Master's thesis

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

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Space Space Revolution - Using Dance Pads in a New Exergame to Promote Physical Exertion

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

This master's thesis aims to create and evaluate a new exergame for the purpose of assisting in increasing the general public's physical activity level. Exergames are video games that focus on making their players physically active. They are significant for generating exercise motivation because they combine the enjoyment of traditional video games with physical exertion, which can positively impact the global physical inactivity problem that causes obesity and cardiovascular diseases. However, designing and creating a successful exergame can be difficult, as it needs to be entertaining and have a high enough physical intensity to be impactful. To address this, we conducted a literature study on the exergame field, game genres, game enjoyment theories, movement tracking technology, and physical activity to gain the required knowledge. This knowledge was used to create the game concept named *Space Space Revolution*, which is a multiplayer platformer that uses dance pads as controllers, requiring players to use their feet when playing. Next, we implemented a prototype to be used in experiments. Before the experiment testing, the game underwent alpha testing with a few external users and a beta test on the Norwegian Game Awards (NGA), where players could voluntarily answer a questionnaire after trying the game (n=30). The final experiment had 47 participants play together in pairs, and it gathered data for evaluating the game regarding physical activity, enjoyment, motivation to continue playing, engagement, game design, and challenges. We collected and analyzed quantitative and qualitative data from observations, questionnaires, interviews, game-generated data, and heart rate monitoring. We found the results to be very positive for all evaluation themes, and the game provided moderate to high-intensity physical exertion. Most notably, being able to play together with another person was crucial for enjoyment, motivation, and engagement. However, some players had difficulty understanding and learning the unconventional controllers. The results indicate that *Space Space Revolution* can be considered a successful exergame since both the entertainment and physical activity level were high. Future research should explore ways to reduce control issues and increase long-term motivation to continue playing.

Sammendrag

Denne masteroppgaven sitt formål er å lage og evaluere et nytt treningsspill som skal bidra til å øke det fysiske aktivitetsnivået i befolkningen. Treningsspill er videospill som krever fysisk aktivitet for å spilles. De kan bidra til å skape treningsglede og motivasjon fordi de kombinerer underholdningen fra tradisjonelle spill med fysisk anstrengelse. Verden står ovenfor et globalt helseproblem skapt av inaktivitet, noe treningsspill kan bidra til å løse. For at et treningsspill skal ha en påvirkningskraft er det nødt til å gi en treningseffekt samtidig som det er underholdende å spille, noe som kan være vanskelig å oppnå. For å tilegne oss nok kunnskap til å løse dette har vi gjennomført en litteraturstudie på treningsspill, spillsjangre, teorier for å lage underholdende spill, teknologier for å spore fysisk aktivitet og ulike treningsformer. Resultatet av studien er *Space Space Revolution*, et plattformspill for to spillere som spilles med dansematter. For å teste spillet hadde vi først en alfatest med få brukere og en betatest på Norwegian Game Awards (NGA) der 30 spillere ga tilbakemeldinger. Deretter utførte vi et eksperiment med 47 deltakere som spilte sammen i par. Eksperimentet samlet inn data for å evaluere spillets evne til å gi fysisk aktivitet, fornøyelse, engasjement og motivasjon til å fortsette å spille. I tillegg ble det samlet data om spillets design og utfordringer. Både kvantitative og kvalitative data ble samlet inn gjennom observasjon, spørreskjema, intervju, spilldata og pulsmåling. Resultatene var svært positive for alle evalueringskriteriene, og spillet gir moderat til høy fysisk aktivitet. Å spille sammen i par var en faktor som bidro til mye glede, engasjement og motivasjon, men enkelte deltakere hadde utfordringer med å forstå og lære seg de uvante spillkontrollerne. Resultatene indikerer at *Space Space Revolution* er et vellykket treningsspill der både underholdnings- og aktivitetsnivået er høyt. Fremtidig forskning bør se på løsninger for å gjøre kontrollerne mer brukervennlig samt øke motivasjonen for å spille spillet jevnlig.

Acknowledgements

We want to thank our supervisor Professor Alf Inge Wang, at the Department of Computer Science (IDI) at the Norwegian University of Science and Technology (NTNU). Thank you for allowing us to work on this exciting project. Your weekly feedback, enthusiasm, and guidance have proven invaluable. We are grateful for the freedom of creating a personalized project while being directed and given advice.

We would also like to thank the game developers and others who tried our game at the Norwegian Game Awards (NGA). It provided valuable feedback to our testing phase, which resulted in us mitigating several challenges with the game.

Thank you to the 47 participants in the experiment using their spare time to test our game. It would not be possible to complete this project without you giving us the required data and feedback.

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Part I

Introduction

Part I presents the project. First, the societal and personal motivations behind the project will be introduced, followed by a description of the project and its context. Next, the project's research questions and methods are presented before ending with a report outline.

Chapter 1

Motivation

This chapter contains text from the specialization project (see Chapter 2).

Studies show that the general public performs less than the recommended amount of physical activity and that the lack thereof is one of the biggest public health problems [213][20][205][100, p. 164-168]. Increased use of digital media is a contributing factor for more sitting [53]. A lack of sufficient physical activity can lead to health problems such as obesity and cardiovascular diseases [50, p. 79][17][214]. Therefore, the absence of physical activity in modern times can be viewed as the 21st century's most prominent public health problem.

One possible way to increase physical activity is by making physical exertion more enjoyable and motivating. Since people use digital devices to play games for enjoyment, there has been a rise in games that encourage physical activity [60]. Combining computer games and physical activity may help increase the general public's health. The popular mobile game *Pokémon Go* illustrates the possible impact of such exercise games [170]. Thus, it is possible to reduce the health problems related to lack of physical activity with exercise motivation through games.

The societal motivation behind this project is to help increase physical activity in the general public through a new game. The game aims to motivate the players to be physically active while enjoying themselves. This way, the users may be more inclined to perform physical activity than they otherwise would, which improves public health.

The other motivational component for this project is of personal interest. We both enjoy playing video games and find their development intriguing. This project is an opportunity to learn more about game design and the practicalities of making a game. Therefore, creating our game will simultaneously be both educational and engaging.

Chapter 2

Project and Context

This project is a continuation of the course *TDT4501 - Computer Science, Specialization Project* at NTNU. The specialization project course serves as a pre-project for our master's thesis, and it consisted of a prestudy of the exergame field. We used the results from the prestudy to suggest several concepts for new exergames, one of which formed the basis for our game. In this report, Part II and Part III is based on the specialization project. Additionally, the text in Chapter 1, Chapter 3, Section 4.1, Chapter 17, and Chapter 18 are primarily from the previous project.

The given project description is:

> ***[ExerGames] Play to get fit***
>
> *In this project, the goal is to come up with new game concepts and game technologies for exergames - games where the player carry out physical exercise at the same time. There are several approaches for exergames, and the challenge is to find the balance between something that is fun to play as well as you get a real physical exercise from playing the game.*
>
> *The first phase of the project will consist of a theoretical study of exergames and mechanisms for how games can be used as a motivator. The second phase focus on implementing a prototype using various technologies. In third and final phase, the prototype will be evaluated and tested.*

The specialization project covers the first phase, and the work done in this master's thesis is the second and third phases. The project started with creating a prototype of our exergame *Space Space Revolution*. Then, we conducted a user experiment to test and evaluate the game against the research questions defined in Chapter 3.

This project is part of the Game Technology for Health (GT4H) Network at NTNU. The GT4H Network "*brings together knowledge and expertise about serious gaming for health benefits from different research groups across Departments and Faculties at NTNU. The network aims to connect researchers and professionals both within and outside NTNU that develop or use game technology for health, in order to deliver high-quality research and advance our knowledge at the best value possible*" [139].

Chapter 3

Research Goal and Questions

This chapter contains text from the specialization project (see Chapter 2).

The research approach in this report is based on the Goal Question Metric (GQM) approach [26]. The GQM model is a hierarchical structure starting with a conceptual goal which is refined into several research questions. Finally, a set of metrics used to answer the questions are described. Our research goal for this project is:

Research goal: Create and evaluate a new exergame to assist in increasing the general public's physical activity level.

The research goal is conceptual and consists of several underlying challenges that we must solve to reach it. Following the GQM model, we phrase them as research questions (RQs). Researching existing exergames and other relevant fields is necessary to provide a good foundation for creating our game. Then, after implementing the game, we need to test and evaluate it to measure the players' enjoyment, motivation, engagement, and physical extortion when playing. Therefore, we have refined the research goal into the following RQs:

RQ1: *How can exergames motivate physical activity?*
This research question studies game enjoyment theories, game genres, existing exergames, technologies, and public health to provide a good foundation for creating our game. The question is answered through a literature review.

RQ2: *What is a new enjoyable game concept that requires physical exertion?*
This research question explores new exergame concepts. The question is answered by creating and reviewing several new concept ideas, where one is selected and further analyzed and explained in detail.

RQ3: *What level of physical exertion does the exergame give its players?*
This research question examines the physical outcome of playing the exergame and to what degree it is suitable to increase the player's general physical activity level to WHO's recommendations.

RQ4: *How does the exergame affect the player?*

RQ4.1: *How is the player's enjoyment affected by the exergame?*
This research question studies to what extent the players enjoy playing the game. The game must be enjoyable for people to keep playing it.

RQ4.2: *How is the player's motivation to continue playing affected by the exergame?*
This research question studies the player's motivation to play the game and which aspects influence it.

RQ4.3: *How is the player's engagement affected by the exergame?*
This research question looks at the level of player engagement the game gives and their level of focus on the gameplay.

RQ5: *How does the game design and gameplay contribute to the player experience?*
This research question studies the effect of game design and gameplay decisions on the player experience with the exergame.

RQ6: *What are the challenges of playing the exergame?*
This research question examines what challenges players had with the exergame. It looks at both technical and game design difficulties.

Chapter 4

Research Methods

This chapter describes our use of the research process introduced by Oates (2006) to structure the thesis and its work. Figure 4.1 shows a model of this process, where the highlighted parts are the ones used in this thesis. Following the model, you should develop research questions based on your experience, motivation, and a literature review. We based our research goal on the given project description shown in Chapter 2, and used the GQM approach to refine it into several research questions (Chapter 3). The questions are a result of our motivation, previous experience, and the prestudy in Part II. The following parts of the thesis start with a preliminary study with a literature review before we design, create, and test an exergame prototype. The experiment utilizes several data generation methods and data analysis types [142, p. 32-38].

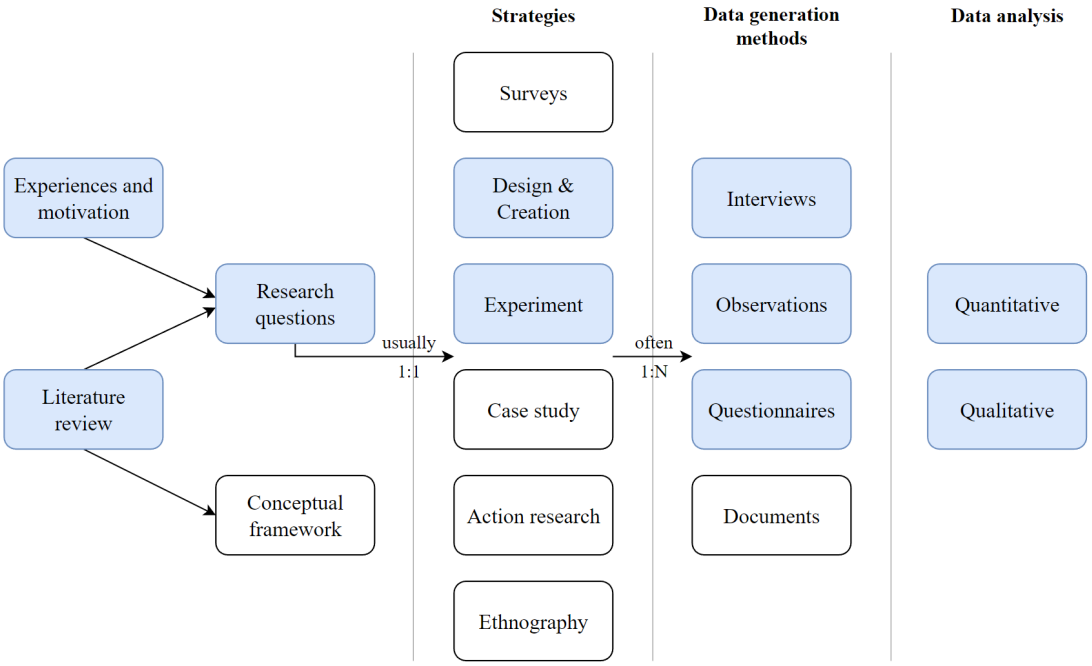


Figure 4.1: Model of the research process highlighting the steps we will take.

4.1 Literature Review

This section contains text from the specialization project (see Chapter 2).

A literature review will be performed on game genres, game enjoyment theories, public health, exercise types, and existing exergames to answer RQ1. A *literature review* is an account of published articles and theories on a topic relevant to the thesis. It should be defined within the research question and convey what knowledge and ideas exist on the topic. The review is more than a set of summaries, as it needs to synthesize and evaluate the published material according to the research question. The purpose is to gain and convey the academic understanding required to research a topic [183][172].

There are three commonly used methods to conduct a literature review, *systematic*, *integrative*, and *semi-systematic*. A *systematic* review identifies, collects, and analyzes relevant research that fits the inclusion criteria. A systematic review aims to answer a research question or hypothesis by using systematic reviewing methods. *Integrative* reviews aim to synthesize research on a specific topic, enabling new frameworks and theories to develop. This report will utilize the last method, a *semi-systematic* literature review. *Semi-systematic* literature reviews, also called narrative reviews or meta-narrative reviews, are "*designed for topics that have been conceptualized differently and studied by various groups of researchers within diverse disciplines and that hinder a full systematic review process*" [173]. A semi-systematic review aims to provide knowledge within a broad topic or multiple research areas. This report will utilize a semi-systematic review to give both readers and authors a state of knowledge and historical overview of exergame concept creation. It will be used as a rationale for decision-making within the new exergame concept. A full systematic review could have given a more precise knowledge map within exergames. However, it was not suitable due to the time constraints of this project and the several broad research areas [173].

The literature review is separated into four phases: *designing*, *conducting*, *analyzing*, and *writing*. Phase one is to create a search strategy for the review, which is done by creating different criteria. Table 4.1 shows the search criteria for this report. They are quite broad because exergames are a relatively new concept with little research done. Broad criteria are also made due to the literature review being conducted on many different research fields, and it only needs to convey the essential concepts of the fields. Note that the prioritized list in the search criteria shows the quality level desired from sources. If a certain topic lacks academic literature, primary sources will be investigated. If no primary source was found, the search ends with non-peer-reviewed sources. The literature review will also include both *forward snowballing* and *backward snowballing* to find relevant academic literature [217]. In other words, find papers from the reference list of key articles and papers that cite the key articles. Phase two is to test the review created in phase one and check if it is sufficient. The third phase is to analyze the information in a structured manner. The data is descriptive information that is relevant to answering a research question. Lastly is the writing phase, where the data must be analyzed and provide a valuable contribution. It is important to present the information clearly and understandably [173].

Table 4.1: The search criteria for literature review in this report.

Search Options	**Criteria**
Year of publication	Information shall be as up-to-date as possible. However, academic articles that are frequently cited can be accepted regardless of the year of publication.
Language	English
Type	Prioritized list: 1. Academic literature 2. Primary sources (documentation, product pages, etc.) 3. Non-peer-reviewed sources (Wikipedia, tech magazines, etc.)

4.2 Design & Creation

Oates presents several possible strategies to answer the research questions defined in Chapter 3. Due to the requirements of the task given and the research questions, it is preferable to use the *design and creation* strategy. The strategy focuses on developing new IT products, which we have divided into concept creation, prototyping, implementation, and testing [142, p. 35]. The result is a new exergame ready for the experiment.

4.2.1 Concept Creation

The concept creation part will use the results from the prestudy in Part II to suggest several concepts for new exergames. The prestudy covers the topics: game genres, game enjoyment theories, available technology, physical activity, and existing exergames. Our goal is to create exergames that are enjoyable and motivate physical activity. We review each concept according to the criteria: technological feasibility, experiment feasibility, innovation, physical exertion, potential reach, and personal motivation. Based on the review, the exergame concept for the project is selected.

4.2.2 Prototyping

The selected concept is further developed into a prototype focusing on game enjoyment theories, physical activity, and usability. We start by detailing the exergame, covering the gameplay, design, and controls of it in Chapter 14. Further on, we will analyze it using the game enjoyment theories *GameFlow*, *Dual Flow*, and Malone's model. Using them helps to make the game more enjoyable and motivating, which is crucial when we want the game to motivate physical activity.

4.2.3 Implementation

The implementation starts by choosing technologies and documenting our requirements. The functional requirements define the specifications of our game regarding what it shall do, its behavior, and reactions. We also have non-functional requirements to help ensure high modifiability, usability, and performance in the game. The software architecture, explained in Chapter 19, describes the implementation and our rationale behind the architecture.

4.2.4 Testing

We test and evaluate the game's software during and after the implementation period to ensure it works as intended, which is a vital part of the creation process. We will use Trello to create tasks based on the functional requirements, and after its implementation, we both test its functionality. After the main development period, the functional and quality attribute requirements are tested.

4.3 Experiment

The *experiment* strategy follows the design and creation strategy, and we use it to answer the research questions regarding our exergame described in Chapter 3. Oates defines an experiment in academic research as a "*strategy that investigates cause and effect relationships, seeking to prove or disprove a causal link between a factor and an observed outcome*" [142, p. 127]. Our experiment starts by observing the participants while they play the game. Afterward, we gather more data through interviews and questionnaires of the participants. We use several data collection methods and data triangulation to improve the quality of the experiment.

4.3.1 Triangulation of Data

Triangulation of data is the process of using multiple methods, data sources, investigators, or theoretical perspectives to increase the validity and strength of a study [185]. These combinations are divided into four basic types of triangulation: *data triangulation*, *investigator triangulation*, *theoretical triangulation*, and *methodological triangulation* [45][185][193], where the last type is the most relevant one for this thesis.

Data triangulation involves using two or more data sources, including time, space, and person, to compensate for any weaknesses in the data and increase the validity of the results. It also gives the possibility of revealing atypical data or identifying similar patterns [185][193].

Investigator triangulation involves using several independent observers, interviewers, researchers, or analysts in the study. Observations have higher credibility if several investigators confirm the data without prior discussion and collaboration [185][193].

Theoretical triangulation involves using two or more theories or hypotheses when examining a situation or phenomenon. It can support or refute findings from the other theories and lend a greater understanding of their results [185][193].

Methodological triangulation involves using several methods to study a situation or phenomenon. Using several methods aims to decrease deficiencies and biases from any single method by utilizing strengths from other methods. It is similar to data triangulation, but it focuses on using data obtained by different methods rather than data collected for a different time, space, or location. There are two types of methodological triangulation: *within-method triangulation* and *across-method triangulation*. They refer to using methods within or across the same design approach. Methodological triangulation using only quantitative approaches or only qualitative approaches classifies as within-method, and if the triangulation uses both approaches, it classifies as across-method [185][193]. We will use methodological triangulation with across-method triangulation in the experiment. We use questionnaires, game recorded data, and heart rate monitoring to gather quantitative data, while observations and interviews are used to obtain qualitative data.

4.3.2 Observation

Observation is a "*data generation method to find out what people actually do, rather than what they report they do when questioned*" [142, p. 202]. It is a quick way to collect data, and it provides a means to gain insights into things that most participants render insignificant. Our type of observation is overt, meaning that the participants know they are observed. We will participate as complete observers, which means we observe everything that occurs, but we do not interfere in the proceedings. [142, p. 202-216] The participants are informed before the observation and can see the observers during the experiment. We will observe every participant when they play the game and write down notable comments and observations through the test. The results are used to answer the research questions regarding the exergame (RQ3 - RQ6, physical exertion, enjoyment/motivation/engagement, player experience, and challenges).

4.3.3 Questionnaires

Using questionnaires is an efficient method to collect standardized data from many people. The goal is to analyze and find patterns in the responses to generalize about a larger population than the sample. The questionnaire must be carefully designed and constructed to produce valid data. Therefore, we need to write the questions so that they are interpreted in the same way by all respondents, and they must be related to our research questions. We give the questionnaire to the participants after they have played the game. It is self-administered, meaning that they complete it on their own without our interference. There are two types of questions asked: factual data and opinions. The first type collects information about things like gender and age. The second type asks what they think about different aspects of the game, and the questions are mostly structured as a Likert scale from "strongly disagree" to "strongly agree" [142, p. 219-230].

4.3.4 Interviews

Interviews are suitable data generation methods to obtain detailed information or ask complex and open questions. It is also helpful for exploring the participants' emotions, experiences, or feelings. We will perform the interviews in a semi-structured format, with predefined topics and themes but few or no predefined questions. This format allows the interviewee to focus on what they want to share and for us to ask questions about our observations. The goal is to get a more in-depth understanding of the observations and participants' feelings [142, p. 186-195].

4.3.5 Game-Generated Data

Game-recorded data are data that the game generates and stores in a database, and it will aid our observations during the play session. It contains statistics for each run the participants take on a level and their total playtime. The run statistics include which user and level it belongs to, whether or not it was finished, its duration, and step and jump count. We can use this data to help answer RQ3 about physical exertion and understand the game better.

4.3.6 Heart Rate Monitoring

We will use a heart rate monitor on each participant to track their heart rate during their play session. The monitoring will help to answer RQ3 and support the players' perceived exertion with measurable quantitative data.

4.4 Data Analysis

The data generated from the experiment is either quantitative or qualitative. Oates (2006) describes them as "*Quantitative data is numeric data, for example, number of website hits, number of employees, annual turnover, last year's profit. Qualitative data is all other types of data: words, images, sounds, and so on*" [142, p. 36]. After generating the experiment data, we need to analyze it to look for relationships and themes. *Quantitative data analysis* uses statistics and other mathematical approaches to examine and interpret the data and is possible to apply to both quantitative and qualitative data. *Qualitative data analysis* looks for themes and categories in the qualitative data [142].

4.4.1 Quantitative

We will collect quantitative data from questionnaires, game generated data, and heart rate sensors. There are four main types of qualitative data: *nominal*, *ordinal*, *interval*, and *ratio* [142, p. 246-248]. The questionnaire provides *ordinal data*, which is ranked but the difference between the ranks are unknown. The game and the heart rate monitors generate *ratio data*, as all of the generated data starts as 0 and the intervals are proportionate.

When analyzing the data, we have the *null hypothesis* (H_0) of no group differences as our basis [142, p. 259]. In other words, we assume there is no true relationship between variables. We measure how far the data deviates from the prediction under H_0 and calculate the pre-experiment probability p that the outcome would be at least as far from H_0 as the results we observe. If this p-value is low, the deviation from the H_0-prediction is unlikely to happen by chance alone. With a p-value of 0.05 or less, the results are considered statistically significant, and H_0 can be discarded.

Mann-Whitney U test and two-sample t-test will be utilized to calculate the p-values. The *Mann-Whitney U test* is a nonparametric test that generates the p-value between two independent samples [114]. The ordinal data gathered will be analyzed using Mann-Whitney. We will use the *two-sample*

t-test for analyzing ratio data. The t-test assumes that the samples are independent, random, and from a normal distribution [180].

4.4.2 Qualitative

Observations and interviews from the experiments will provide qualitative data. Qualitative data is either textual or non-textual. Both observations and interviews generate textual data and will be analyzed separately. We will conduct a *theme analysis* on both data sources. Creating the overall categories will be done with a *deductive approach*, based on the research question themes. We will use a more freely *inductive approach* for sub-categories within each main categorization [142, p. 266-270].

4.5 Summary

This chapter described our use of Oates's research process to structure the thesis. The literature review, and our experiences and motivation, were used to refine the research goal into research questions. We will use the *design and creation* strategy to design, implement, and test our exergame concept. The *experiment* strategy follows the design and creation phase and will be used to gather data to answer the research questions regarding our exergame (RQ3 - RQ6). It uses data obtained from five different methods to increase its validity and strength. The quantitative data will be analyzed with *Mann-Whitney U test* and *two-sample t-test*, and qualitative data with a *theme analysis*.

Chapter 5

Report Outline

The report consists of the following eight parts:

Part I presents the project. First, the societal and personal motivations behind the project will be introduced, followed by a description of the project and its context. Next, the project's research questions and methods are presented before ending with a report outline.

Part II is the prestudy of the project. It starts by introducing exergames before reviewing game genres. Next, three different theories for designing enjoyable games are reviewed. Furthermore, relevant technologies are analyzed, and challenges to global public health are discussed. The part ends with a study on existing exergames and how they increase the general public's physical activity level. This part is based on the specialization project (see Chapter 2).

Part III presents our concept for a new exergame. First, the results from the prestudy are used to suggest several new exergame concepts, one of which will be the primary one for the report. All concept ideas are reviewed according to relevant criteria, including technological feasibility, physical exertion, and innovation. Next, the primary concept is presented in more detail before it is analyzed using the game enjoyment theories. Then it is evaluated according to its physical activity aspect. This part is based on the specialization project (see Chapter 2).

Part IV presents the implementation. It starts by describing and justifying our chosen technologies before showing the game's functional and non-functional requirements. Next, it shows the software architecture. Then, the software testing is described, including the implementation status of the functional requirements and the quality attribute scenarios. The part ends by showing how we designed the visual and audio aspects of the game.

Part V presents the experiment design. First, it explains the experiment execution, including ethics, participant recruitment, experiment setup, and the data analysis methods. It ends by describing the different types of data we gather during the experiment and how we gather it.

Part VI presents the results from the experiment. It starts with the test population and the different groups used for the data analysis. Next, it gives the results for the physical activity, enjoyment, motivation, engagement, and gameplay and challenges.

Part VII is the discussion of the results. It starts by discussing the game's physical aspect before reviewing the enjoyment, engagement, motivation, and game design results. Lastly, it discusses factors that may affect the validity and reliability of the data generated in the experiment.

Part VIII is the conclusion of the report. It starts by answering the research questions presented in Part I. Then, we suggest future research and development for the project.

Different parts of the report may be of more interest to the reader than others. For theoretical information from the literature review, read the prestudy (Part II). For information about the game concept, the most relevant chapter is Chapter 14. Part IV contains technical details about the concept, including requirements and architecture. Part VI shows the results from the user testing, and Part VII discusses the results. Conclusion to the research questions is presented in Chapter 34.

Part II

Prestudy

Part II is the prestudy of the project. It starts by introducing exergames before reviewing game genres. Next, three different theories for designing enjoyable games are reviewed. Furthermore, relevant technologies are analyzed, and challenges to global public health are discussed. The part ends with a study on existing exergames and how they increase the general public's physical activity level. This part is based on the specialization project (see Chapter 2).

Chapter 6

What Are Exergames

This chapter presents the concept of exergames. It starts by defining exergames, followed by a brief history of exergames and a description of pervasive games.

6.1 Defining Exergames

Exergames, also called fitness games, are a combination of video games and physical activity [60]. The word *exergame* is often described as a portmanteau of the words *exercise* and *game*. However, this is an inaccurate representation of what exergames are due to the definition of exercise [143]. A more accurate combination of words would be *exertion* and *game*. Exergaming is defined as "*an experiential activity in which playing exergames or any videogames that require physical exertion or movements that are more than sedentary activities and also include strength, balance, and flexibility activities*" [143]. This definition will be used throughout the project, meaning that exergames are a combination of games and physical activity that is not sedentary.

6.2 History of Exergames

The exergame industry started in the early eighties when the *JoyBoard* for the Atari 2600 video game console was launched [62]. The *JoyBoard* was used as input for games, making the player balance on the board [92]. In 1982, Atari almost launched a system named the *Atari Puffer* project. The *Atari Puffer* would be a pedal system, where the player used a bike as input [62]. However, due to financial reasons, the Atari Puffer was never released. In 1988, Nintendo released the *Power Pad* for the Nintendo Entertainment System (NES) in the United States [21]. The *Power Pad* is a floor mat game controller with twelve pressure sensors [154]. The majority of games for the Power Pad were designed for professional athletes, but they were considered unsuccessful because of the controller's inaccuracy [62]. Nonetheless, the Power Pad saw success with some games, for example, *Dance Aerobics*, that simulated an aerobic class [21][39].

In 1992, two new exergames were provided to fitness centers, *Tectrix VR Bike* and *VR Climber* [62]. *Tectrix VR Bike* had a similar pedal concept as the Atari Puffer, where the player used a bike as the controller. Figure 6.1a displays the bike in use. One version of the Tectrix VR Bike was developed for military usage. *VR Climber* was similar to the Tectrix VR Bike, but with an apparatus step instead. The VR Climber system is shown in Figure 6.1b. Neither game had much commercial success due to their high cost.

(a) Tectrix VR Bike (b) VR Climber

Figure 6.1: The VR exergames created in 1992.

One of the most successful commercial exergames came in 1998, called *Dance Dance Revolution* (DDR) (see Section 11.1) [62]. It had a dance mat (see Section 9.4), making the players move to the rhythm of songs. The game made the players reach a cardio expenditure level recommended by the American College of Sports and Medicine (ACSM). At first, DDR was only accessible in arcades. Later it was ported to the PlayStation, where it sold over three million copies [60].

In the 2000s, exergaming had become much more prominent as a game category. In 2003, the *EyeToy* camera was released for PlayStation 2 (PS2) [60]. This camera could track movement, which would be used as input for games. The EyeToy sold over ten million units and had successful games such as *EyeToy Play*. It was also used for mini-games in popular franchises, for example, the *Harry Potter and the Prisoner of Azkaban* game for PS2 [77]. Figure 6.2 shows the EyeToy camera and gameplay of the game EyeToy: Play, where the players use their bodies to remove soap from the screen within a time limit. Later in the decade, the *Nintendo Wii* was launched, which utilized a motion control for input [136]. The Nintendo Wii saw big success, and other companies followed as a result. For example, the Kinect for XBOX and PlayStation Move for PlayStation (see Section 9.3). The following decade saw the launch of popular exergames such as *Wii Fit*, *Beat Saber*, *Pokémon Go*, and *Ring Fit Adventure* (see Chapter 11).

(a) Gameplay visualisation of EyeToy: Play (b) EyeToy camera

Figure 6.2: Photos of the EyeToy accessory and its usage for the PlayStation 2.

Exergames have become increasingly relevant as a resource for active living and a healthy lifestyle [62]. The *Wii Fit* demonstrated that exergames could be viewed as a *home fitness center*. It motivated the players to become physically exerted and gave health improvement advice. For example, the *Wii Fit* would provide personalized tips together with a body test [215], offering the player increased knowledge about their physical health and how to improve it.

6.3 Pervasive Games

Pervasive games is a relatively new game genre, blending the real world with the game world [111]. A *pervasive game* is defined as "*a game that has one or more salient features that expand the contractual magic circle of play socially, spatially, or temporally*" [129]. The *magic circle* refers to the boundaries of play. A pervasive game is, in other words, a game that blurs the line between the game and the physical world either socially, spatially, or temporally. To expand a game *socially* means including a social aspect into the game, for example, making unknown players interact with each other. *Spatial* expansion makes the game location unlimited or unclear. Lastly, *temporal* expansion means intertwining the game session with the real world. A pervasive game example is *Pokémon Go*, which expands all these three elements. *Pokémon Go* expands *spatially* through being location-aware, *socially* by adding elements such as raids, and *temporally* by providing notifications. There are many different sub-genres of pervasive games, for example, *smart toys*, *affective games*, *table top games*, *augmented reality games*, and *location-aware games* [111].

Exergames can be viewed as a type of pervasive game. Exergames often provide a physical or spatial expansion by using unique input sensors. For instance, the Wii Balance Board and DDR use specific controllers, and other games use non-console controllers, such as GPS. Social and temporal expansions can also be a part of exergames. Therefore, exergames and pervasive games have a lot in common because both blur the line between the physical world and the game world.

6.4 Summary

Exergames are a combination of *exertion* and *games*, which aim to motivate players to perform physical activity through gameplay. The exergame genre can also be seen as a type of *pervasive game* due to the usage of physically measurable data, which often blurs the line between the game and the real world. The history of exergames starts in the eighties with the *JoyBoard* and the *Atari Puffer*, which used specific devices requiring the player to be physically active as input. Later, the exergame genre would see popular games using devices such as the *dance mat*, *EyeToy camera*, *Wii motion controller*, *smartphone* and *VR-headset*. Many of the first exergames struggled due to technological constraints and imprecise input sensors. After several decades of technological improvement, exergames are now more viable. For example, the *JoyBoard* was a balancing board controller which suffered due to inaccuracy, but later the Wii Balance Board would provide a similar exergame idea with more success. Some modern exergames can also be viewed as *home fitness centers*.

Chapter 7

Game Genres

This chapter highlights different game genres, with their usage and suitability within exergames. The genres included are some of the most commonly defined game genres, presented in alphabetic order [110].

7.1 Adventure Games

Adventure games focus on narrative, puzzles, and exploration, without reflex challenges [118][110]. These games can either be text- or graphics-based [4]. They often lack action, making the games' demographic wider. Implementation of social interaction is problematic due to the centralization of story and player creativity. The genre peaked in popularity in 1993 because of the best-selling PC game up to that point being released, *Myst*. Figure 7.1 shows the graphics within Myst. There have not been any widely known exergames within this genre, most likely because of the absence of action and time constraints. Therefore, creating an adventure exergame would be a challenge, but it might provide a new and unique exergame.

Figure 7.1: Screenshot of the adventure game *Myst*.

7.2 Fighting Games

Fighting games focus around battles between 2 or more players [110]. The combat style is often meleed and takes inspiration from different martial arts. Some popular fighting game franchises are *Mortal Combat*, *Street Fighter* and *Super Smash Bros.*, where the latter is shown in Figure 7.2. No widely known fighting exergames are currently on the gaming market, but a previous master's thesis [197] illustrates possible success with fighting exergames. The game named *Super Stomp* is an example of a fighting exergame using trampolines as input [94]. A fighting exergame can be

seen as a natural combination since fighting already involves physical activity.

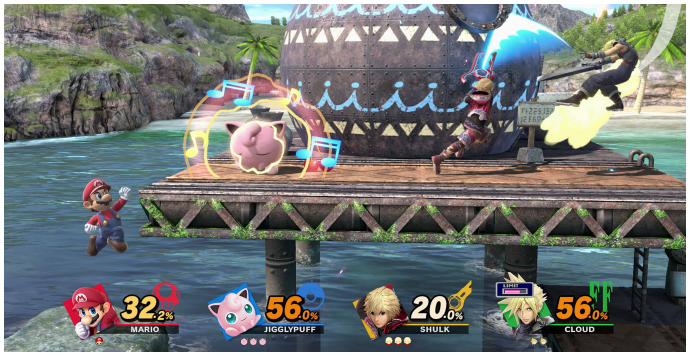


Figure 7.2: Screenshot of the fighting game *Super Smash Bros. Ultimate*.

7.3 Idle Games

A relatively new game genre is *idle games*, where the player interaction with the game is minimal-to-none [5]. These games often continue even while the application is closed. The core mechanic of the games is usually simple, such as clicking or rubbing. Idle games have a gameplay cycle that starts with an *active participation*, followed by an *inactive progress*, and then a *return reward* phase [198]. A screenshot of the popular *Cookie Clicker* idle game is shown in Figure 7.3, where the core mechanic is to click on the cookie.

Idle games have much potential within exergames. There exist guidelines for long-term engagement and mitigation of the snowball effect within idle exergames [198]. There has not been any widely popular idle exergame, but idle gameplay has been a part of existing exergames. For example, *Pokémon Go* (see Section 11.7) provides an *adventure sync* option, which tracks the player even when the application is closed [133]. This mechanic allows the player to hatch eggs while the game is idle and get the reward when opening the application.

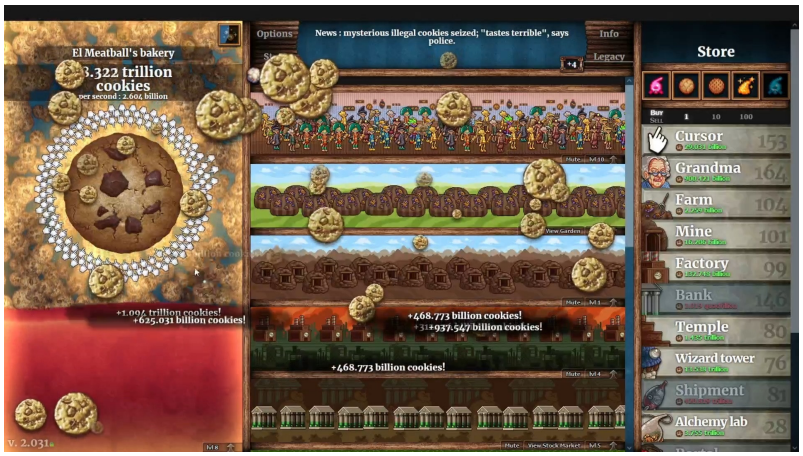


Figure 7.3: Screenshot of the idle game *Cookie Clicker*.

7.4 Massively Multiplayer Online Games (MMO)

Massively Multiplayer Online (MMO) games are games where thousands of players simultaneously interact with the game and each other [106]. *Massively Multiplayer* refers to the massive player base supported by the game, and *Online* requires the game to be network-based [175]. MMOs

usually focus on player communication and collaboration. The most popular subgenre is to mix MMOs with RPGs, creating MMORPGs. Figure 7.4 displays a screenshot of *World of Warcraft* from 2007, where two players in a group are sitting next to each other.

Research of MMOs often focuses on their social aspects or learning possibilities [175]. However, there does exist some research on MMO exergames (MMOEs) and games that incorporate some aspects of the MMO genre [91]. A framework for MMOEs that combines exergames, pervasive games, and MMOs to provide a social and physically measurable long-term engagement is also available. Popular exergames such as *Pokémon Go* (see Section 11.7), and *Run an Empire* (see Section 11.10) can all be considered MMOs because of their large player base that can interact with other players.

Figure 7.4: Screenshot of the MMO game *World of Warcraft*.

7.5 Open World Games

Open world games, also associated as *sandbox games*, are not specifically a game genre but rather a gameplay aspect often used to describe games. Even though *open world games* is not a game genre, it is included in this list due to the usage of the term as a game genre. *Open world games* are games that provide the player with a big open world to explore, often combined with freedom and creativity. There is usually no requirement for the player to follow a linear path toward the goal, and some open-world games do not have any predefined goals. A popular open-world game is *The Legend of Zelda: Breath of the Wild*, shown in Figure 7.5 [110].

Location-based exergames can be viewed as open-world games since using the real world as the game world provides a big and open game world. Multiple exergames do this and use the player's location to place them in the game world. For example, *Pokémon Go* (see Section 11.7), and *Run an Empire* (see Section 11.10) are both location-based, and can therefore be seen as open-world games. They demonstrate that the open-world game genre can provide the potential for more successful exergames.

Figure 7.5: Screenshot of the open world game *The Legend of Zelda: Breath of the Wild*.

