants were not provided or asked to provide any point of reference for what the level of exertion means, beyond the questionnaire referring to 1 as ”not at all intense” and 10 as ”extremely intense”. Had the test participants been asked to also rate an activity already established as sufficient exercise, this would have provided a useful point of comparison. For example, they could have been asked to rate moderate walking on the same 10-point scale. Despite this, scoring so close to ”extremely intense” is a strong sign in favor of the level of exertion being sufficient.

During the experiment, the test participants were observed to be visibly sweating, and breathing heavily after playing a few rounds of the game. They also claimed exhaustion at the end of each session.

With all three forms of data pointing to physical exertion, the data strongly indicates that for these test subjects the game provided more than enough exercise to count toward the weekly recommended exercise. More sessions per week or combining the game with other forms of exercise should therefore provide sufficient exertion.

RQ5: Does the resulting game provide enjoyable exercise?

During the experiment four forms of data related to enjoyment was collected. Subjective, quantitative data was collected on the level of enjoyment experienced by the test subjects. Subjective data was collected regarding the test participants' own perception of their enjoyment. Further subjective data was collected regarding their flow state. Objective data regarding how long they chose to play the game was collected, as were subjective observations of signs of enjoyment or lack thereof.

The participants rated their enjoyment of the game highly, averaging 8.4 on a 10-point scale. They also found the game challenging, giving it 7.8 out of a max of 10. A majority of the responses also stated that the game made it easier for them to exercise than normal. However, when asked if the presence of the game at a gym near them would make it more likely for them to exercise, the answers all ranged negative to neutral.

The section of the questionnaire regarding flow state established high levels for 7 of the 9 components of flow, with two lagging behind to some extent. Of these two, one improved significantly between the first and third sessions, indicating that entering a state of flow might get easier as the player becomes more used to the game. It is also possible that some or all of this effect was due to the fixing of bugs and balance issues in the prototype between the first and third session. By the third session, the data makes it clear that except for action-awareness merging, the test participants had established all aspects of flow, indicating a high degree of enjoyment.

The test participants had been told they only had to play the game for a period of 30 minutes, but in practice averaged more than twice this playtime each session. Continuing to play despite no obligation is a positive sign, though a lack of a point of comparison means that it is not possible to use this alone to establish how the game compares to other activities such as exercising without a game.

In the course of the experiment, the test participants showed occasional signs of enjoyment. Two other groups that played the game casually at the end of two sessions also appeared to enjoy the game. There were however occasional signs of frustration, though most appeared to be aimed at their own performance rather than the game itself.

Of these four forms of data, the first three all indicate the test participants found the game enjoyable. The observations are not nearly as clear, though also appear to indicate enjoyment more so than frustration. The questions regarding whether it would encourage them to exercise were however more ambiguous; they stated it made exercise easier, but also that the existence of the game would not cause them to exercise more. The participants consistently playing longer than necessary however appears to indicate that while the game might not spur them to exercise more often, it does encourage them to exercise for longer and more intensely than they otherwise would.

RQ1: What game design principles a good level of exercise?

The report identifies a selection of game concepts and design principles, grounded in Malone's theory on enjoyment [22] and flow theory [19], as well as investigating concepts utilized by commercially successful games. The most significant factor is that the game be enjoyable enough to distract from the exercise, while still tying the exercise into the game in an intuitive fashion. The exercise mechanism must be core to the gameplay so that the user does not feel they are exercising just for the sake of exercising, but instead that it is a natural way to control the game itself. Tying in-game movement to exercise is

an effective way to do this. This makes cardiovascular exercise an especially well-suited form of exercise for exergames, as it is simple to map this it to in-game movement. It also has the benefit of not requiring an especially formulaic training regimen, and has little risk of the player harming themselves. When tying the exercise into the game mechanics it is then important to ensure that the player feels they have significant choice in their exercise output, while still providing strict enough boundaries that the player is neither exhausted nor barely winded. On top of this, the game needs to challenge the users enough that they feel at risk of losing, but not to such an extent that they end up frustrated.

The success of the experiment indicates that this approach to exercise games can be effective, at least in the short to mid-term.

Furthermore, the game has to provide long-term enjoyment if it is to provide any lasting impact on the health of the user. It needs to provide strategic depth to keep the player interested, and provide progression mechanics to keep the user coming back. The experiment was not able to investigate whether the design principles outlined in this report succeed in doing so.

RQ2: What design principles should be used to make an enjoyable exergame?

The main constraint identified is that the exercise should map well to the gameplay. This also includes providing a sufficiently high level of exercise without exhausting the player. As long as this constraint is fulfilled, most concepts found in commercially successful games map well to exergames. The experiment showed that this can be difficult to get right, as the action-awareness merging element of flow scored lower than the other elements.

As mentioned above, replayability is key. Multiplayer is especially well-suited for exergames, as social interaction is a big part of why many people exercise. Multiplayer also assists replayability as it is often easier to ensure the player is sufficiently challenged by providing them the right human opponents than by balancing a game's artificial intelligence. Multiplayer also inherently provides significant variation, as humans are unpredictable in their actions. The experiment strongly supports social interaction being key, with the test subjects rating the social aspect as a significant contributor to their enjoyment and their willingness to exercise. Social interaction was also repeatedly brought up as a positive in the free-form part of the questionnaire.

RQ3: What limitations does the exercise bike platform impose on the design of an exergame?

The Pedal Tanks platform constrains the game design in two main ways. Firstly, the form of exercise means that the most natural mapping between exercise and the game is movement. This eliminates many forms of gameplay, as most games would either barely provide exercise or drive the player to exhaustion if their movement was mapped directly to pedaling. Secondly, the limited number of inputs significantly limits the amount of complexity in the game. The user is essentially limited to four unique actions beyond movement if the control scheme is to remain intuitive. As a result, the design must make concessions in the way of limiting what the player can directly influence.