7.6 Party Games

Party games are designed for multiplayer and often provide a wide range of mini-games [110]. These games are often played cooperatively on one screen. Figure 7.6 shows gameplay of a mini-game from *Mario Party*. There have not been any widely known exergames within this genre. However, this provides possibilities for new concepts within exergames.

Figure 7.6: Screenshot of the party game *Mario Party*.

7.7 Platform Games

One of the first developed game genres was *platform games*, also referred to as *platformers*. *Platform games* focus on controlling a character by running and jumping concurrently while avoiding obstacles or defeating enemies. Figure 7.7 shows a screenshot of the popular arcade game *Donkey Kong*, where the player had to jump between platforms. Even though the platform game genre is old, it is still popular. In modern times, a sub-genre called *endless runners* emerged on primarily smartphones. *Endless runners* provide simple input where the levels are endless, and the playable character runs automatically [126].

No widely popular platform exergames are known. However, a paper by Erhard-Olsson shows that it is possible. He created a platformer exergame where a motion controller controls the character. The motion controller tracked the player's movement through a camera, and there were high

amounts of physical activity in the results [55]. It is, therefore, potential for new and successful platformer exergames.

Figure 7.7: Screenshot of the platform game *Donkey Kong*.

7.8 Rhythm Games

The *rhythm games* genre started in the seventies and revolves around music [159]. *Rhythm games* challenge the player to do some action in sync with the game music, and it is often to press a button [174]. This genre spawned some very successful games, such as *Guitar Hero*, *osu!* and the popular exergame *Dance Dance Revolution* (DDR) [159]. The gameplay from *osu!* is shown in Figure 7.8, where players have to press the circles on the screen at the right time.

Rhythm games and exergames is a prominent combination within the game industry. Games like *Dance Dance Revolution* (DDR) (see Section 11.1), *Just Dance* (see Section 11.5), and *Beat Saber* (see Section 11.8) are some of the few popular rhythm exergames that exist [159]. As mentioned in Section 6.2, DDR provides physical activity that made the players reach a cardio expenditure level recommended by the American College of Sports and Medicine (ACSM) [62].

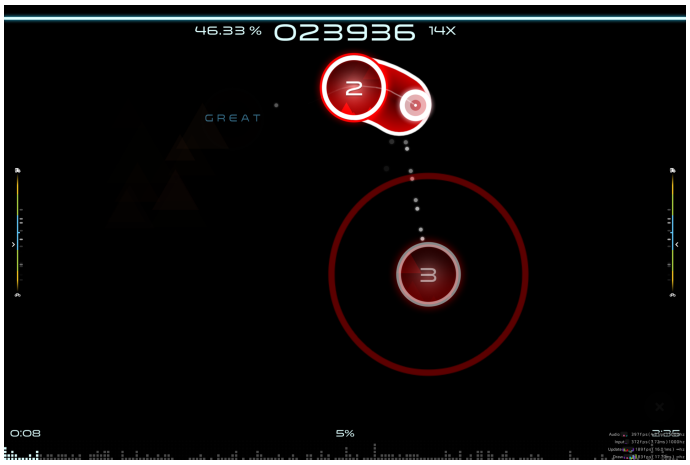


Figure 7.8: Screenshot of the rhythm game franchise *osu!*.

7.9 Role-Playing Games (RPG)

The popular video game genre *role-playing games* (RPGs) stems from the traditional role-playing games, such as *Dungeons and Dragons* [106]. The video RPG genre bloomed from the digitization of these physical role-playing games, where the computer got the gamemaster role. In RPGs, the player controls a character in a well-defined world, and the character can often develop [163]. The genre is quite wide and includes sub-genres such as MMORPGs, JRPGs, and Action RPGs. Examples of RPGs include *The Elder Scrolls V: Skyrim*, *Final Fantasy* franchise, and *Pokémon*. *Pokémon* is the best-selling RPG series worldwide, and is shown in Figure 7.9.

Many exergames can be classified as RPGs due to the genre's wide definition. Having a player-controllable character that develops inside a defined game world is quite common in games. Therefore, games such as *Pokémon Go* (see Section 11.7) are RPG exergames. However, the newly released *Ring Fit Adventure* (see Section 11.9) is a prime example of combining exergames and RPGs. In *Ring Fit Adventure* the player controls a character and explores a fantasy adventure world while developing the character. All main RPG characteristics, such as a story of saving the world, exploration, quests, items, inventory, character abilities, experience points, levels, and combat, are all present in the game. It shows that there is a high potential for creating successful RPG exergames.

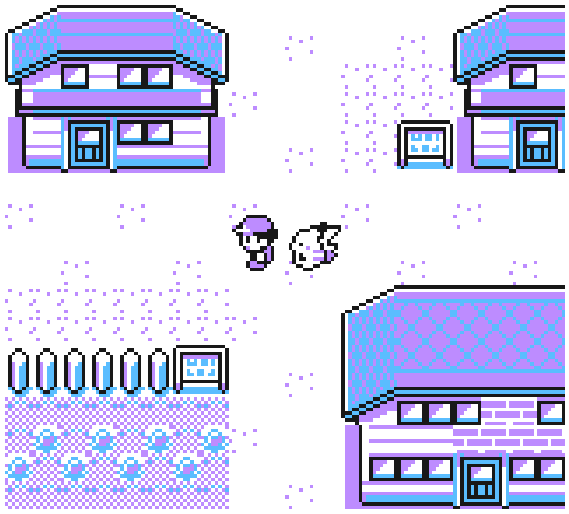


Figure 7.9: Screenshot of the RPG game *Pokémon Yellow*.

7.10 Simulation Games

Simulation games are games that focus on replicating a fictional world or the real world [110]. The simulation often tries to be as accurate as possible. The three main types of simulation games are *life*, *vehicle*, and *construction and management*. One of the most well-known simulation game franchises is *The Sims*, shown in Figure 7.10. There have not been any widely known exergames within the simulation game genre. However, prior research has been conducted on the creation of a virtual pet simulation exergame [38].

Figure 7.10: Screenshot of the simulation game *The Sims 4*.

7.11 Sports Games

Sports games can be seen as a sub-genre of *simulation games*, because they simulate sports [110]. The *sports games* genre revolves around either playing or managing the sport. This genre is one of the oldest, since the first interactive computer game was a simulation of tennis called *Tennis for Two*, which was developed in 1958 [146]. There are still popular sports games being developed in modern times, for example, *Madden NFL*, *Rocket League*, and *FIFA*, the latter is shown in Figure 7.11.

There are multiple sports exergames already present on the game market. Physical sports already provide physical activity to the players. By simulating a sport, adding physical activity comes quite naturally. Exergames such as *Wii Sports* (see Section 11.3), *Wii Fit* (see Section 11.4), and *EA Sport Active* (see Section 11.10), all provide a combination of sport mini-games.

Figure 7.11: Screenshot of the sports game *FIFA 21*.

7.12 Stealth Games

Stealth games focus on challenges where the players have to avoid being seen [98]. The scene of a stealth game is often a guarded area that the player has to sneak through by using different gameplay mechanics. Stealth games are considered slower than other game genres due to players planning how to evade confrontations. Examples of stealth game franchises are *Metal Gear Solid*,

and *Sly Cooper* [110]. Figure 7.12 displays gameplay of *Sly Cooper and the Thievius Raccoonus*, where the player is hiding from a guard. There are no widely known stealth exergames. Nonetheless, using a combination of low-intensity activity during stealth sections and more high intensity when the player is spotted might achieve interval training.

Figure 7.12: Screenshot of the stealth game *Sly Cooper and the Thievius Raccoonus*.

7.13 Strategy Games

Strategy games evolved from board games [110]. The player usually has an overview of the whole game state and requires skillful planning. Strategy games are often categorized as either *turn-based* or *real-time*. However, a combination is also possible, as proved in *Valkyria Chronicles*, which uses both turn-based and real-time [196]. The two types of gameplay are displayed in Figure 7.13. Combining strategy games with exergames can provide difficulties due to the strategy games' slow pace. The slow pace might fit exergames focusing on strength training, as shown with the strategy card game *Brain & Brawn* [160]. The successful strategy exergame *Run an Empire* (see Section 11.10) also shows that combining strategy games and exergames is possible.

(a) Turn-based (b) Real-time

Figure 7.13: Screenshots of the strategy game *Valkyria Chronicles*.

7.14 Survival Games

Survival games revolve around collecting resources used to survive in a dangerous environment [110]. The goal of *survival games* is often to live as long as possible. A popular overlapping genre is *survival horror games*. *Survival horror games* add supernatural and horror elements. Some

examples are the *Resident Evil* and *Silent Hill* franchises. Figure 7.14 shows gameplay from *Silent Hill*. The popular exergame *Zombies, Run!* (see Section 11.6) is a *survival horror game* that shows a successful combination of the genre and exercise.

Figure 7.14: Screenshot of the survival game *Silent Hill 2*.

7.15 Summary

This chapter has presented different game genres and their suitability for exergames. Some of these categories already have many exergames, such as *rhythm games* and *sports games*. These two genres provide a natural link to exertion as dancing and sports provide physical activity naturally. Other genres that have successful exergames are *MMO*, *open world*, *role-playing*, *strategy* and *survival* games. The rest of the genres are less used within exergaming, often due to pacing difficulties. However, they provide opportunities for new and innovative exergame concepts.

Chapter 8

Theories of Designing an Enjoyable Game

Enjoyment is an essential element of creating exergames. If an exergame, or any game, is unenjoyable, it will not be played. Making it enjoyable causes the player to get physical activity while enjoying themselves. Therefore, creating an enjoyable exergame is crucial to generating motivation for physical activity.

This chapter will present three different player enjoyment models for games. The first is the *GameFlow* model, used to evaluate the player's enjoyment of a game according to the attributes: concentration, challenge, player skills, control, clear goals, feedback, immersion, and social interaction [181]. The second model illustrates how to use *challenge, fantasy, and curiosity* to make a game fun [112]. Lastly, the *Dual Flow* framework will be presented, which depicts a method to evaluate an exergame using its attractiveness and effectiveness [168].

8.1 GameFlow

The GameFlow model is based on the psychology field's *flow* model made by the psychologist Mihaly R. Csikszentmihalyi. The flow model is a general model which illustrates how to achieve enjoyment [37]. When someone gains a deep sense of enjoyment, it is called an *optimal experience* or *flow*. The flow state is *autotelic*, which means the experience itself becomes rewarding. Flow is reached when these eight components are present [181]:

1. A task that can be completed
2. The ability to concentrate on the task
3. That concentration is possible because the task has clear goals
4. That concentration is possible because the task provides immediate feedback
5. The ability to exercise a sense of control over actions
6. A deep but effortless involvement that removes awareness of the frustrations of everyday life
7. Concern for the self disappears, but the sense of self emerges stronger afterward
8. The sense of the duration of time is altered

There are many different ways to achieve the flow state. A person can reach it as long as an activity can complete the eight mentioned elements. This requirement means anything from the body to the mind can be a means to deep enjoyment. It is mentioned that " *The more a job resembles*

a game with variety, appropriate and flexible challenges, clear goals, and immediate feedback, the more enjoyable it will be regardless of the worker's level of development." [37]. The quote indicates that, for example, physical activity can be made more enjoyable through exergames.

The *GameFlow* model takes the structural foundation of the flow model and narrows it down to game enjoyment [181]. Through the eight flow components: concentration, challenge, player skills, control, clear goals, feedback, immersion, and social interaction, it maximizes enjoyment. *Immersion* represents both flow component 7 and 8, and *social interaction* is new. All elements have their unique criteria, which together can produce an overall game enjoyment rating. There also exists a modified version of the criteria that focuses on pervasive games, called *pervasive game flow*. However, this project will focus on the GameFlow elements and criteria.

Concentration

The player must be able to *concentrate* on the game to be able to enjoy it. In other words, the game should grab the player's attention and maintain it. The player must be given enough central tasks, but not too many. Additionally, the game should minimize distractions, such as unnecessary user interface elements, to maintain the player's concentration.

Challenge

Within game design, *challenge* is considered the most vital component. The player would be reluctant to play the game if the challenge level does not match his skill because too much challenge creates anxiety and too little results in apathy. Therefore, the game's challenge level must match the player's skill and follow their learning curve. Having different player-choosable challenge levels can accomplish a balanced game.

Player Skills

A good game should facilitate *player skill* progression. The player should not be required to read any manuals or other exterior content to play the game. The game itself should teach the player how to play through a non-intrusive short tutorial with as little text as possible. Too much text breaks the immersion, and the game might be perceived as boring. The player's learning speed will increase by following user interface trends and using appropriate analogies from the real world. After the player has learned the basics of the game, the game should reward them for their continued play.

Control

Another influential part of game enjoyment is *control*. The player must be able to translate their desired action into the game, either through the character, interactions, impact on the game world, user interface, or game shell. Different people may want to interact with a game in distinct ways, so games should allow customization of the controls. One example is to let the players choose the input buttons for each action. In other words, giving the player control to interact with the game in their desired way gives them more enjoyment.

Clear Goals

To be able to achieve flow, games must have *clear goals*. A *clear goal* should be simple and easy to understand. The game should provide the overriding one early and the intermediate ones later at appropriate times. One example is to show the main goal in a cinematic scene at the beginning while giving small intermediate goals throughout the game. To put it concisely, giving the player an easy-to-understand goal early in the game provides more enjoyment.

Feedback

Feedback makes the player understand how the game interprets their actions. It is important to give players immediate feedback on their performed actions, status, and progress in the game. It makes the player understand the game's internal state more easily. A game can give feedback through in-game interfaces and sound. In conclusion, immediate feedback can make games more enjoyable for players and help them reach flow.

Immersion

In the GameFlow model, to be *immersed* means that "*players should experience deep but effortless involvement in a game*" [181]. GameFlow's immersion contains Csikszentmihalyi's 7th and 8th flow components, where the player loses concern for both themselves and time. The loss creates an experience where the player interacts with the game without noticing the interface. When a game immerses a player, it is often portrayed as an escape from the world. A game can create more immersion for a player by using a compelling narrative and audio such as sound effects and soundtrack.

Social Integration

Players receive higher enjoyment from a game if it supports *social interactions* with other players. The GameFlow's social interaction component is not part of Csikszentmihalyi's flow model and can be seen as an immersion breaker [37]. However, social interaction has proved to be a significant element of game enjoyment. Competition, cooperation, and connection can all create game socialization. Games should also support in-game chat and online boards.

8.2 Challenge, Fantasy, and Curiosity

The three categories presented in this section are created by MIT professor Thomas W. Malone and provide a taxonomy of motivation needed to make an activity rewarding in itself [112]. Creating a fun game is assisted by using the categories as heuristics or guidelines. Good games and general enjoyable situations both consist of *challenge, fantasy, and curiosity.*

Challenge

For a game to be fun and challenging, it has to have a good *goal.* For a simple game, it has to be clear and compelling. More complex games should be structured so that players themselves can create appropriate, challenging goals. A good goal should be practical or fantasy-related rather than just using a skill. An example of this is to have a goal of saving a village instead of just pressing buttons. Additionally, the player should get performance feedback during gameplay, showing their progression towards the goal.

Another way to create an appropriate challenge level in a game is by adding *uncertainty.* Games become dull if the player already knows if they will win or lose. There are four ways to generate it in a game. Firstly, by adding variable difficulty levels, chosen either by the game, the player, or an opponent. Secondly, a game should provide several level goals, including primary and meta goals. Another way to create uncertainty is by hiding information from the player, which can cause both challenge and curiosity. Lastly, it will increase by adding randomness into a game.

Having the right challenge level will increase the player's *self-esteem* and make the game more fun. Self-esteem is connected to success and failure in games. Completing goals creates enjoyment while failing them decreases their self-esteem and desire to play. Therefore, games should have variable difficulty levels so that the challenge matches the player's skill. Performance feedback should also minimize self-esteem damage.

Fantasy

Fantasy is defined as the ability to "*show or evoke images of physical objects or social situations not actually present*" [112]. Malone separates it into two categories: *extrinsic fantasy* and *intrinsic fantasy. Extrinsic fantasy* is domain-independent use of skill, where the skill does not depend on the fantasy itself. On the other hand, in *intrinsic fantasy*, it depends on the skill and vice versa. Figure 8.1 displays the skill and fantasy dependencies in the two different fantasy categories. Intrinsic fantasies can be seen as more interesting since it uses elements from the fantasy world to illustrate the problems presented by the game.

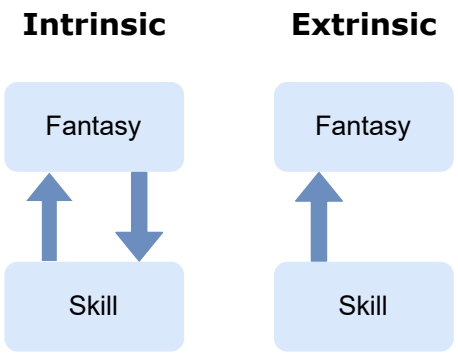


Figure 8.1: Dependencies between *skill* and *fantasy* in *intrinsic fantasy* and *extrinsic fantasy* [112].

The *emotional* aspects of fantasy also create fun. Games that include emotionally involved stories, for example, war, destruction, or competition, are considered more fun. However, people are unique and find enjoyment in different fantasies. For example, one person might enjoy a game based around a war fantasy, while another does not find it appealing. Games can reach a broader audience by having many different fantasies.

Curiosity

Curiosity is motivation to learn, which makes an activity more fun. An environment that has an optimal level of information complexity evokes it in its players. In other words, the environment must be novel, surprising, and comprehensible to the player. Too much or too little complexity will not evoke it. Therefore, the environment must have the right amount of complexity.

There are two different kinds of curiosity: *sensory curiosity* and *cognitive curiosity*. Changes in stimuli patterns such as light and sound evoke *sensory curiosity*. Using audio and visual effects in games can thus create sensory curiosity. The effects can be used as, for example, decoration, fantasy enhancement, a reward, or a representation of the system. By applying sensory effects to create curiosity, a game becomes more fun.

Cognitive curiosity, on the other hand, comes from the desire to complete one's knowledge structures. People wish for completeness, consistency, and parsimony in their cognitive structures. If it is incomplete in any way, then curiosity will arise. This incompleteness is achievable by withholding information from the player. Giving the player surprising feedback creates curiosity, which can be done through, for example, randomness or incomplete knowledge. A game can also maintain a cognitive model of the player, making it possible to tailor the feedback, which in turn maximizes the player's curiosity.

8.3 Dual Flow

The Dual Flow model illustrates factors for successful exergames [168]. It takes the previously mentioned *GameFlow* and *challenge, fantasy, and curiosity* models and builds further upon them. According to the research, the main two success factors for an exergame are *attractiveness* and *effectiveness*. Figure 8.2 shows the two success factors and the importance of balance to achieve flow.

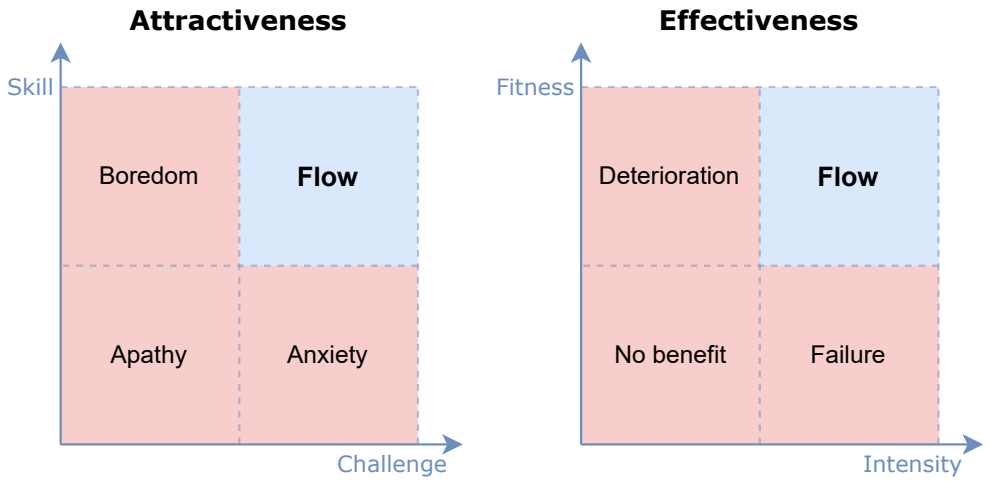


Figure 8.2: The two exergame success factors illustrated through flow [168].

Attractiveness

The *attractiveness* of a game is based on the idea of flow, the GameFlow model, and the challenge, fantasy, and curiosity model for fun. The models show how to make a game that maximizes enjoyment and makes the game attractive to players. The most important part of attractiveness is the correct balance between challenge and skill. As mentioned in Section 8.1, it requires a good match of player skill and challenge to achieve flow.

Effectiveness

A similar execution of flow, as with attractiveness, is done to illustrate the *effectiveness* of an exergame. Here, the player's skill level is represented by the player's fitness, and the challenge is the intensity of the activity. Too high of it for the player leads to failure. On the other hand, too little either results in no benefit or deterioration. Therefore, having a good balance between intensity and fitness is crucial to achieving flow for the effectiveness component.

8.4 Summary

This chapter has presented three different models for game enjoyment. Designing a motivating exergame will be more feasible by considering the previously described models. It is not required to fulfill all of the requirements to be able to create an enjoyable game [181]. However, being aware of the enjoyment components helps design a more fun game.

GameFlow is the first model presented, structured on the general idea of flow. Achieving a flow state through a game makes the experience itself the reward by being highly entertaining. The enjoyment components in games are concentration, challenge, player skills, control, clear goals, feedback, immersion, and social interaction. The *challenge* element of GameFlow, matching game challenge and player skill level, is considered the most important one.

Malone's model illustrates how to create a fun game by using *challenge, fantasy, and curiosity.* Games should have the right amount of challenge with goals, uncertainty, and variable difficulty levels. A fantasy that is exciting for a broad audience is also crucial. Adding both sensory and cognitive curiosity with an optimal level of information creates fun.

The last model, *Dual Flow*, is also based on the flow idea. Dual Flow separates a game's attractiveness and effectiveness into different dimensions. Both attributes must be in the flow state for an exergame to succeed. In other words, an exergame should have a good balance between challenge versus skill and intensity versus fitness.

One important takeaway is the importance of *challenge*. All the presented models mention that the challenge is of great importance. Therefore, the new exergame concept should focus on having a good challenge for the players. There are multiple ways to achieve a good challenge level. For example, having different choosable challenge levels will increase the number of possible players. Adding uncertainty and goals is also crucial for the challenge attribute, and both attractiveness and effectiveness should be thoroughly user-tested. All criteria listed are not necessarily required, but the challenge level is necessary to keep in mind during the game design.

Chapter 9

Technology Review

This chapter presents the relevant technologies used to develop exergames on different game platforms.

9.1 Smartphones

This section reviews how sensors in smartphones can be used to create exergames. Mobile gaming is dominating the gaming market [128] and approximately 96% of Norwegians owned a smartphone in 2020 [178]. Most smartphones have a set of sensors that can collect input data from the physical world, and unlike console exergames, mobile exergames could take place outdoors [73][24]. Together, these factors make smartphones a suitable technology platform for exergames.

9.1.1 GPS

The Global Positioning System (GPS) is a satellite-based navigation system that allows smartphones to receive their geographic location and time information, provided that they have a GPS receiver. GPS is commonly used in mobile exergames, e.g., in *Pokémon Go* and *Zombie, Run* [108].

GPS-enabled smartphones usually have an accuracy of 4.9 meters under the open sky. However, the accuracy decreases when in proximity to buildings, bridges, and trees [191]. This property makes GPS-based exergames suitable for games with a large playing field, like *Pokémon Go*, but less suited for fast-paced games located in smaller areas, for instance, running between checkpoints in a park.

9.1.2 Pedometer (step counter)

Pedometers are used to count steps by utilizing the built-in accelerometer in smartphones. Both Android and iOS have support for retrieving the daily step count and adding event listeners to get live walking data [69][8]. This support makes it possible to create exergames based on the user's walking activity.

However, we have not been able to find up-to-date information about the step accuracy and time difference between the physical step and the received event from the listener. Therefore, if we want to utilize this feature in the concept, a small practical study to test the reliability of the listeners should be conducted.

9.1.3 Augmented Reality

Borko Furht defines Augmented Reality (AR) as "*a real-time direct or indirect view of a real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it*" [64, p. 3]. Smartphones can be used as a handheld display that uses video-see-through techniques to enhance the video with graphics onto the environment. AR in smartphones is achieved with the phone's CPU, camera, accelerometer, GPS, and solid-state compass. The input device for controlling the application could be the phone itself, for instance, used as a pointing device [64, p. 10-12]. Both iOS (ARKit) and Android (ARCore) have frameworks for developing native AR applications [7][70].

9.1.4 Health and Fitness Data

Apple Health and Google Fit (Figure 9.1) are health platforms created by Apple and Google, respectively. Both platforms use the phones' sensors and connected activity wristbands to monitor and record the user's health-related data into one application. Examples of data collected are step count, walking distance, and exercise time [6][68]. Both platforms provides APIs giving other applications access to this data (with user permission) [9][72]. The APIs provide an easy way to track users' activity levels in an exergame without accessing the phone's raw sensor data.

Figure 9.1: Apple Health (left) and Google Fit (right).

9.1.5 Other Sensors

This section shows an overview of other sensors that may be relevant when creating a mobile exergame. Both Android and iOS have support for retrieving raw sensor data in applications [73][10].

Accelerometer

The accelerometer sensor "*measures the acceleration force in m/s2 that is applied to a device on all three physical axes (x, y, and z), including the force of gravity*" [73]. It makes detecting the phone's physical movements in space possible, enabling an exergame to use the device as a motion controller.

Proximity Sensor

The proximity sensor "*measures the proximity of an object in cm relative to the view screen of a device*" [73]. Helpful if one needs to detect how close to the phone the user is. For instance, the game Exermon uses the proximity sensor to register push-ups by placing the phone on the floor below the player's chest [82].

Gyroscope

The gyroscope "*measures a device's rate of rotation in rad/s around each of the three physical axes (x, y, and z)*" [73]. The sensor makes it possible to detect the player rotating the phone. It is possible to use it with the accelerometer to get a more accurate controller.

Barometer

The barometer measures the ambient air pressure in hPa or mbar [73]. It can be helpful if the game design needs to detect changes in the device's altitude. An example of this is an exergame that determines the players' physical activity using the number of stairs climbed and steps walked.

Magnetometer

The magnetometer "*measures the ambient geomagnetic field for all three physical axes (x, y, z) in μT*" [73]. This sensor makes it possible to use the device as a compass and give directions in exergames.

9.2 Activity Wristband

Activity wristbands are devices that monitor and track a person's daily physical activity and other health-related data. Which metrics are collected, and their quality differs between the different models, but usual metrics are step count, walking/running distance, calorie consumption, and heartbeat [2].

The four biggest wearable device companies by market share in Q1 2021 were Apple, Samsung, Xiaomi, and Huawei, as shown in Figure 9.2 [87]. There is a large diversity in what operating systems (OS) the different devices use and their integration with other platforms such as Apple Health and Google Fit. For instance, Samsung uses either Tizen or Wear OS, Huawei uses HarmonyOS and LiteOS, and Xioamis' devices do not have an OS. In addition, Fitbit devices use Fitbit OS, and Garmin uses Garmin OS [23][83]. The OS diversity makes creating an exergame that can connect to and read real-time data from most activity wristbands a task not suited for the project's scope. APIs exist, such as Human API and ZivaCare, that provide a single endpoint to connect to almost any wearable device. However, Human API is not free of charge, and ZivaCare does not support real-time data [84][219]. The easier choice is to use the health platforms created by Apple and Google (Apple Health and Google Fit) and only support the activity wristbands that can sync to their platforms.

Figure 9.2: Activity wristbands from Apple, Samsung, Xiaomi, and Huawei with market share (Q1 2021) [87].

9.3 Motion Controllers

A motion controller is a game controller that allows the player to control the game through physical activity. The controllers track motion and provide input to the game with accelerometers or other sensors [130]. The use of motion controllers became popular with the launch of Wii in 2006 with over 100 million units sold and the bundled exergame *Wii Sports* (see Section 11.3).

9.3.1 Nintendo Switch

In 2017, Nintendo released Nintendo Switch together with its Joy-Con controllers featuring traditional controls and motion sensing [135]. The Joy-Con controllers contain an accelerometer and gyroscope to track motion. Motion tracking plays an important part in many Switch games to track hand movements. There exists many popular exergames for Nintendo Switch, including *Just Dance* (Section 11.5), *Ring Fit Adventure* (Section 11.9), *Zumba Burn It Up*, and *Arms* [1]. Even though the controllers usually only track hand movements, it is possible to create exergames that make the player use their whole body. For instance, *Just Dance* is played by dancing with your entire body (see Section 11.5).

9.3.2 PlayStation Move

Both Microsoft and Sony released their motion controllers after Nintendo's success with the Wii. Sony launched PlayStation Move for the PlayStation 3 console, and they later expanded the compatibility to the PlayStation 4, PlayStation 5, and their PlayStation VR platform. It works similar to the Wii, but it never lived up to Sony's expectations [151].

9.3.3 Kinect

Microsoft released Kinect for their Xbox 360 console. Unlike the Wii and PlayStation Move, it uses a sensor array mounted close to the TV instead of handheld controllers. It works by projecting a near-infrared pattern across the space in front of the Kinect and then captures the reflected light with an infrared sensor. An upgraded version was released for Xbox One, with greater accuracy and capabilities than the original Kinect. It is capable of detecting players' heart rates, facial expressions, speed of player movements, position and orientation of individual joints, and more [99]. Microsoft has also released Kinect for Windows along with an SDK (Software Development Kit) that makes it possible to use Kinect in Windows applications with the same capabilities as the Kinect for Xbox One [122]. Microsoft has discontinued the mentioned Kinects, but their technology makes it highly relevant for creating a robust exergame that ensures the players get a physical benefit from the game. Figure 9.3 shows the different motion controllers for Nintendo, PlayStation, and Xbox.

Figure 9.3: Motion controllers for different consoles. Nintendo Switch (left), PlayStation Move (middle), Kinect (right).

9.4 Dance Pads

Dance pads, or dance mats, are game controllers used for input in dance games. They are usually divided into a 3x3 grid of panels for the player to stand on and have arrow buttons that correspond to directions within the game, as shown in Figure 9.4 [41]. It is possible to connect dance pads to PCs, either directly for dance pads with a USB connection or through a USB adapter [43]. This possibility allows the dance pad to be used as a regular keyboard input for the arrow buttons and is therefore simple to integrate into a PC game. Even though dance pads' primary use is dance games, they have many other possibilities and applications. For instance, Meyers et al. experimented with creating step user interfaces for desktop applications (mail and photo) intended to be used by office workers [120].

Figure 9.4: Dance pad with USB connection.

9.5 Virtual Reality

Virtual reality (VR) enables persons to interact with artificial visual environments through computer modeling and simulation. VR applications simulate reality through the use of interactive devices, such as headsets and motion controllers, to immerse the user in a computer-generated environment [199]. Different VR solutions track the user's position and orientation differently, but inertial tracking is a popular choice for solutions intended for the consumer market. Inertial tracking uses data from accelerometers and gyroscopes to track the user's translational and rotational movement [204]. There are multiple popular VR headsets, including the standalone headset Oculus Quest 2, Valve Index for PC, and PlayStation VR for PlayStation 4 and 5, as shown in Figure 9.5 [18].

There exist many VR exergames that increase the physical activity of the players. The VR Institute of Health and Exercise is "*an independent research & ratings organization created to study the health impact of virtual and augmented reality*" that provides ratings for energy expenditure in VR exergames [203]. For instance, The *Thrill of the Fight* is a boxing game that is equivalent to rowing with 8-10 kcal/min and *Beat Saber* (see Section 11.8) is equivalent to playing tennis with 6-8 kcal/min [202][201]. There also exists a modded version of the rhythm game *Audioshield* that is equivalent to biking (10-13 kcal/min) [200].

Figure 9.5: Popular VR headsets. Oculus Quest 2 (left), Valve Index (middle), PlayStation VR (right).

9.6 Smart Exercise Equipment

It is possible to use gym equipment enhanced with different tracking sensors to create exergames. For instance, Pedal Tanks uses a stationary bicycle with optical sensors connected to an Arduino to track the wheel's rotational speed. It is an online multiplayer capture the flag arena game where each player controls a tank and uses the bike pedals to control its speed [76]. This game shows that it is possible to use conventional exercise bikes as controllers in exergames, and most gym equipment is possible to use as game controllers with the correct sensors. Using gym equipment as controllers can be very effective in achieving player exertion because exercise is their original purpose.

There exist several different solutions for exergames based on exercise equipment. One example is the company Exergame Fitness, which provides smart exercise equipment solutions for organizations and health centers, including treadmills, stationary bicycles, and rowing machines [58]. For instance, runBEAT (Figure 9.6) is a running game played on treadmills where each player controls an avatar running on a track and competes against each other [59]. Another relevant product is BitGym, a mobile app that provides interactive scenic tours on your cardio machine. It works by tracking the user's exercise intensity through the phone's front-facing camera using optical flow image processing [19]. This technology makes it possible to track physical activity with a mobile camera and use it as input in exergames.

Figure 9.6: runBEAT.

9.7 Summary

This chapter has reviewed relevant technologies used to develop exergames on different game platforms. *Smartphones* have many accurate sensors that could be used alone or together to give motion input to an exergame. Both iOS and Android also provide APIs for retrieving the sensor data, making smartphones suitable for exergames. *Activity wristbands* collect several relevant metrics, but the OS disparity makes developing games that support the majority of wristbands

challenging. However, it is possible to use their collected metrics indirectly through Apple's and Google's health platforms for the platform-compatible wristbands. *Motion controllers* allow the player to control the game through physical activity, and several exergames utilizing them have had great success. They are also prominent in tracking motion accurately, making them a good choice if it is crucial to ensure player exertion. *Dance pads* are simple devices that are easy to integrate into games, and they have several possibilities outside their primary use. *Virtual reality* simulates reality through the use of interactive devices and is good at achieving player immersion. Many VR exergames are proven to increase the players' physical activity. Lastly, using *smart exercise equipment* is a good choice for an exergame if achieving player exertion is vital. However, it may be challenging to create enjoyable games that do not feel like regular exercise. The review has given insight into opportunities and limitations for technologies used in exergames. There are a variety of technologies and platforms that we can use to create an exergame.

Chapter 10

Physical Activity

Our research goal is to create a new exergame concept to increase the general public's physical activity level. Therefore, a literature review is performed on this topic to understand how and which activities an exergame should promote to give its players positive health effects. This chapter starts by describing health problems related to inactivity and health benefits related to physical activity. Next, it looks at the recommended physical activity levels and how an exergame could encourage its players to reach them. Lastly, the chapter reviews different types of physical activity.

10.1 Health Problems Related to Inactivity

The World Health Organization (WHO) defines physical inactivity as less than 150 minutes of moderate-intensity activity per week, or equivalent [213]. As mentioned in Chapter 1, studies show that the general public performs below the recommended amount of physical activity, and it is one of the biggest public health problems. According to WHO, the health risks of sedentary behavior include all-cause mortality, cardiovascular disease mortality, and cancer mortality. Additionally, it increases the incidence of cardiovascular disease, cancer, and type-2 diabetes [213].

According to WHO, more than 25% of the world's population is insufficiently active. In high-income countries, this number increased by 5% from (from 31.6% to 36.8%) between 2001 and 2016 [213]. However, this indicator is based on self-reporting and not objective measurements. The Norwegian Institute of Public Health (FHI) has created an indicator that estimates physical inactivity in Norwegian adults where they both used questionnaires and objectively measured physical activity using accelerometers. Their results show that around 34% of the participants reported that they were not meeting the physical activity recommendations of 150 minutes per week, but; the objective measurements showed that the actual number was closer to 68% in 2014 [138].

10.2 Health Benefits of Physical Activity

Extensive research conducted on the health benefits of physical activity shows significant benefits of exercising. The risks listed in the previous section can be significantly reduced by being physically active. Additionally, it can improve muscular and cardiorespiratory fitness, improve bone and functional health, and help maintain a healthy body weight [213][210]. Physically active people have an increased life expectancy compared to inactive individuals. The results from a review aiming to synthesize the literature on life expectancy with physical activity show 13 studies reporting a higher life expectancy in physically active subjects, ranging from 0.43 to 6.9 additional years [158].

Physical activity affects your physical health but is also beneficial for psychological health. The effects of being physically active as a prevention and treatment method for mental illness are well-documented. Studies show that regular physical activity helps alleviate symptoms of depression and anxiety, and strength, flexibility, and aerobic training are all equally effective. In addition to having an immediate effect after the activity itself, it also has a long-term effect. However, note that excessive physical activity may cause overtraining, leading to other psychological disorders. Physical activity has also shown a positive impact on mood, sleep quality, stress, and self-esteem [137][147].

10.3 Recommended Activity Level

A large variety of government and health agencies recommend you to be physically active each week. The most agreed-upon recommendation of minimal weekly exercise is 150 minutes of moderate-intensity aerobic physical activity or 75 minutes of vigorous aerobic activity. Additionally, people should also do muscle-strengthening activities of moderate or greater intensity at least two times a week. This recommendation is supported by WHO [213], the U.S. Department of Health and Human Services [190], and the UK National Health Service [192]. Our exergame concept should help its users to reach the recommendation, for instance, by having a weekly challenge that rewards the user for playing the game for more than 150 minutes.

10.4 Different Activity Types

The exergame concept must provide efficient and safe exercise to reach the project's research goal of increasing the general public's physical activity level. Four main types of exercise are identified by the Harvard Medical School and the U.S. Department of Health and Human Services: aerobic, strength, balance, and flexibility [79][189]. There are examples of exergames for each type of exercise, and the chosen types for an exergame may cause implications for both game design and technology choice.

Aerobic

Aerobic exercises, also called endurance exercises, increase your breathing and heart rates. They help to keep you healthy and improve your endurance. Typical activities include jogging, dancing, swimming, and biking [189]. Figure 10.1 shows an example of aerobic exercise. There exist many benefits from aerobic exercises, like reduced risk of heart disease, stroke, diabetes, and depression. It also helps lower blood pressure, improves cholesterol levels, burns body fat, and relaxes blood vessel walls [79]. A design challenge in aerobic-based exergames is to ensure a sufficient level of player exertion without exhausting the player too quickly. Several existing exergames focused on aerobic training exists, including *Dance Dance Revolution* (see Section 11.1), *Just Dance* (see Section 11.5), and *Beat Saber* (see Section 11.8).

Figure 10.1: The aerobic exercise *Marching in place*.

Strength

Strength exercise activities make your muscles work harder than usual, where the main goal is to build or maintain muscle mass. A common type of strength training is weight training, where one repeatedly lifts a set of weights. Another common type is bodyweight training (e.g., push-ups and chin-ups), which utilizes the body's weight. Figure 10.2 shows an example of a strength exercise. Performing strength exercises makes your muscles stronger, improves balance and posture, reduces blood sugar, stimulates bone growth, and assists with weight control [79][189]. For exergames focused on strength training, a significant design challenge is to allow players to make interesting decisions within the constraints of the strength training's repetitive and controlled motion [161]. Examples of existing exergames containing strength training are *Wii Fit* (see Figure 11.4) and *Ring Fit Adventure* (see Section 11.9).

Figure 10.2: The strength exercise *Squat*.

Balance

Balance exercises consist of "*positions or movements that challenge the individual to maintain posture and stability over a base of support*" [148]. Typical exercise activities are standing on one foot, walking heel to toe, and line walking. Figure 10.3 shows an example of a balance exercise. Balance exercises are relevant for older adults to help prevent falls and injuries and improve proprioception (the ability to know your body position in space), but they are also useful for others. [79][189]. *Wii Fit* (see Figure 11.4) is an exergame that uses a balance board as a motion controller and contains several minigames focusing on balance exercises.

Figure 10.3: The balance exercise *Standing knee lift*.

Flexibility

Flexibility exercises, also called stretching exercises, consist of flexing or stretching specific muscles to increase their range of motion and reduce the risk for injury. Figure 10.4 shows an example of a flexibility exercise. There are many different flexibility exercises, which target various muscles, tendons, and muscle groups. Regular stretching keeps the muscles flexible, strong, and healthy, which reduces the risk of pain, damage, and cramps in the muscle [79][189]. *Ring Fit Adventure* (see Section 11.9) contains some exercises with stretching as part of the activity (e.g., yoga exercises).

Figure 10.4: The flexibility exercise *Single knee rotation.*

10.5 Summary

This chapter has reviewed general physical health, health problems related to inactivity, health benefits of physical activity, and different activity types. There are many severe health risks of sedentary behavior, including all-cause mortality. However, the risks can all be mitigated through physical activity. WHO recommends a minimal weekly exercise of 150 minutes of moderate-intensity aerobic physical activity or 75 minutes of vigorous aerobic activity. The results from FHI show that most people in Norway do not meet this recommendation, despite the significant health benefits. All four main exercise types have possibilities for new exergame concepts, but aerobic is the easiest to adapt. Designing exergames requires understanding which activities an exergame should promote to give health effects.

Chapter 11

Existing Exergames

This chapter provides examples of existing exergames and their impact on the general public's health. Each game will have a gameplay summary, followed by the game's enjoyment, activity type, and exertion level. The game's physical exertion, enjoyment, and popularity are considered when reviewing the game's public health influence. The games are presented in the order of release, starting with the oldest.

11.1 Dance Dance Revolution

Dance Dance Revolution (DDR) is a popular rhythm exergame, based on pressing arrows on a dance pad [40]. DDR was released in 1998 in Japan as an arcade game and later in arcades worldwide and for home consoles. The game's primary concept is to press the dance pad arrows corresponding to the ones shown on the screen at the correct time. Some DDR games, for example, *Dancing Stage Fusion*, used the dance pad together with the EyeToy camera [42]. The game provides different difficulties for each song, allowing the player to choose the correct challenge level. The players receive immediate feedback on the screen about the correctness of their timing according to the rhythm. The arcade versions often provided two dance pads, shown in Figure 11.1, which allowed and encouraged local multiplayer. A free, open-source clone of DDR called *StepMania* was released in 2001 and was downloaded 6.3 million times between 2001 and May 2017 [179].

DDR makes the player train motor coordination and is an aerobic type of training [195]. There is much research done on DDR due to its popularity. The research suggests that the game can be used for exercise and reaching recommended amount of physical activity. Based on a study from 2013 with 208 third and fifth graders, DDR-based play improved the children's cardiorespiratory endurance [65]. Anthony Whitehead et al. from 2010 show that the average energy expenditure for DDR is a little over 8 kcal/min [212]. Another study also showed that when twelve-year-old children used DDR, it reduced their waist circumference compared to the control group [121]. This study indicates that DDR can be used for weight loss. A study of university students using DDR showed that they reached a good fitness condition and almost the caloric expenditure recommended by the American College of Sports and Medicine (ACSM) [62]. The same study revealed that the subjects found the game more enjoyable than jogging on a treadmill. In West Virginia, DDR has become part of the curriculum [177]. Adding DDR into school classes has been shown to provide more participation from the students [156]. A study of 35 children between eight and twelve years old found that DDR was more enjoyable than regular dancing or television watching [54]. In conclusion, DDR has impacted the general public's health considerably due to the high aerobic exertion combined with its enjoyment and popularity.

Figure 11.1: Arcade version of *Dance Dance Revolution*.

11.2 Geocaching

Geocaching is a game that combines technology with treasure-hunting. Different physical capsules called *geocaches* are placed around the world, containing a logbook. Its coordinates are given to players, meaning players locate the caches using GPS. Once it is located, the player signs the book and returns it to its original position. Figure 11.2 shows two players with a geocache. The first instance of the game was in 2000, and the currently largest site for the game is geocaching.com [67].

The geocaching activity motivates players to go outside but does not require much exertion. Studies reveal that it has the same levels of activity as walking [13][127]. Walking provides only light aerobic training. A study with 82 participants between the ages of 14-18 showed through a survey that looking for treasures would be more enjoyable than regular walking [14]. The results indicate that it is possible to use geocaching for physical activity motivation. According to 12 geocachers with a minimum of 5 years of experience, the primary reasons to play are: being outdoors, social interaction, physical activity, and relaxation [66]. Despite this, a study with 68 participants showed that walking and geocaching provided the same amount of enjoyment [13]. In conclusion, the game might not provide the required motivation to impact the general public's health.

Figure 11.2: Two players with a geocache.

11.3 Wii Sports

In 2006 the Nintendo Wii console was released together with the game *Wii Sports*. It is the fourth best-selling game ever, with over 82 million copies sold by late 2017. Critics gave *Wii Sports* good reviews, and it became popular to play during social gatherings due to the multiplayer support and intuitive controls. The game utilized the Wii's motion controller to simulate five different sports: tennis, baseball, bowling, golf, and boxing. Figure 11.3 shows a photo of two people boxing in *Wii Sports* [216].

Wii Sports is enjoyable but does not require much exertion. The Wii motion controller only measures hand movements in three dimensions, which makes it lacking in detecting the players' actual movement [195]. The sports games in *Wii Sports* are relatively easy to do without much physical activity. All the sports have an average energy expenditure of less than 5 kcal/min [212]. The most tiresome is *boxing*, which has the highest average energy expenditure and can be categorized as aerobic training [212][195]. Playing *Wii Sports* requires more energy than sedentary activities but less than the actual sports themselves [74]. The energy expenditure of the game is not enough to significantly facilitate children to get the recommended amount of exercise. However, a study on stroke patients using *Wii Sports* found that the patients improved their time-up-and-go (TUG) test performance and were less likely to drop out [28]. Wii exergames are also shown to provide more positive attitudes towards physical activity than regular PE lessons [195].

Figure 11.3: Boxing in *Wii Sports*.

11.4 Wii Fit

The *Wii Fit* exergame was released in 2007 in Japan and 2008 world-wide [215]. It is an exergame that provides 40 physical exercise activities using the Wii Balance Board. Yoga, push-ups, hula hoop, and ski jump are examples of *Wii Fit* exercises. Figure 11.4 shows gameplay of the *Sideways Leg Lift* activity. The game sold over 43 million copies and is currently in 9th place of best-selling video games of all time [109]. In 2009 an enhanced version of the game was released, called *Wii Fit Plus*.

Wii Fit became popular with the physical therapist community because of the body movement focus [186]. The game provides activities within all of the four different activity types, making the player train aerobic, balance, strength, and flexibility [195]. Using *Wii Fit* as part of rehabilitation has shown positive results for both the TUG test and Berg balance score (BBS). One of the most promising health improvement parts of *Wii Fit* is the balance games. However, studies indicate that the game can not be used as a strategy for young adults and children to get the recommended amount of physical activity [186].

Figure 11.4: Demonstration of *Wii Fit*.

11.5 Just Dance

The rhythm exergame franchise *Just Dance* started in 2009. It is a motion-based dance game where the player either has a motion controller or uses a camera such as Kinect. The game shows a video of a person dancing, which the players mimic. According to the timing and accuracy of the movement, the player will get feedback on how well they danced specific moves [93]. Figure 11.5 displays four kids trying out *Just Dance*.

Just Dance provides both fun and aerobic training [195]. In a paper by Quinn, *Just Dance* was added as part of PE classes, and results showed that students had increased participation as well as time active [156]. Another study of *Just Dance* was done on 126 undergraduate students between the ages 18 and 26 [107]. The results show an average heart rate mean of 109.23 BPM and a maximum BPM mean of 130.66. In other words, *Just Dance* makes the player enjoy themselves as well as provide moderate levels of aerobic energy.

Figure 11.5: *Just Dance*.

11.6 Zombies, Run!

The survival horror exergame *Zombies, Run!* was released in 2012 [220]. Its logo is shown in Figure 11.6. It quickly became one of the highest-grossing Health & Fitness apps and currently has over 1 million players [221]. The gameplay consists of walking and running on missions where the player automatically collects items that can be used to upgrade the player's town. A player can get chased while on a mission, making the player increase their tempo.

Zombies, Run! focuses on enhancing enjoyment from aerobic training such as walking and running. It is possible to use the game to reach recommended amounts of physical activity since the game makes the players run or walk. However, [49] found no physical activity change in their study between the group that used *Zombies, Run!* and the control group. On the other hand, another study found that using the app made the participants more motivated and active [31]. More research is needed on *Zombies, Run!*, but the game might provide a good amount of physical activity motivation.

Figure 11.6: *Zombies, Run!* logo.

11.7 Pokémon Go

In the summer of 2016, Niantic released *Pokémon Go* [152]. It is a location-based augmented reality RPG game where the players catch different creatures from the well-known Pokémon franchise. When released, it got downloaded 10 million times during the first week. After 33 days on the market, *Pokémon Go* had been downloaded over 100 million times on Google Play. By May 2018, the app had over 147 million monthly active users. The main gameplay aspect of the game is to walk around in the real world, and different Pokémon will appear on the map, which the players can catch. Figure 11.7 shows screenshots of the gameplay. After being released, the main focus was catching all the different Pokémon. However, other elements have later been added, for example, raids, trading, quests, and battles. The game also provides eggs that the players can hatch by walking a specified distance. Hatching eggs can be done while the application is idle by using the Adventure Sync [133]. Niantic also released a similar exergame called *Harry Potter: Wizards Unite* in 2019 [78]. However, it did not garner as much popularity as *Pokémon Go*.

Pokémon Go improves the players' physical activity level while being fun to play. The game's physical aspect comes from walking, which does not require intense exertion. A key point of *Pokémon Go*'s impact on the general public's health is encouraging players to have less sedentary time. The motivations for playing include having fun, having an immersive experience, getting physical activity, social reasons, and nostalgia for the franchise [206]. The game is shown to have the highest benefit for physically inactive individuals and can be seen as a gateway to exercise more [104]. One systematic review found that the number of steps increased by 1,446 per day [97]. The increase significantly impacts the general public's health when considering the number of active players. Additionally, the game is shown to manage to motivate groups with low physical or social activity, and those groups got a more substantial positive physical effect from playing it [207]. However, studies show that people often return to their baseline physical activity when they stop playing the game [104]. A lot of scientific papers related to *Pokémon Go* exist, but there is a lack of longitudinal studies.

Figure 11.7: Screenshots from *Pokémon Go*.

11.8 Beat Saber

The VR rhythm game *Beat Saber* was officially released in 2019 on PlayStation 4 and Microsoft Windows. In its first week, the game became the highest-rated game on Steam and sold over 4 million copies by February 2021. The player cuts boxes coming towards them with two lightsabers. The correct lightsaber must cut a box at the right time and angle. The box cutting timing is matched to the song playing. Players must also squat to avoid obstacles such as walls. Figure 11.8 shows a screenshot of the game [15].

Beat Saber requires aerobic physical activity and is very enjoyable at the same time. Little research is done on *Beat Saber*, however, a study with 36 participants evaluates the game's physical activity and enjoyment [56]. In the study, the game provided light aerobic training to the participants, where most of the work was in the upper part of the body. *Beat Saber* was the most enjoyable game studied, with a mean enjoyment score of 90.9 out of 100. The light intensity might provide little exertion to the player, but *Virtual Reality Institute of Health and Exercise* mentions in its rating of the game that energy expenditure increased with challenge level [201]. In other words, when the player gets better at the game, they can increase the difficulty, which will make the player reach higher heart rates. In the rating, *Beat Saber* was estimated to require energy expenditure of 6-8 kcal/min.

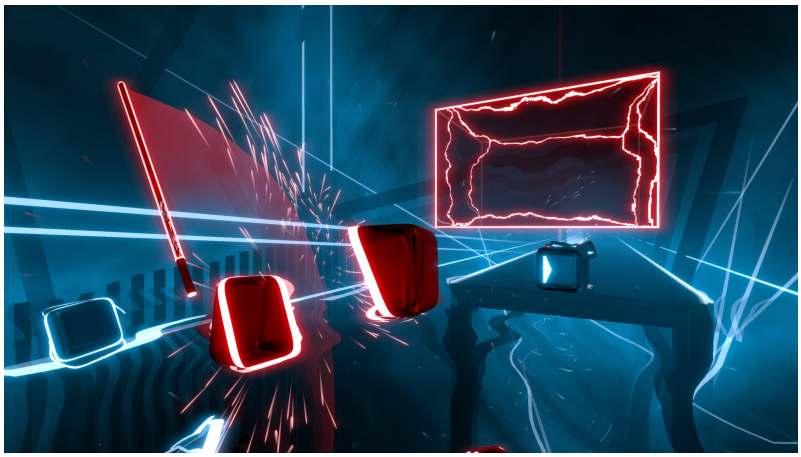


Figure 11.8: Screenshot from *Beat Saber*.

11.9 Ring Fit Adventure

The turn-based RPG exergame *Ring Fit Adventure* was released on October 18, 2019, for the Nintendo Switch. The Joy-Cons are inserted into a Pilates ring and a leg strap to retrieve input from the player. The game's primary mode consists of different game levels, which combine in-place jogging and battles that require exercise. Figure 11.9 shows a battle where the player has to perform the yoga move "Tree Pose". The game also provides mini-games, fitness tips, workout routines, challenges, and a rhythm game. As of June 2021, over 11 million copies have been sold, making it one of the best-selling Nintendo Switch games [162].

Ring Fit Adventure can be used as a fun and effective energy expenditure strategy. Similar to *Wii Fit* (see Section 11.4), *Ring Fit Adventure* provides exercise activities from all the different activity types. Aerobic with running in levels, strength, and balance through enemy battles and flexibility from yoga and after-session stretching. There is little research done on the game because it is relatively new. However, a study with 45 overweight or obese children show that *Ring Fit Adventure* is a very effective exergame [29]. In the study, *Ring Fit Adventure* had an average energy expenditure that was higher than *Dance Dance Revolution* (see Section 11.1). The high energy usage is probably due to the game requiring full-body movement. Additionally, the game has shown to provide reduced pain in patients with chronic low back pain [166]. *Ring Fit Adventure*

has had a positive impact on the general public's health due to the game's popularity and effective energy expenditure.

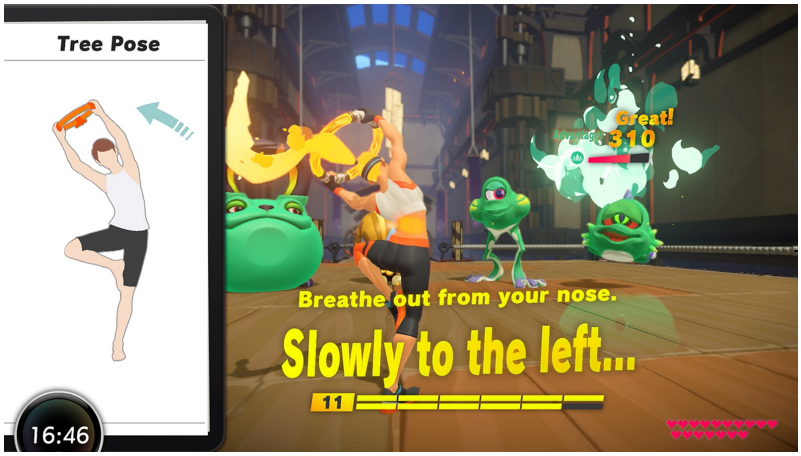


Figure 11.9: Screenshot from *Ring Fit Adventure*.

11.10 Other Exergames

There are currently many different exergames, and this section mentions a few other noteworthy exergames. *EA Sport Active* and the sequel is similar to *Wii Sports* (see Section 11.3), but provides activities within all the different exercise types [195]. The Nintendo 3DS *StreetPass* provided motivation to walk outside with the 3DS either active or in idle mode [176]. By being near another 3DS, the consoles would exchange data. Meeting other players provided in-game rewards. The mobile strategy exergame *Run an Empire* is a location-based game that motivates its players to walk or run [164]. The game makes the players compete against each other by having different empires. *Exermon* is a mobile exergame which focuses on strength training [82][208]. The players own virtual pets that get stronger when the player performs different exercises.

11.11 Summary

This chapter has presented some of the most noteworthy existing exergames and their impact on the general public's health. The games provide a variety of activity types and use several different technologies. Some of the games demand high energy expenditure, for example, *DDR*, while others are not as intense, such as *geocaching*. The popularity and intensity of a game are highly relevant to the general public's health impact. Therefore, *DDR* and *Ring Fit Adventure* might be the most successful exergames because of their exertion level and popularity. However, the immense usage of *Pokémon Go* also had a prominent influence on health, even with low energy expenditure. Rhythm exergames tend to succeed, for example, *DDR*, *Just Dance*, and *Beat Saber*. The success might be because people associate music with dancing, which is already a physical activity.

Part III

Concept

Part III presents our concept for a new exergame. First, the results from the prestudy are used to suggest several new exergame concepts, one of which will be the primary one for the report. All concept ideas are reviewed according to relevant criteria, including technological feasibility, physical exertion, and innovation. Next, the primary concept is presented in more detail before it is analyzed using the game enjoyment theories. Then it is evaluated according to its physical activity aspect. This part is based on the specialization project (see Chapter 2).

Chapter 12

Concept Ideas

This chapter will use the results from the theoretical study and technology testing to suggest several concepts for new exergames, one of which will be the primary concept for the report. Our goal is to create exergames that are enjoyable and motivate physical activity.

12.1 Space Space Revolution

Space Space Revolution is a concept that combines a platform game with dance pads. The gameplay is inspired by the *endless runner* sub-genre discussed in Section 7.7 and our wish to create an exergame with dance pads that is not a rhythm game. The goal is to conquer space by completing levels on planets. The game levels are played through concurrently running and jumping across gaps or obstacles.

Gameplay

The players control their in-game avatar by stepping on the arrow buttons on a dance pad. Stepping back and forth on the side arrows makes the avatar run. The player can make the avatar jump by standing on the side arrows and then jumping. The game/camera moves forward at a base speed, and the avatar's running speed is determined by how fast the player is stepping on the side arrows. The camera speed has some variation depending on the position of the avatar. It is faster if the avatar is close to the right side of the game view, and it slows down if you are closer to the left side. You have three lives, and if the avatar fails to stay inside the game view, a life is lost. If you run out of lives, the level is failed. Each level has a fixed length, and the objective is to finish the level and get a good score by running fast and collecting various items along the way. Figure 12.1 illustrates the gameplay in the game and a suggested setup.

One or two players can play the game on the same device. If you play multiplayer, both avatars are visible in the same game view, and they have to work together to reach the goal. It is also possible to add online multiplayer support to allow online competition.

Exercise

The exercise component of the game is stepping on a dance pad to control your game character, which is an aerobic exercise (see Section 10.4). The levels become more challenging, requiring the player to put in more effort as they progress through the game. The varying camera speed allows the player to run at a preferred pace and makes it feel natural. The levels have hills and valleys, and it requires more effort to run uphill than downhill, making the exercise more similar to interval training.

Figure 12.1: *Space Space Revolution* idea sketch.

12.2 King of the Pad

King of the Pad is a concept that combines a platform fighter game with dance pads. The gameplay is inspired by the fighting game genre (see Section 7.2) but uses dance pads to control the fighters. Figure 12.2 illustrates the game concept. The goal is to eliminate your opponent by either knocking him out of the platform or inflicting enough damage.

Gameplay

The players control their in-game fighters by stepping on the dance pads. The pad's arrow buttons control directional movement and jumping/dodging, and the remaining buttons control offensive and defensive moves. It is also possible to press button combos that will execute special attacks. The game can be played against another player on the same device or a bot.

Exercise

The exercise component is similar to *Space Space Revolution* presented in the previous section with aerobic exercise. However, in King of the Pad, the intensity is more varied. When two players are playing against each other, they decide how intensive they want to play. If a player plays against a bot, they can set the bot difficulty to adjust how physically demanding the game is.

Figure 12.2: *King of the Pad* idea sketch.

12.3 Survival of the Fittest

Survival of the Fittest is a survival horror concept for mobile. The game is inspired by *Don't Starve Together*, where the players must survive as long as possible [52]. The game uses GPS to place the players into the game world. Figure 12.3 illustrates the game concept.

Gameplay

By moving around in the real world, the players move in the game world. The players have to collect materials such as wood and stone to create tools for survival. Different resources have higher spawn rates at specific real-world locations, for example, more trees to chop in parks and forests. The day cycle speed is increased in the game world, and monsters come out at night. If a player is not protected during the night, they will get attacked by monsters. To escape them, the player must run. The game is over if a monster manages to kill a player. Optimally, two-player is supported, where they can cooperate to find materials and survive as long as possible.

Exercise

The game concept provides aerobic training. Gathering resources requires walking or running to the material locations. Fleeing from monsters demand running.

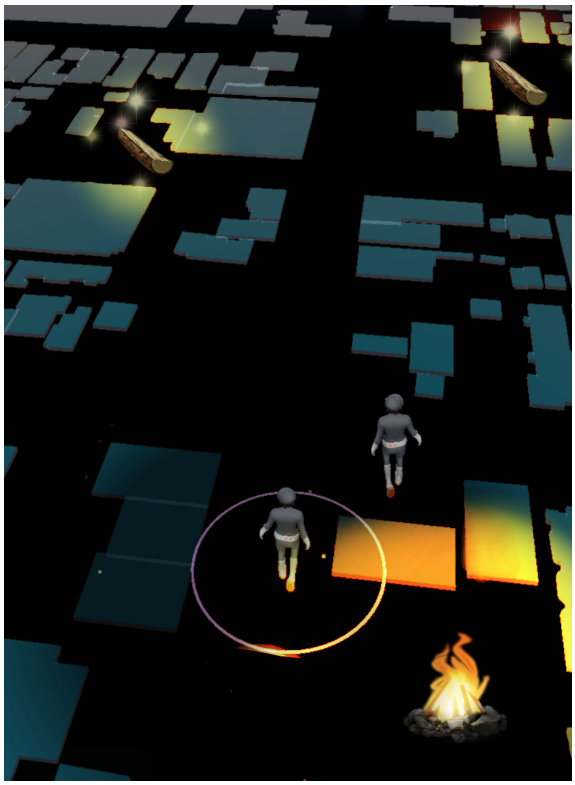


Figure 12.3: *Survival of the Fittest* idea sketch.

12.4 Pirate Riches

The *Pirate Riches* concept is a location-aware mobile RPG. The main goal is to collect different treasure types and level up the character. Figure 12.4 illustrates the game concept.

Gameplay

The player gets treasure maps/quests to find specific treasure chests. Treasure chests are placed at real-world locations that the player has to visit. When a player opens a treasure chest, it can either be a new map to another treasure chest, a treasure, or a monster. If it is a monster, the player has to get away from it as quickly as possible before losing health. If the number of health points drops to 0, the player loses treasure. The treasures can either be kept or sold for gold. The player can purchase customization products and items with gold. They can, for instance, be something that tells the player if the treasure chest contains a monster or not.

The player can add other players as friends and make a pirate crew. Challenges are given to pirate crews, and all members get a reward if they complete them. An example of a challenge is "Find a total of 50 treasures within this week". There can also be high-score boards for pirates and pirate crew, showing who has gathered the most treasures this week. Players can also share treasure maps/quests with friends to go and collect the treasure chests together.

Exercise

Pirate Riches provides mild aerobic training. The main gameplay aspect is done by walking or jogging. However, the intensity is increased by having to run away from monsters.

Figure 12.4: *Pirate Riches* idea sketch.

12.5 Exertica

The *Exertica* concept is an exercise-focused RPG exergame for mobile and possibly the web. The game is inspired by *Habitica* and can be viewed as an exercise version of the game. *Habitica* is an online task management game which *gamifies* daily life [75]. Figure 12.5 shows a screenshot from *Habitica*. The player chooses the tasks themselves and ticks the checkbox when they complete them. Every player has a customizable character that can level up. Experience points and gold is rewarded after completing daily habits and To-Dos. Not completing a daily habit results in the player losing health. If all health points are lost, then the player's level drops. The character can make parties with other players, and they can go on quests together. The new exergame concept *Exertica* would implement similar gamification.

Gameplay

The player's character will improve through exercise. The player can either choose between standardized exercises or write their own. When it is completed, the player ticks a checkbox. If the player finishes pre-defined exercises, the game will provide exercise suggestions with increased difficulty. For example, if a player does ten push-ups, then the game might suggest to the player that they should do 13 push-ups next time. The player receives extra experience points and gold if the player completes the proposed exercise. Gold can be used to buy different character cosmetics. The game will also provide quests such as "Complete 2 suggested exercises". Global and friend high-score boards can be added to create social interaction.

Exercise

Exertica is very versatile and is usable by anyone. All kinds of exercises can be part of *Exertica* since the game creates an opportunity for the player to create their own exercises. This functionality means you can use it for all four activity types and rehabilitation purposes. However, no sensors are used to measure the users' exertion, so the game has to trust its users.

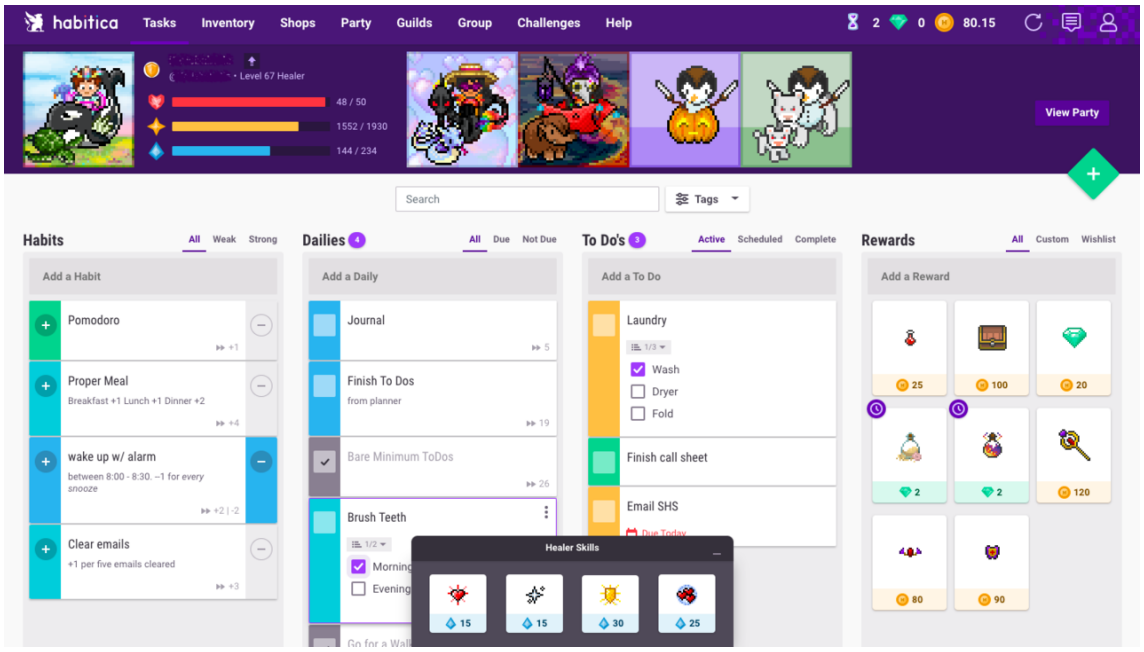


Figure 12.5: Screenshot of *Habitica*.

12.6 Beat Runner

Beat Runner is a rhythm exergame concept for smartphones where the aim is to run to the beat of a music track. The goal is to be as close to the beat with your steps as possible. Figure 12.6 illustrates the game concept.

Gameplay

The player starts a new run session in the game, and the phone is then placed in a pocket or somewhere else on your body. The music will then begin to play, and you have to run to the beat. When running, the player will receive performance feedback from the music track. The tracks are multi-tracks where we can add or disable elements from the music based on the player's performance. The run will last the song duration, and the player will receive his final score when they complete it.

Exercise

Beat Runner is a running game, which is an aerobic exercise. The music tracks will start slow, giving the runner a chance to warm up before the main part of the music starts. It is also possible to have songs that vary their tempo to support interval training. There will also be multiple tracks with different average speeds, which allows the players to choose an exercise level that is challenging for them.

Figure 12.6: *Beat Runner* idea sketch.

12.7 Summary

This chapter has presented six possible exergame concepts. Two concepts use the dance pad as input: the platformer *Space Space Revolution* and the fighting game *King of the Pad*. The four remaining concepts are made for smartphones. Both the survival horror concept *Survival of the Fittest* and the RPG *Pirate Riches* make use of GPS. The RPG *Exertica* is unique in that it does not use any sensors to measure physical activity. The last concept, a rhythm game called *Beat Runner*, uses audio as its primary stimulus and is highly dependent on the smartphone's accelerometer.

Chapter 13

Review of Concept Ideas

This chapter reviews the concepts presented in the previous chapter according to technological feasibility, experiment feasibility, innovation, engagement, physical exertion, potential reach, and motivation.

13.1 Space Space Revolution Review

Technological Feasibility

The *Space Space Revolution* concept is for computers, requiring the dance pad to be usable on computers. Computer compatibility means that the player has to either have a dance pad with a USB cable or an adapter. We already had a PS2 dance pad and a PS2 to USB adapter. These were used to test the feasibility of the exergame concept. Dance pads are recognized as a *USB Gamepad* by Windows. However, the dance pad arrows are categorized as an axis. The y-axis is the up and down arrows, and the x-axis is left and right. The axis problem complicates development, as pressing opposite arrows will result in input cancellation. It means that, for example, pressing the left arrow will not be registered if the right arrow is being pressed simultaneously. The axis problem makes the input register when arrows are un-pressed instead of pressed down, which is less intuitive.

A workaround exists for the axis problem. The arrows are mappable to keyboard arrows by using an AutoHotkey script [11], presented by a post in the *StepMania* forum [12]. The mapping makes it possible to register opposite arrow presses simultaneously. AutoHotkey scripting is only possible for Windows. However, Mac and Linux have similar alternatives. If the script is used, it should be integrated with the game, or else the player has to first run the script manually before running the game.

The AutoHotkey script does have one flaw, but it is not vital. It registers a new arrow press when un-pressing an opposite arrow. For example, when a player presses the left and right buttons simultaneously. If the player then un-presses the left-arrow button, it will register both a left-arrow un-press and a new right-arrow press. That means a new right-arrow press is reported, even though no new right-arrow press has occurred.

We also had a USB dance pad with a different mapping than the PS2 pad. The USB dance pad arrows are categorized as buttons, which means they do not have the same axis problem. However, one problem is that the buttons on the USB dance pad are all mapped differently than on the PS2. For example, PS2 pad button 3 is not the same as the USB pad button 3. Another problem is that the USB pad has a sensor in the middle, which maps to the down axis. This problem means that running the AutoHotkey script on a USB pad makes standing in the middle of the pad register as pressing the down arrow key. In other words, to make the game playable for both PS2 and USB dance pads, a different mapping script will have to be run on the different types of dance pads.

Space Space Revolution is technologically feasible. The concept will still work even with the axis problem and might operate better with the Windows AutoHotkey script. Compatibility with multiple dance pad types requires specified mapping since the buttons are categorized differently.

Experiment Feasibility

Using dance pads for a game makes it possible to have a controlled experiment. An experiment could use a lab room with different sensors, such as a heart rate sensor, and provide a similar experience to all participants. However, getting results for a dance pad exergame over time is problematic since most people do not own a dance pad usable on computers.

Innovation

Space Space Revolution is a new concept that has not previously been researched. It is possible to use dance pads for other games by plugging them in as a controller. However, DDR is the only widely known game that has been specifically designed around the dance pad. The exergame concept can provide new insight into the exergame and platformer combination.

Physical Exertion

The player continuously moves their feet on the dance pad. The pace required by the game can create intervals. The player can get a high level of aerobic exertion by repeatedly pressing the dance pad buttons.

Potential Reach

There might be many people with a dance pad that is not in use due to *Dance Dance Revolution*'s popularity. The number of devices sold may indicate the number of potential users. The DDR sales are not available presently, but the game sold over three million copies when ported to PlayStation [60]. However, the dance pads might have been thrown away or broken. In addition, the ones sold for home use were usually for the PS2, which means that most of them are not eligible for our concept idea. But, some console dance pads used USB, making them usable on PC. Furthermore, adapters and USB dance pads are currently still available on the market. In conclusion, the potential reach for the exergame concept is low, but a few might have the right equipment already or can buy it if not.

The *StepMania* community might be the group with the highest potential to try this new exergame concept. StepMania already requires the players to have a dance pad that is usable on PC, which means that people who play StepMania already have the right equipment for this concept.

Motivation

We have a high motivation for this concept. Creating a game using dance pads that is not a rhythm game has a high innovation, and it is feasible to both develop and test. Additionally, its potential for aerobic interval training enables players to get a high level of physical exertion. The only downside is the low potential reach compared to our other concepts that are not dependent on dance pads.

13.2 King of the Pad Review

Technological Feasibility

Similar to *Space Space Revolution*, the *King of the Pad* concept uses a dance pad. Therefore, the exergame concept has the same technological challenges with different key mappings between dance pad types and the PS2 pad's arrows being categorized as an axis. The axis problem can be ignored by not requiring opposite arrow input concurrently. However, if such input is desired, the AutoHotkey script [11][12] will work for this concept too. In conclusion, *King of the Pad* is technologically feasible but has the same challenges as *Space Space Revolution*.

Experiment Feasibility

Identical to *Space Space Revolution*, *King of the Pad* provides opportunity for a controlled experiment. An experiment with a dance pad game could use a lab room with different sensors, such as a heart rate sensor, and provide a similar experience to all participants. However, getting results for the game over time is problematic since most people do not own a dance pad usable on computers.

Innovation

The fighting exergame *King of the Pad* is a new type of dance pad game not researched before. DDR is the only widely known game that has been specifically designed around the dance pad. The exergame concept can provide new insight into the exergame and fighting genre combination.

Physical Exertion

The physical exertion is similar to *Space Space Revolution* but is more varied and less intensive. The player will move their feet on the dance pad, providing a medium level of aerobic exertion.

Potential Reach

The potential reach is the same as *Space Space Revolution*. There might be many people with a dance pad that is not in use due to *Dance Dance Revolution*'s popularity. However, the dance pads might have been thrown away or broken. The *StepMania* community might be the group with the highest potential reach since they already own a dance pad usable on a computer. Dance pads are also not expensive, meaning that if the game is good enough, it might motivate users to buy a pad along with it.

Motivation

King of the Pad is similar to *Space Space Revolution*, causing our motivation for this concept to be high. Creating a game using dance pads that is not a rhythm game has a high innovation, and it is feasible to both develop and test. It has a medium physical exertion level, but it is still a concept that we believe would be a great exergame. The only downside is the lower potential reach.

13.3 Survival of the Fittest Review

Technological Feasibility

Survival of the Fittest is a mobile location-based exergame. Several other exergames already use GPS for placing the player into the game world, for example, *Pokémon Go* (see Section 11.7). There are problems with the accuracy of the GPS over small areas, but that will not be an issue because the concept uses a large area. Therefore, this exergame is technologically feasible.

Experiment Feasibility

Creating an experiment for a mobile exergame can be done in many ways, but it will most likely not be in a controlled environment. It will require participants to download the exergame and try it for a few weeks, maybe combined with some observations. Even though such an experiment is not highly controlled, it will yield results that indicate the game's impact on physical activity motivation and exertion in daily life. Getting participants will be easier than with the dance pad concepts since the exergame will be available on phones.

Innovation

Location-based mobile exergames are not a new concept. However, *Survival of the Fittest* is directly multiplayer and session-based. These aspects make the exergame concept more unique than those already on the market.

Physical Exertion

Survival of the Fittest requires a medium level of physical exertion. The player has to run or walk. The urgency of surviving as long as possible in a session might make the players more inclined to run.

Potential Reach

The potential reach for *Survival of the Fittest* is high due to being available on smartphones, which creates a lot of potential users. The game is also a new concept that might intrigue people.

Motivation

Survival of the Fittest is a game with high technological feasibility and potential reach, making it a compelling choice. However, it is not very innovative and has a medium level of physical exertion, resulting in our motivation for this concept to be medium.

13.4 Pirate Riches Review

Technological Feasibility

Pirate Riches is a mobile location-based exergame similar to *Survival of the Fittest*, making it technologically feasible. Several other exergames already use GPS for placing the player into the game world, and since it takes place over a large area, GPS accuracy is not an issue.

Experiment Feasibility

Pirate Riches will have a similar experiment to *Survival of the Fittest* in an uncontrolled environment. It will require participants to download the exergame and try it for a few weeks, maybe combined with some observations. It is not ideal but will give results that indicate the game's impact on physical activity and motivation.

Innovation

Pirate Riches shares a lot of similarities with already existing exergames such as *Pokémon Go* (see Section 11.7). The concept has a different theme and gameplay aspects. Nonetheless, related exergames exist and have been researched. Therefore, *Pirate Riches* is not as innovative as other concept ideas presented.

Physical Exertion

Walking is the main activity in *Pirate Riches*, which provides a low level of physical exertion.

Potential Reach

The potential reach for *Pirate Riches* is high because it will be available on smartphones, which creates a lot of potential users.

Motivation

We believe that *Pirate Riches* is a concept that would be fun to design, develop, and test. But, as mentioned, similar exergames already exist, and this concept is not very different. Therefore, our motivation for this game is medium.

13.5 Exertica Review

Technological Feasibility

Exertica does not use any sensors to measure physical activity and is easily implementable.

Experiment Feasibility

Exertica will have a similar experiment to *Survival of the Fittest* in an uncontrolled environment. It will require participants to download the exergame and try it for a few weeks, maybe combined with some observations. However, physical exertion measurement will be difficult due to the app not requiring specific physical activity from players.

Innovation

Exertica is not as innovative as other concepts ideas, since it is an exercise version of *Habitica* [75]. *Habitica* can already be used for exercise, even though it is not specialized in it. Therefore, *Exertica* does arguably not provide new exergame research possibilities.

Physical Exertion

Evaluating *Exertica's* physical exertion is not applicable due to being able to use the game for any physical activity. For example, someone using it as motivation to walk more will get less physical exertion than someone using it for more intense exercises. Therefore, it is not possible to grade the concept's exertion level.

Potential Reach

Exertica is on smartphones, which provides a high number of potential users. However, *Habitica* is already available as a mobile app. The existence of a mobile version of *Habitica*, lowers the reach of *Exertica* since people might use *Habitica* instead. Therefore, the potential reach of *Exertica* is medium.