The experiment directly ran into one unexpected constraint: the level of resistance when pedaling. If set too low, the momentum of the wheel made it very difficult to slow down, while if set too high, the game became exhausting. Luckily a sweet spot between

the two existed, but this does constrain the amount of braking the gameplay can include. Coming to nearly a full stop for instance is very difficult to do in a short period of time, meaning that further development cannot include that as a mechanic given the current movement mechanics.

Part VII

Conclusion and Further Work

This final part will summarize to what extent the questions first stated in the introduction have been answered. It will also describe what work could be done to further develop the prototype into a full-blown product.

Chapter 28

Conclusion

The goal of this project was to design and prototype an exergame capable of providing the weekly recommended exercise, while being enjoyable enough to spur people to exercise more. The project also included investigation into ensuring long-term enjoyment so that people would keep playing and exercising even when the novelty has worn off.

The result of this has been an exergame called Pedal Kart, which builds on the well-tested formula of Mario Kart. It provides exercise using an exercise bike. The racing game loop causes intuitive variation in intensity, providing a form of interval exercise. This variation helped ensure sufficient exercise without quickly exhausting the player. Beyond the features implemented in the prototype, the original design also discusses a number of features such as account progression designed to contribute to long-term enjoyment.

In order to determine whether Pedal Kart has the potential to provide sufficient exercise and be enjoyable in the short to mid-term, an experiment was conducted on four participants across three sessions of play.

The limited scope of the experiment makes it difficult to make conclusions about the entire potential audience of the game, but some conclusions can still be drawn. The test subjects all clearly received intense workouts by playing the game, and the results show that they highly enjoyed it. They quickly grasped the controls, indicating that the mapping between exercise and game is intuitive. The test subjects stated that playing the game made it easier for them to exercise than it otherwise would be.

This indicates that Pedal Kart is worth investigating further, as the results from this test were highly positive. The most important thing to investigate further would be long-term enjoyment, as time and resource constraints meant that only short to mid-term enjoyment could be tested as part of this report.

The design principles utilized to create Pedal Kart appear to have worked well. The inclusion of multiplayer in particular was repeatedly brought up by the test subjects as a major contributor to their enjoyment of the game, as well as them continuing to exercise even when tired.

The design principles of tying real-world movement directly to in-game movement, and ensuring varying intensity of movement, contributed to ensuring a good level of ex-

ercise. This movement mapping proved important, with the test subjects quickly grasping the basic controls, but having occasional issues with advanced maneuvers such as sharp turns.

The use of an exercise bike narrowed the field of possible designs, but the gameplay loop adapted from Mario Kart worked well. The game had to be designed with a relatively limited set of inputs in order for the interaction via the exercise bike be simple enough, and the need to map real-world movement to in-game movement eliminated many forms of gameplay.

Given these results, the goal of the project can be considered to be largely accomplished. Significant research on the state of the art of exergames has been undertaken, and based on that a design has been created and tested in practice. Further investigation is still warranted to determine the long-term enjoyability of the game, and ascertain how wide an audience the game will appeal to.

Chapter 29

Further Work

While the experiment was able to establish that the game provided short to mid-term enjoyment for the test subjects, the questions of long-term enjoyment, and applicability to a larger population, are still open. A longitudinal study would be ideal for determining long-term enjoyment. For applicability to a larger population, a larger and more randomized set of test participants would be needed.

A longitudinal study might also investigate the long-term effects of the exergame on the health of the players. Especially interesting would be whether playing the game would end up replacing traditional exercise, or be used in addition to regular exercise. The game should also be tested on a large group of people who currently get little to no exercise, to investigate whether it is an effective tool in spurring people to start exercising.

The test participants were all students of a similar age, so it is possible the wider appeal of the game is limited. This does not mean the game cannot be successful, just that it might only appeal to a limited audience. If it turns out the broader appeal is limited in such a manner, it would make sense to investigate game designs targeted at other groups, such as the elderly or teenagers.

Investigating more rigorously which features of the game contribute to the enjoyment of the game would also be interesting, providing potentially useful information for other exergame projects. For instance, one could make a version of the game where the item pickup feature was deterministic rather than random, to see how randomness affects enjoyment of the game.

Another natural way to expand the game would be a single-player mode. The appeal of this would be not needing to find three other people to play with, significantly lowering the barrier to playing the game. Such a single-player mode could have the player competing with AI opponents only. The single-player mode could also show a phantom car indicating how they performed in their best run of the map.

Given the positive results, an additional possibility would be to develop a commercial version of the game for use in exercise studios or universities. This would entail implementing the remaining parts of the original game design, as well as creating or obtaining higher quality art assets, and the addition of sound effects and music. It should be possible

for a small team to create a more polished game based on the design either by developing the prototype further, or building a new game from scratch.

As no single game can appeal to everyone, it would be best if a large varied set of exergames was created, catering to a wide range of different groups and play-styles. The other exergames previously mentioned in this report provide a start, but a broader range than this would be useful, especially as many of these were never developed beyond the prototype stage. With such a set of games created, experiments could be conducted to directly compare different games to one another. This could determine which games provide better exercise, which retain players for longer, and what sort of audiences they appeal to.

Bibliography

[1] Electronic Software Association. *Essential Facts About the Computer and Video Game Industry*. URL: http://www.theesa.com/about-esa/essential-facts-computer-video-game-industry/ (visited on 12/05/2017).

[2] Ipsos Connect. *GameTrack Digest: Quarter 2 2017*. URL: http://www.isfe.eu/sites/isfe.eu/files/gametrack_european_summary_data_2017_q2.pdf (visited on 12/05/2017).

[3] Centers for Disease Control and Prevention. *Prevalence of Obesity Among Adults and Youth: United States, 2015–2016*. URL: https://www.cdc.gov/nchs/products/databriefs/db288.htm (visited on 10/15/2017).

[4] Ross C Brownson, Tegan K Boehmer, and Douglas A Luke. "Declining rates of physical activity in the United States: what are the contributors?" In: *Annu. Rev. Public Health* 26 (2005), pp. 421–443.