Motivation

We initially thought that *Exertica* would be a good concept, but the review revealed that it is not very innovative. Additionally, it is closer to gamification rather than an actual game. Therefore, our motivation for this concept is low.

13.6 Beat Runner Review

Technological Feasibility

Beat Runner is a mobile exergame for Android that relies on accurate and timely step measurements to match the steps to the music. To test the feasibility of the concept, we created a small pedometer app for Android. There are three main options to detect and monitor step data in Android:

The first option is to use Google Fit's Sensors API for reading raw sensor data in our app in real-time with its data type `TYPE_STEP_COUNT_DELTA`, which returns the number of steps taken since the last reading [69]. The steps measurements had high accuracy, but the high delay and delay variation makes this option infeasible to use in *Beat Runner*.

The second option is to use Android's sensor framework to monitor step sensors directly. The two options available are `TYPE_STEP_COUNTER`, which provides the number of steps taken by the user since the last reboot while the sensor was activated, and `TYPE_STEP_DETECTOR`, which triggers an event each time the user takes a step. The problem with both sensors is that they may be either hardware-based or software-based, depending on the device. The step counter has higher accuracy than the step detector, but at the cost of higher latency (10 vs. 2 seconds) [71]. Our testing revealed that both sensors are too inaccurate and have a latency of 5-15 seconds, making both options infeasible for the concept.

The last option is to use the accelerometer sensor directly and write a step detection algorithm that meets our requirements. This sensor is always hardware-based and gives fast and reliable data that can be used as input to an algorithm [71]. The problem is creating an algorithm that is both accurate and low latency. We created a small step detection algorithm to test if it is feasible to achieve this within the project's scope and looked at papers describing step detection

algorithms. It is not difficult to create an algorithm that is either accurate or has low latency. However, achieving both is challenging and would require too much time for this project.

Experiment Feasibility

Beat Runner will have a similar experiment to *Survival of the Fittest* in an uncontrolled environment. It will require participants to download the exergame and try it for a few weeks, combined with some observations. It is not ideal but will give results that indicate the game's impact on physical activity and motivation.

Innovation

There are currently no existing exergames that are similar to *Beat Runner*. *Beat Runner* uses mainly audio as a stimulus to the player. There are not many existing games with audio as the primary feedback source. This feature means that the concept idea can provide new research and a new exergame experience. Thus, the exergame concept can be regarded as highly innovative.

Physical Exertion

Beat Runner makes the player jog or run for a specific duration and tempo, which requires a high level of exertion.

Potential Reach

The potential reach for *Beat Runner* is high because it will be available on smartphones, which creates a lot of potential users.

Motivation

Our motivation for this game is high because it is innovative, has a high potential reach, and has a high physical exertion. Designing a game based on audio rather than graphics is an intriguing challenge that we believe would be fun to explore. Sadly, the step detection challenge makes this concept a risky choice.

13.7 Summary

This chapter has reviewed the different concept ideas according to technological feasibility, experiment feasibility, innovation, engagement, physical exertion, potential reach, and motivation. Table 13.1 shows a summary of the review. Based on this review, the concept of our choice for the project is *Space Space Revolution* (SSR). SSR is a feasible concept, and we are motivated by it. The main downside is the low potential reach. However, SSR can be a fun and innovative exergame that can require physical exertion and generate motivation. SSR can also provide new insight into exergames and their potential.

Table 13.1: Review of concept ideas. H = high, M = medium, L = low, NA = not applicable.

Concept	Technological Feasibility	Experiment Feasibility	Innovation	Physical Exertion	Potential Reach	Motivation
Space Space Revolution	M	**H**	**H**	**H**	L	**H**
King of the Pad	M	**H**	**H**	M	L	**H**
Survival of the Fittest	**H**	M	M	M	**H**	M
Pirate Riches	**H**	M	L	L	**H**	M
Exertica	**H**	L	L	NA	M	L
Beat Runner	L	M	**H**	**H**	**H**	**H**

Chapter 14

Space Space Revolution

This chapter gives a detailed description of *Space Space Revolution* (SSR), the chosen exergame concept for this project.

14.1 Game Synopsis

In year 6174, an ever-going conflict between the Striders and the Spuds is ravaging the universe. The couch-loving Spuds have grown strong and taken control, promoting their sedentary lifestyle. The world as we know it is slowly turning to a standstill. Now you and your friends must help the sporty Striders regain control. Planet by planet, step by step, you must run to save the world from an indolent life.

14.2 Gameplay

SSR consists of several planets that the player needs to conquer to save the universe. Each has several game levels that unlock new levels and planets when completed. A level is played by stepping on the dance pad. The player needs to repeatedly step back and forth on the side arrows to make the avatar run, and the player's step frequency determines its speed. The game level moves forward steadily, and the goal is to stay within the game view. In addition, the player has to jump across gaps or obstacles. The players jump by standing on both side arrows simultaneously and then jump straight up and land back on the arrows. You jump when you release the arrows on your way up, and the jump height is determined by the duration you are in the air. The player starts a level with three hearts, and if the avatar fails to stay inside the game view, one is lost. If all are lost, the player fails the level but can restart it. The avatar plants a flag at the end of the level to show its completion.

There are three item types in each level that the player can utilize. The first type is *power-ups*, which gives a power usable to overcome an obstacle or make it easier. Examples of possible power-ups are jet-pack, jump boost, and slowing down the level speed. They are temporary (around 3 seconds) and are activated when picked up. New power-ups are introduced when unlocking a new planet. The first planet may not have any power-ups, and the second could introduce the jump boost.

The second type is *stars*, and there are a total of 3 stars in each level. They are located so that they are hard to reach, and the objective is to collect them all. The stars do not contribute to the game's progress but are intended to be an extra challenge for the player. The number of stars acquired on each level is visible when choosing which level to play, hopefully motivating players to retake ones where they failed to obtain all three stars.

The last type is *coins*, which players can use to purchase items in an item shop. The item shop is accessible from the menu, and it is possible to buy new avatars and spaceships. None of them affect the gameplay and are purely cosmetic.

After completing a level, the game shows the players' score, stars collected, remaining lives, and other statistics (e.g., time, steps, and jumps). The game calculates the score according to the number of coins and stars collected, lives lost, and the time it took to reach the end of the level. The player avatar can do different poses in the victory scene to celebrate.

Some levels are shorter with a specific challenge. These challenge levels provide more variety to the gameplay. There are no stars on challenge levels since they are short and unique. These levels should also add some extra difficulty to the game. Challenge levels are purely optional.

One or two players can play the game on the same device. If two people are playing, both avatars are visible in the same game view, and the objective is still the same. However, the players share the three hearts. The motivation behind this is to avoid someone dying at the beginning of the level and then waiting for the other player to finish. The sharing also makes the game more cooperative since the players have to match each other's speed. Playing together is mainly cooperative, but each player gets an individual score, so there is some competition.

14.3 Design

The general aesthetic of the game is fun and colorful. The design's purpose is to enhance the player's fun and excitement. The sprites and backgrounds of the game are 2D because of personal preference, rigging ability, and increased performance. Figure 14.1 shows concept art of different avatar designs. They have the same shape, so we can reuse the same animation rig on all avatars to save time. The avatar heads and colors vary greatly to distinguish them. Making the avatars distinct is important for the players to know which character is theirs.

Levels have different planet themes and designs. Figure 14.2 shows a level on a planet inspired by Mars. The figure also shows an example placement of the character, coins, and a star. Other planet themes can, for example, be a moon, snowy mountains, a volcano, or a jungle. The collectible items must be easy to spot. It is also crucial to have a high contrast between the platforms and the background to make it intuitive to know where the character can stand. The avatar must be easy to spot and not blend into the level. Therefore, we must choose colors carefully.

Figure 14.3 shows the level selector design. The figure's planet is Mars-based. Levels are visualized with big buttons on the ground. Each level has three stars, and the amount obtained and the high score are shown on the selected level. Red buttons are locked levels, blue are unlocked but uncompleted, and green are completed levels. Completed levels have a Strider flag to show that the player has conquered them. If the level is completed without losing a life, it is marked with a gold heart. The smaller levels are challenge levels. The selected challenge level displays the name of the challenge to provide the player a hint on what the challenge is. The bigger level button is the final level of the planet. Focusing on making it intuitive where the player has to go is important.

Figure 14.1: *Space Space Revolution* character designs.

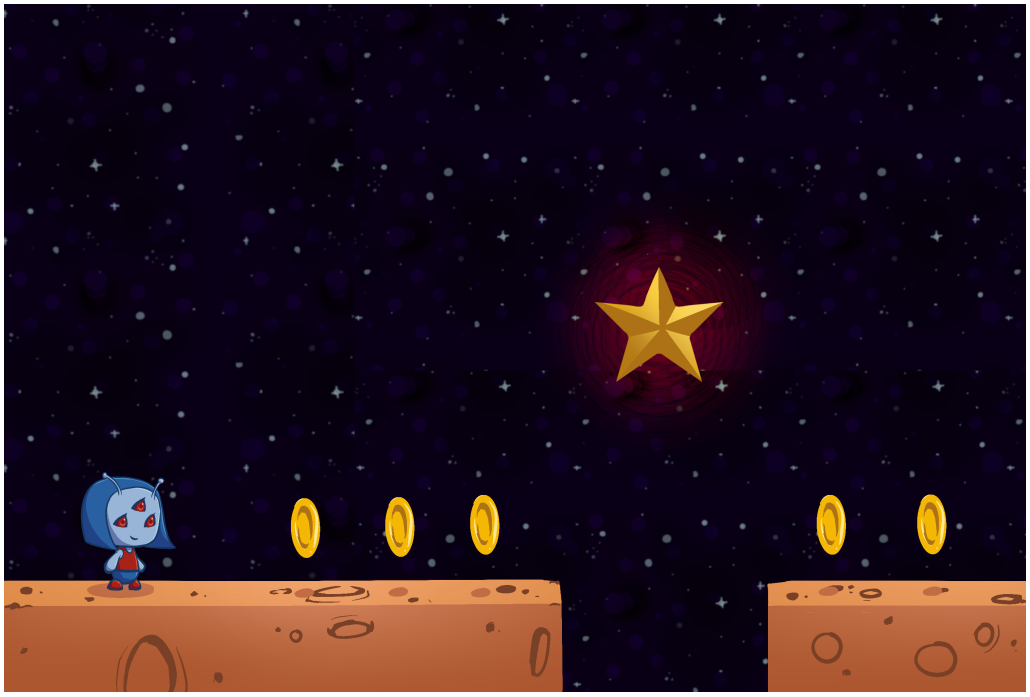


Figure 14.2: *Space Space Revolution* level design.

Figure 14.3: *Space Space Revolution* level selector design.

14.4 Sound and Music

SSR will have upbeat music playing when playing a level and a more relaxed soundtrack otherwise. The level music should have a fast-paced style suited for running. It should also be different depending on which planet it is on or if it is the final level to provide more variety and immersion. Additionally, sound effects are played when taking a step, jumping, collecting items, and activating power-ups. The player can adjust the menu music, level music, and sound effects volumes individually from the menu.

14.5 Menu

After registering the dance pad(s), the players start in the *main menu*. From here, they have the option to begin a new game, continue on the current save file, change players, change options, or exit the game. By pressing *Continue*, the player is presented with the *planet selector*. The game will have a separate *in-game menu*, which is accessible throughout the whole game, except in levels. It contains options for changing players, returning to the main menu, options, viewing controls, and statistics. The *level menu* is the menu available while playing a level or the tutorial. It gives access to options, controls, and the ability to restart or exit the level.

In the *planet selector* the user first gets an overview of the different planets and their progression. By selecting a planet, the player moves to the *level selector*. In the *level selector* the player can see the levels on a planet and select which one they want to play. The completed ones also show the player's level score and stars. The *Co-op* menu screen shows the dance pads connected and provides the ability to disconnect or add players. In the *options* menu, there are settings for controlling music and sound effects. The *statistics* page shows the user's accumulated statistics from playing the game, including general statistics like time played, levels completed, and stars collected. It also has individual statistics for each player, including the number of steps and jumps, distance traveled, and average step frequency.

14.6 Controls

The dance pad will be used to play the game and to navigate the different menus and screens. We don't want to force the players to use the PC keyboard to navigate the game.

The controls perform different actions inside and outside of a level. Figure 14.4 shows SSR's control scheme. The left one illustrates the controls when the player is inside a level, and the right one is for the rest of the game. Another notable matter is that the *menu* buttons do nothing while in the main menu. The player can exit the level menu and in-game menu by pressing "START" or "SELECT" inside a menu. Figure 14.5 shows the mapping from keyboard to dance pad.

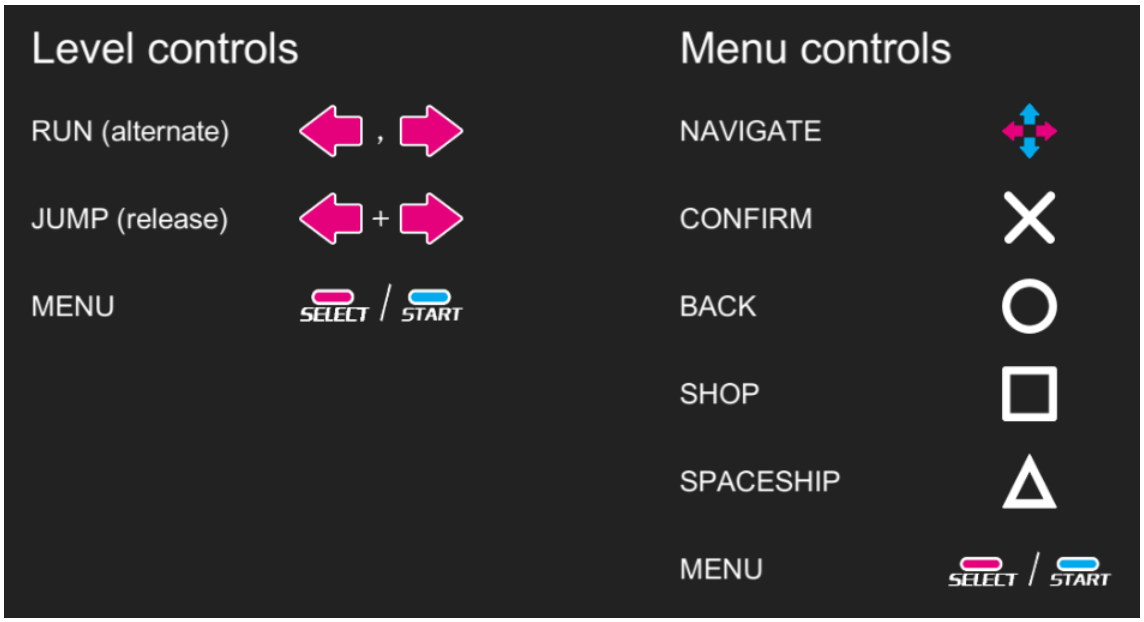


Figure 14.4: *Space Space Revolution* control scheme.

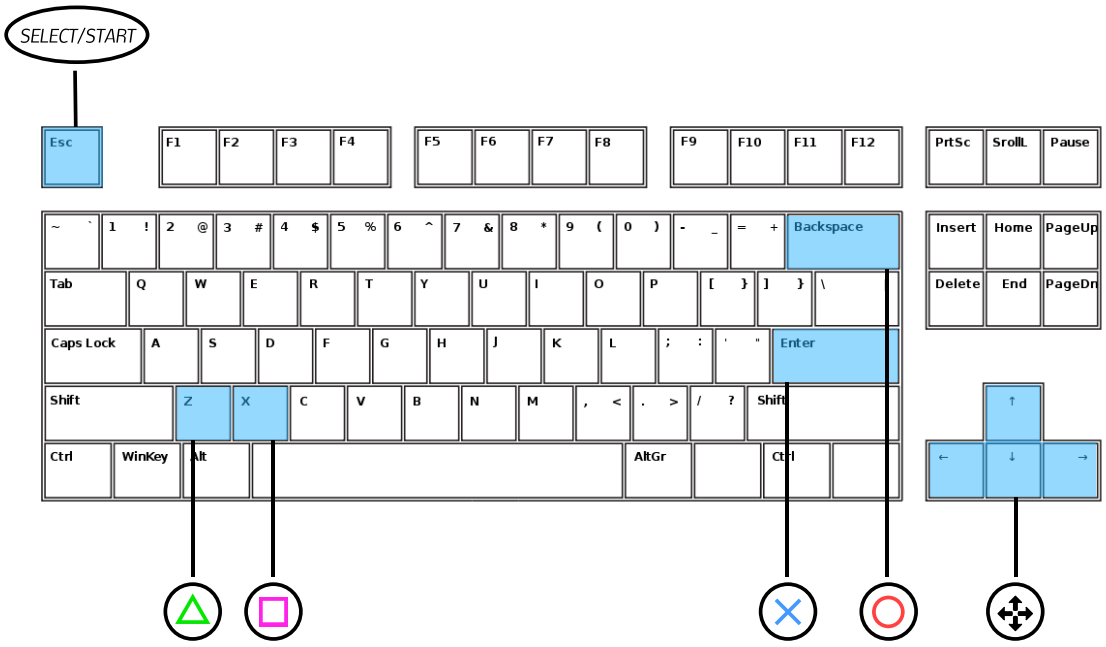


Figure 14.5: *Space Space Revolution* keyboard mapping to dance pad.

14.7 Accessibility

We want SSR to be accessible to users with various types of impairments. The authors of "Game accessibility: a survey" [218] categorize video game accessibility problems into four categories that correlate to a specific type of impairment:

- *Visual impairment* is a loss of vision, such as low vision, a degree of blindness, or color blindness.
- *Hearing impairment* is a partial or complete loss of the ability to hear from one or both ears.
- *Motor impairment* refers to a limitation of function in muscle control or a limitation in mobility.
- *Cognitive impairment* is a mental and psychological disorder such as Alzheimer's, autism, and Down syndrome.

Our strategies to improve accessibility to *visually impaired* users are to have high-contrast color schemes accommodating color blindness in our menus and game levels and fonts that are easy to read. Since visuals are the primary stimulus in our game, it is challenging to accommodate severely visually impaired players. They require us to have an option to replace visual feedback with auditory or haptic feedback, which is not within the project scope.

Users with a *hearing impairment* can play SSR with no issues. Our use of audio and sounds enhance the game experience. However, it does not help the players perform better by, e.g., giving audio cues.

Users with a *motor impairment* often find it difficult or impossible to use conventional game input devices (e.g., mouse and keyboard, controllers). Therefore, they revert to alternative input devices such as switch inputs or one-handed controllers [218]. SSR uses a dance pad as its game input, which should give users with upper-body motor impairments a chance to play the game regularly. It is also possible to play the game with a keyboard if a dance pad is not possible. Using a keyboard removes the exercise aspect of the game, but it would still be playable and enjoyable. We do not plan to support other input devices directly, but it is possible to map switches or other devices to the keyboard inputs used in the game. Since SSR requires no analog input, it is easy to create alternative controls for users that can only produce binary inputs.

SSR is a fast-paced game, making it hard to accommodate players with *cognitive impairments*. Cognitive impairments are variable and complex, causing different and varying barriers for individuals with cognitive impairments. Games for cognitively impaired players often require the game to be specially designed for a specific disorder [218]. Therefore, we will not develop SSR with this impairment in mind.

14.8 Player Scenarios

We have created player scenarios that show how players might interact with our game as part of the design process. Figure 14.6 is the first scenario, which pictures a player starting up SSR, playing a level, and viewing his score. It is the general intended flow when a user starts up the game.

Figure 14.7 is our second scenario. This scenario is the same as the previous one, but with two players instead of one. The play flow is similar to playing solo.

Figure 14.8 is the final scenario, which shows a player viewing his game statistics. The player can press "Statistics" from the menu to get statistics tracked by the game.

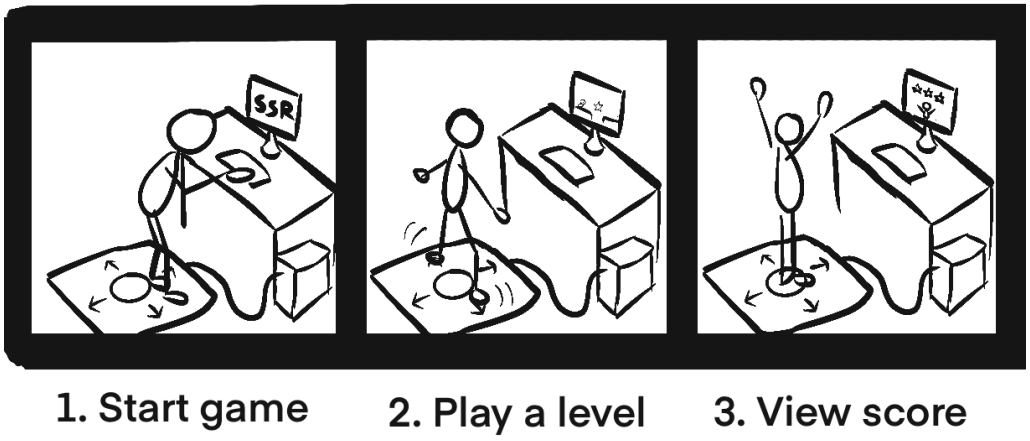


Figure 14.6: Player scenario of a single player playing a level in single-player.

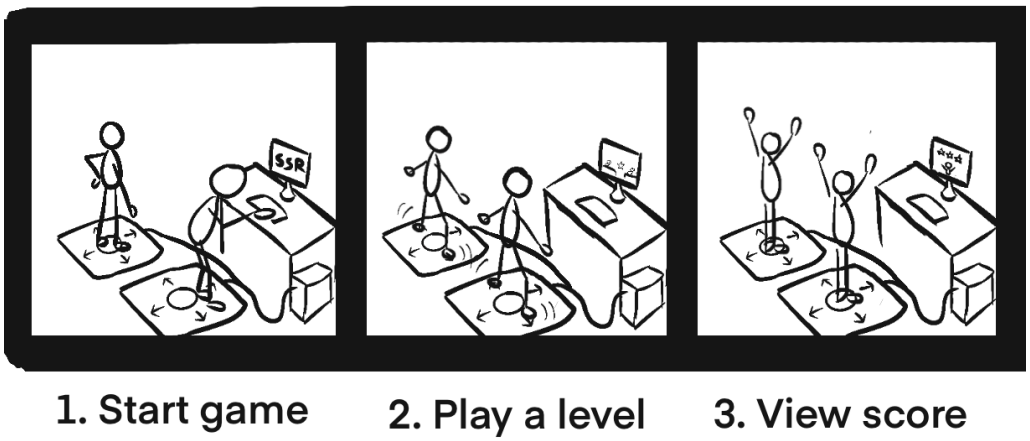


Figure 14.7: Player scenario of two players playing a level in multi-player.

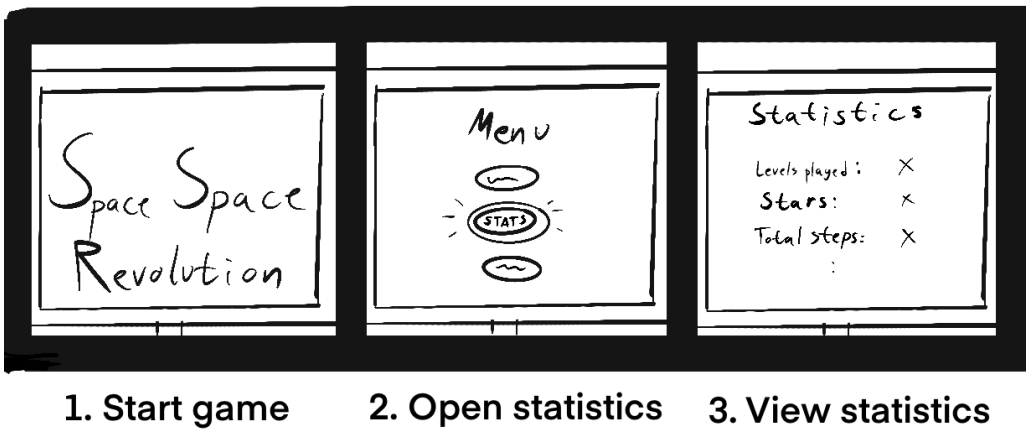


Figure 14.8: Player scenario of viewing statistics.

14.9 Summary

SSR is a game that combines a 2D platform game with dance pads, and the goal is to conquer space by completing levels on planets. The player must help the Striders regain control of the

universe and save the world from an indolent life controlled by the Spuds. It is played by stepping on the dance pad, and the running mechanic consists of the player repeatedly stepping back and forth on the side arrows. The player must run fast enough to stay within the moving game level.

The game's general aesthetic is fun and colorful to enhance the player's fun and excitement. The different avatars have a variation in colors and head design. However, for convenience, their size is the same. Levels have different planet themes and designs ranging from jungles to wastelands. SSR will have upbeat music playing during a level and a more relaxed soundtrack otherwise. Additionally, sound effects are played when, for example, taking a step, jumping, collecting items, and activating power-ups.

We use the dance pad to play the game and navigate the different menus and screens. It is also possible to control the game with a PC keyboard. Figure 14.4 and Figure 14.5 show the control scheme for the game. We want SSR to be accessible to users with various types of impairments. Therefore, we have several strategies used in our design and controls to improve accessibility.

Chapter 15

Mapping Game Enjoyment to Concept

This chapter describes the use of different game enjoyment theories from Chapter 8 in the *Space Space Revolution* (SSR) concept. Utilizing them may help in making the exergame concept more enjoyable and motivating. The game enjoyment theories have different criteria that we used when designing SSR.

15.1 GameFlow in Concept

The *GameFlow* criteria have been considered when designing SSR. Some elements are more crucial than others. For example, *Challenge*, *Controls*, and *Social Interaction* can be considered more important due to their high impact on enjoyment.

Concentration

The concept shall provide significant stimuli from both the audio and visuals. The audio will include upbeat music and motivating sound effects. Visually, the game shall have attractive animation. The game will have a 2D cartoon-like style but is detailed enough to provide extra information with the art. The game quickly grabs the player's attention with stimuli, intuitive gameplay, and a fun narrative. The concentration is maintained by slowly introducing varied goals, challenge increases, and rewards. For example, the game will wait a bit to introduce power-ups. One important aspect is that it should be easy and quick for the player to start levels and use as little time in menus as possible.

The player must not be cognitively overloaded. The player might be more easily overwhelmed with things to concentrate on because of the unconventional controller. The overload may result in the player being unable to focus on the game while correctly using the physical dance pad. It is still essential to maintain the player's attention but balancing the cognitive load is also crucial. If the game is unbalanced, the player might get confused and stressed, resulting in not wanting to play the game. SSR will use feedback to help balance the cognitive load and facilitate the player in knowing if they are using the controller correctly. The feedback lets the player focus more on the game and less on the physical pad.

Challenge

The game/camera moves forward at a base speed, and the avatar's running speed is determined by how fast the player is stepping on the side arrows. The camera speed has some variation depending on the position of the avatar. It is faster if the avatar is close to the right side of the game view, and it slows down if you are closer to the left side. This variation allows the player to adjust the challenge level to their preference. Additionally, the levels will become harder and

introduce new mechanics as the player progresses through the game. The player receives a time bonus depending on their time, which encourages a fast pace throughout the level. The difficulty should be thoroughly tested since it is a crucial part of *GameFlow*.

Player Skill

It shall be effortless for new players to understand how to play the game. Information about the controls is always present in the menu. A skippable interactive tutorial level is shown at the beginning. The tutorial describes as much as possible with images instead of text. The tutorial starts slowly and gives the player time to get used to the controls and dance pad arrow locations. The player is paid for their effort with in-game rewards such as coins, avatars, and spaceships.

Controls

Making the player feel a good sense of control is very important for SSR due to being an exergame that uses unconventional controllers. Therefore the input required should follow conventions and be thoroughly tested. The avatar will move their feet following the dance pad input. In other words, when the player steps on the right arrow, the avatar will move their right foot. The jumping mechanic is designed to feel natural. To jump, players must stand on both side arrows and jump upwards. The avatar jumps if both side arrows are released simultaneously, and the height is determined by how long the player stays in the air before landing back on the arrows. The game will follow conventions and include confirmation boxes for central choices, such as starting a new game save. The player's impact on the world is shown with their flag being present on completed levels.

Clear Goals

The main goal is presented early, and intermediate goals later. When starting the game, a cutscene plays. The cutscene shows the objective of conquering the universe. The tutorial is shown after the cutscene. It is interactable and introduces intermediate goals such as high scores, coins, and stars. This way, the player is not overwhelmed while still having enough to do.

Feedback

The player receives feedback for goal progression, actions, and status. The game uses both visual and audio stimuli feedback. Goal progression feedback is shown by changing the visuals to illustrate completion, such as a flag on a completed level or displaying all stars collected. Levels show the player's score while playing them. The player's number of steps and jumps are presented at the end. The player receives feedback on their actions by having the character move their feet following the dance pad input. This feedback is extra paramount because it lessens the player's cognitive load. With this feedback, the player knows which arrow they pressed and can focus more on the game instead of the pad. If the players fail the level or pause it, a progress bar shows how close they are to completing it.

Immersion

SSR makes the players less aware of their surroundings and more involved in the game by providing a lot of stimuli and enjoyable controls. Creating pleasant gameplay controls allows the player to get immersed in the game.

Social Interaction

The game supports social interactions with local multiplayer where the players cooperate and compete. Two players can choose to work together to finish levels. The cooperation is enhanced by having a shared life system. There is also a slight competition aspect since the players receive individual scores. On the victory screen, the player with the highest score is highlighted.

15.2 Challenge, Fantasy, and Curiosity in Concept

Malone's model has similarities with the *GameFlow* model but also some unique aspects. All components were used to design SSR, and elements are higher weighted when mentioned in multiple models. For example, the usage of *challenge* is essential.

Challenge

The *challenge* aspect is improved by having a fun and simple goal which is fantasy-related. The game provides uncertainty with several level goals like high scores, coins, and stars. SSR also tries to minimize the self-esteem damage from failing a level by making the player keep the coins collected and instantly ask if they want to restart it.

Fantasy

SSR provides *intrinsic fantasy* where both the *skill* and *fantasy* are dependent on each other. The goal is to conquer planets by finishing levels. The goal itself is not to only step on the dance pad arrows. The game also provides an emotional aspect by having a fun and compelling narrative.

Curiosity

The game makes the player more curious by balancing environment complexity with the different mechanics, items, and level designs. The player feels sensory curiosity from the visual and audio stimuli. It is also enhanced by providing new elements. The player is shown different planets and locked levels, which might boost curiosity as the player wonders about what these new places will be. Curiosity also increases with collectibles such as avatars and spaceships.

15.3 Dual Flow in Concept

We designed SSR around maximizing attractiveness while still providing a moderate level of effectiveness. The enjoyment of the game is prioritized over maximizing physical exertion.

Attractiveness

The attractiveness is based on the GameFlow model, which we used when designing SSR. The players will hopefully enter an enjoyment flow state when playing the game. The flow state is expectedly more easily reachable because SSR uses the GameFlow elements.

Effectiveness

SSR can provide a moderate level of effectiveness to the player. By having a variable camera speed, the player can choose the right intensity. This way, the game is effective regardless of the player's fitness. However, the player might have to familiarise themselves with the controls before getting to the right intensity. The effectiveness might not be equally balanced when playing co-op due to both players having the same difficulty. The difficulty in co-op follows the player furthest behind. These effectiveness problems are, however, inconsequential due to SSR's focus. The focus is not on maximizing effectiveness but rather on being a more casual game that provides some physical activity. Maximizing it might harm the user experience as the player may lose concentration when exhausted.

15.4 Summary

SSR is created around the enjoyment theories mentioned in Chapter 8. They contain different aspects that one should consider when designing a game. SSR follows the enjoyment theories by, for example, having a clear overriding goal, providing a fantasy to get invested in, and a moderate amount of physical activity. Some theory elements were more relevant in the SSR design process

than others, such as challenge, controls, concentration, and feedback.

Challenge and controls were essential aspects when designing SSR. The balance between the challenge level and player skill needs to be thoroughly tested during implementation. It is also paramount that the controls themselves are fun and intuitive so the player can focus on the game challenge instead of struggling with the controller. SSR will provide a well-adjusted challenge level by having a variable camera speed. Optional intermediate goals are presented throughout the game to make it harder if the player desires it.

Concentration and feedback are both very significant to not cognitively overwhelm the player. Due to the unconventional controller, the player has to get used to it. The controller familiarization requires the player to focus on the game and their physical location on the pad. Therefore, it is necessary not to overburden the player with aspects to focus on in the game. However, there must be enough game components to grab the player's attention, or else they might become bored. In other words, it is crucial to have the right balance between the elements that require focus. The player can pay less attention to the physical dance pad by implementing a feedback system. The feedback should provide the player with enough information to know if they are using the controller correctly or need to adjust their position.

Chapter 16

Physical Activity in SSR

Space Space Revolution is a dance pad-based exergame, which requires the player to step on a dance pad to play it. As described in Chapter 14, the player needs to repeatedly step back and forth on the side arrows to make the avatar run, and the player's step frequency determines its speed. The game level moves forward, forcing the players to run if they want their avatar to stay alive. They also have to jump to get across obstacles. Therefore, the exergame focuses on aerobic activity types (see Section 10.4), as its activities combine jogging and dancing.

The game is also similar to interval training. The game levels have hills and valleys to give the players an intensity variation. Going uphill requires the player to have a higher step frequency to keep the same pace, and downhill requires a lower frequency. This variation will help ensure a sufficient level of player exertion without exhausting the player too quickly, which is a design challenge in aerobic-based exergames (see Section 10.4).

As described in Chapter 15, *challenge* is an essential aspect of our concept. When players play over time, their fitness will improve. This improvement requires the exergame's intensity and difficulty to increase if we want it to stay effective. Therefore, the levels' speed is determined by the players. Additionally, as a player progresses in the game, the levels become more challenging.

Part IV

Implementation

Part IV presents the implementation. It starts by describing and justifying our chosen technologies before showing the game's functional and non-functional requirements. Next, it shows the software architecture. Then, the software testing is described, including the implementation status of the functional requirements and the quality attribute scenarios. The part ends by showing how we designed the visual and audio aspects of the game.

Chapter 17

Chosen Technologies

This chapter presents the chosen technology stack to develop *Space Space Revolution*. It is included in this report from the specialization project (see Chapter 2). The different technologies are tested and reviewed to verify that they meet the project's requirements.

17.1 Unity

Unity is a popular cross-platform game engine for developing 3D games, 2D games, interactive simulations, and other experiences, and it supports over 25 different platforms, including Windows. It has an active community with online forums and thousands of tutorials. Additionally, it is easy to use for indie game development and developers without previous game engine experiences. The Unity editor has a drag and drop GUI and supports scripting in C# [194][44].

Two disadvantages of Unity are that it is unsuitable for big projects and does not promote good code practice [44]. Our project is not aiming to be an AAA game or a large open landscape, which makes the first disadvantage insignificant. Good code practice is still doable, but it requires us to be more careful with our choice of architecture.

To test that our concept is feasible in Unity, we created a small proof-of-concept (POC) of *Space Space Revolution* in Unity, as shown in Figure 17.1. The POC is a simple implementation of the core gameplay in our game, and we had no issues using a dance pad to control the game. It also showed that the game could potentially be enjoyable and give its players a high physical activity level.

Figure 17.1: *Space Space Revolution* proof-of-concept in Unity.

17.2 Django and PostgreSQL

The game needs a backend to keep track of users and statistics. We will also use the statistics for our testing and evaluation of the game. A simple REST API in conjunction with a relational database is sufficient to meet these requirements.

Django is our choice for the server. It is a high-level Python web framework that is free and open-source. It focuses on rapid development and less code [51]. To create a REST API with Django, we use the Django REST Framework, a toolkit for building web APIs with Django. We both have experience with it, and choosing it helps us quickly develop a backend, which enables us to spend more time on the gameplay and the evaluation of the game.

The data that the database needs to store is relational. Therefore, a relational database is best suited for this game. Several popular relational databases exist that are more than adequate for our needs. We have chosen to use PostgreSQL since it is free and open-source, and we have used it together with Django in previous projects. The database will run on a Heroku Hobby tier server [80]. Heroku has limits for query timeout, data size, and the number of calls to the API per hour [81], but these are not relevant for our game because it is a low-scale project.

17.3 Summary

Our chosen technologies for SSR are Unity, Django, and PostgreSQL. Unity is a simple cross-platform game engine that is easy to use. It has a few disadvantages, but none are significant to this project. Django and PostgreSQL were chosen due to the simplistic backend requirements for this project and the group's prior experience.

Chapter 18

Requirements

This chapter defines the functional and quality attribute requirements for SSR. It is included in this report from the specialization project (see Chapter 2).

18.1 Functional Requirements

The functional requirements define the specifications of a system regarding what it shall do, its behavior, and reactions [103]. Table 18.1 shows the created functional requirements for SSR with their priority, ranking between low, medium, and high.

Table 18.1: The functional requirements for SSR. High = "needs to be implemented", Medium = "should be implemented" and Low = "would be nice to have".

ID	Description	Priority
FR1	As a player, I should be able to play the game alone	High
FR2	As a player, I should be able to play the game with another person	High
FR3	As a player, I should be able to play with a dance pad	High
FR4	As a player, I should have access to an in-game menu	High
FR5	As a player, I should be able to start a new game	High
FR6	As a player, I should be able to continue on a save file	High
FR7	As a player, I should lose a life when not within the game screen	High
FR8	As a player, I should share lives when playing multiplayer	High
FR9	As a player, I should lose a level when I have no hearts remaining	High
FR10	As a player, I should get auditory and visual feedback on my actions	High
FR11	As a player, I should be able to see my progress in the game	High
FR12	As a player, I should be able to have a variable difficulty level	High
FR13	As a player, I should get access to new levels after completing a level	High
FR14	As a player, I should be able to collect stars in a level	High
FR15	As a player, I should be able to collect coins in a level	High
FR16	As a player, I should get a personal level score when completing a level	Medium
FR17	As a player, I should be able to view personal statistics	Medium
FR18	As a player, I should be able to buy new avatars and spaceships	Medium
FR19	As a player, I should be able to choose an avatar and spaceship to play with	Medium
FR20	As a player, I should be able to edit the game's settings	Medium
FR21	As a player, I should be able to view the control scheme	Medium
FR22	As a player, I should have access to a tutorial	Medium

Continued on the next page

Table 18.1 – continued from the previous page

ID	Description	Priority
FR23	As a player, I should get access to a new planet after completing the final level on a planet	Medium
FR24	As a player, I should be able to skip the tutorial	Low
FR25	As a player, I should be able to move my character on the level victory screen	Low

18.2 Quality Attribute Requirements

This section presents the chosen quality attribute requirements. The primary quality attribute is modifiability, while usability and performance are our secondary ones. Quality attribute requirements annotate functional requirements [103]. We use scenarios to measure each quality attribute. Note that "application" as the artifact refers to the application running on the player's device, not the server or database. The scenarios contain these attributes:

- **Source of stimulus**: The trigger of the scenario.
- **Stimulus**: What is done to trigger the scenario.
- **Artifact**: The part of the system being affected.
- **Environment**: The state of the system.
- **Response**: How the system reacts to the stimulus.
- **Response measure**: How the reaction is measured.

18.2.1 Modifiability

Modifiability is about the cost of adding or modifying system functionality and is measured in time or money. It also includes how a modification affects other functions or quality attributes [103].

Table 18.2: Modifiability scenario - M1: Add a new avatar.

Source of stimulus	Developer
Stimulus	Add a new avatar design into the game
Artifact	Application
Environment	Design time
Response	New avatar available in shop or as a reward
Response measure	Less than 20 minutes

Table 18.3: Modifiability scenario - M2: Add a new level to a planet.

Source of stimulus	Developer
Stimulus	Add a new level to a planet
Artifact	Application
Environment	Design time
Response	New level added and playable from level selector
Response measure	Less than 30 minutes

18.2.2 Usability

Usability is the system's capability to provide a condition for its users to accomplish desired tasks in a safe, efficient, and enjoyable manner. Focusing on usability is proven to be an efficient way to improve the user's perception of the system's quality [103]. The players should quickly be able to understand the game.

Table 18.4: Usability scenario - U1: Player satisfaction with level controls.

Source of stimulus	Player
Stimulus	Player plays a level
Artifact	Application
Environment	Normal operations
Response	Player finds the controls intuitive and enjoyable
Response measure	Player enjoyment with the controls is on average over 7/10

Table 18.5: Usability scenario - U2: Player understands how to move the character in a level.

Source of stimulus	Player
Stimulus	Plays the tutorial for the first time
Artifact	Application
Environment	Normal operations
Response	Understands the control scheme when inside a level
Response measure	Within 5 minutes

Table 18.6: Usability scenario - U3: Player satisfaction with menus.

Source of stimulus	Player
Stimulus	Player uses the menus
Artifact	Application
Environment	Normal operations
Response	Player is satisfied with the menus
Response measure	Player satisfaction with the menus is on average over 7/10

18.2.3 Performance

Performance is about how well the system can meet timing requirements and achieve acceptable timing behavior, and it is measured by throughput and latency [103]. The game should be easy to run and responsive to user input.

Table 18.7: Performance scenario - P1: Loading a level.

Source of stimulus	Player
Stimulus	Player presses confirm on a level
Artifact	Application
Environment	Normal operations
Response	The selected level is loaded
Response measure	The level is loaded within 5 seconds

Table 18.8: Performance scenario - P2: Consistent frame rate.

Source of stimulus	Player
Stimulus	Plays the game
Artifact	Application
Environment	Normal operations
Response	Maintains consistent frame rate
Response measure	At least 50 frames per second

18.3 Summary

This chapter provided the project's functional and quality attribute requirements. The functional requirements order the different functionalities to prioritize what to implement. The primary quality attribute is modifiability, while performance and usability are the secondary.

Chapter 19

Software Architecture

This chapter explains the software architecture for SSR. It describes the rationale behind the architecture and which tactics and patterns were used. The 4 + 1 architectural view model [101] is used to illustrate the architecture.

19.1 Architectural Drivers / Architectural Significant Requirements (ASRs)

Architectural drivers, also known as *architectural significant requirements* (ASRs), are requirements that have a profound impact on the architecture and a high business or mission value. ASRs are generally extracted from business goals and shaped by quality attribute requirements. However, functional requirements and *Components and Technical Constraints* (COTS) can also influence the architecture [103, p. 292-304]. In this section, we describe the different ASRs related to SSR.

19.1.1 Functional requirements

This section describes general functional requirements for SSR that were significant for the software architecture.

Single-player and Multiplayer

The game is playable both alone and with two players. The multiplayer impact is not as profound since we decided to have a local co-op and not online multiplayer. However, the game is developed with multiplayer in mind, which influenced the architecture. The architecture can also support more than two players if desired in the future.

Different Input Methods

An influential functional requirement is the ability to play with both a dance pad and keyboard. This requirement requires the architecture to generalize the input and consider which input device each player uses.

Player Customization

Players shall be able to customize both how their avatar looks and the spaceship used to travel between planets. The architecture must support the customization in a good way that simplifies adding new skins and spaceships.

Power-Ups

Multiple different power-ups are present throughout various planets. The architecture must assist in making it easy to add new power-ups into the game.

19.1.2 Quality attributes

This section describes quality attributes for SSR that were significant for the software architecture.

Modifiability

Modifiability is SSR's primary quality attribute and is crucial for architecture. The architecture should support effortless modifiability for creating levels and planets. It must also, as mentioned, make it easy to add new avatars, spaceships, and power-ups.

Performance

Performance is a secondary quality attribute for SSR, but it is still very significant. Due to being an exergame, the architecture should support a low input delay. Substantial lag can cause the game to be unplayable. The architecture should facilitate a general high frame rate for fast feedback. Performance is also essential for the game experience to feel smooth and fluid.

Usability

Usability is another secondary quality attribute that influences the software architecture. The game shall be easy to understand and navigate, and the architecture should support this. Having an extra focus on usability is in this game necessary as the game uses dance pads, which players might not have previously used. Therefore, the game must have high usability so that the unconventional input device does not become a hindrance for players.

19.1.3 Business requirements

Here we will present the business requirements that affect the architecture. The first one is *meeting the goals* of this master thesis. This thesis includes an experiment to learn about the new exergame's physical activity and player experience potential. Gathering quantitative data from the experiment is often easiest with a database, which influenced the architecture.

Another significant architectural business requirement is the *time constraint*. We had 20 weeks to implement the game, design and conduct an experiment, analyze the experiment results, and write this thesis. The time constraint will also shape the architecture, especially since we do not have much experience with Unity or game development.

19.1.4 COTS

This section describes the *Components and Technical Constraints* (COTS) chosen for SSR that were significant for the software architecture.

Unity

Using Unity has a tremendous influence on the architecture, as using it practically requires the developers to follow its structure. As mentioned in Section 17.1, it does not promote good code practice. Therefore, using Unity may negatively influence the architecture, making it unnecessarily complex. However, we still follow good code and architecture practices.

Dance Pads

Dance pad controllers are not widely used, and the existing Unity input management does not support dance pads. Therefore the usage of dance pads requires the architecture to consider how

to receive the controller's input in the best way. In addition, different dance pad types are mapped differently. For example, a USB dance pad does not have identical button mapping as a PS2 dance pad. A custom input module is part of the architecture to identify dance pad input correctly.

19.2 Architectural Tactics

Through the usage of *architectural tactics*, one can realize the required quality attributes [103, p. 66-67]. The tactics can help maintain desired quality attributes and heighten the system's quality. The chosen tactics compliment mostly modifiability, but tactics for the secondary quality attributes are also present. However, some tactics can have different quality attribute trade-offs. For example, there is often a trade-off between modifiability and performance. All tactics mentioned are defined in the book *Software Architecture in Practice* [103].

19.2.1 Modifiability Tactics

This section explains the modifiability tactics used in the implementation of the exergame. Modifiability tactics aim to decrease the complexity of making changes to the system. The sections below show chosen tactics to enhance modifiability.

Reduce Size of a Module

If a module gets too large, we split it into several smaller modules. This tactic reduces the cost of making changes in the future and often makes the structure less complex.

Increase Cohesion

The application has increased cohesion by maintaining semantic coherence. Each module should have one responsibility. If a module has several unrelated responsibilities, place the irrelevant responsibility in a new or existing module.

Reduce Coupling

Below is the list of tactics used to reduce coupling in the system.

- **Encapsulate** restricts access to the data and methods within a unit. It is often also achieved by creating an explicit interface to a module. C#'s auto-implemented properties for `get` and `set` [123] are frequently used in the project for fast encapsulation.
- **Use an Intermediary** to break up dependencies. This tactic is used in the application, for example, by having the `SaveSystem`. The `SaveSystem` is an intermediary for retrieving anything from the GameData. The tactic is also a part of the publish-subscribe pattern as the event channel is an intermediary.
- **Refactor** is used on variables and names to avoid confusion. The implementation considers the usage of inheritance if modules are similar.
- **Abstract Common Services** is used when there are similar modules with the same core. An example of this is the abstract `PowerUp` class.

Defer Binding

It is best to bind values as late as possible. This tactic is achieved by, for example, using parameters instead of assuming variable values.

19.2.2 Performance Tactics

This section explains the performance tactics used in the implementation of the exergame. Performance tactics aim to decrease the system time to complete different tasks. The sections below show chosen tactics to enhance performance.

Control Resource Demand

Below is the list of tactics used to control resource demand in the system.

- **Manage Sampling Rate** reduces the sampling frequency and demand. This tactic often introduces some loss of fidelity too. The tactic is used for the statistics recorded throughout levels. The system sends all statistics, for example, the step count, when a player finishes a level. The tactic implementation creates fidelity loss because if the system crashes in the middle of a level, the statistics for that level are lost. However, this increases performance by not having to send statistics continuously throughout levels.
- **Reduce Overhead** is used by disposing of the disposable objects in a scene. If they are not removed when not needed, it can lead to a memory leak. A severe memory leak may reduce the amount of available memory leading to slower performance. The tactic is implemented by, for example, destroying level elements such as coins and stars instead of only making them inactive.

Manage Resources

Below is the list of tactics used to manage resources in the system.

- **Introduce Concurrency** is a tactic that focuses on making processes work in parallel if possible. The tactic reduces the blocked time of the system. The game uses concurrency, for example, when posting the statistics to the database. When finishing a level, the game creates a separate thread for sending the statistics and receiving the database's response. Without making the system run this process asynchronously, the game would see a frame freeze until receiving the database response.
- **Bound Queue Sizes** is a tactic for controlling the maximum number of queued arrivals and the related resources. The system implements the tactic by using Heroku. Heroku APIs limit the rate of calls to at most 4500 per hour [81]. Heroku PostgreSQL also has a timeout limit, where it cancels queries after 10 minutes.

19.2.3 Usability Tactics

This section explains the usability tactics used in the implementation of the exergame. Usability tactics aim to make it effortless for users to perform desired tasks. The sections below show chosen tactics to enhance usability.

Support User Initiative

Below is the list of tactics used to support user initiatives in the system.

- **Cancel** provides the user with the ability to cancel actions. The application does not support action cancellations when a process has started. However, for crucial actions, the game opens an overlay. Here, the player can always cancel and not perform the action they pressed. One example of the possibility to cancel is when deleting a save file to create a new game save.
- **Pause/Resume** gives the user the possibility to pause and resume the game as they please. Throughout the game, the player can pause the game by pressing *START* or *SELECT*. This input opens the pause menu, either the `In game menu` or the `Level menu` depending on the system's currently active scene. However, database calls can not be paused since that creates the ability for users to interfere with the statistics.

Support System Initiative

Below is the list of tactics used to support the system initiatives.

- **Maintain User Model** is about representing the player's knowledge about the game. GameData stores information about the player's progress in the game. For example, when a player completes a level for the first time. The level's button and its flag will change their sprite according to the system's state.
- **Maintain System Model** concerns the maintaining of an explicit model of itself. The tactic is implemented by, for example, showing the word "Loading" at the beginning of the game. Similarly, the system displays "Joining" when adding a player.

19.3 Architectural and Design Patterns

Patterns are packaged solutions to problems that often arise when developing systems [103]. In other words, a pattern establishes the relationship between a context, problem, and solution. Patterns are separated into either *architectural* or *design* patterns. The first often has a more direct and crucial impact on the overall architecture, while the latter is more relevant for specific parts of the architecture. There are three categories of architectural patterns: *module*, *component-and-connector (C&C)*, and *allocation*. A pattern is placed in a category by the pattern's dominant type of elements shown. We have utilized relevant patterns to structure the architecture to achieve its requirements. Table 19.1 shows the different architectural and design patterns used in *Space Space Revolution*'s development.

Table 19.1: The architectural and design patterns used in the architecture.

Pattern	**Description**
Client-Server	The architectural (C&C) pattern *client-server* consists of multiple clients wanting to access a shared resource or service. All clients have to communicate with a server to receive desired service [103, p. 219], which is useful for the project's ability to store experiment data in a database. The server and client will communicate through a REST API.
Publish-Subscribe	The *publish-subscribe* (C&C) architectural messaging pattern is a variant of the observer pattern. Several independent objects want to be notified about certain messages or events when they occur [103, p. 228]. The pattern will be used in the project to have different subscribable events.
Singleton	The *singleton* pattern is a design pattern that makes sure there can only be one instance of a class and provides global access to it [169].
Template method	The *template method* is a design pattern that avoids duplicate code for methods with identical core. It is used to implement a core template method that has internal operations overridden by sub classes [184].
Game Loop	The *game loop* pattern is a sequencing design pattern. The loop is a continuous lifecycle that processes player input, updates state, and renders the game [140]. It decouples the game time progression from player input to processor speed. It is essential for most games and is provided by Unity.
Update Method	The *update method* sequencing design pattern makes it easy to simulate multiple objects by having each of them process one frame of behavior at a time [141]. Combining it with the game loop makes it simple to have multiple unique and independent game objects. The update method is already established by using Unity.

19.4 4 + 1 Architectural View Model

We use the 4+1 architectural model to visualize and represent the project's architecture. The four main views, which are *logical*, *process*, *physical*, and *development* view, are used to represent stakeholders' distinct points of view [101]. Table 19.2 displays the different selected views with their purpose, target audience, and diagram types used to represent the view visually. The diagrams follow the Unified Modeling Language (UML) notation except for the entity-relationship diagram. Distinct colors are used throughout all diagrams to provide higher readability and understandability. Figure 19.1 shows the general color notation used in the diagrams.

Table 19.2: The selected architectural views.

View	**Purpose**	**Target Audience**	**Diagram Types**
Logical view	Describes the end-user functionality of the finished system. It decomposes the software architecture into its fundamental abstractions with object models and describes pattern usage.	Test subjects, GT4H, supervisor, and examinator.	Class diagram and entity-relationship diagram
Process view	Illustrates the system during runtime. It focuses on synchronization, concurrency, and quality attributes such as performance and availability.	Developers, supervisor, and examinator.	State diagram
Development view	Depicts the programmers' perspective, with the center of attention on packages, libraries, and subsystems. It looks at module organization in the development environment and subsystem decomposition.	Developers, GT4H, supervisor, and examinator.	Package diagram
Physical view	Depicts how the software components are mapped to physical hardware and its distributed aspect. The view focuses on the perspective of a system engineer.	Developers, supervisor, and examinator.	Deployment diagram

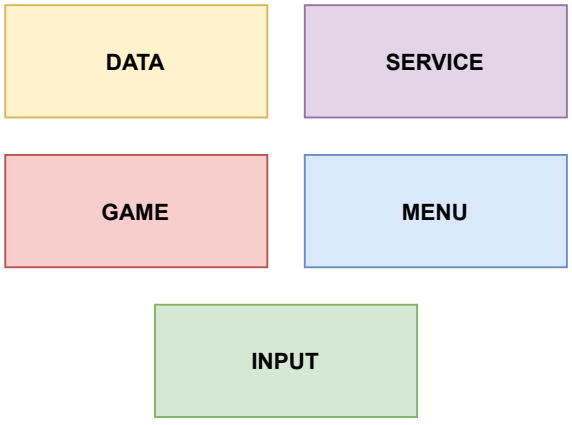


Figure 19.1: The color notation for different parts of the system.

Logical View

The *logical view*, also referred to as the *Object-Oriented Decomposition*, displays the architecture's fundamental abstractions through object models from the perspective of end-user functionality. The view focuses on the functional requirements and identifies common structures in the system [101]. We have used class diagrams and an ER diagram to illustrate the logical view. Figure 19.2 shows the most important classes and their folder placements. The other figures depict more specific parts of the system in more detail to easier explain certain functionality and pattern implementation.

Figure 19.2 shows a simplified class diagram of the architecture made in Unity. Only the most crucial classes are displayed, and the most influential ones are highlighted with a thicker border. The structure follows Unity's layout, with `GameObjects` that can contain any number of `MonoBehaviour` components to provide behavior and functionality. Generally, the red game classes and the blue menu classes are the ones that inherit from `MonoBehavior`. However, `AudioManager` is an exception since it is part of a prefab.

Unity supports the *game loop* and *update method* patterns by default. The architecture implements the game loop pattern by following the Unity lifecycle. The script lifecycle executes various event functions in a predefined order. This cycle is also where the update method pattern is used, as the update method call is part of the Unity lifecycle. The various scripts we created utilize this update method for receiving player input and updating individual game objects. These two patterns work well together for game time decoupling and individual object behavior.

The architecture implements the *publish-subscribe* pattern by using C#'s `delegate` and `event` keywords. Various publishers throughout the application define a `delegate` and an `event`. Other classes can subscribe to the `event`, which notifies all subscribers when the publisher class invokes the `event` [124]. The publish-subscribe pattern is, for example, used in the `PlayerController`. The `PlayerController` has a `LevelStartAction` `delegate` and a related `event` for when a level starts, whenever any player takes a step for the first time. Other classes, such as the `CameraController`, can subscribe to the `event` to receive a notification. This way, classes can subscribe to the `event` without the publisher class knowing about the subscribers.

The architecture applies the *singleton* pattern in the `AudioManager`, located in the `Managers` folder shown in Figure 19.2. The singleton pattern ensures that there is only one instance of the class and that instance is global and static. The manager contains all sound-related logic and assets. It is created in the first scene of the game and persists throughout the whole game. Therefore, other scripts can use the `AudioManager` to play any sound or music. We have utilized a lazy singleton implementation for simplicity.

The application consists of both a *client* and a *server*. The reason for having a server is to log statistics into a database. The server is only relevant due to the existence of the experiment. The server stores the players' statistics and shows them in the game. However, this would be part of the locally stored game data if the game was not part of an experiment. All server communication in the SSR application goes through the intermediate `ServerUtils`.

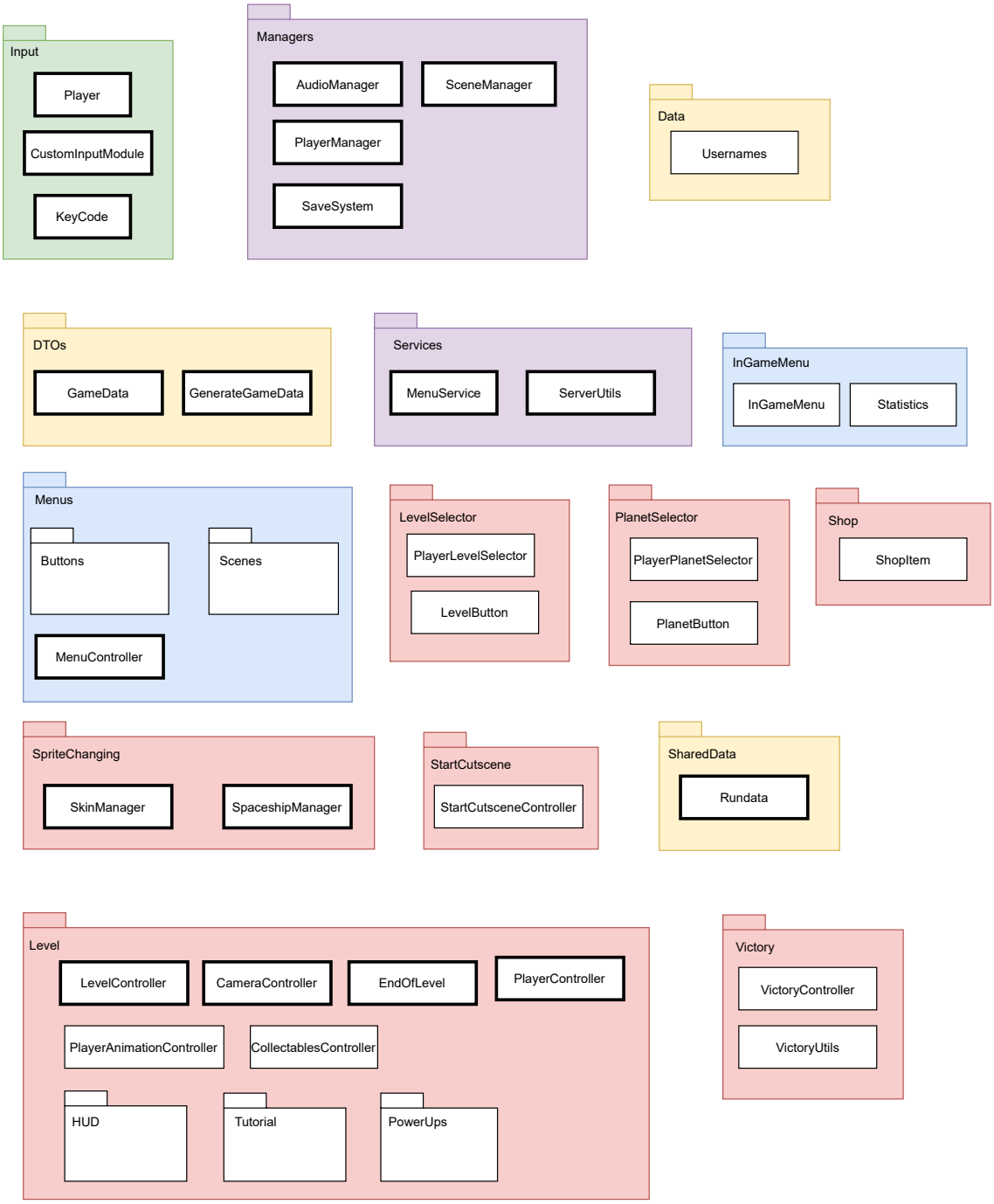


Figure 19.2: Simplified class diagram with the most important classes.

Figure 19.3 shows how SSR achieves player input from different devices. We use the `CustomInputModule` to send different input events, which is possible since it overrides `StandaloneInputModule`'s `Process()` method. Each `Player` is initiated with a `GamePad` type that correlates to what type of `IKeyCode` the player is assigned. This structure allows other dance pad types to be added in the future easily. For example, one can add PS2 dance pad support by adding PS2 to the `GamePad` enum and a new class that implements `IKeyCodes` for the PS2. Since the dance pad type recognition depends on the correct button press, one could add the requirement of pressing two buttons simultaneously when joining the game to minimize usability error.

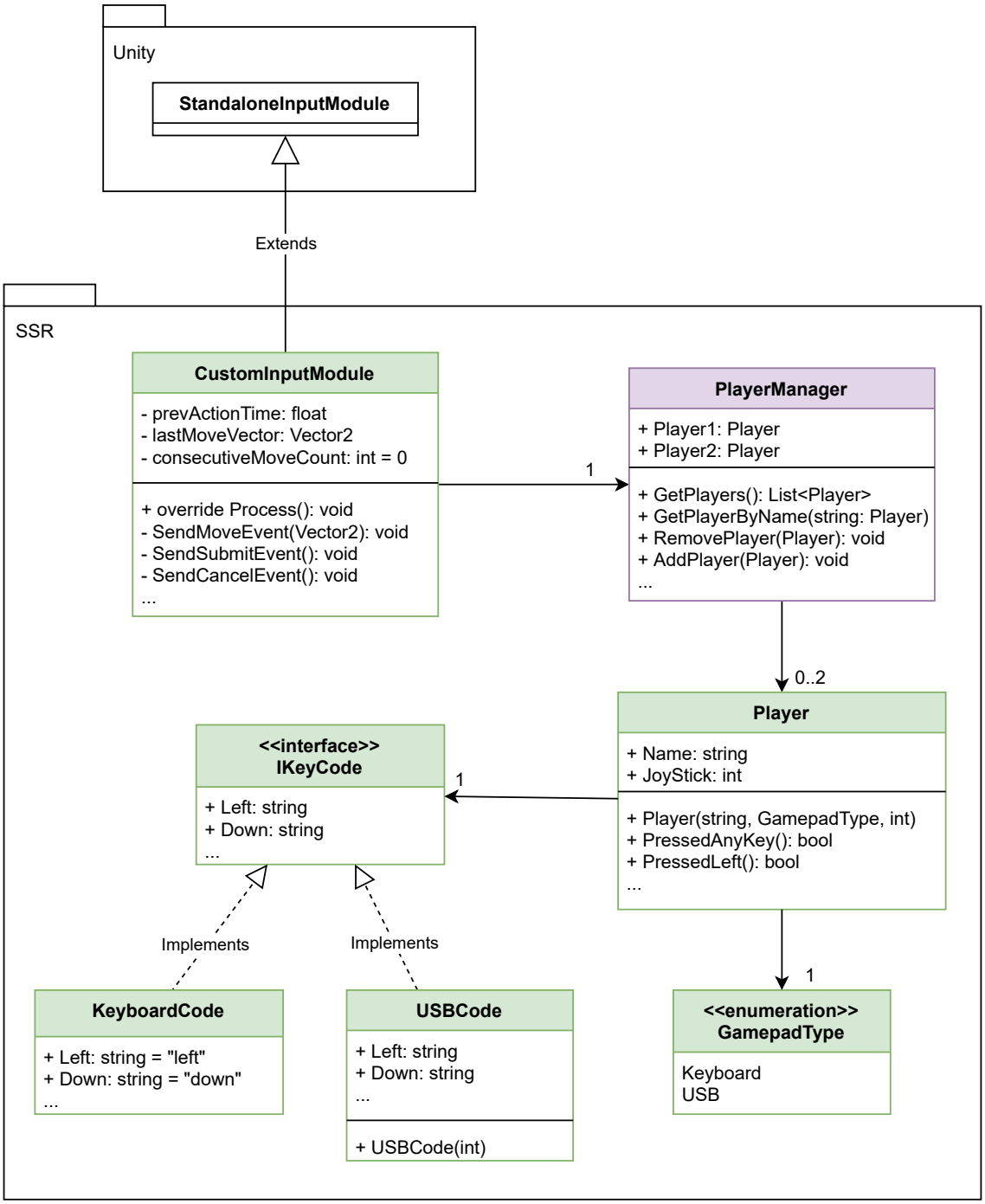


Figure 19.3: Class diagram of how the player input architecture is structured.

Figure 19.4 illustrates the usage of the *template method* pattern. The game should have high modifiability regarding adding new power-ups for later planets. Using an abstract base class with the core code for activating and deactivating the power-up enhances the modifiability. For example in Figure 19.4 the `ActivatePowerUpTemplate` method uses the abstract `ActivatePowerUp` method. All concrete power-ups define their version of `ActivatePowerUp`, and the parent does everything at the core required by all power-ups. One can easily add new power-ups, which only have to define what happens when that specific power-up is activated and deactivated.

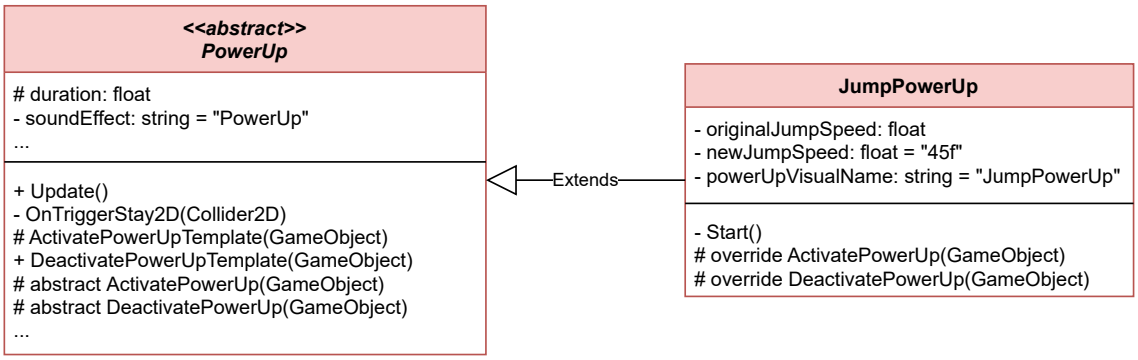


Figure 19.4: Class diagram of the power-up structure implementing the template pattern.

The database structure is shown in Figure 19.5. As previously mentioned, the database is quite simple, and its only purpose is to store statistics. The `User` model extends Django's `AbstractUser`, while the two others are subclasses of the general `models.Model`. A `Run` contains data of one specific `User` playing a `Level`. If two players are playing, then a `Run` will be created for each. Both the `User` and `Level` can have any number of `Run` relationships.

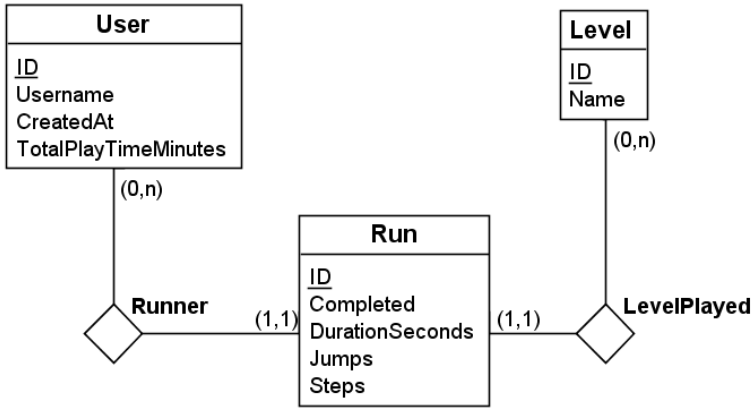


Figure 19.5: Entity-relationship diagram of the database.

Process View

The *process view*, also known as the *Process Decomposition*, describes the system during runtime. It looks at how the logical view components communicate inside the process architecture. Quality attributes, such as performance and availability, are focused on in the process view. Concurrency, distribution integrity, and fault tolerance are also relevant aspects. In other words, the process view looks at the dynamic elements of the system [101].

We have used a state diagram to visually depict the scene transition in the game, shown in Figure 19.6. There are two custom notations: dotted line on a state and the colors used. The addition of the notations lessens the number of arrows and hopefully adds higher readability. A dotted outline means that there is an option of going back to the previous state. In other words, the dotted outline indicates that the player can not necessarily use the state as an intermediary to go to another state. For example, both *Planet selector* and *Level selector* can transition to the *Shop*, but the player can not go from the *Shop* to the *Planet selector* if they were originally from *Level selector*.

The other custom notation of Figure 19.6 is the color usage. The *In game menu* is fully colored blue, which means that if the player presses a menu button *START* or *SELECT* in a state with a

blue outline, the player will transition to the blue *In game menu* state. This notation is the same for red. If the player presses a menu button in a red outlined state, they will go to *Level menu*. It is important to note that the colors used here do not follow the color notation from Figure 19.1 entirely. Red is used for the menu inside a level, even though it is a menu. Game states, such as *Level selector*, have blue outlines even though they are red in the class diagram in Figure 19.2. But using the general color notation here would defeat the purpose of the colors in this diagram.

The happy path of a player starts in `Start screen`, which is at the top of Figure 19.6. When a user goes from `Start screen` to `Add Players`, the game initializes Player 1. A second player can be added in the `Add Players` state. After choosing the number of players, the game presents the `Main menu`. The player might then change some settings in `Options` and the number of players in `CO-OP`. With no save file, the player must start a new game. If a save file exists, the player can choose to continue on that file. A new game file begins by showing a video in the `Cutscene` state, which provides the backstory. After the cutscene finishes, the player goes to the skippable `Tutorial` level. Now the player is part of the general play cycle of playing a `Level`, seeing their performance in `Victory`, and then going to the `Level selector` to choose a new `Level` to play. In between `Levels`, the player can buy new avatars and spaceships in the `Shop`. The player can select these shop items in the `Spaceship`.

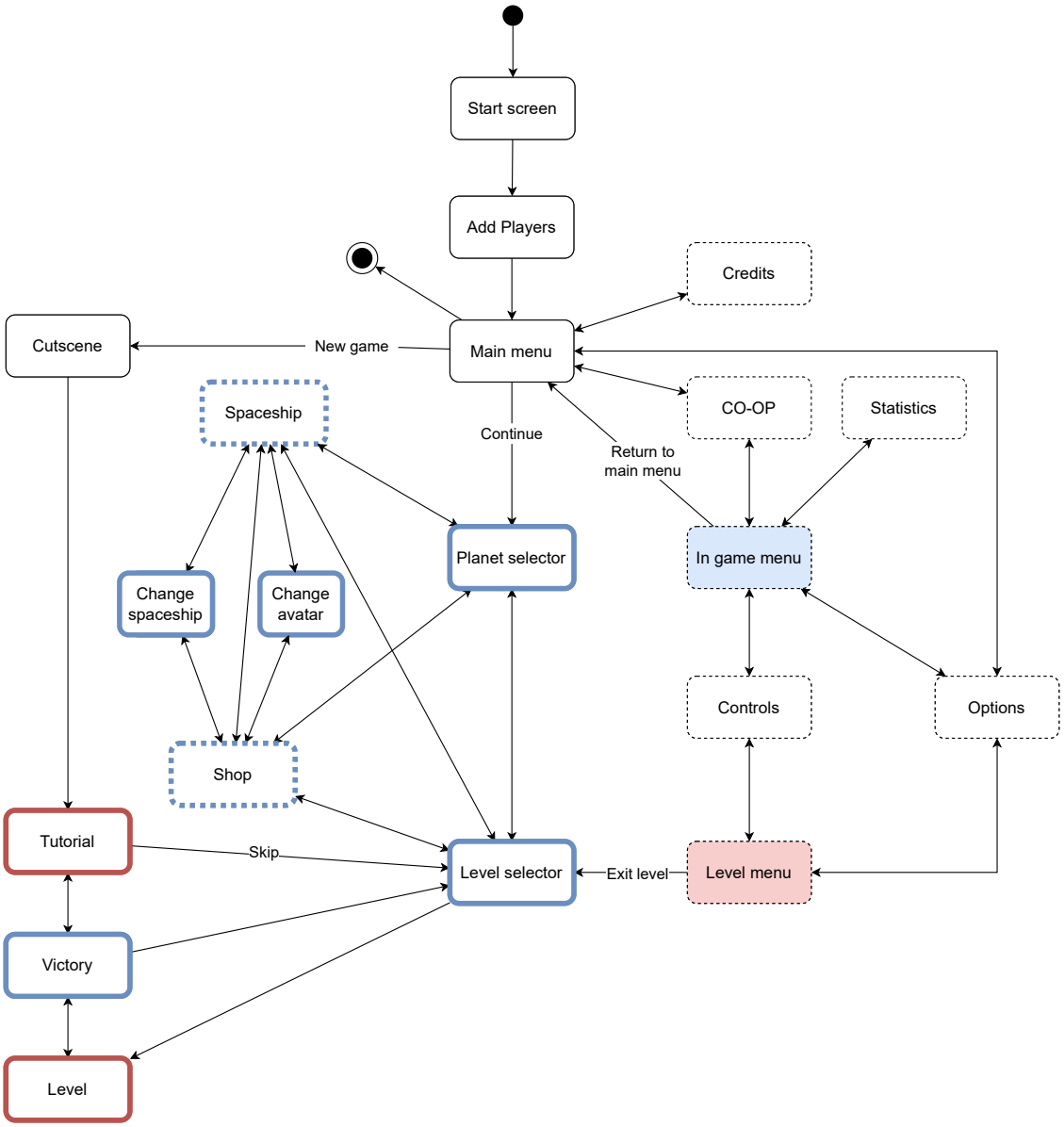


Figure 19.6: SSR state diagram of scene transitions.

Development View

The *development view*, also called the *Subsystem Decomposition*, focuses on the programmer's point of view. Central components of this view are the different subsystems and their relationships in the development environment. The software organization of modules and libraries provides practical information for developers [101]. A package diagram, shown in Figure 19.7, is created to show the main package parts, and their *use* relationship with other packages. It is important to note that the diagram is simplified and does not show all usages but provides the general structure of the package usages.

Since the game is a local Unity game, the implementation uses a few Unity packages. Unity has a Package Manager where it is easy to import Unity packages directly into a project. We have used packages such as PSD Importer, 2D Animation, and 2D SpriteShape. The two first-mentioned packages make it possible to use PSB files for characters that can be rigged with a predefined animated bone structure. The 2D SpriteShape provides the opportunity to create organic-looking level designs quickly. The Unity packages are effortless to use and make game creation much faster.

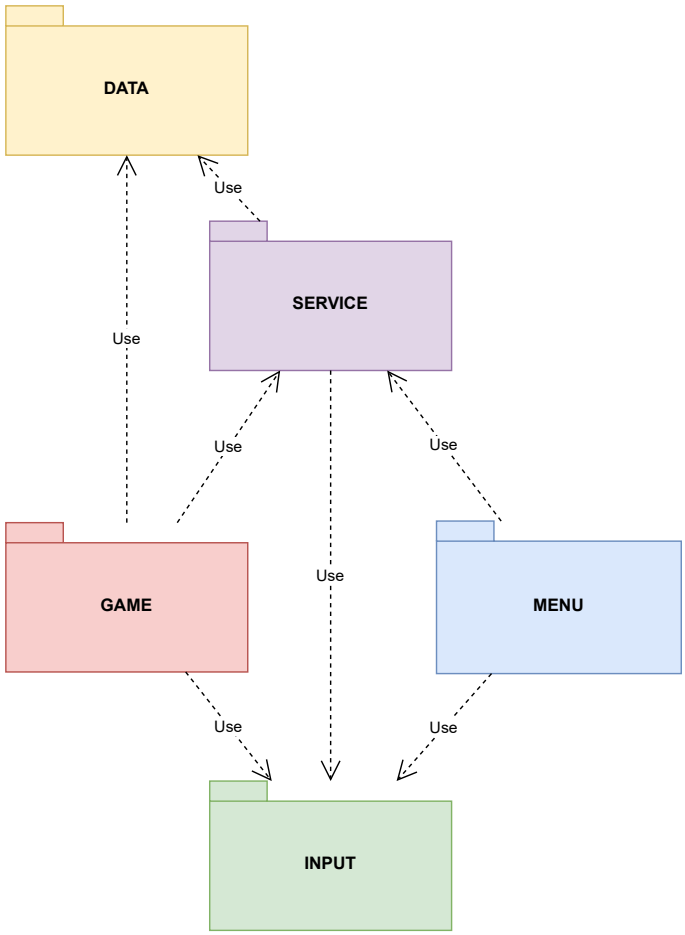


Figure 19.7: Simplified package diagram with *use* relationships.

Physical View

The last view is the *physical view*, also referred to as *Mapping the Software to the Hardware*. The view presents the physical mapping between the software and hardware components of the system. The perspective of the view is that of a system engineer. The availability and performance quality attributes are a focal point. The system does have a server, so availability is relevant but not that essential. It is only crucial that the server is available during experiments. Performance is, as previously mentioned, quite vital for the game. With too much lag, the game might become

unplayable [101].

Figure 19.8 shows a deployment diagram for the implementation of SSR. The computer is the client where the game is running. When logging statistics in the database, the client sends the data to the Django REST Framework running on a Heroku server. The server then sends the data to the PostgreSQL database. The Heroku PostgreSQL follows the Hobby plan, making the downtime tolerance less than four hours downtime per month [80].