[5] Elizabeth A Vandewater, Mi-suk Shim, and Allison G Caplovitz. "Linking obesity and activity level with children's television and video game use". In: *Journal of adolescence* 27.1 (2004), pp. 71–85.

[6] Mitchell A Lazar. "How obesity causes diabetes: not a tall tale". In: *Science* 307.5708 (2005), pp. 373–375.

[7] Anna Peeters et al. "Obesity in adulthood and its consequences for life expectancy: a life-table analysis". In: *Annals of internal medicine* 138.1 (2003), pp. 24–32.

[8] Leonard H Epstein, KAREN J Coleman, and Michelle D Myers. "Exercise in treating obesity in children and adolescents." In: *Medicine and science in sports and exercise* 28.4 (1996), pp. 428–435.

[9] Frank J Penedo and Jason R Dahn. "Exercise and well-being: a review of mental and physical health benefits associated with physical activity". In: *Current opinion in psychiatry* 18.2 (2005), pp. 189–193.

[10] World Health Organization. *Physical Activity and Adults*. URL: http://www.who.int/dietphysicalactivity/factsheet_adults/en/ (visited on 10/09/2017).

[11] Thomas D Raedeke. “The relationship between enjoyment and affective responses to exercise”. In: *Journal of Applied Sport Psychology* 19.1 (2007), pp. 105–115.

[12] Victor R Basili. *Software modeling and measurement: the Goal/Question/Metric paradigm*. Tech. rep. 1992.

[13] Veronica A Thurmond. “The point of triangulation”. In: *Journal of nursing scholarship* 33.3 (2001), pp. 253–258.

[14] Yoonsin Oh and Stephen Yang. “Defining exergames & exergaming”. In: *Proceedings of Meaningful Play* (2010), pp. 1–17.

[15] Stefan Göbel et al. “Serious games for health: personalized exergames”. In: *Proceedings of the 18th ACM international conference on Multimedia*. ACM. 2010, pp. 1663–1666.

[16] Alf Inge Wang. “The wear out effect of a game-based student response system”. In: *Computers & Education* 82 (2015), pp. 217–227.

[17] Roger Smith. “The long history of gaming in military training”. In: *Simulation & Gaming* 41.1 (2010), pp. 6–19.

[18] Firas Khatib et al. “Crystal structure of a monomeric retroviral protease solved by protein folding game players”. In: *Nature structural & molecular biology* 18.10 (2011), pp. 1175–1177.

[19] Mihaly Csikszentmihalyi. “Toward a psychology of optimal experience”. In: *Flow and the foundations of positive psychology*. Springer, 2014, pp. 209–226.

[20] Penelope Sweetser and Peta Wyeth. “GameFlow: a model for evaluating player enjoyment in games”. In: *Computers in Entertainment (CIE)* 3.3 (2005), pp. 3–3.

[21] Jeff Sinclair, Philip Hingston, and Martin Masek. “Considerations for the design of exergames”. In: *Proceedings of the 5th international conference on Computer graphics and interactive techniques in Australia and Southeast Asia*. ACM. 2007, pp. 289–295.

[22] Thomas W Malone. “What makes things fun to learn? Heuristics for designing instructional computer games”. In: *Proceedings of the 3rd ACM SIGSMALL symposium and the first SIGPC symposium on Small systems*. ACM. 1980, pp. 162–169.

[23] GameSpot. *Dance Dance Revolution hits 6.5 million in sales*. URL: https://www.gamespot.com/articles/dance-dance-revolution-hits-65-million-in-sales/1100-6084894/ (visited on 09/24/2017).

[24] GameSpot. *Just Dance 3 sells 7 million, series climbs to 25M*. URL: https://www.gamespot.com/articles/just-dance-3-sells-7-million-series-climbs-to-25m/1100-6348597/ (visited on 09/24/2017).

[25] Nintendo. *Official Site - Wii Fit Plus*. URL: http://wiifit.com/ (visited on 12/05/2017).

[26] Nintendo. *IR Information : Financial Data - Top Selling Title Sales Units - Wii Software*. URL: https://www.nintendo.co.jp/ir/en/finance/software/wii.html (visited on 09/23/2017).

[27] MetaCritic. *Wii Fit for Wii Reviews*. URL: http://www.metacritic.com/game/wii/wii-fit (visited on 09/23/2017).

[28] Lee EF Graves et al. "The physiological cost and enjoyment of Wii Fit in adolescents, young adults, and older adults". In: *Journal of Physical Activity and Health* 7.3 (2010), pp. 393–401.

[29] Alzan Studios. *Alzan Studios*. URL: http://www.alzanstudios.com/ (visited on 11/11/2017).

[30] The Pokémon Company. *Homepage — Pokémon Go*. URL: https://www.pokemongo.com/ (visited on 12/05/2017).

[31] Polygon. *Pokémon Go hits 650 million downloads*. URL: https://www.polygon.com/2017/2/27/14753570/pokemon-go-downloads-650-million (visited on 09/24/2017).

[32] BGR. *Four out of five 'Pokemon Go' users have quit*. URL: http://bgr.com/2017/04/03/pokemon-go-popularity-2016-users/ (visited on 09/24/2017).

[33] VentureBeat. *How Pokémon Go will benefit from Niantic's lessons from Ingress on location-based game design*. URL: https://venturebeat.com/2015/12/16/how-niantic-will-marry-animated-characters-with-mobile-location-data-in-pokemon-go/ (visited on 12/05/2017).

[34] Vice. *The King Of Augmented Reality Street Fighting*. URL: https://motherboard.vice.com/en_us/article/z4mgzy/the-king-of-augmented-street-fighting-the-worlds-best-ingress-player (visited on 10/12/2017).

[35] Chad Richards and TC Graham. "Developing compelling repetitive-motion exergames by balancing player agency with the constraints of exercise". In: *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*. ACM. 2016, pp. 911–923.