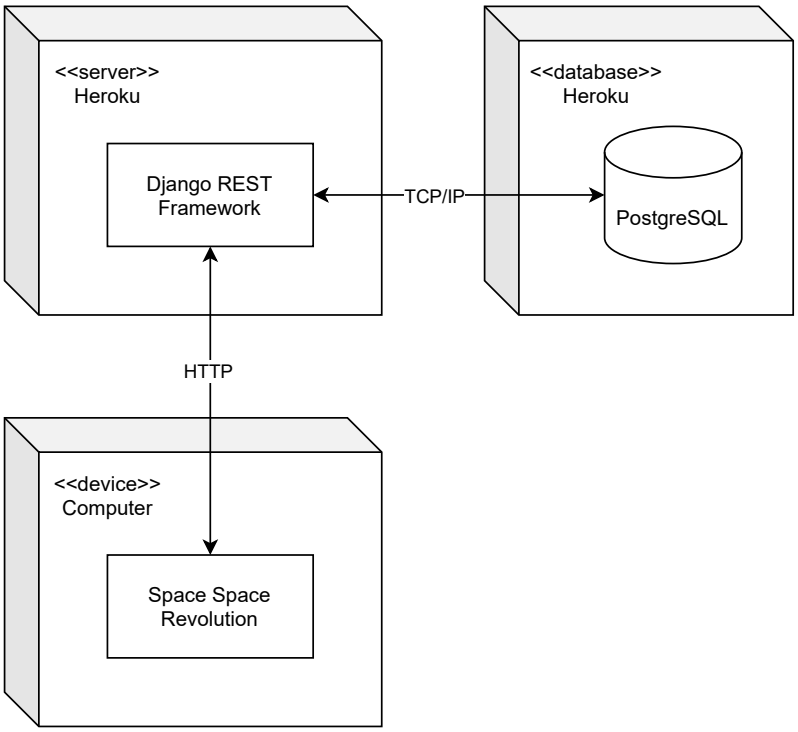


Figure 19.8: Deployment diagram of SSR.

19.5 Summary

The game's architecture has multiple architectural drivers. Some functional requirements impact the architecture, such as the possibility to use different input devices to play the game. Additionally, the chosen quality attributes: modifiability, performance, and usability, influence the structure. Business requirements are essential for architectural design, as the goal is to collect experiment data within a short time. The project's chosen COTS also affects the architecture by using Unity and dance pads.

Several architectural tactics are used throughout the project to realize the chosen quality attributes. We have been using modifiability tactics to increase cohesion and reduce coupling. The implementation utilizes performance tactics for controlling resource demand and managing resources. The game improves its support of user and system initiatives through usability tactics.

The game implements various architectural and design patterns. The *client-server* pattern is used for the statistics database. Events are used throughout the application with *publish-subscribe*. *Singleton pattern* globalizes a single class instance. The *template method* is used for removing duplicate code and enhancing modifiability in regards to power-ups. These patterns are all built around the Unity *game loop* and *update method*.

We illustrate the architecture's different perspectives with the 4+1 architectural view model. The application has five main parts: data, service, game, menu, and input. The logical view shows the use of patterns and relations between objects, and we use multiple class diagrams and an

entity-relationship diagram to display it. The process view shows the game's runtime transitions with a state diagram. The development view describes the usage of different packages and libraries. Lastly, the physical view shows the hardware relationship between the client, server, and database.

Chapter 20

Testing

This chapter describes how we tested and evaluated the software of *Space Space Revolution* during and after development. First, it presents our quality assurance methods and then the alpha and beta testing. It ends by documenting the implementation status of the functional requirements and the quality attribute scenarios.

20.1 Quality Assurance

ISO 9000:2015 [88] defines quality assurance to be a "*part of quality management focused on providing confidence that quality requirements will be fulfilled*". Ensuring that the product works as intended is essential within software development.

We created tasks in Trello based on the functional requirements, which we used to keep track of the implementation progress. Using a Trello board made it easy to track their state. After a person implemented a task, both tested the functionality, and the other person performed a code review. This method ensures that we tested all new functionality twice and that the code has good quality.

20.2 Alpha Testing

After the main development period, we spent a few weeks testing and improving the game. During these weeks, we played through the entire game several times. We also got some feedback from a few external users. The main focus was to remove bugs and improve the general look and feel. We found several bugs and many minor improvements. For instance, there were several bugs when finishing a level regarding the camera, gravity, and timer. There were also some improvements to usability, e.g., making the co-op menu available from the main menu to enable multiplayer before starting the game save. Addressing the bugs and areas of improvement resulted in SSR feeling more like a finished product.

20.3 Beta Testing

The following testing phase was to get more feedback from external users unrelated to the project. We participated in the Norwegian Game Awards (NGA) and used this opportunity to let game developers try out our game and provide feedback. Using experienced game developers was beneficial to getting insightful feedback. We also got to test it on people without developing experience. Figure 20.1 shows us playing *Space Space Revolution* at NGA. Link to our submission with more information about the game and download link: https://ivarnm.itch.io/space-space-revolution.

Figure 20.1: Two players playing SSR during NGA

Figure 20.2 shows the results from a survey answered by the people testing our game at NGA, with a total of 30 respondents. Most participants stated that the game was a fun and unique game concept, and the game received substantial attention. 96.7% of the respondents agreed that they got good exercise from playing the game, and several compared it to regular physical exercise. Over 90% found the game enjoyable, engaging, and motivating, and everyone liked the game concept. From our observations and the participant comments, playing together is the most contributing factor to the results. Competing and cooperating caused the participants to be highly engaged, which facilitated a high physical activity level.

The largest area of improvement regards the technical details of the game, which the results also show. The *first challenge* is the aggressive playstyle of competitive users, which causes the dance pads to move around. To combat this issue, we duct-taped the pads to the floor. Other solutions involve using non-slip pads below the dance pads or metal dance pads, such as in arcades.

The *second challenge* is accidental key presses from players pressing the wrong buttons or not realizing they are standing on a button. This challenge was especially a problem in the tutorial, where it is possible to press *Circle* on the pad to skip the tutorial. The circle button is next to the right arrow, and many players step on it without realizing it. To resolve this issue, we removed the skip button from the tutorial. It is still possible to skip it from the pause menu. It is also a problem that the users are standing on buttons after finishing the game. This problem caused some to accidentally restart the level or scroll fast through the different levels in the level selector. To combat it, we removed the play again option from the victory scene and the possibility to hold down a button to send continuous input. It is still fast to replay a level through the level selector, and the input feature did more harm than good.

The *last challenge* is understanding the controls and how to use a dance pad. People are not very familiar with dance pads, and additionally, SSR's controls are not something that people have used before. The jumping mechanic, where you have to stand on both side arrows and jump up, is difficult to understand in the beginning. Your character height jump is also determined by how high the player jumps. Before the beta testing, we tried several different jump mechanics, and this one is the most natural and intuitive. After getting used to it, it is not very difficult to use. The first levels must avoid having too many difficult jumps to mitigate the jumping mechanic's steep learning curve.

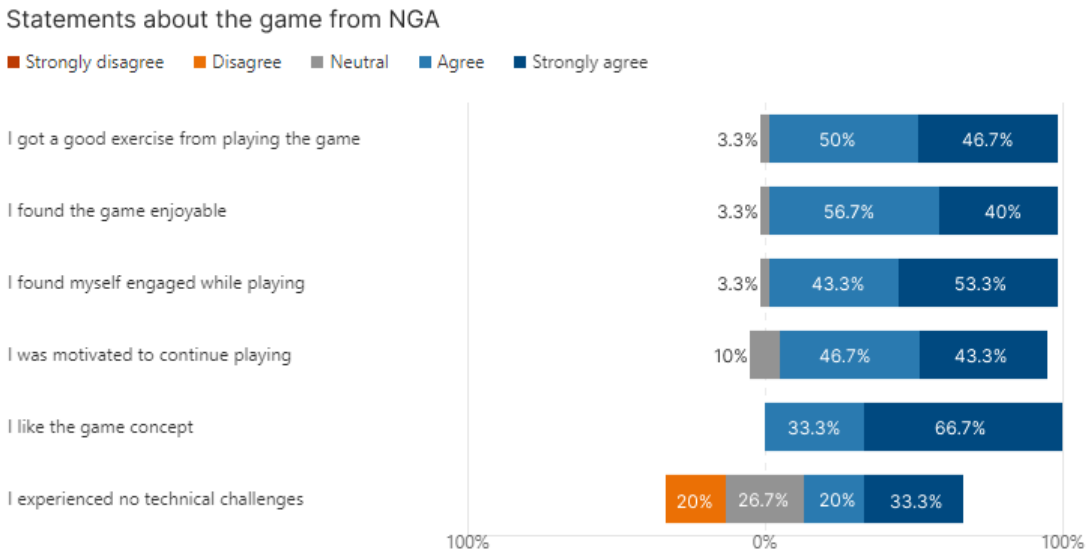


Figure 20.2: Results from questionnaire answered by people playing SSR at NGA.

20.4 Functional Requirements Testing

Table 20.1 shows the functional requirements' implementation status. *FR20* and *FR25* are the only requirements that are not fully implemented. *FR20 - As a player, I should be able to edit the game's settings* - is partly implemented. The game has an options menu where the user can adjust the sound settings. Ideally, the game should give the players the option to change the key bindings and the game's resolution. However, these options are not relevant to our user test and thus not prioritized. *FR25 - As a player, I should be able to move my character on the level victory screen* - is not implemented because we did not prioritize it due to its low priority and contribution to the game.

Table 20.1: Functional requirements evaluation.

ID	Description	Priority	Implemented
FR1	As a player, I should be able to play the game alone	High	Yes
FR2	As a player, I should be able to play the game with another person	High	Yes
FR3	As a player, I should be able to play with a dance pad	High	Yes
FR4	As a player, I should have access to an in-game menu	High	Yes
FR5	As a player, I should be able to start a new game	High	Yes
FR6	As a player, I should be able to continue on a save file	High	Yes
FR7	As a player, I should lose a life when not within the game screen	High	Yes
FR8	As a player, I should share lives when playing multiplayer	High	Yes
FR9	As a player, I should lose a level when I have no hearts remaining	High	Yes
FR10	As a player, I should get auditory and visual feedback on my actions	High	Yes
FR11	As a player, I should be able to see my progress in the game	High	Yes
FR12	As a player, I should be able to have a variable difficulty level	High	Yes

Continued on the next page

Table 20.1 – continued from the previous page

ID	Description	Priority	Implemented
FR13	As a player, I should get access to new levels after completing a level	High	Yes
FR14	As a player, I should be able to collect stars in a level	High	Yes
FR15	As a player, I should be able to collect coins in a level	High	Yes
FR16	As a player, I should get a personal level score when completing a level	Medium	Yes
FR17	As a player, I should be able to view personal statistics	Medium	Yes
FR18	As a player, I should be able to buy new avatars and spaceships	Medium	Yes
FR19	As a player, I should be able to choose an avatar and spaceship to play with	Medium	Yes
FR20	As a player, I should be able to edit the game's settings	Medium	Partly
FR21	As a player, I should be able to view the control scheme	Medium	Yes
FR22	As a player, I should have access to a tutorial	Medium	Yes
FR23	As a player, I should get access to a new planet after completing the final level on a planet	Medium	Yes
FR24	As a player, I should be able to skip the tutorial	Low	Yes
FR25	As a player, I should be able to move my character on the level victory screen	Low	No

20.5 Quality Attribute Scenarios Testing

The quality attribute testing consists of testing our non-functional requirements scenarios defined in Section 18.2, and all tests passed. The result for each scenario is shown in Table 20.2 - Table 20.8.

Modifiability

Table 20.2: M1: Add a new avatar.

Executor	Turid Cecilie Dahl
Date	08.03.2022
Environment	Design time
Stimuli	Add an already designed avatar to the game
Expected response measure	Avatar available in less than 20 minutes
Observed response measure	Avatar available in 15 minutes
Evaluation	Success. Adding an avatar to the list of avatars requires the developer to add the image files to Unity, select the animation rig, and create a sprite library asset for the avatar. Additionally, it must be added to a prefab and the GameData.
Comment	Creating a sprite library asset is a bit cumbersome. The rest of the process is mainly drag and drop.

Table 20.3: M2: Add a new level to a planet.

Executor	Turid Cecilie Dahl
Date	10.02.2022
Environment	Design time
Stimuli	Create and add a new level to a planet
Expected response measure	Level available in less than 50 minutes
Observed response measure	Level available to play in 30 minutes
Evaluation	Success. Creating a new level is started by creating a new scene from the planet's base level prefab. Then you can easily drag and drop platforms and adjust them to your desire. Next, you add coins, stars, and power-ups from prefabs. The level must also be added to the planet's level selector, which is done by copy-pasting an existing road and button and then updating a few variables. Lastly, you need to add it to the GameData and the database.
Comment	This scenario assumes that the executor already has a sketch of the desired level design. Creating the level consists mainly of drag and drop and duplicating existing game objects or prefabs.

Usability

Table 20.4: U1: Player satisfaction with level controls.

Executor	Ivar Nordvik Myrstad and external test subject
Date	17.03.2022
Environment	Runtime
Stimuli	The user plays a level
Expected response measure	The user starts a level and finds the controls intuitive and enjoyable, with an enjoyment score of at least 7/10
Observed response measure	Player enjoyment with the controls is 7/10
Evaluation	Success. It takes some time to get used to the dance pad and understand how to run efficiently.
Comment	Using dance pads as a game controller is generally not something people have tried before, and they need time to get comfortable with it. This inexperience also makes it harder to learn the controls because they also need to figure out the dance pad. From our experience, people find the controls fun and natural after playing a few levels. The results from the experiment gave an average of 8.15 (see Figure 29.3).

Table 20.5: U2: Player understands how to move the character in a level.

Executor	Ivar Nordvik Myrstad and external test subject
Date	17.03.2022
Environment	Runtime
Stimuli	The user plays the tutorial for the first time
Expected response measure	The user understands the control scheme within 5 minutes
Observed response measure	The user needed 2 minutes to understand the controls.
Evaluation	Success. The user quickly understands the run mechanic and basic jumping. Jumping over high obstacles was more challenging to understand on the first run, but the user figured it out on the second one.
Comment	None

Table 20.6: U3: User satisfaction with menus.

Executor	Ivar Nordvik Myrstad and external test subject
Date	17.03.2022
Environment	Runtime
Stimuli	The user uses the menus
Expected response measure	The user is satisfied with the menus, with a score of at least 7/10
Observed response measure	The user's menu rating is 7/10
Evaluation	Success. The user finds the menus easy to understand and navigate, but they could be less bland and have more features.
Comment	The results from the experiment gave an average of 7.94 (see Figure 29.2)

Performance

Table 20.7: P1: Loading a level.

Executor	Ivar Nordvik Myrstad
Date	17.03.2022
Environment	Runtime
Stimuli	Player presses play on a level in the level selector
Expected response measure	The selected level is loaded within 5 seconds
Observed response measure	Level is loaded within a second
Evaluation	Success. It works better than expected. The level is loaded almost instantly.
Comment	Tested on a laptop with AMD Ryzen 5 4600H CPU, Nivida GTX 1660 Ti GPU, and 16 GB of RAM.

Table 20.8: P2: Consistent frame rate.

Executor	Ivar Nordvik Myrstad
Date	17.03.2022
Environment	Runtime
Stimuli	Player plays a level
Expected response measure	The frame rate is consistent and above 50 frames per second (FPS)
Observed response measure	The level is played with an average FPS over 500, and it generally stays above 400 FPS.
Evaluation	Success. The game runs smoothly with no major frame drops
Comment	Tested on a laptop with AMD Ryzen 5 4600H CPU, Nivida GTX 1660 Ti GPU, and 16 GB of RAM.

20.6 Summary

The testing was successful, and we discovered and mitigated several issues. The quality assurance helped maintain a high code quality throughout the implementation phase. Next, the alpha testing revealed several bugs related to finishing levels and areas for usability improvements. Addressing them resulted in SSR feeling more like a finished product. Participating at NGA and using it as our beta testing proved fruitful, giving us feedback from the game industry and enabling us to try out the game on a larger user group. As a result, we fixed several technical and usability issues. The test results of the functional requirements and the quality attribute scenarios were as expected.

Chapter 21

Artistic Design

This chapter shows how we designed the visual and audio aspects of the game. It starts by going through the graphical parts of the game and the rules for art style consistency. We explain how we created the avatars, spaceships, other sprites, backgrounds, the cutscene, and the different planets. Additionally, the audio section describes how we chose and obtained music and sound effects for the game. Lastly, this chapter includes some screenshots to show how the sprites are combined. The finalized game and its trailer can be viewed at https://ivarnm.itch.io/space-space-revolution.

21.1 Visuals

The visual design follows the general art style sketches from Section 14.3. We made the graphic elements colorful and fun to provide an energetic feeling. All visual parts of the game were created by us, either with *Figma*, *Procreate*, or *Paint.NET*. The game, in general, has two primary colors, a very dark purple (#282646) and a light yellow (#D2D69D). These were chosen due to being complementary colors, and purple is associated with space while yellow is with stars. Graphic elements, such as backgrounds and buttons, typically use the two primary colors.

The general rule for the art style was that elements, such as characters or spaceships, had one primary color. Each element usually also has two secondary colors, commonly chosen by using the *triad*, *complementary*, or *shared complementary* harmony rules present in Adobe Color Wheel [3]. An example of this is shown in Figure 21.1, displaying the colors for the character named Pinku. After choosing the colors, each color gets one lighter and one darker version of itself to give the illusion of light. The lighter colors are pushed towards cooler parts of the color spectrum, and shadows are moved to the warmer regions of the color wheel. This temperature usage in light and shadows avoids muddy colors, creates more depth, and makes the sprites more vibrant. In addition, sprites generally have a bold outline, which is a darker shade of the primary color.

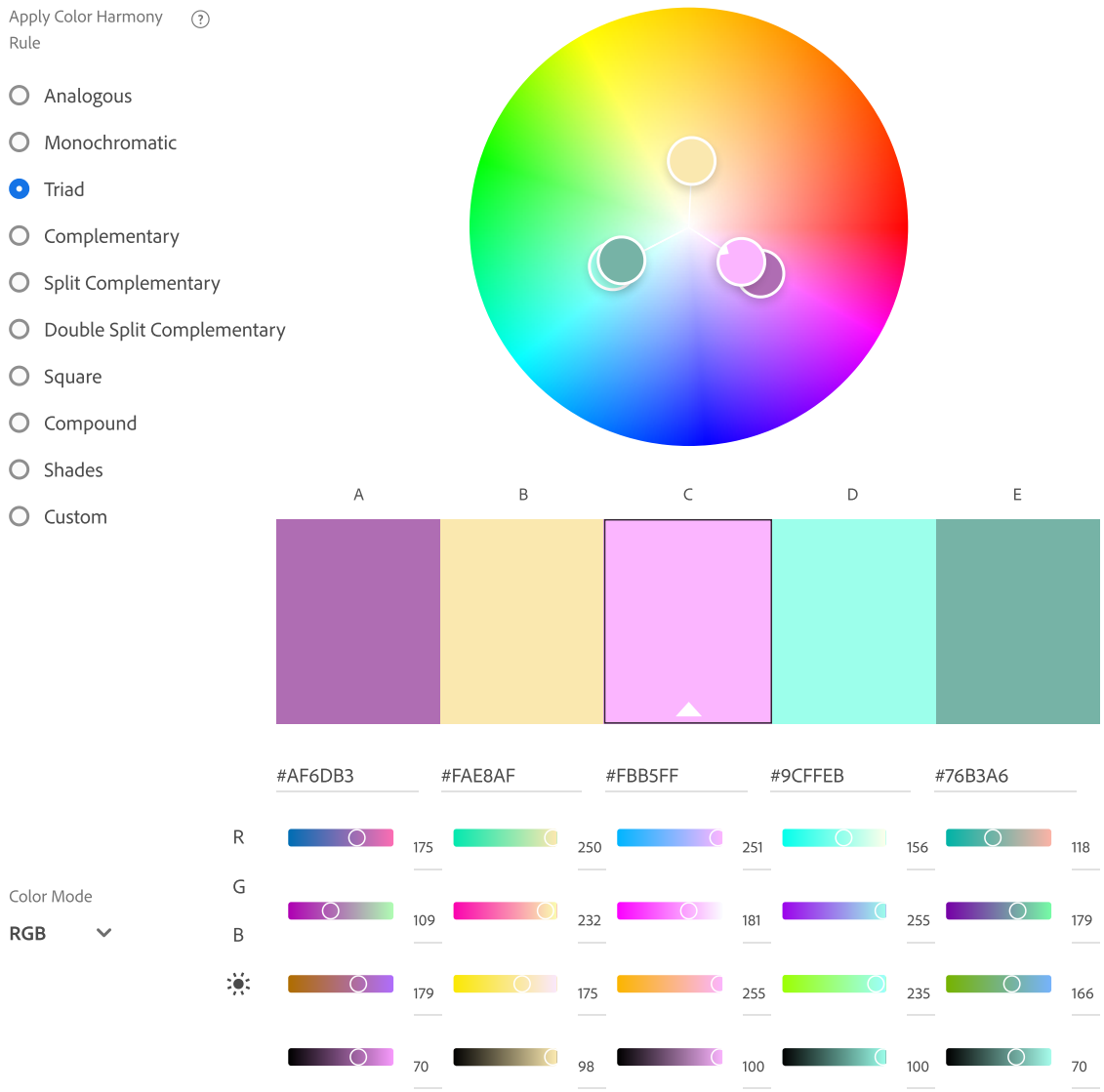


Figure 21.1: Choosing colors for a sprite in Adobe Color Wheel.

Avatars

We created the playable avatars in the game by using an Apple Pencil in Procreate on an iPad. All characters look unique and are easily recognizable from afar. We created a base avatar, which the other characters build on. This way, one can easily change the outline and fill colors for each avatar while keeping the same body structure. Figure 21.2 shows a screenshot of a character file in Procreate. Each avatar part that will move or change is on a separate layer. We use PSB files for the avatars in the project to preserve the layers. Figure 21.3 displays the bone structure used for the playable characters. So all characters had to approximately fit the bone structure to have correct animations and hitbox.

Figure 21.4 shows all playable characters in the game, where the inspiration for the different avatars varied greatly. The top three avatars shown in Figure 21.4 were designed during concept creation and were to fit well into the game's setting. The astronaut and robot were also designed from the space setting of the game. The cat is inspired by one of the authors' pets, while the penguin is the other author's favorite animal. The general anime style inspired the creation of the pink-haired girl. We made the last one by changing the colors of an existing character.

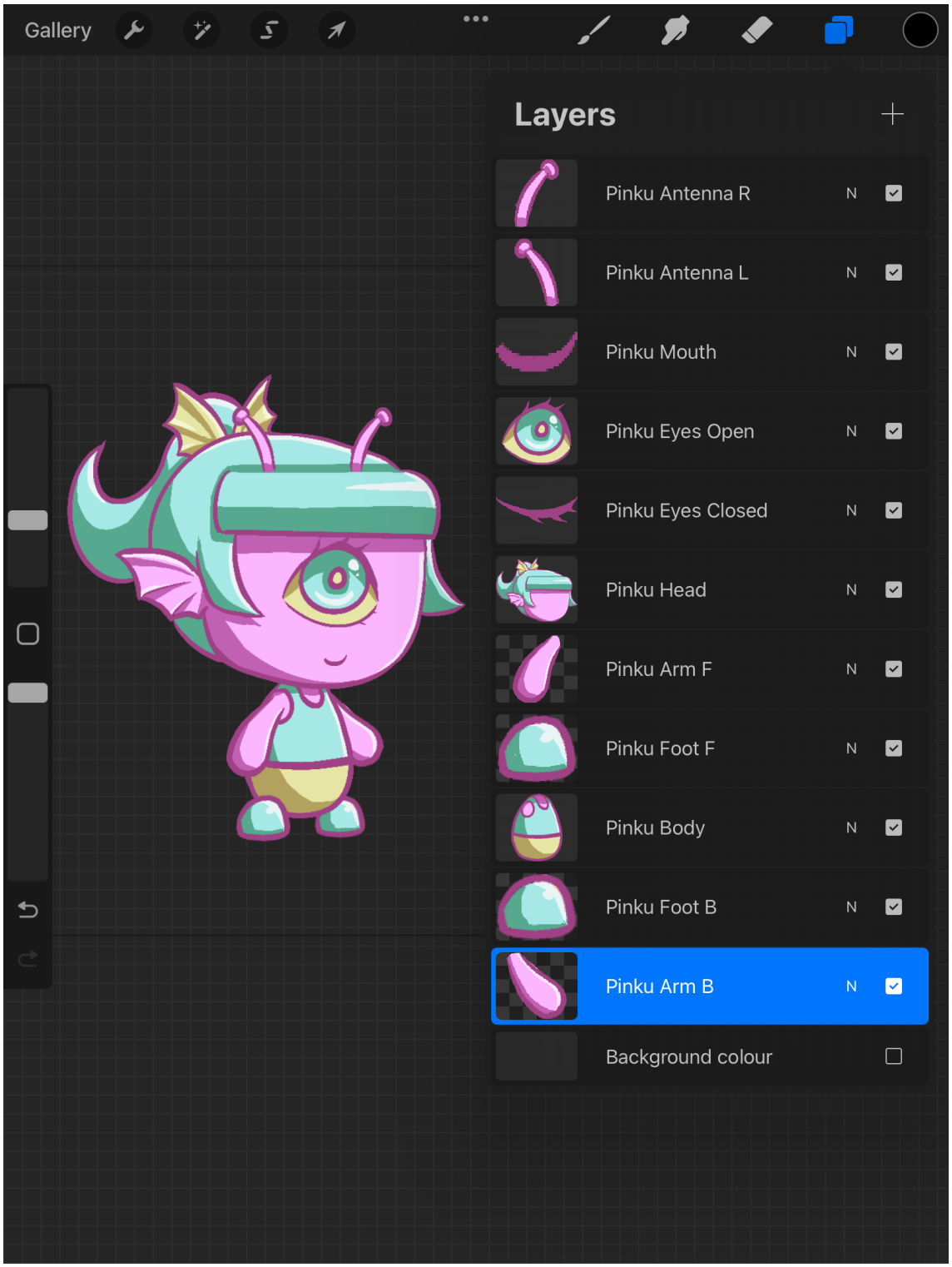


Figure 21.2: The layer structure of the avatars.

Figure 21.3: The bone structure used for animating the avatars.

Figure 21.4: Avatar designs.

Spaceships

The spaceships creation was similar to that of avatars. They usually have one primary and two secondary colors, with colder light and warmer shadows. The spaceships do not need bone structure animations. Therefore, all spaceships are single-layer PNG files. Every spaceship has two color variations for more personalization and rewards. A few of the spaceships were illustrated in Procreate. However, Paint.Net was used for most spaceships. Figure 21.5 and Figure 21.6 show all spaceship designs.

Figure 21.5: Spaceship designs.

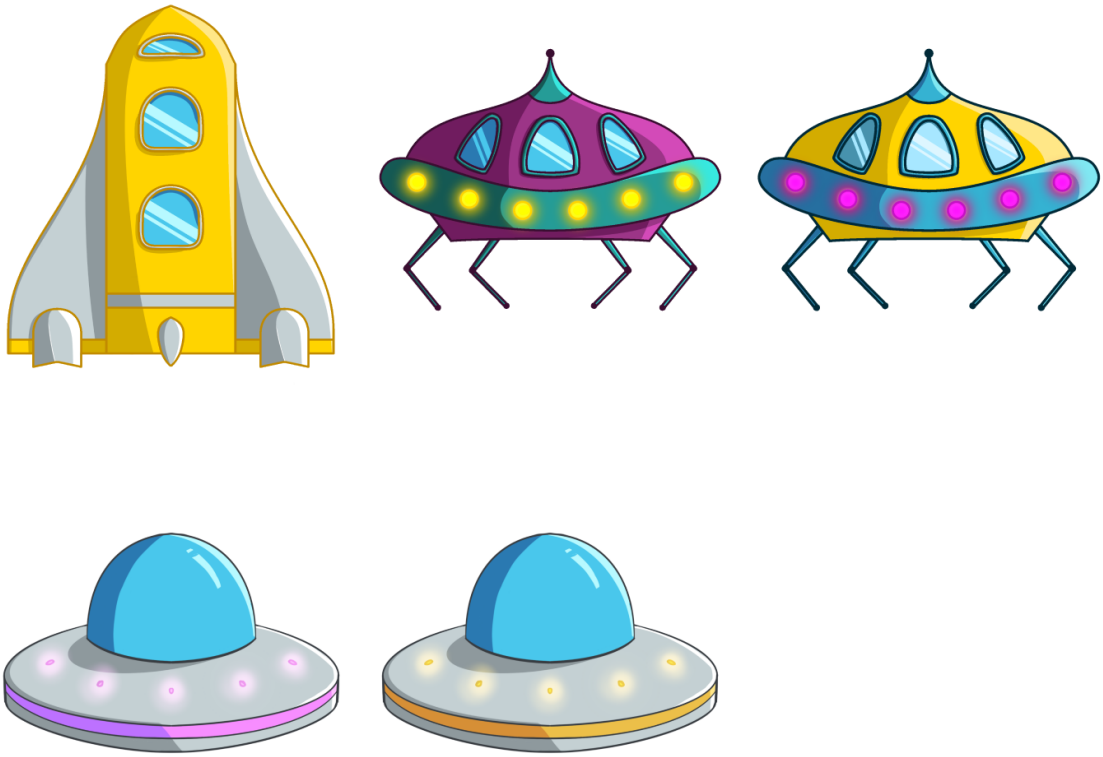


Figure 21.6: Additional spaceship designs.

Other Sprites

Various other sprites were designed and created to get a consistent art style and feel for the game. These sprites also follow the general color rules, but usually only with none or one secondary color. Figure 21.7 shows the game icons for coins, hearts, and stars. Figure 21.8 displays some of the other sprites created, the flag, the power-up initializer, and the level buttons. We made more sprites than shown in this report to increase cohesion. The ones shown in this section are made in Procreate. However, more menu-looking elements, for example, the tutorial pop-ups, were made in Figma.

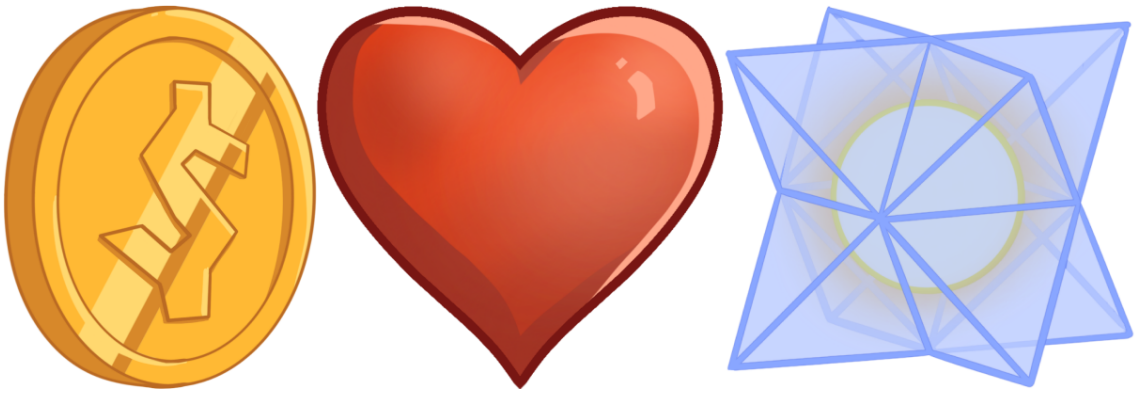


Figure 21.7: Level sprites.

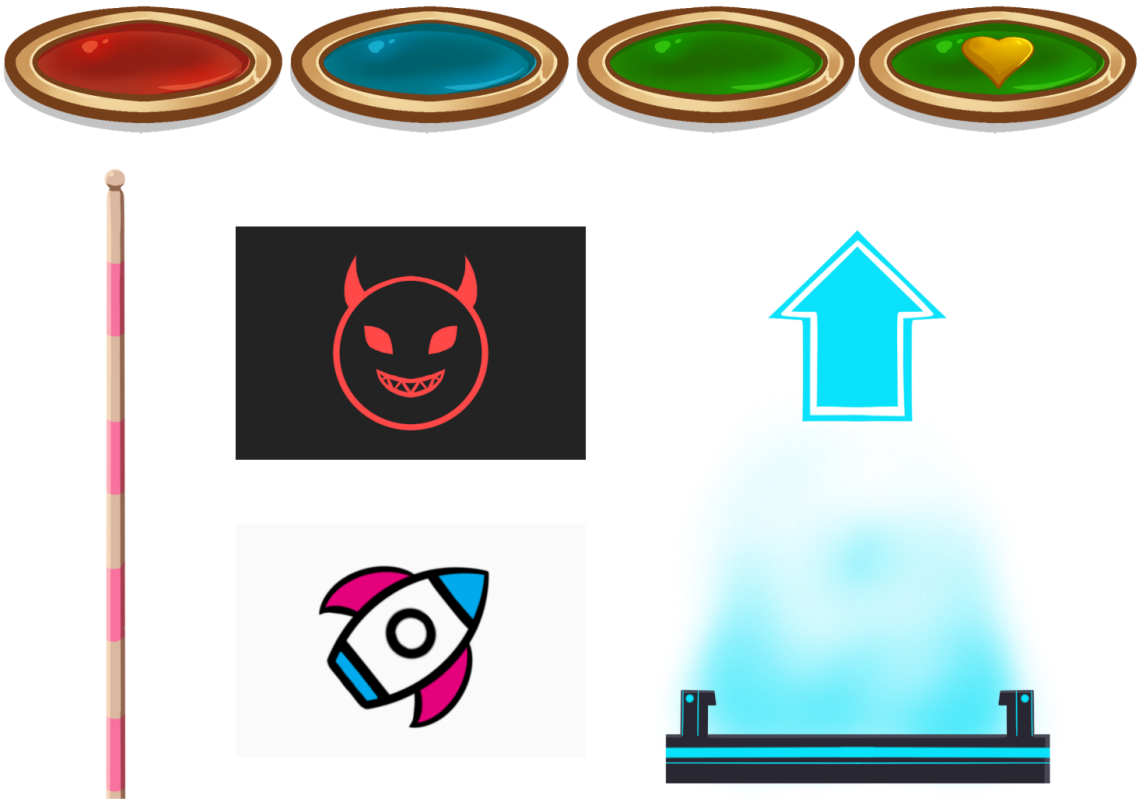


Figure 21.8: Some level and level selector sprites.

Backgrounds

The backgrounds of SSR often use the two main colors chosen for the game. Figure 21.9 shows a few of the backgrounds created for SSR. The bottom right background of *space* only uses the two primary colors. This *space* background is often used as part of the other backgrounds, such as in the shop, spaceship, and menus. It is also the main background in both the level selectors and the planet selector. Procreate was used to design them.

Figure 21.9: Some of the backgrounds.

Cutscene

The cutscene quickly sets the setting and story of the game. The cutscene is made short since the story is not the game's focal point. The player should also be able to get to play a level as fast as possible. With this in mind, we made a quick storyboard of the cutscene, shown in Figure 21.10. It illustrates a news anchor explaining the situation and why the players have to run through levels. Choosing a news anchor to explain the story makes it a realistic circumstance inside the game world and still provides all necessary information to the player. Figure 21.11 shows screenshots from the finalized cutscene in the game.

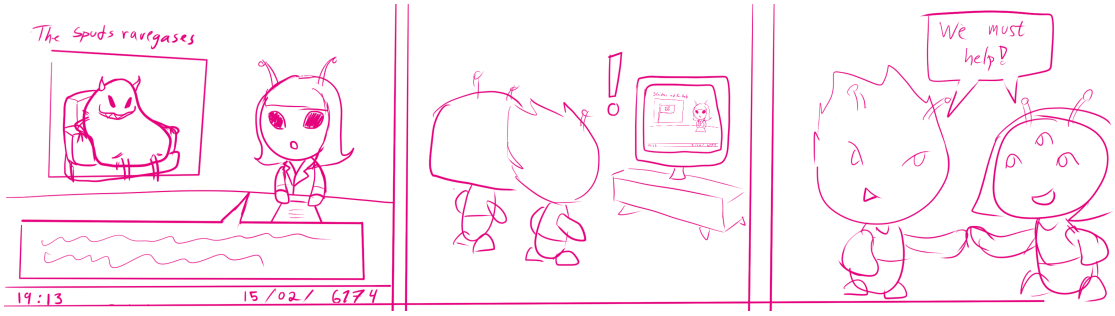


Figure 21.10: Storyboard for the intro cutscene.

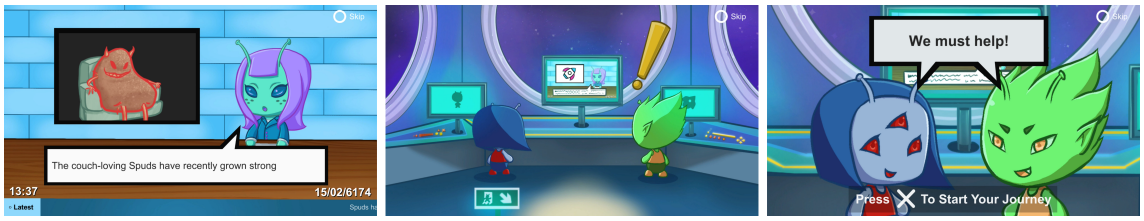


Figure 21.11: Screenshots of the finalized cutscene.

Planets

The planets have unique and distinct designs. This version of SSR contains two of them. However, a finalized version of the game would have more planets present. Each has its own artistic design in the planet selector, level selector, and inside a level.

Mars

Mars inspired the first planet. However, it has a dust ring around itself to make it more unique, shown in Figure 21.12. This sprite is used in the planet selector. Figure 21.13 displays the level selector sprites for Mars. It consists of the background, ground, and foreground. The background and foreground consist of dust and rocks sprites that create the ring around the planet. The foreground slowly moves to the right while the background moves to the left to make it seem like the ring is spinning. This illusion also requires the left and right parts of the sprites to be identical to create a seamless transition for when the sprites reach their end.

Figure 21.14 shows the level sprites used to create the ground on Mars levels. Figure 21.14a is used to fill the inside of the ground, while Figure 21.14b is used as the outline. Figure 21.14c displays a Mars ground in edit mode. It presents how a ground element looks with the fill and outline and the white dots used to shape it.

We added moving background and foreground to levels for more visual interest and design. Figure 21.15 shows the foreground and background sprites inside Mars levels. Figure 21.15a is placed behind the main ground and is darker so it does not confuse players about what ground they can stand on. In addition, Figure 21.15b displays the other background part which is furthest back. It is even darker for more contrast and is blurred with Gaussian blur. Figure 21.15c displays the foreground sprite, which is the darkest and blurriest for correct focus and perspective. These background and foreground elements move in correspondence to the camera to create a parallax scrolling effect.

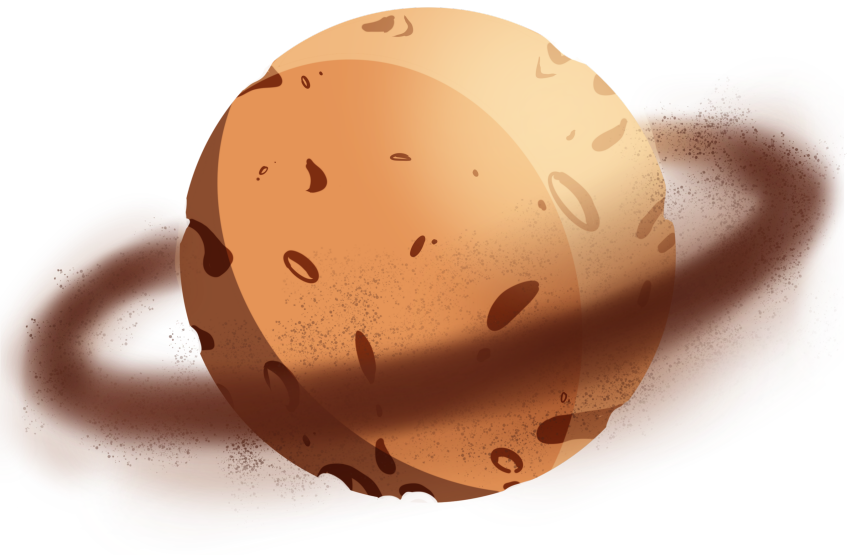
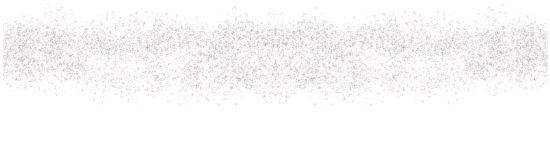


Figure 21.12: Mars planet sprite.

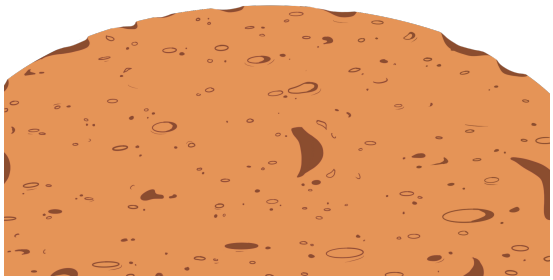
(a) Background dust



(b) Background rocks

(c) Foreground dust

(d) Foreground rocks

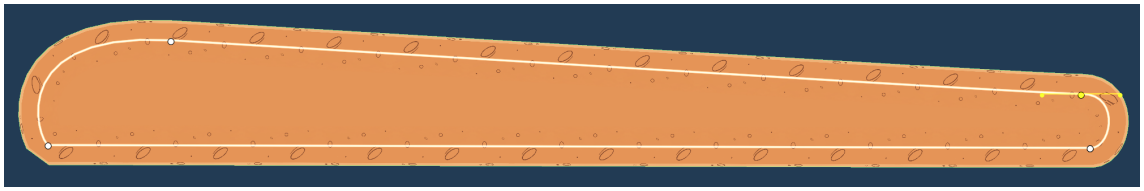


(e) Ground

Figure 21.13: Mars level selector sprites.

(a) Mars level ground fill

(b) Mars level ground outline



(c) Mars level ground sprite shape

Figure 21.14: Mars level ground sprites.

(a) Background one

(b) Background two

(c) Foreground

Figure 21.15: Mars level background and foreground sprites.

Moon

The other planet created was inspired by the moon. It has the same sprites as the Mars planet but with different designs. However, the Moon planet does not have any background and foreground sprites in the level selector due to having no ring, as shown in Figure 21.16. Therefore, the only sprite needed for the level selector is the one displayed in Figure 21.17. The textures for creating the ground in Moon levels are displayed in Figure 21.18, and Figure 21.19 shows the sprites used for the parallax scrolling.

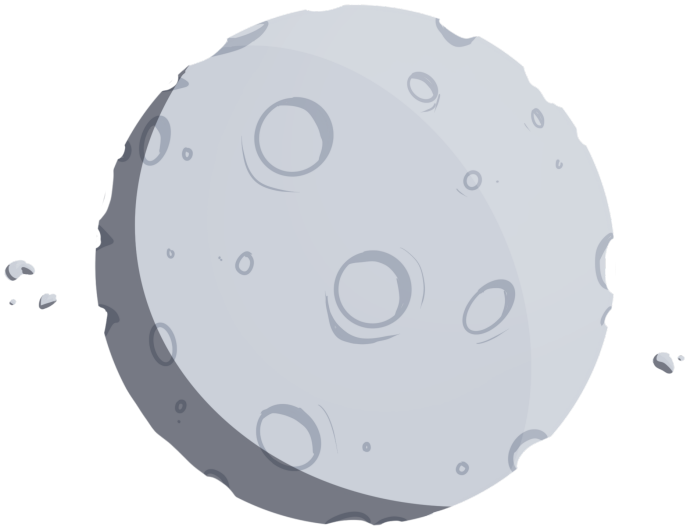


Figure 21.16: Moon planet sprite.

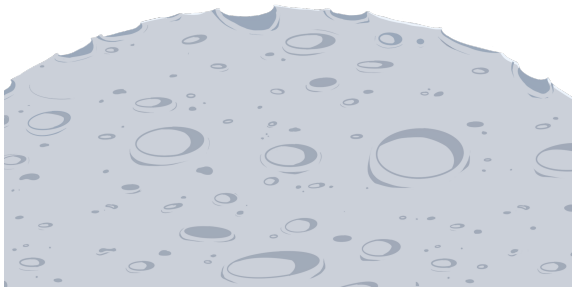
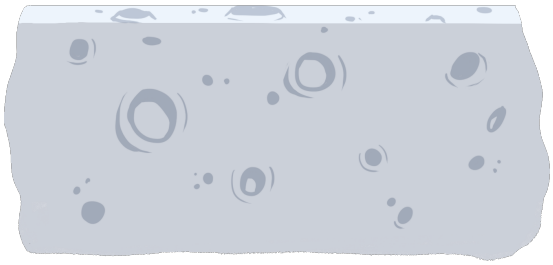
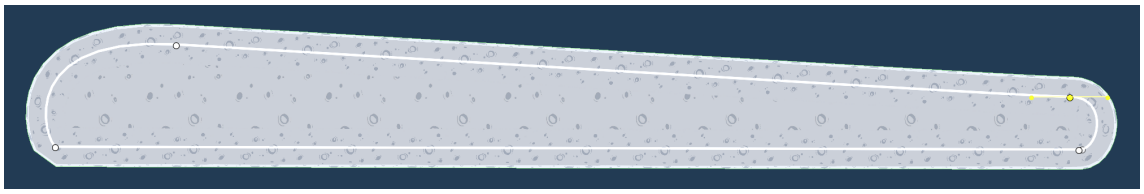


Figure 21.17: Mars level selector ground.

(a) Moon level ground fill



(b) Moon level ground outline



(c) Moon level ground sprite shape

Figure 21.18: Moon level ground sprites.

(a) Background one

(b) Background two

(c) Foreground

Figure 21.19: Moon level background and foreground sprites.

21.2 Audio

We did not create the audio elements of SSR, but they are used with permission. The audial aspect of the game must fit the general fun and energetic feeling of the game. The music is made by Ole Halvor Dahl [144] with permission to use in the game. The songs are energetic and inspired by retro games. This music genre provides a satisfying combination with the game, taking influence from Mario and using old game technology while still being a new game. The game has five songs, and these are used for the menus, selectors, Mars levels, Moon levels, and final levels. The levels have different music depending on which planet it is on to make them more unique and compelling.

The sound effects accompany the *space* theme and are used appropriately regarding their licenses. All sound effects are from freesound.org. Most of the sounds are under the *CC0 1.0 Universal (CC0 1.0) Public Domain Dedication* licence [36]. These are not credited, as that is not necessary. However, nine sound effects used are under CC BY 3.0 [32], CC BY-NC 3.0 [34], CC BY 4.0 [33], or CC BY-NC 4.0 [35]. These require appropriate credit, which the game provides in the Credits scene available from the Main menu.

21.3 Screenshots

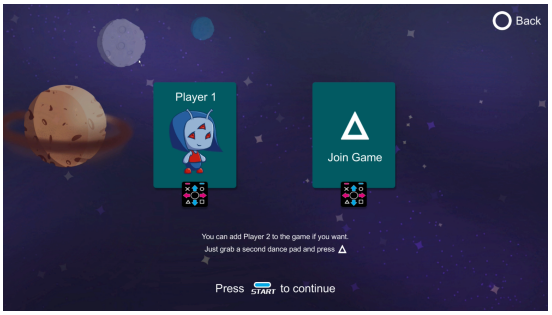
Figure 21.20 shows some screenshots from the finalized game. The pictures display how the different sprites are combined to create each scene. All visuals fit together due to the general art style rules used when creating them. As shown in the screenshots, multiple sprites are present in different places inside the game. This sprite reusing is for both consistency and time limitations.

21.4 Summary

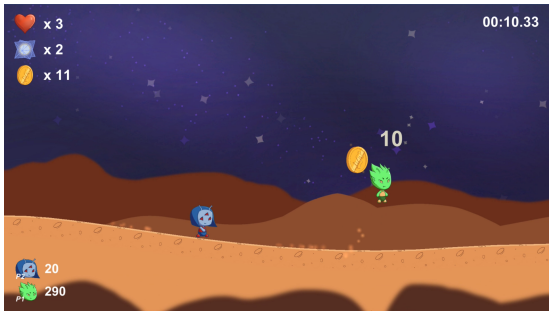
SSR's visual elements are created by us. The game has dark purple and light yellow as the prime colors. Graphical components, such as avatars and spaceships, have a primary color and often up to two secondary colors. We choose colors with the help of harmony rules. Sprites have a bold outline and a darker shade of the primary color. The game gets an overall cohesive look and feel by setting these general art style rules.

SSR gives credit to its audial parts in regards to their respective licenses. The music is made by Ole Halvor Dahl and is reminiscent of retro game music. freesound.org provided all sound effects used. All sounds that are not under CC0 are given credit in the Credit scene.

(a) Start scene

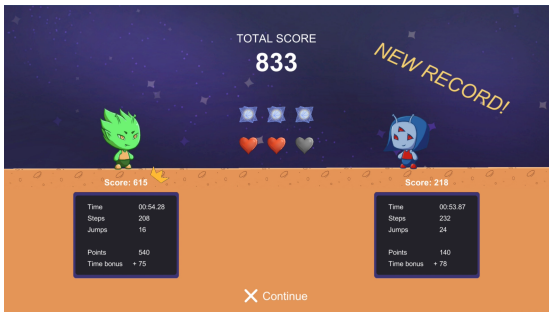


(b) Adding players

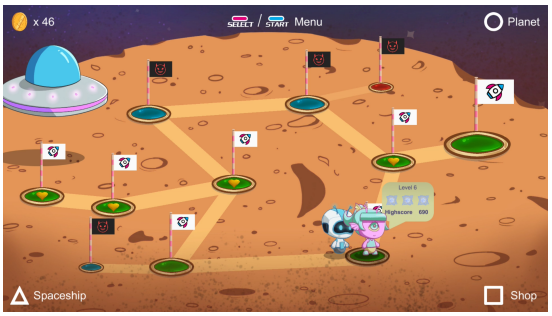


(c) Level

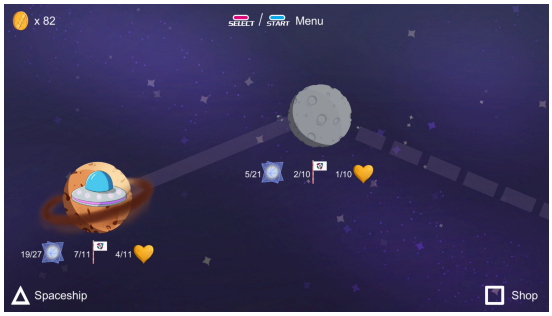
(d) Finishing a level



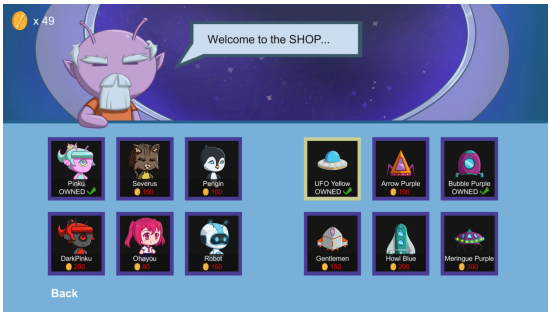
(e) Victory scene



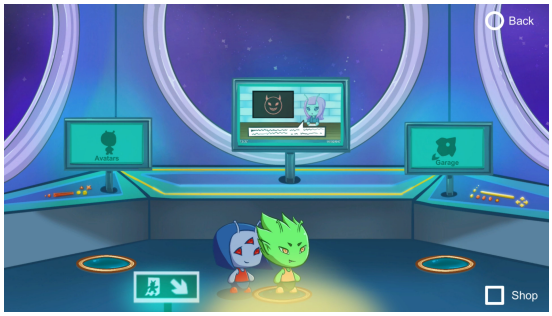
(f) Level selector



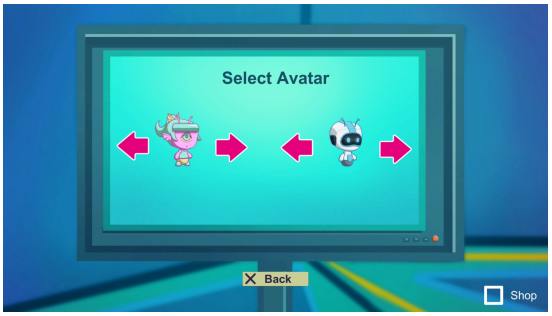
(g) Planet selector



(h) Shop



(i) Spaceship



(j) Select avatar

Figure 21.20: Some screenshots from SSR.

Part V

Experiment Design

Part V presents the experiment design. First, it explains the experiment execution, including ethics, participant recruitment, experiment setup, and the data analysis methods. It ends by describing the different types of data we gather during the experiment and how we gather it.

Chapter 22

Experiment Execution

This chapter presents the execution of the experiment. It describes ethical aspects, participant recruitment, the experiment setup, and the data analysis.

22.1 Ethics

When conducting a research project in Norway that collects and processes personal data, it is necessary to apply for permission from the Norwegian Centre for Research Data (NSD). We applied for permission on the 24th of January 2022 and got the approval on the 3rd of February 2022. The approval is attached in Appendix A. The application included which personal data we will process, project information, data processing responsibilities, participant information, information security, and project period.

Personal information gathered from the experiment is stored separately from the rest of the data and connected to it with an identification key, ensuring the participant's anonymity. It is stored inside NTNU's SharePoint system, which provides transfer and storage encryption, access control, and multi-factor authentication. At the project's end, all personally identifiable information is deleted.

The participants need to give formal consent because the experiment gathers personal information. Therefore, each user has to read and sign an agreement contract (see Appendix B). The contract informs the users about the project, what data we gather, and how it is used in the research and final report. It also presents their rights and how to submit a complaint to the Norwegian Data Protection Authority.

22.2 Participant Recruitment

Participants were recruited through convenience sampling, using social media to get friends and acquaintances to volunteer. The invitation message included information about the game and the experiment execution. The participants' contact information was saved to schedule their testing appointment and provide further info about the experiment and what we expected of them. We recruited a diversity of people, both in gender and education. However, most of them are students due to convenience sampling.

22.3 Setting Up the Experiment

This section describes the experiment design, which is based on the experiment strategy described in Section 4.3. The experiment starts by explaining information about the test and then observing the participants while they play the game. Afterward, more data are gathered through interviews and questionnaires of the participants. We use several data collection methods and data triangulation to improve the quality of the experiment. The goal is to collect data to answer the research questions RQ3 - RQ6:

- **RQ3:** *What level of physical exertion does the exergame give its players?*
- **RQ4:** *How does the exergame affect the player?*
- **RQ5:** *How does the game design and gameplay contribute to the player experience?*
- **RQ6:** *What are the challenges of playing the exergame?*

The participants will test the game in pairs since it is a two-player game. The test starts by explaining who we are, the purpose of it, that they can quit at any time, the equipment in the room, the test execution, and then each participant signs the agreement contract (see Appendix B). They will be encouraged to say their thoughts and questions out loud, even though we will not answer, to know their thoughts.

Next, they are observed playing SSR for 25-30 minutes, which is a sufficient time to test out and play most of the game based on our alpha and beta testing. We observe every test group and write down notable comments and observations throughout the test. Each observation note contains a short description of the problem, where in the game it occurred, and additional comments if needed. The focus is on observing issues and how the players interact with the game. Additionally, we write down expressions such as reactions to failure and success. If we are unsure about some of the observations, they are questioned in the interview to get more details.

Each user wears a heart rate sensor to record their physical activity level during the play session. The sensor used is the Polar H10. The game also records game-generated data, e.g., jump and step statistics, and stores it in a database. Figure 22.1 shows a picture of the test setup.

Figure 22.1: Experiment setup.

After the play session, the participants answer a questionnaire. The *first part* of the questionnaire contains questions about their personal information and habits regarding video games and physical exercise. The *next part* asks about their experience with the gameplay and the game design, and the goal is to discover what challenges players had with the exergame. The *third part* focuses on the physical activity in SSR and contains questions about the intensity of the game's physical exercise and its quality. The *last part* looks at how the exergame affects the players' enjoyment, motivation, and engagement. The goal is to get qualitative and standardized data we can analyze to answer RQ3 - RQ6. Table 22.1 shows some of the different questions and question types in the questionnaire. The questionnaire is attached in Appendix C.

Table 22.1: Some of the questions included in the questionnaire.

Question	**Type**
How many hours a week do you normally play video games?	Number input
How many hours per week do you normally perform physical exercise?	Number input
What kind of video games do you play?	Checkboxes question
How intense do you feel the game's physical exercise was?	Range (1-10)
I got a good exercise from playing the game	Likert statement
I became less aware of my surroundings while playing	Likert statement

The test ends by conducting a group interview with each test group to obtain more detailed information about their thoughts on the different aspects of the game. We will perform it in a semi-structured format, where the predefined questions are general and open. We also ask more specific questions to get more information about some of our observations. Table 22.2 shows the questions that are the basis of the interview.

Table 22.2: Interview questions.

ID	**Question**
Q1	What do you think about the game? (what is good/bad? challenges?)
Q2	What do you think about the physical activity in the game?
Q3	Did you find the game enjoyable? (why?)
Q4	Did you find the game motivating? (why?)
Q5	Did you find the game engaging? (why?)
Q6	Ask about observations that are not yet discussed in the previous questions
Q7	Do you have any other feedback you would like to give?

22.4 Experiment Data Analysis

This section explains how we will analyze the data gathered from the experiments.

22.4.1 Data Analysis Methods

MATLAB is used to analyze the collected quantitative data. All Likert statements and 1 to 10 questions will be inspected with the Mann-Whitney U test as mentioned in Subsection 4.4.1. We will create group categories, where subjects are dichotomized into two sub-groups and examine their p-values to potentially discover response differences to statements and 1 to 10 range questions. The calculations for generating the p-values are done by utilizing the MATLAB function `ranksum(x,y)` with default arguments, which is equivalent to a two-tailed Mann-Whitney U test with continuity correction and tie adjustment [116]. The Likert options shall be mapped from "Strongly disagree" as 1 to "Strongly agree" as 5 to make the analysis possible. The heart rate data will be analyzed by using MATLAB's `ttest2(x,y)` function with default arguments, which is equivalent to a two-tailed two-sample t-test [117]. This t-test will examine whether there are significant differences in

measured maximum and average heart rate between sub-groups within a group category. Both the t-test and Mann-Whitney U test are two-tailed because the estimated values may depart from the reference by being either higher or lower [145]. For example, it is unknown whether the *Gamer* sub-group will enjoy the game more or less than the *Not Gamers*.

We will conduct a theme analysis of the qualitative data, as described in Subsection 4.4.2. The categorization of observation notes uses the themes: *physical*, *enjoyment*, *motivation*, *engagement*, and *gameplay/challenges*. Interview records will be separated into the same categories. The sub-categories within a theme are chosen freely depending on what is relevant, for example, "Controls" or "Skins". If we have much data within a sub-category, we place similar data together for higher readability. After finishing the categorization, we will highlight the most relevant and unique data to more easily find connections. Relevant quotes will be translated from Norwegian to English when included in this thesis.

22.4.2 Group Creation

The quantitative data will be analyzed by separating the participants into several *group categories*, where each group category contains two *sub-groups*. There will be a total of four different group categories: *Gender*, *Gaming habits*, *Exercise habits*, and *Heart rate zone*. The first one is separation by gender, *Male* and *Female*. Participants that choose the option "*Other*" for gender are not included in any of the two gender sub-groups. We will make another group category by dichotomizing the participants according to their gaming habits, where *Not Gamer* plays video games for zero to one hour per week, and *Gamers* play more than that. The third group category is *Exercise habits*, which splits the participants into *Active* and *Less Active*. Performing more than two hours of weekly exercise places a test subject into the *Active* sub-group. The threshold is placed at two hours because getting two or fewer hours of exercise per week indicates that they are insufficiently physically active according to WHO's recommendations mentioned in Section 10.3.

The last group category, *Heart rate zone*, divides the test subjects into *Vigorous* or *Not Vigorous*. If a participant's maximum heart rate measured during the play session is equal to or above 80% of their maximum heart rate, we place them into the *Vigorous* sub-group. The split between the sub-groups is set to 80% due to being a percentage of max heart rate considered to be of vigorous-intensity [153][63][27][30]. The calculation for each player's maximum heart rate is done with the formula $211 - 0.64 \cdot age$ [132]. The formula is created based on 3320 healthy men and women in Nord-Trøndelag between 19 and 89 years old. Our test subjects will be within the same population, so the formula should be relatively accurate. However, we will keep in mind that the formula has a standard error of 10.8 beats per min.

22.4.3 Multiple Comparisons Problem

The *multiple comparisons problem* is a problem that occurs when making many inferences. Analyzing groups on many different attributes increases the likelihood of getting low p-values that are false positives because of random sampling error [131]. We have four group categories, 46 Likert statements, three 1 to 10 questions, and will look at participants' maximum and average heart rate during the play session. However, we will not analyze the maximum and average heart rates for the *Heart rate zone* group category due to separating the sub-groups based on heart rates. This concludes to $4 \cdot (46+3+2) - 2 = 202$ inferences in total. One could perform a Bonferroni correction [22] to ensure that the entire analysis has only a 5% probability of making a single false claim. But, we consider this too strict for the present application. Therefore, we will be mindful of the multiple comparisons problem when reviewing the results.

22.5 Summary

It is necessary to apply for permission from NSD before conducting the experiment and storing personal information correctly. We also need to get formal consent from each participant. The participants are recruited through convenience sampling, using our social network to get friends to volunteer as participants. The experiment consists of the users playing the game during observation, followed by a questionnaire and interview session. Its goal is to collect data we can use to answer the relevant research questions. We will analyze the quantitative data using MATLAB's `ranksum` and `ttest2` functions on different group categories. The qualitative data will be categorized according to relevant themes.

Chapter 23

Data Collection

This chapter describes the collection of the different data types during the experiment. It goes through the physical aspect, motivation, enjoyment, engagement, and gameplay data types. The chapter explains how the experiment used the different data gathering methods to measure each data type. Section 4.3 explains the data gathering methods utilized. The data collected will be used to answer research questions about the game's effect on the players and the player experience (RQ3-RQ6). Every data type section starts with the related research question(s).

23.1 Physical Aspect Data Collection

RQ3: *What level of physical exertion does the exergame give its players?*

Multiple kinds of *observations* can provide insight into the game's physical aspect. Firstly, we will see if the test subjects start sweating and how much. However, it is necessary to keep the room's temperature in mind. Secondly, we will observe the test subjects' intensity while playing and how it changes during the play session. Lastly, we will write down comments that the participants say regarding the physical aspect of the game. For example, if they say something about getting tired or sweaty.

Other data sources for the physical aspect of the game are the *game-generated data* and the *heart rate monitoring*. The game stores information about both players when completing or failing a level. The collected data is the number of steps, number of jumps, the level name, the completion status, and the run duration. Another source is the heart rate sensors which measure the player's pulse every second. The heart rate data is exportable into a CSV file. This file format makes it possible to look at the raw data from the sensors. We will use *imputation* if the sensors fail to register for a short amount of time [85]. If only one data point is missing, we will impute by taking the mean value of the points before and after the missing one. We will use linear interpolation if multiple data points are missing. However, we will discard a subject's heart rate data if there is a hole in the data of one minute or more, as that much data loss may lead to biased results.

Physical aspect data was also collected by asking the participants questions in a *questionnaire* and an *interview*. The questionnaire includes questions about the physical aspect of the game. The test subjects must answer the 9 Likert structured statements shown in Table 23.1. The test subjects were also asked: "*How intense do you feel the game's physical exercise was?*" answered on a scale from 1 to 10. The question Q2 from Table 22.2 provides the opportunity for subjects to explain their experience with the physical aspect of the game.

Table 23.1: Questionnaire physical aspect questions.

ID	Statement
S1	The game motivated me to exercise
S2	I got a good exercise from playing the game
S3	I felt that the exercises matched my fitness level
S4	I forgot that I was working out while playing the game
S5	I pushed myself physically when playing
S6	The game can replace a workout session
S7	Going uphill required more physical effort
S8	Going downhill required less physical effort
S9	It was easy to keep up with the level tempo

23.2 Enjoyment Data Collection

RQ4.1: *How is the player's enjoyment affected by the exergame?*

We will write down noticeable enjoyment-related events during the experiment. Enjoyment can be troublesome to observe. However, we will look for facial expressions such as smiling. We will also note if and when the participants laugh. Comments about having fun and their likes or dislikes about something are also relevant. Additionally, we take notes on remarks related to enjoyment theory.

The questionnaire and interview collect data concerning players' enjoyment. Table 23.2 shows the Likert statements from the questionnaire. We generated most of the statements through *GameFlow*'s criteria, see Section 8.1. However, not all GameFlow criteria within a component are present in the questionnaire. Including all criteria would make the questionnaire too long, and removing some gives space for other general statements such as S10. Malone's *Challenge, Fantasy and Curiosity* are also asked upon where *challenge* is already a part of GameFlow, *fantasy* is asked about in S21 and S22, and *curiosity* is present in S24. By asking about the game enjoyment theories, we get insight into if we succeeded in using them. The interview provides an open question about if and what they thought was enjoyable about the game.

Table 23.2: Questionnaire enjoyment questions.

ID	Statement
S10	I found the game enjoyable
S11	I was not overwhelmed with tasks
S12	I found the challenge level to match my skill
S13	The game provided information on how to play
S14	I felt in control of my character
S15	The game gave me clear goals
S16	The game provided feedback for my actions
S17	I was given feedback on my progress in the game
S18	The game supported competition between players
S19	The game supported cooperation between players
S20	I enjoyed the game's music and sound effects
S21	I enjoyed the game's story and setting
S22	I enjoyed the game's characters
S23	The game increased the challenge level according to my skill improvement throughout the play session
S24	I enjoyed the game's graphics
S25	I was curious to learn more about the game while playing

23.3 Motivation Data Collection

RQ4.2: *How is the player's motivation to continue playing affected by the exergame?*

The observations will provide insight into the players' motivation to continue playing. We will see which tasks the players prioritize to do with the 25 minutes they have to play. For example, if they use their time to complete many levels, collect stars, or buy skins. We will also write down remarks about what the players want to do, such as "*I want to complete that level first*". Comments on collectibles will likewise be noted, as their central role is to provide motivation.

Table 23.3 shows the questionnaire's Likert statements related to the test subjects' motivation to continue playing. It collects data on which elements motivate the players and if it is more motivating than other aerobic exercises. The interview includes an open question on if they felt motivated to continue playing and what motivated them.

Table 23.3: Questionnaire motivation to continue playing questions.

ID	Statement
S26	The game was motivating
S27	Playing together is more motivating
S28	Playing against/with another person motivated me to perform better
S29	I feel more motivated to workout by playing the game than an aerobic exercise
S30	I was motivated by having different characters to choose from
S31	I was motivated by having different spaceships to choose from
S32	I was motivated by collectibles (coins, stars, golden heart)
S33	I was motivated by scores

23.4 Engagement Data Collection

RQ4.3: *How is the player's engagement affected by the exergame?*

We will observe the test subjects' visual and audial engagement during the play session. Observations include shouts, sounds, and movements that appear as a result of the game, for example, failing a level. We will also look at how their observable engagement changes during the session. Comments on engagement and immersion, such as an altered sense of time, will likewise be noted.

The questionnaire's engagement-related statements are shown in Table 23.4. We have included GameFlow criteria for the *immersion* component as part of the engagement because engagement and immersion are intertwined and related. However, the data from these statements can also provide some insight into enjoyment as it is part of game enjoyment theory. The interview gives the participants an open question about if and why they found the game engaging.

Table 23.4: Questionnaire engagement questions.

ID	Statement
S34	I found myself engaged while playing
S35	I lost track of time while playing
S36	I became less aware of my surroundings while playing
S37	I became less self-aware while playing
S38	I was emotionally involved in the game

23.5 Gameplay Data Collection

RQ5: *How does the game design and gameplay contribute to the player experience?*
RQ6: *What are the challenges of playing the exergame?*

Observations related to gameplay include comments about game design and mechanics that they like or dislike. Gameplay observations also cover mentions of anything about the game concept and the usage of dance pads as input. How the two participants interact is also relevant. We will write down observations about their control of the game and their progression. The database stores all *runs*, so we know every group's progression. We will also note different challenges and technical issues that we see the test subjects face.

The questionnaire and interview collect data about both gameplay and challenges. Statements regarding the gameplay and the game, in general, are shown in Table 23.5. The participants will also have to answer if they experienced any technical or gameplay issues with a multiple-choice question. Table 23.6 presents which issues they can choose. However, they can write a unique issue by choosing "Other" if there is an unexpected challenge. The questionnaire also contains the questions: "*How satisfied are you with the menus in the game?*" and "*How intuitive and enjoyable were the level controls?*". These questions provide data on the usability of the game and help measure the quality attribute scenarios U1 and U3 from Section 18.2. The interview includes a general question about their likes and dislikes about the game and which challenges they faced during the play session.

Table 23.5: Questionnaire gameplay questions.

ID	Statement
S39	I liked the game
S40	I liked the use of dance pads
S41	I found the menus to be intuitive
S42	I found the controls to be intuitive
S43	I liked the length of the levels
S44	I liked the variety the challenge levels gave
S45	The game was good at tracking my movements
S46	I liked receiving a score for each level

Table 23.6: Questionnaire challenges multiple choice question.

ID	Technical or gameplay issue
C1	None
C2	The game did not register my steps
C3	The game did not register my jumps
C4	Standing correctly on the dance pad
C5	Both players press a button at the same time when navigating the menus
C6	Pressing a button I did not intend to press
C7	Other

23.6 Summary

We will collect data related to relevant research questions from multiple sources, including observations, interviews, and the questionnaire. All categories contain Likert statements in the questionnaire. The physical aspect and gameplay also include 1 to 10 rating questions, and there is a multiple-choice question for gameplay or technical issues experienced. The database data provides game-generated data relevant to the gameplay and physical aspect. The physical also includes heart rate sensor data from the play sessions.

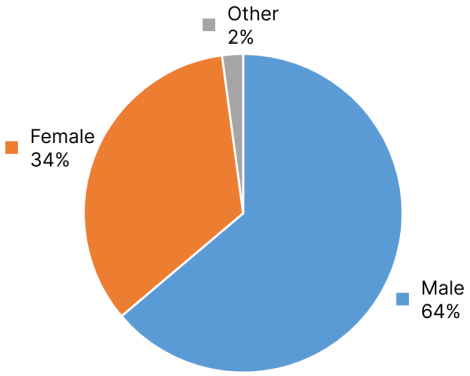
Part VI

Results

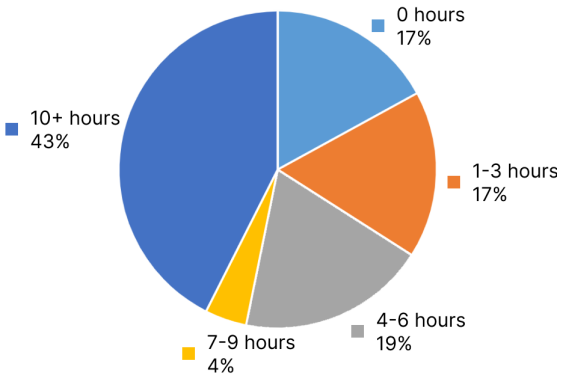
Part VI presents the results from the experiment. It starts with the test population and the different groups used for the data analysis. Next, it gives the results for the physical activity, enjoyment, motivation, engagement, and gameplay and challenges.

Chapter 24

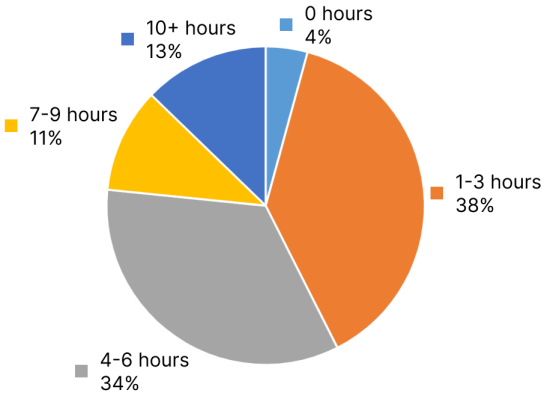
Test Population



(a) Gender distribution



(b) Weekly video game consumption



(c) Weekly exercise

Figure 24.1: Test population demographic results.

The test population consisted of 47 people, and all of them participated in the observation, questionnaire, and interview. One person that was supposed to be a part of the experiment could not participate due to illness, so one participant played the game twice as the experiment required

participants to play in pairs. However, results from that person were only recorded on their first play session. All participants are between 20 and 30 years old, mainly because of the recruitment from our social network. Figure 24.1a shows the population's gender distribution, which shows that the population consisted of 64% males, 34% females, and 2% others.

Figure 24.1b shows the average weekly video game consumption of the participants. As the figure shows, the population's majority plays video games regularly, and only 17% do not. 66% plays more than 4 hours each week.

Figure 24.1c shows the participants' average weekly exercise hours. As shown in the figure, only 4% do not usually exercise in a week. Most (72%) exercise between 1-6 hours weekly, and the remaining 24% do it for more than 6 hours each week.

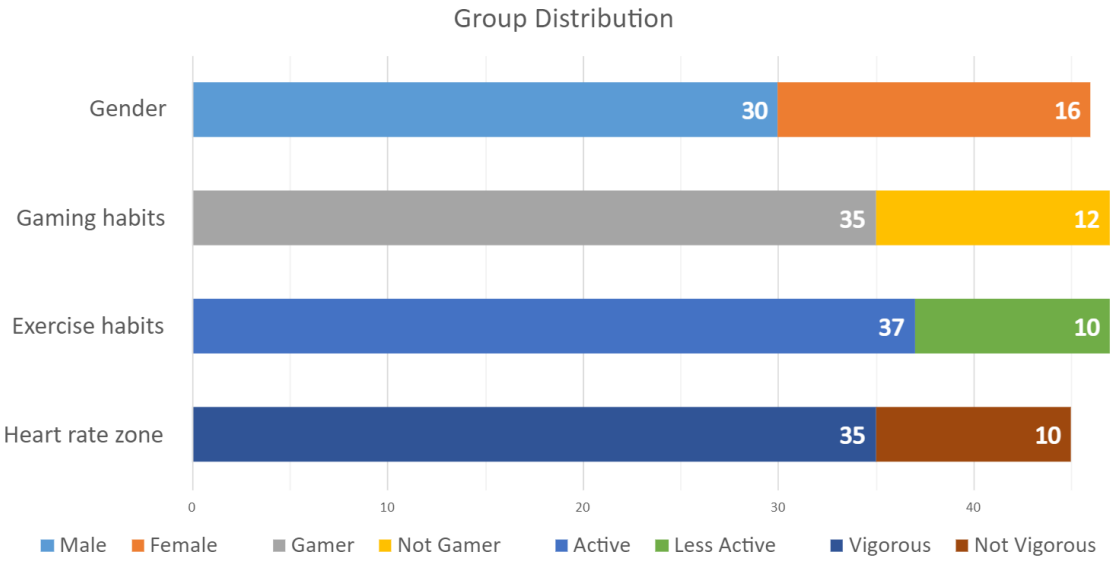


Figure 24.2: Group distribution for the data analysis.

Figure 24.2 shows the distribution of the different group categories for the data analysis described in Subsection 22.4.2. The *Gender* category has a total of 46 members since we do not include the option "*Other*" for the analysis. The *Gaming habits* group category consists of all 47 participants, where 35 of them are considered a *Gamer* (plays more than one hour each week on average). The *Exercise habits* category has 37 members we consider as *Active* (exercise over two hours each week on average) and 10 as *Less Active*. The *Heart rate zone* group category has 45 members since we were unable to record heart rate data for two of the players. Those with a max BPM over 80% of their calculated max BPM in the play session are labeled *Vigorous* and had 35 members.

Chapter 25

Physical Activity Results

This chapter presents the physical activity data results. It starts by showing the questionnaire results, including any statistically significant results from the data analysis. Next, it shows the gathered data from the observations and interviews. The chapter ends by presenting the heart rate and game-generated data.

25.1 Questionnaire

Figure 25.1 shows the responses to the statements in the questionnaire on physical aspects (see Table 23.1). The responses have a high percentage of agreement. For instance, 85.1% agreed that the game motivated them to exercise, and only 4.3% disagreed (S1). Additionally, almost everyone (97.8%) felt that they got good exercise from playing the game, according to their response to S2. The results from S9 are more dispersed and show that several experienced challenges with the level tempo.

Figure 25.2 shows the result of the question "*How intense do you feel the game's physical exercise was?*" where the participants answered on a scale from 1 to 10. The result shows that most participants found the game intensive, with an average of 6.79, a median of 7, and a standard deviation (SD) of 1.25.