[36] Soojeong Yoo, Callum Parker, and Judy Kay. "Designing a Personalized VR Exergame". In: *Adjunct Publication of the 25th Conference on User Modeling, Adaptation and Personalization*. ACM. 2017, pp. 431–435.

[37] Kristoffer Hagen et al. "Gameplay as exercise". In: *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. ACM. 2016, pp. 1872–1878.

[38] PlayPulse. *PlayPulse - High intensity training made fun!* URL: http://playpulse.no/ (visited on 12/05/2017).

[39] Mathias Rørstad Mikalsen. "Creation and Evaluation of Exer Dungeon-A multiplayer exergame using exercise bikes". MA thesis. NTNU, 2017.

[40] Alf Inge Wang et al. "Evaluation of the Game Exermon - a Strength Exergame Inspired by Pokémon Go". In: *14th International Conference on Advances in Computer Entertainment Technology (ACE 2017), 14-16 December, London, UK*. 2017.

[41] National Institutie on Aging. *4 Types of Exercise*. URL: https://go4life.nia.nih.gov/4-types-exercise (visited on 10/08/2017).

[42] Seamus P Whelton et al. “Effect of aerobic exercise on blood pressurea meta-analysis of randomized, controlled trials”. In: *Annals of internal medicine* 136.7 (2002), pp. 493–503.

[43] Christopher A DeSouza et al. “Regular aerobic exercise prevents and restores age-related declines in endothelium-dependent vasodilation in healthy men”. In: *Circulation* 102.12 (2000), pp. 1351–1357.

[44] Robert E Dustman et al. “Aerobic exercise training and improved neuropsychological function of older individuals”. In: *Neurobiology of aging* 5.1 (1984), pp. 35–42.

[45] Keith Baar, Gustavo Nader, and Sue Bodine. “Resistance exercise, muscle loading/unloading and the control of muscle mass”. In: *Essays in biochemistry* 42 (2006), pp. 61–74.

[46] George A Kelley and Kristi Sharpe Kelley. “Progressive resistance exercise and resting blood pressure”. In: *Hypertension* 35.3 (2000), pp. 838–843.

[47] LC Shackelford et al. “Resistance exercise as a countermeasure to disuse-induced bone loss”. In: *Journal of Applied Physiology* 97.1 (2004), pp. 119–129.

[48] Brian E Maki and William E McIlroy. “Control of rapid limb movements for balance recovery: age-related changes and implications for fall prevention”. In: *Age and ageing* 35.suppl_2 (2006), pp. ii12–ii18.

[49] Che-Hsiu Chen et al. “Effects of flexibility training on eccentric exercise-induced muscle damage”. In: *Medicine & Science in Sports & Exercise* 43.3 (2011), pp. 491–500.

[50] Margareta Wiktorsson-Moller et al. “Effects of warming up, massage, and stretching on range of motion and muscle strength in the lower extremity”. In: *The American journal of sports medicine* 11.4 (1983), pp. 249–252.

[51] American Heart Association. *American Heart Association Recommendations for Physical Activity in Adults*. URL: http://www.heart.org/HEARTORG/HealthyLiving/PhysicalActivity/FitnessBasics/American-Heart-Association-Recommendations-for-Physical-Activity-in-Adults_UCM_307976_Article.jsp (visited on 10/09/2017).

[52] National Health Service. *Physical activity guidelines for adults*. URL: http://www.nhs.uk/Livewell/fitness/Pages/physical-activity-guidelines-for-adults.aspx (visited on 10/09/2017).

[53] World Health Organization. *How much physical activity do adults need?* URL: https://www.cdc.gov/physicalactivity/basics/adults/index.htm (visited on 10/09/2017).

[54] National Center for Health Statistics. *Early Release of Selected Estimates Based on Data From the 2016 National Health Interview Survey*. URL: https://www.cdc.gov/nchs/data/nhis/earlyrelease/earlyrelease201705.pdf (visited on 10/09/2017).

[55] Oculus. *Oculus Rift — Oculus*. URL: https://www.oculus.com/rift/ (visited on 12/05/2017).

[56] HTC Corporation. *VIVE — Discover Virtual Reality Beyond Imagination*. URL: https://www.vive.com/eu/ (visited on 12/05/2017).

[57] Sony. *PlayStation VR*. URL: https://www.playstation.com/en-us/explore/playstation-vr/ (visited on 12/09/2017).

[58] Business Insider. *VR headsets comparisons*. URL: http://www.businessinsider.com/vr-headsets-comparison-popularity-price-features-details-2017-6 (visited on 12/09/2017).

[59] Ars Technica. *Oculus cuts Rift price for second time this year, now $399 with Touch*. URL: https://arstechnica.com/gaming/2017/07/oculus-cuts-rift-price-for-second-time-this-year-now-399-with-touch/ (visited on 10/02/2017).

[60] The Verge. *The HTC Vive just got a $200 price cut*. URL: https://www.theverge.com/2017/8/21/16176862/htc-vive-vr-headset-price-cut (visited on 10/02/2017).

[61] Popular Science. *How It Works: The Oculus Rift*. URL: https://www.popsci.com/oculus-rift-how-it-works (visited on 12/05/2017).

[62] The Verge. *Sony's PlayStation VR is getting a price cut*. URL: https://www.theverge.com/2017/8/28/16215038/sony-playstation-vr-camera-move-bundle-price-drop-september (visited on 12/09/2017).

[63] The Verge. *Sony's PS4 Slim now comes with a 1TB hard drive for the same price*. URL: https://www.theverge.com/circuitbreaker/2017/4/18/15344360/sony-ps4-slim-1tb-hard-drive-announced (visited on 12/09/2017).

[64] Microsoft. *Kinect for Xbox One*. URL: https://www.xbox.com/en-US/xbox-one/accessories/kinect (visited on 12/05/2017).

[65] The Verge. *Microsoft kills off Kinect, stops manufacturing it*. URL: https://www.theverge.com/2017/10/25/16542870/microsoft-kinect-dead-stop-manufacturing (visited on 11/11/2017).

[66] Harmonix. *Dance Central*. URL: http://www.harmonixmusic.com/games/dance-central/ (visited on 12/05/2017).

[67] TechRadar. *PS4 vs Xbox One: which is better?* URL: http://www.techradar.com/news/gaming/consoles/ps4-vs-xbox-720-which-is-better-1127315/4 (visited on 10/04/2017).

[68] Microsoft. *Kinect for Xbox One*. URL: http://web.archive.org/web/20170712150335/https://www.xbox.com/en-US/xbox-one/accessories/kinect (visited on 11/11/2017).

[69] Pew Research Center. *Mobile Fact Sheet*. URL: http://www.pewinternet.org/fact-sheet/mobile/ (visited on 10/05/2017).

[70] Pradeep Buddharaju and Naga Siva Chandra Prasad Pamidi. "Mobile exergames-Burn Calories while playing games on a smartphone". In: *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops*. 2013, pp. 50–51.

[71] Ross A Clark et al. “Validity and reliability of the Nintendo Wii Balance Board for assessment of standing balance”. In: *Gait & posture* 31.3 (2010), pp. 307–310.

[72] Maayan Agmon et al. “A pilot study of Wii Fit exergames to improve balance in older adults”. In: *Journal of geriatric physical therapy* 34.4 (2011), pp. 161–167.

[73] Gillian Barry, Brook Galna, and Lynn Rochester. “The role of exergaming in Parkinson’s disease rehabilitation: a systematic review of the evidence”. In: *Journal of neuroengineering and rehabilitation* 11.1 (2014), p. 33.

[74] Nintendo. *Wii Fit U Bundle*. URL: https://www.nintendo.com/games/detail/rK_4Ln_ru27SWO1fxusaVkpdEwk3kFQY (visited on 10/05/2017).

[75] Destructoid. *Wii U 32GB finally returns to $200 price at the Nintendo Store*. URL: https://www.destructoid.com/wii-u-32gb-finally-returns-to-200-price-at-the-nintendo-store-405316.phtml (visited on 10/05/2017).

[76] DDR Game. *Dance Dance Revolution*. URL: http://www.ddrgame.com/ (visited on 12/05/2017).

[77] The International Arcade Museum. *Prop Cycle*. URL: http://www.arcade-museum.com/game_detail.php?game_id=9139 (visited on 12/05/2017).

[78] Nintendo. *Pokéwalker*. URL: https://www.nintendo.com/consumer/downloads/Pokewalker_Tri.pdf (visited on 12/05/2017).

[79] Unity Technology. *Unity - Game Engine*. URL: https://unity3d.com/ (visited on 10/13/2017).

[80] Unity Technology. *Unity - Unity Personal*. URL: https://store.unity.com/products/unity-personal (visited on 10/13/2017).

[81] Unity Technology. *Asset Store*. URL: https://www.assetstore.unity3d.com/en/ (visited on 10/13/2017).

[82] Alejandro Santos-Lozano et al. “Is the SenseWear Armband accurate enough to quantify and estimate energy expenditure in healthy adults?” In: *Annals of translational medicine* 5.5 (2017).

[83] Heather A Haugen, Lingtak-Neander Chan, and Fanny Li. “Indirect calorimetry: a practical guide for clinicians”. In: *Nutrition in Clinical Practice* 22.4 (2007), pp. 377–388.

[84] Ryan E Rhodes, Darren ER Warburton, and Shannon SD Bredin. “Predicting the effect of interactive video bikes on exercise adherence: An efficacy trial”. In: *Psychology, health & medicine* 14.6 (2009), pp. 631–640.

[85] Entertainment Software Association. *Two-Thirds of American Households Regularly Play Video Games*. URL: http://www.theesa.com/article/two-thirds-american-households-regularly-play-video-games/ (visited on 10/15/2017).

[86] Valve Corporation. *Top 100 Best Sellers of 2016*. URL: http://store.steampowered.com/sale/2016_top_sellers/ (visited on 10/20/2017).

[87] Stewart G Trost et al. “Correlates of adults’ participation in physical activity: review and update”. In: *Medicine & Science in Sports & Exercise* 34.12 (2002), pp. 1996–2001.

[88] Steven Allender, Gill Cowburn, and Charlie Foster. “Understanding participation in sport and physical activity among children and adults: a review of qualitative studies”. In: *Health education research* 21.6 (2006), pp. 826–835.

[89] Amanda E Staiano, Anisha A Abraham, and Sandra L Calvert. “Adolescent exergame play for weight loss and psychosocial improvement: a controlled physical activity intervention”. In: *Obesity* 21.3 (2013), pp. 598–601.

[90] Amanda E Staiano, Anisha A Abraham, and Sandra L Calvert. *Motivating effects of cooperative exergame play for overweight and obese adolescents*. 2012.

[91] Domen Novak et al. “Increasing motivation in robot-aided arm rehabilitation with competitive and cooperative gameplay”. In: *Journal of neuroengineering and rehabilitation* 11.1 (2014), p. 64.

[92] Wei Peng and Julia Crouse. “Playing in parallel: The effects of multiplayer modes in active video game on motivation and physical exertion”. In: *Cyberpsychology, behavior, and social networking* 16.6 (2013), pp. 423–427.

[93] Forbes. *Here Are The Five Best-Selling Video Games Of All Time*. URL: https://www.forbes.com/sites/insertcoin/2016/07/08/here-are-the-five-best-selling-video-games-of-all-time/ (visited on 11/23/2017).

[94] Óscar Arias-Carrión and Ernst Pöppel. “Dopamine, learning, and reward-seeking behavior.” In: *Acta neurobiologiae experimentalis* (2007).

[95] Neal Hallford, Jana Hallford, and Andre LaMothe. *Swords and Circuitry: A Designer’s Guide to Computer Role-Playing Games*. Premier Press, Incorporated, 2001.

[96] Jonathan D Bartlett et al. “High-intensity interval running is perceived to be more enjoyable than moderate-intensity continuous exercise: implications for exercise adherence”. In: *Journal of sports sciences* 29.6 (2011), pp. 547–553.

[97] I Elaine Allen and Christopher A Seaman. “Likert scales and data analyses”. In: *Quality progress* 40.7 (2007), p. 64.

[98] Susan A Jackson and Herbert W Marsh. “Development and validation of a scale to measure optimal experience: The Flow State Scale”. In: *Journal of sport and exercise psychology* 18.1 (1996), pp. 17–35.

[99] Anita S Acharya et al. “Sampling: Why and how of it”. In: *Indian Journal of Medical Specialties* 4.2 (2013), pp. 330–333.

[100] Newzoo. *Male and Female Gamers: How Their Similarities and Differences Shape the Games Market*. URL: https://newzoo.com/insights/articles/male-and-female-gamers-how-their-similarities-and-differences-shape-the-games-market/ (visited on 05/10/2018).

[101] Fitbit Community. *Charge 2 Heart Rate Accuracy*. URL: https://community.fitbit.com/t5/Charge-2/Charge-2-Heart-Rate-Accuracy/td-p/1571539 (visited on 05/27/2018).

[102] Norwegian Social Science Data Services. *Will you be processing personal data?* URL: http://www.nsd.uib.no/personvernombud/en/notify/notification_test.html (visited on 05/27/2018).

[103] Regional Committees for Medical and Health Research Ethics. *Examples of activities that do not require approval from REC*. URL: https://helseforskning.etikkom.no/reglerogrutiner/soknadsplikt/sokerikkerek?p_dim=34999&_ikbLanguageCode=us (visited on 05/27/2018).

Appendix

A Questionnaire

On the next pages is all the questions in the questionnaire the test participants filled out each session. Note that question 16 was only present for the second and third sessions of the experiment.

Pedal Kart

1. **ID**

2. **Age**

3. **Height (cm)**

4. **Weight (kg)**

5. **Gender**
   Mark only one oval.
   - ◯ Male
   - ◯ Female
   - ◯ Other: _____

6. **How often do you exercise?**
   Average number of sessions per week

7. **How much time do you spend playing computer games?**
   Average number of hours per week

8. *Mark only one oval per row.*

	1 (Strongly Disagree)	2	3 (Neither agree nor disagree)	4	5 (Strongly Agree)
I found the experience rewarding					
The experience left me feeling great					
I was challenged, but I felt my skills allowed me to meet the challenge					
I knew clearly what I wanted to do					
It was no effort to keep my mind on the game					
I was not concerned with how I was presenting myself					
It felt like I could control what my in-game avatar was doing					
My goals were clearly defined					
It was clear to me that I was doing well					
I had a good idea while I was playing about how well I was doing					
I lost track of time while playing					
The challenge and my skills were at an equal level					
Time passed quickly during play					
I did things spontaneously and automatically without having to think					
I really enjoyed the experience					
My attention was focused entirely on what I was doing					
I felt in control of my body					
I had total concentration					
At times, it almost seemed like things were happening in slow motion					
I felt in control of my actions					
I was not worried about my performance during the game					
I made the correct movements without thinking about trying to do so					
I played automatically					
I was aware of how well I was performing					
I was not concerned with what others may have been thinking of me					
I felt I was competent enough to meet the demands of the situation					

9. **The game was fun**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not at all fun	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Extremely fun

10. **The game was challenging**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not at all challenging	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Extremely challenging

11. **The game was physically intense**
Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not at all intense	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	Extremely intense

12. **The game made it easier for me to exercise than it otherwise would be**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	⬭	⬭	⬭	⬭	⬭	Strongly agree

13. **The social aspect of the game made it more fun**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	⬭	⬭	⬭	⬭	⬭	Strongly agree

14. **The social aspect of the game encouraged me to push myself harder**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	⬭	⬭	⬭	⬭	⬭	Strongly agree

15. **If this game was available at a gym near me, I would exercise more**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	⬭	⬭	⬭	⬭	⬭	Strongly agree

16. **If you've ever used an exercise bike without gameplay, how does Pedal Kart compare?**

17. **What parts of the game did you like the most?**

18. **What parts of the game did you like the least?**

19. **What would you like to see changed or improved in the game?**

B Heart Beat Data

The following figures show the heart beat data from the three sessions. The data includes 5 minutes before and after each play session. Note that for the first session, this only includes data from five minutes before the first successful race; the first races that ended early due to technical issues (as mentioned in Section 26) are not included.

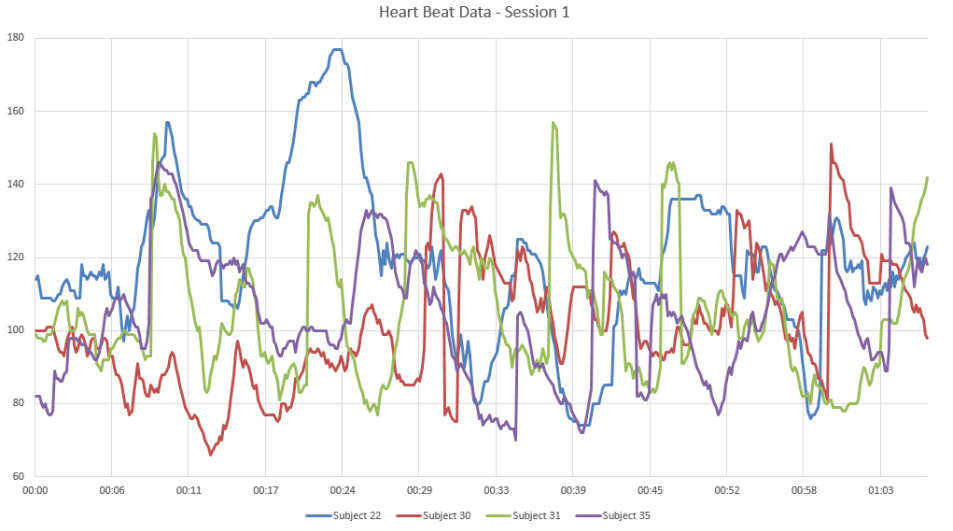

Figure 29.1: Heart beat data from session 1

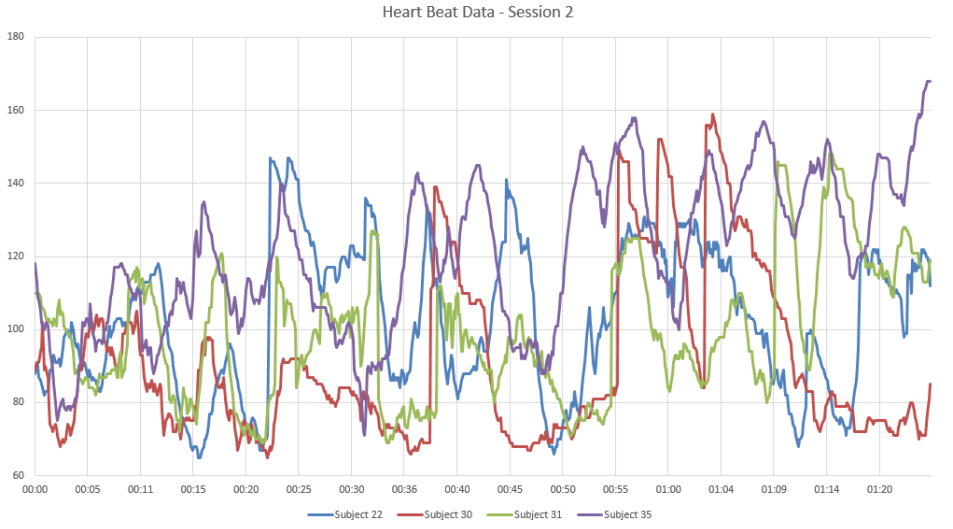

Figure 29.2: Heart beat data from session 2

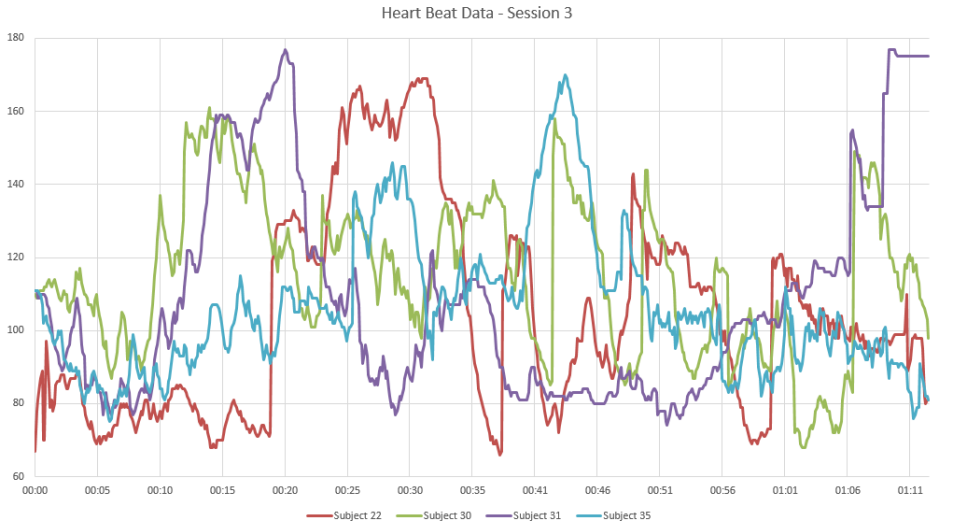

Figure 29.3: Heart beat data from session 3

C Questionnaire Answers

Below are the results of the questionnaire. The flow-state questions have been sorted based on flow element.

Particpant	22	30	31	35	22	30	31	35	22	30	31	35
Question	Session 1				Session 2				Session 3			
I was challenged, but I felt my skills allowed me to meet the challenge	2	5	5	5	3	5	5	5	4	5	4	5
I felt I was competent enough to meet the demands of the situation	4	5	5	5	4	5	5	4	5	5	5	4
The challenge and my skills were at an equal level	3	5	5	3	4	5	4	4	5	4	5	4
I made the correct movements without thinking about trying to do so	2	2	4	2	2	3	5	1	4	4	4	1
I played automatically	4	3	5	3	4	5	5	4	5	4	4	4
I did things spontaneously and automatically without having to think	2	3	5	3	3	3	5	4	4	4	4	2
I knew clearly what I wanted to do	5	5	4	4	5	5	4	4	5	5	4	4
My goals were clearly defined	5	5	3	5	5	5	4	5	5	5	5	5
It was clear to me that I was doing well	4	4	4	5	4	5	3	5	4	5	4	4
I was aware of how well I was performing	4	5	4	4	4	5	5	4	4	5	4	5
I had a good idea while I was playing about how well I was doing	3	5	4	5	3	5	4	4	5	5	4	5
My attention was focused entirely on what I was doing	5	5	5	4	5	5	4	5	5	5	5	3
It was no effort to keep my mind on the game	5	3	5	5	5	5	5	4	5	5	4	4
I had total concentration	5	3	5	4	4	4	4	4	5	5	5	4
I felt in control of my actions	3	4	4	4	5	3	5	5	5	4	5	5
It felt like I could control what my in-game avatar was doing	3	4	4	5	4	4	4	5	4	4	4	5
I felt in control of my body	4	5	4	4	4	5	5	4	5	5	5	4
I was not concerned with what others may have been thinking of me	4	3	4	5	5	5	5	4	5	5	4	5
I was not worried about my performance during the game	3	1	2	4	5	1	2	4	4	1	4	3
I was not concerned with how I was presenting myself	5	1	5	5	4	5	4	4	5	5	5	4
I lost track of time while playing	5	5	5	4	5	5	5	5	5	5	5	5
At times, it almost seemed like things were happening in slow motion	1	5	4	2	1	2	3	3	1	5	3	2
Time passed quickly during play	4	5	5	5	5	5	5	5	5	4	5	5
I really enjoyed the experience	5	5	5	5	4	5	4	5	5	5	4	5
The experience left me feeling great	4	5	4	4	4	5	4	4	5	5	4	4
I found the experience rewarding	5	5	5	5	5	5	4	4	5	5	4	5
The game was fun	8	10	8	9	8	7	7	9	9	10	7	9
The game was challenging	9	10	7	6	8	7	8	7	9	8	8	7
The game was physically intense	9	10	8	8	9	8	9	8	8	10	8	8
The game made it easier for me to exercise than it otherwise would be	5	3	4	4	5	1	4	4	5	1	3	4
The social aspect of the game made it more fun	5	5	5	5	5	5	5	5	5	5	5	5
The social aspect of the game encouraged me to push myself harder	4	5	5	5	5	5	5	5	5	4	5	5
If this game was available at a gym near me, I would exercise more	3	1	2	3	2	1	2	3	2	1	2	3

Figure 29.4: Numerical results from the questionnaire

What parts of the game did you like the most?

Participant 22

(Session 1) The ability to adjust the bike resistance to your own level. This allowed me to compete on a better level with people more fit than me, and also to challenge myself while competing with the others.

(Session 2) The rubber banding is better, so it feels like I have a chance to catch up.

(Session 3) The new spawning mechanism feels much better, and makes it less punishing and disappointing to crash. This also makes it easier to concentrate on the other players, and not just on your own performance.

Participant 30

(Session 1) The competition

(Session 2) The competition part
(Session 3) The social and competitive part of the game.

Participant 31
(Session 1) The competitive element, competing with friends
(Session 2) The competitive part
(Session 3) The social aspect. The competitive nature of the game

Participant 35
(Session 1) The competition with friends, and the social aspect. It was a fun game, where the exercise came as a bonus, making it a good combination.
(Session 2) The social aspect and competing with friends. It also is nice to create your own exercise session, where you can decide how tough you want it to be. It also feels like a normal game, which makes it fun to play and exercise.
(Session 3) The social aspect, the competition with friends and the fun twist to regular exercise.

What parts of the game did you like the least?
Participant 22
(Session 1) Hard to know how far in the route you are, and how much of the route is left.
(Session 2) Don't know.
(Session 3) I still can't seem to drive through the sharpest turns without crashing into a wall or landing far out on the grass, but this is probably more my own fault, and can be seen as a good challenge. Can't think of anything else.

Participant 30
(Session 1) Nothing
(Session 2) The physics of the game and the cars
(Session 3) How the cars react when they bump into each other.

Participant 31
(Session 1) The way the cars reacted when crashing with others were very uncontrollable and punished the player in a to a very large extent. Made me be more careful and not give it all when close to other cars.
(Session 2) The repetitiveness makes it less attractive the more we play, this is somewhat fixed with the new maps
(Session 3) Some physics are a bit wonky.

Participant 35
(Session 1) The game could be more challenging, since the gameplay was very similar every time/round.
(Session 2) Maybe too much punishment from crashing with the AIs. Could also be more different lanes and more obstacles to make it more challenging.
(Session 3) Could be more challenging and be given more information about how well you were performing in the perspective of training.

What would you like to see changed or improved in the game?
Participant 22
(Session 1)Better show of progress, for example a mini map. Also some goal posts to show the end of the route.
(Session 2) Easier to see your status in the race. The list at the top right is not something you can glance at during the game, and immediately know where you stand in the race. Since the cars are color coded, the list should also probably be color coded, not the text that takes too long to read.
(Session 3) Still hard to judge your rank while playing, but with the color coding and after getting used to the game it is easier to glance up at the score board to see where you stand. It is also helpful that the AIs are clearly marked as such.

Participant 30
(Session 1) Easier to see and notice my items
(Session 2) The physics of the game and the cars - if you are unlucky, the start of the game will ruin your whole race
(Session 3) The start of the race - it's a total mess and I don't like it because it can ruin your whole game, if you are unlucky - and how the cars react when they collide.

Participant 31
(Session 1) Special effects, explosions. Car physics on collisions with other cars.
(Session 2) The crashing physics. Punished too much collisions with other cars
(Session 3) Some physics in crashing, UI. After we have played the game a bit now only the four power-ups become a bit normalized and somewhat boring, not as exciting as it was

Participant 35
(Session 1) More power-ups and maybe more challenging maps. Could also be more punishment when you drive on the grass.
(Session 2) Screen which shows if you are in the lead, and by how much. Could also be fun competing with yourself with a ghost mode. It would also be nice with a timer, which motivates to beat your time from the last round. A minimap to show the lead would be motivating and fun to keep it going at a high level.
(Session 3) Information about how many calories, how far you have gone with the bike and information about how the others are doing to make it more competitive. Finish line, ghost mode and maybe a cup with more races could also be nice additions to the game. It would also be fun to know the total score over more races and more diverse lanes.

If you've ever used an exercise bike without gameplay, how does Pedal Kart compare?
Participant 22
(Session 2) Did not answer
(Session 3) Did not answer

Participant 30

(Session 2) Did not answer
(Session 3) Did not answer

Participant 31
(Session 2) Way more fun and intense, but less relaxing
(Session 3) More fun and varied.

Participant 35
(Session 2) The game make it easier to push myself harder, and the social aspect makes it more fun. Using exercise bikes it not very fun over time, but the game made me loose track of time and enjoy myself for a long time.
(Session 3) It's more fun because the competition makes it more interesting. You also loose track of time since you are not too worried about much time you have been on the bike, which makes the training more exciting.