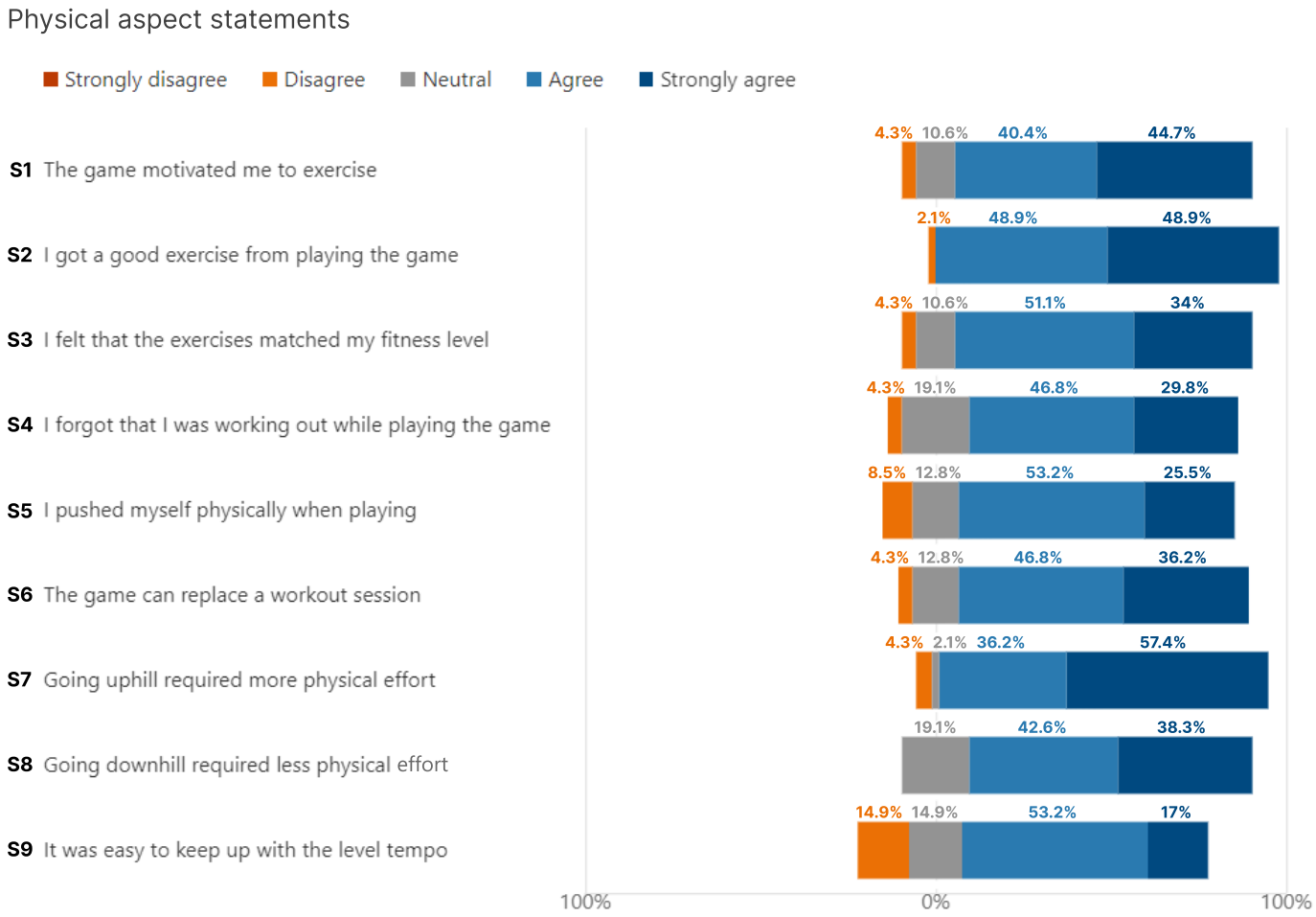


Figure 25.1: Physical activity statements results.

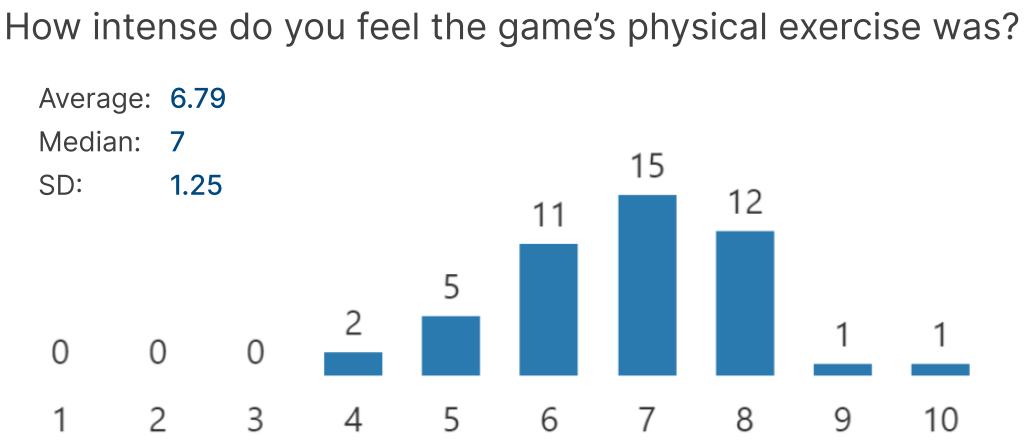


Figure 25.2: Physical intensity results.

The questionnaire results are analyzed using the Mann-Whitney U test to examine whether there are any significant differences between the groups (see Section 22.4). Table 25.1 shows the data analysis results that had a p-value less than 0.10. It reveals eight p-values, where six are statistically significant ($p < 0.05$). Appendix Section D.1 contains the results from the complete physical activity analysis. In general, the biggest difference in the results was between the *Vigorous* and *Not Vigorous* sub-groups. The *Vigorous* sub-group generally gave higher scores, having a high percentage of "Strongly agree" on S1, S2, S3, S5, and S6. None in the *Not Vigorous* sub-group strongly agreed that they pushed themselves physically when playing (S5, p-value=0.0074). Females agreed to a larger degree than men that downhill running requires less physical effort. Of the females, 69% strongly agreed with it, while only 23% of the males answered the same (p=0.0011).

Table 25.1: Results of physical activity statement analysis using the Mann-Whitney U test with $p < 0.10$.

ID	Statement	Group	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	P
S1	The game motivated me to exercise	Vigorous	0%	3%	9%	34%	54%	**0.0432**
		Not Vigorous	0%	10%	20%	50%	20%	
S2	I got a good exercise from playing the game	Active	0%	3%	0%	41%	57%	0.0593
		Less Fit	0%	0%	0%	80%	20%	
		Vigorous	0%	0%	0%	43%	57%	**0.0248**
		Not Vigorous	0%	10%	0%	70%	20%	
S3	I felt that the exercises matched my fitness level	Vigorous	0%	0%	11%	49%	40%	0.0737
		Not Vigorous	0%	20%	0%	70%	10%	
S5	I pushed myself physically when playing	Male	0%	7%	10%	43%	40%	**0.0219**
		Female	0%	6%	19%	75%	0%	
		Vigorous	0%	6%	9%	54%	31%	**0.0074**
		Not Vigorous	0%	20%	30%	50%	0%	
S6	The game can replace a workout session	Vigorous	0%	3%	9%	46%	43%	**0.0194**
		Not Vigorous	0%	10%	30%	50%	10%	
S8	Going downhill required less physical effort	Male	0%	0%	30%	47%	23%	**0.0011**
		Female	0%	0%	0%	31%	69%	

25.2 Observations

We observed several signs of high physical exertion during the play sessions, and many of the players commented on their exercise level. One participant commented: "*This is equivalent to a proper exercise session*", and another said that he got exhausted but did not want to stop because it was too fun. The majority were visibly sweating, some took off clothes during the session, and others regretted not wearing a more appropriate outfit for exercise. Several of them also commented on their level of sweating. If there was a big stamina difference between the two players playing together, we noticed that the high stamina player was significantly less exhausted because they had to wait for their teammate to catch up.

The intensity was high throughout the play session after the first 5 minutes with the cutscene and tutorial. One of the groups agreed to reduce their pace to endure the rest of the session, and another asked for permission to stop playing after 23 minutes because they were too exhausted. It was also common to take water breaks or explore the game to catch their breath before starting a new level.

Running uphill requires the players to increase their pace to keep up with the level tempo, which changes the intensity. We observed a significant increase in the step frequency during uphill running, and several participants expressed exhilaration for it. One said that "*I like that I have to run fast when going uphill*", another one stated that *"This is kinda similar to interval exercise"*.

We also observed that the challenge levels provided an ability to change the intensity. Some of them require a high pace to complete, resulting in a significant increase in heart rate for several

players. One player's heart rate changed from around 150 bpm to over 180 bpm when playing the "As Fast As You Can" challenge. Other challenge levels, e.g., the jump challenge, have a slower pace, allowing the players to lower their intensity without needing to stop playing.

Several participants expressed that the game was physically demanding for their legs and feet. One participant shouted: "*Oh my god, my legs are burning!*", and another one stated that "*I get tired in my legs because I am running on my toes*". There was also a wish by one participant to wear shoes to reduce the strain on the legs.

25.3 Interviews

The majority stated that the game gave good exercise and that it was exhausting. Some of the statements included: "*It was really tiring*", "*This was a good exercise*", and "*I feel like I could use this as regular exercise*". One also said that he exercises frequently and was happy that this game gave a good exercise for him too and not only for people with low stamina. There were also several that disagreed or were more neutral to the game's exercise level. One participant said that "*I view it as physical activity but not an exercise session*", and another stated that for him, it was equivalent to fast-paced walking or running slowly. People also commented that playing multiplayer requires the players to be on the same physical level to get good enough exercise.

Some participants compared SSR to other exergames. One of the players in a group said that she did not get as exhausted as when playing *Just Dance*, but the other player disagreed with her and stated that "*This is more similar to running and it provides a better exercise than Just Dance*". Two others believe that the game has a similar exercise level as *Ring Fit Adventure* and *Just Dance*. A possible disadvantage for SSR compared to other exergames is the lack of movement variations. People said it would be nice to have more variation and use different parts of your body, including one person who expressed that a crossover with *Beat Saber* would be great.

People mostly liked the game's intensity level and that you could influence it. We observed that most players were sweating, and seven players also commented upon this. One said that *"It was a good exercise, it increased my heart rate, and I got sweaty"*. Several also mentioned that playing multiplayer makes them competitive and pushes them to a higher intensity than they would have if they were playing alone. A player said that "*I needed to take a short water break to catch my breath. If I were playing alone without being observed, I would have taken a 5-minute break*".

To require the players to run faster uphill and that the jump height is dependent on the player's air time when jumping contributed to a higher intensity. One said, "*I like the uphills a lot. You have to run faster, but you do not necessarily think you are running quite intensively*", and another said that "*You can certainly feel the uphill in your legs*". According to one user, jumping when having a jump boost makes you instinctively jump higher to get your avatar above higher obstacles.

A common topic discussed in the interviews was the lack of variation. Several said that the motions were repetitive and that they missed movement variations. They believe it would be nice to have a higher variation in the existing levels or different types to have other movements and step patterns on the dance pad. One also said that it would be nice to use the rest of your body, for instance, hand movements.

Several commented on the strain on their legs and that they got more tired in their legs than exhausted. One said that "*I felt that I had a high heart rate, but it was not the cardio that limited me but my legs.*" and another one said that "*I felt that I might get a cramp in my legs*". Other ones said that they got tired and tense in the back leg muscles because of the game's repetitiveness and that it was unnatural to run with the legs so far apart.

25.4 Heart Rate Data

As described in Section 22.3, each subject in the experiment wore a Polar H10 heart rate sensor to record their physical activity level during the play session. However, due to one of the sensors failing during a play session and the sensor not fitting one of the participants, we have heart rate data for 45 of the 47 participants. The last 30 seconds of the session are missing 5 of the 45 heart rates because some participants stopped playing before reaching 25 minutes. One data point (one second) was missing from one of the heart rate recordings, which we imputed by taking the mean value of the points before and after the missing one. Figure 25.3 show the median heart rate for the participants along with Q1 and Q2, and we can see that the median stabilizes around 140 - 160 bpm after the players have warmed up. Figure 25.4 shows the heart rate data of one of the players that played with high intensity.

Figure 25.5 visualizes the results for the heart rates' data analysis, with a box plot. As described in Section 22.4, we analyzed the heart rate data with a two-sample t-test on the *gender*, *gaming habits*, and *exercise habits* groups. Our analysis discovered only one difference within group categories related to heart rates ($p < 0.10$) (see Appendix Section D.1 for complete heart rate analysis). The results indicate that females had a higher heart rate than males (p=0.064).

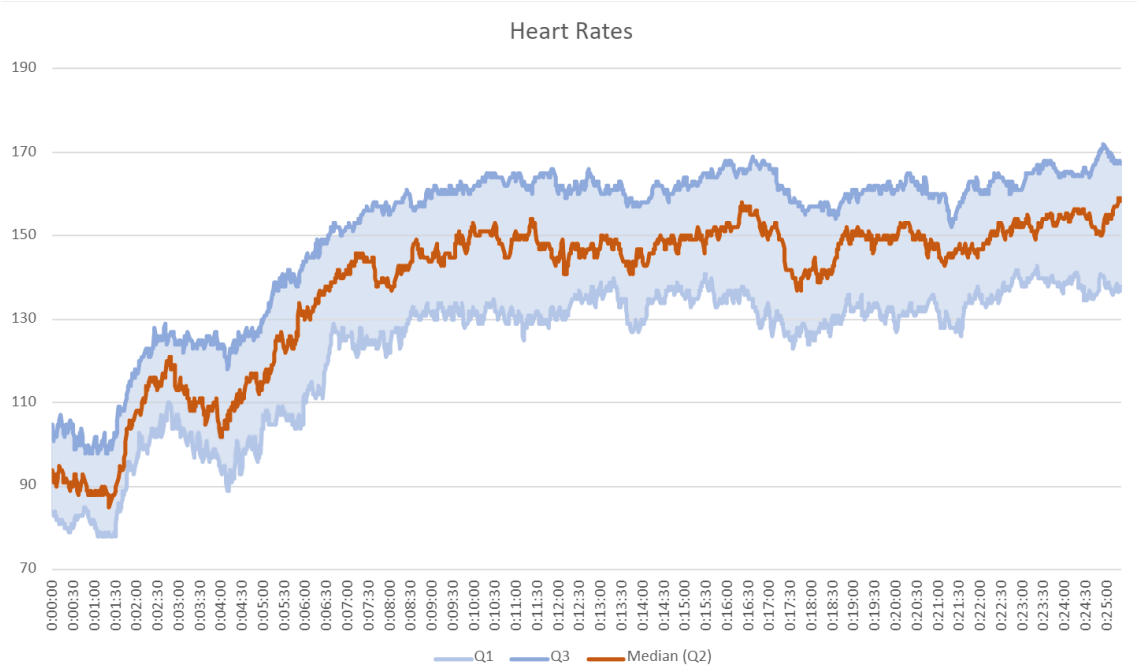


Figure 25.3: Heart rates of 45 participants showing Q1, Q2 (median), and Q3.

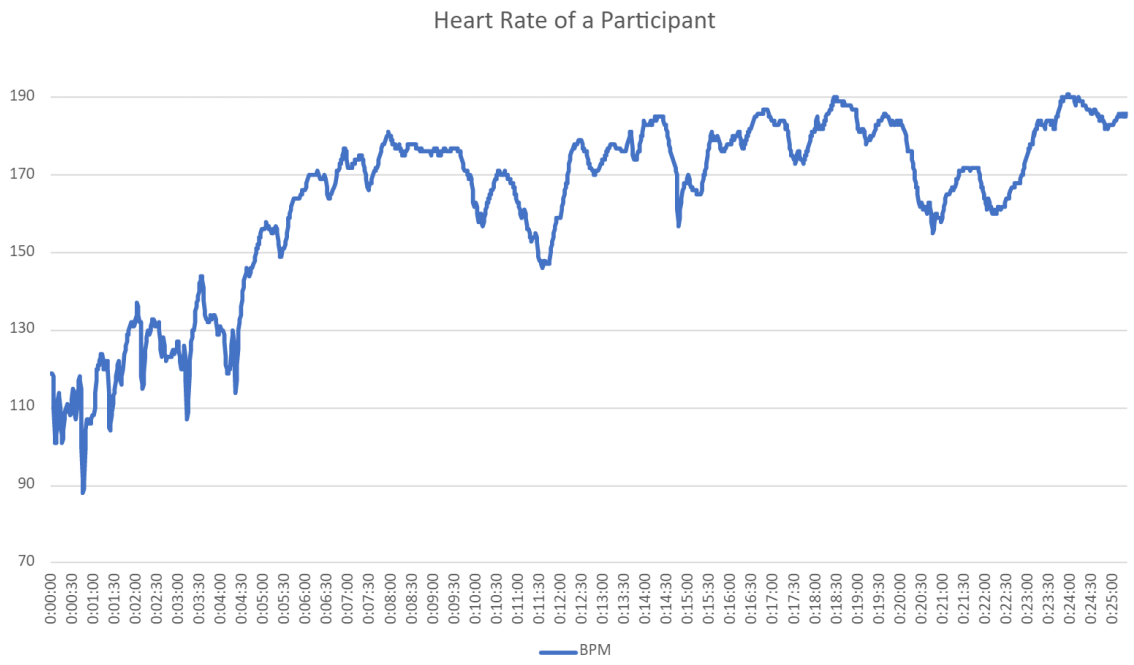


Figure 25.4: Heart rates of one of the participants showing a high-intensity play session.

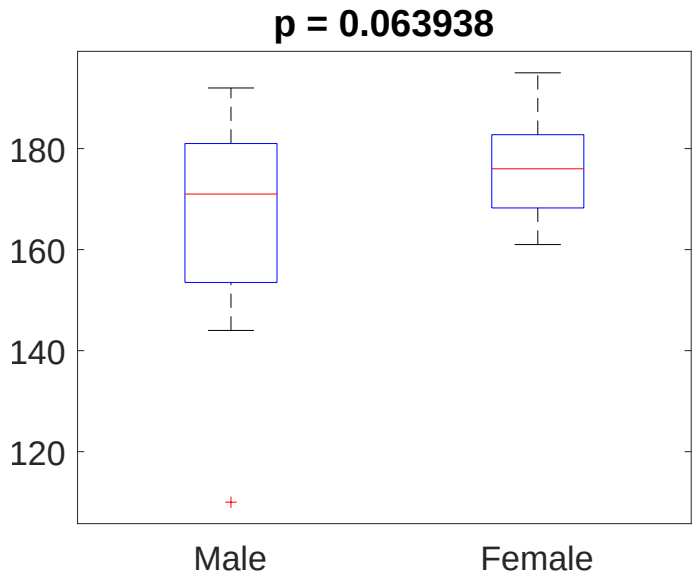


Figure 25.5: Results from the maximum heart rate data analysis using a two-sample t-test with $p < 0.10$.

25.5 Game-Generated Data

The game-generated data contains statistics for each run the participants take on a level, including its duration and the step and jump count. It is from all 47 participants with a total of 1696 runs. Table 25.2 shows the aggregated results from the game data with the average, median, and standard deviation. The participants' mean total step and jump counts were 3615.4 steps and 218.4 jumps, and the mean step frequency when playing a level was 230.2 steps per minute. More than 170 000 steps were taken in total on the dance pads by the participants.

Table 25.2: Results from the game-generated data.

	Average	**Median**	**SD**
Steps	3615.4	3650	477.7
Jumps	218.4	220	45.2
Steps/min	230.2	236.0	25.8

25.6 Summary

This chapter presented the physical activity results collected during the experiment, including qualitative and quantitative data obtained from the questionnaire, observation, interviews, heart rate data, and game-generated data. The results show that the game gives a moderate to high physical activity level, and 97.8% agreed that they got a good exercise from playing the game.

Chapter 26

Enjoyment Results

This chapter provides the enjoyment data collected from the experiments. It starts by presenting the data from the questionnaire and the results from statistical tests with low p-values. Lastly, it shows the results from the observations and interviews.

26.1 Questionnaire

Figure 26.1 displays the results from the enjoyment-related statements using the Likert's scale from the questionnaire (see Table 23.2). Most participants answered neutral, agree, or strongly agree, but there was some disagreement regarding the challenge level, feedback, and social interaction.

Regarding S10, all participants agreed or strongly agreed that they found the game enjoyable. For S12, 2.1% strongly disagreed that the challenge level matched their skill, and in S23, 10.6% disagreed that the challenge level increased according to their skill improvement throughout the play session. There was disagreement on the feedback from actions and progress, as 4.3% and 6.4% disagreed on S16 and S17, respectively. The results also show some debate on whether the game supported cooperation. However, there is a high amount of disagreement regarding competition, where 25.6% disagreed or strongly disagreed that the game supported competition.

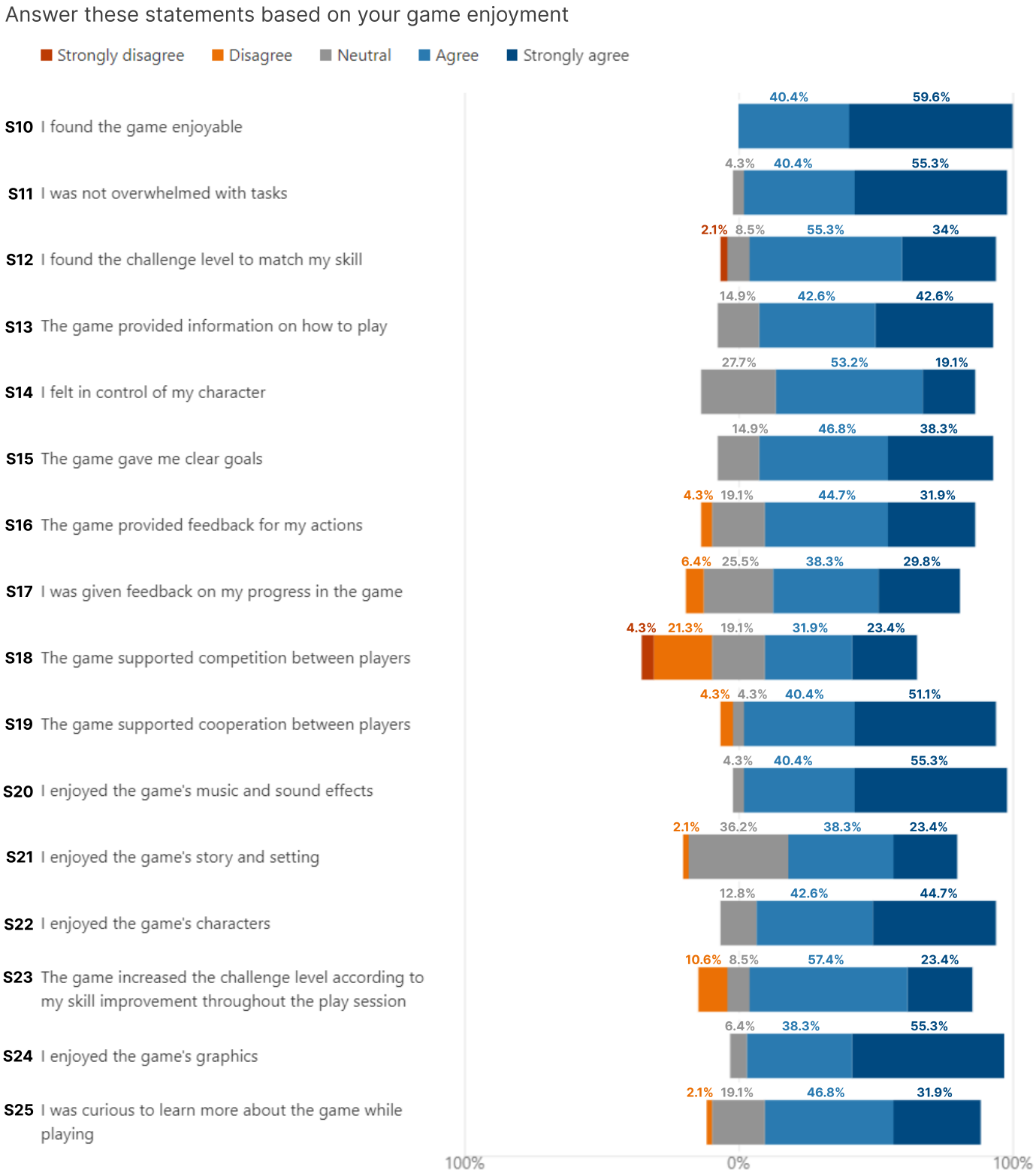


Figure 26.1: Enjoyment statements results.

The questionnaire results are analyzed using the Mann-Whitney U test to examine whether there are any significant differences between the groups (see Section 22.4). Table 26.1 shows the data analysis results that had a p-value less than 0.10. It reveals eight p-values, where six are statistically significant ($p < 0.05$). Appendix Section D.2 contains the results from the complete enjoyment

analysis. In general, the highest difference in enjoyment was within the *Heart rate zone* group category. The *Vigorous* sub-group agreed to a larger degree to the statements, having a high percentage of "Strongly agree" on goals, story, character, and curiosity. None in the *Not Vigorous* sub-group strongly agreed that the game supported competition, but 29% of the *Vigorous* sub-group selected "Strongly agree" (p=0.0605). The *Not Gamer* sub-group found the game to support competition more than the *Gamer* sub-group. One may also note that females enjoyed the game's characters more and were more curious about the game than the males.

Table 26.1: Results of enjoyment statement analysis using the Mann-Whitney U test with $p < 0.10$.

ID	Statement	Group	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	P
S15	The game gave me clear goals	Vigorous	0%	0%	11%	46%	43%	**0.0392**
		Not Vigorous	0%	0%	30%	60%	10%	
S18	The game supported competition between players	Gamer	3%	26%	23%	37%	11%	**0.0242**
		Not Gamer	8%	8%	8%	17%	58%	
		Vigorous	0%	23%	17%	31%	29%	0.0605
		Not Vigorous	20%	20%	20%	40%	0%	
S21	I enjoyed the game's story and setting	Active	0%	3%	27%	43%	27%	**0.0450**
		Less Active	0%	0%	70%	20%	10%	
S22	I enjoyed the game's characters	Male	0%	0%	17%	47%	37%	0.0516
		Female	0%	0%	0%	38%	63%	
		Vigorous	0%	0%	9%	40%	51%	**0.0422**
		Not Vigorous	0%	0%	30%	50%	20%	
S25	I was curious to learn more about the game while playing	Male	0%	3%	20%	57%	20%	**0.0278**
		Female	0%	0%	13%	31%	56%	
		Vigorous	0%	0%	14%	49%	37%	**0.0353**
		Not Vigorous	0%	10%	30%	50%	10%	

26.2 Observations

We observed enjoyment from the participants regarding the game's story and artistic design. Most of the players smiled or laughed while the intro cutscene played, often commenting to the other person on story elements or names they found to be funny. Two subjects commented on the text speed being slow. One person said: "*I have time to read, yay dyslexia friendly*" but the other said that it was a bit too slow.

Most test groups mentioned that they liked the game's graphics. The participants often said that the characters were cute, and one person said that the visuals gave them "*Pokémon vibes*". Subjects also seemed to enjoy the level visuals. A participant mentioned that they liked the dust particles that appeared when running. Another player commented, "*It is easy to interpret what is the level and what is the background. There is great clarity on the screen*".

Test subjects seemed to enjoy the music. Multiple people said during the play session that they thought it was awesome. They also seemed to enjoy the change in music depending on the level, saying, "*The music is different now! Yes!*".

We observed high amounts of enjoyment while the subjects were playing a level. Both players usually smile and laugh, especially when dying. We heard most laughter when they died simultaneously or at the same place. Players also commented on enjoying the level controls, for example, "*How the coding is done for the jumping mechanic is very cool!*" The participants frequently smile and look at each other when finishing a level. Some participants had trouble with the controls, making it tough to complete a level. After failing multiple times, a few participants started sighing. Struggling with it seemed to make the test subjects frustrated and unhappy.

Various subjects commented that the level designs were enjoyable. Levels often include uphill and downhill slopes, which require more and less physical effort. Multiple players said they enjoyed

the increased effort needed to go uphill. One group increased their speed intensely when going uphill, which also made more sound from the dance pads, making both players laugh when going uphill. Test subjects also commented on liking the power-up by saying, "*Woah, exciting! There is something new here!*" when seeing it and "*It feels a bit like we are flying*" while using the power-up. The most commented-on enjoyable level design element is when the path splits into two, having one platform at the top and the other at the bottom. Many commented on liking those elements when they appeared, for example, "*That was a good challenge and very fun*". A few players expressed disappointment when commenting that they expected a boss on a planet's final level.

26.3 Interviews

When asked, all participants said they enjoyed the game. Some compared it to tabletop games, as it fitted well to play together with family or friends but would not necessarily play alone. One participant without much gaming experience also noted that it was more fun to play *Space Space Revolution* than to be on the phone. Most subjects said they enjoyed the overall concept and the uniqueness of combining dance pads with a platformer. Some also mentioned that it was fun and nostalgic to use dance pads. A few participants said they would lose enjoyment if they played for a long while, and others prefer to play until they get too physically tired.

Almost all participants said they enjoyed the game's artistic design. A couple of subjects thought the intro cutscene was fun, referencing the potato (spud). When we asked about what they enjoyed, most players started by stating that they enjoyed the graphics and music. Most people liked the general art style and that the music was "*Upbeat and not annoying*". One person commented on their enjoyment of the fore- and background movement. Another test subject mentioned that the backgrounds were a bit boring, saying: "*Just the same deserted look the whole time*". Many of the participants said they liked the characters and having a shop. They enjoyed the spaceships less as they did not see them that much. Some said they would have enjoyed the spaceships more if the inside of the spaceship menu reflected which spaceship you were using.

Enjoyment came from playing multiplayer. Some enjoyed the competition aspect of trying to be first to get the most coins. On the other hand, others liked to cooperate by attempting to run in sync and coordinate when the platforms split into two paths. Most said they would have less enjoyment by playing alone, and one participant stated that "*I would not have bothered playing so long if I was alone*". One test subject emphasized that having both players have approximately the same skill level was significant for enjoyment. This pair had one person with excessive gaming experience while the other had barely played games. They usually do not play games together due to the high skill difference. However, they found this game enjoyable as the unique controllers resulted in both having the same skill level.

The test subjects enjoyed the levels. Controls and gameplay were prominent for enjoyment. For example, by saying "*It was fun to control the character with your own movement. It had very close mapping*". The controls were not that advanced but still very enjoyable, and they felt in control of the character. The jumping mechanic was amusing, peculiarly that depending on how high you jump in real life, the higher the character jumps. One person stated, "*This is more fun than running on a treadmill. I hate cardio, but this was fun*". However, having issues with learning and using the controls harmed their enjoyment. Many got frustrated when they felt the controls did not register their inputs. This frustration was most present for the jumping mechanic, as participants often had trouble understanding and performing jumps.

Difficulty and a feeling of mastery were crucial for enjoyment. Some people said the difficulty was too hard. A few stated it was too easy, while most said it was fine. Getting a mastery feeling was one of the most enjoyable aspects, and they felt like they could manage to complete a level by practicing more. However, it was frustrating to repeat the same level multiple times after dying.

People also got enjoyment and frustration from the level and game design. The uphills and downhills, as well as splitting platform paths in levels, were fun. On the other hand, respawning into a hole was frustrating, and the level designs were slightly one-sided. The level tempo was enjoy-

able, particularly the ability to be in control of the pace themselves. Most participants enjoyed collectibles. Some liked the statistics at the end of a level, while others did not pay attention to them. Players enjoyed the challenge levels saying, for example, " *The challenges were fun and they provide a pause*". Many mentioned that they would have had a higher enjoyment from the final level if it were a boss battle instead of a slightly longer but standard level.

26.4 Summary

This chapter presented the enjoyment data collected from the experiments, which were highly positive. All participants agreed on the questionnaire that the game was enjoyable, and all Likert statements mostly got positive results. The one with the most disagreement was if the game supported competition between players. The *Vigorous* sub-group generally gave more positive answers. *Gamers* disagreed more than *Not Gamers* about the game's competition support, and females enjoyed the game's characters and were more curious than the males. Observations show that people smiled and laughed while playing, especially while playing a level. Many mentioned that they found the game's artistic design enjoyable. Multiplayer was crucial for amusement, and some said they would not play the game alone. Participants also mentioned that the controls were enjoyable and got a feeling of mastery.

Chapter 27

Motivation Results

This chapter shows the results regarding motivation to continue playing the game. It starts by providing results related to the questionnaire answers, followed by the outcome from the statistical analysis with low p-values for the group categories. Then it describes results from the conducted observations and interviews.

27.1 Questionnaire

Figure 27.1 presents the results from the statements on motivation in the questionnaire (see Table 23.3). The overall results are mostly positive, but two of the statements had higher disagreement than the others. 89.4% in total agreed or strongly agreed that the game was motivating to play, while the rest were neutral. All test subjects agreed that it was more motivating to play together. Statement S29 shows that 72.3% agreed or strongly agreed that they were more motivated to exercise with the game instead of performing a normal aerobic exercise.

The answers regarding motivation are diverse, most notably about spaceships and scores. Results for S31 show that about 30% were not motivated by having multiple spaceships to choose from, while approximately 40% were neutral, and 30% were motivated. Further, 19.2% disagreed or strongly disagreed on S33 that they were motivated by scores.

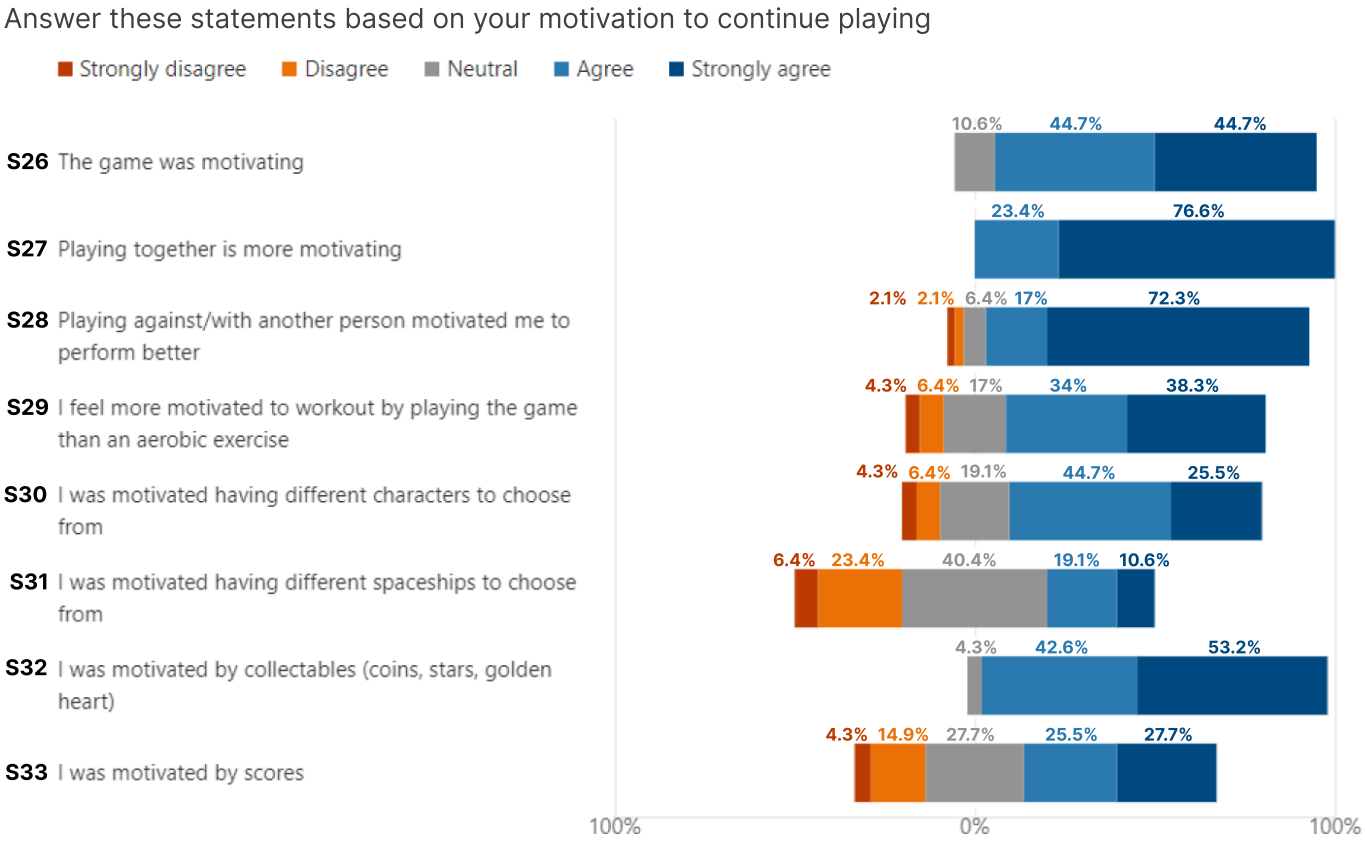


Figure 27.1: Motivation to continue playing statements results.

The questionnaire results are analyzed using the Mann-Whitney U test to examine whether there are any significant differences between the groups (see Section 22.4). Table 27.1 shows the data analysis results that had a p-value less than 0.10. It reveals four p-values, where two are statistically significant ($p < 0.05$). Appendix Section D.3 contains the results from the complete motivation analysis. The *Gaming habits* group category is the most frequent, and *Gamers* gained higher motivation from choosable characters and spaceship skins than *Not Gamers*. However, the analysis shows that the *Not Gamers* to a higher degree were motivated by playing against or with another person than *Gamers* (p=0.0160), as 100% of the *Not Gamer* sub-group chose "Strongly agree".

Table 27.1: Results of motivation statement analysis using the Mann-Whitney U test with $p < 0.10$.

ID	Statement	Group	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	P
S28	Playing against/with another person motivated me to perform better	Gamer Not Gamer	3% 0%	3% 0%	9% 0%	23% 0%	63% 100%	**0.0160**
S30	I was motivated having different characters to choose from	Gamer Not Gamer	0% 17%	6% 8%	14% 33%	49% 33%	31% 8%	**0.0103**
		Vigorous Not Vigorous	6% 0%	0% 20%	17% 30%	49% 40%	29% 10%	0.0826
S31	I was motivated having different spaceships to choose from	Gamer Not Gamer	3% 17%	23% 25%	37% 50%	26% 0%	11% 8%	0.0848

27.2 Observations

We observed that the players were motivated by levels. They often completed all levels in the order according to the level name, even though it is not necessary to finish all to progress in the game. They also commented on getting motivated to run, for example, "*It feels like something is chasing us*". We observed participants getting motivated to successively try the same level when they saw their progress with the progress bar. Challenge levels gave many people motivation, as they got curious about what new challenges would be. Players would often want to try all challenge levels on a planet. For example, we observed players pointing and saying, "*I want to try that challenge over there too after we finish the boss*". Having the final level in the level selector be big made test subjects curious about it, and players often said it was their goal. For example, "*There's a boss fight at the end, we should get to it*" or "*Maybe we can manage to get to that larger level*". A few times, players would switch level selection when noticing the final level, changing from completing all levels to only the necessary ones to get to it faster. Some also commented on wanting to get to new planets, for example, "*Wouldn't it be fun to get to a new planet?*".

One of the dominant motivators observed was the collectibles. Players often tried to get the stars and commented on how many they obtained. For example, "*We only got one out of three stars here*". However, many test subjects stated that they were confused about their purpose. Coins motivated players to be faster than the other player. People were also encouraged by coins because it is the currency for the shop. Some groups got motivated by having a shop and discussing what to purchase. Though, a few groups forgot or did not notice the shop. Skins motivated players to a high degree, as test subjects often stated that buying new characters or spaceships was their goal. One participant stated during the play session, "*I only care about the coins, because I want skins*" another commented, "*Now we have a goal, we have to get a spaceship to become the coolest*". However, players talked more about character skins than spaceships.

The story, score, and time bonus provided motivation as well. We observed that the game's story gave some encouragement to continue playing, and some players also said "*We must help!*" during the cutscene. However, participants did not talk much about the story after the cutscene. Some wanted to get higher scores than the other player, and a few commented on getting *new record*. One test subject was motivated by having the time bonus stating "*There is a bonus for being fast. That is the goal! We have to be fast!*". Nevertheless, most participants did not comment on the time bonus.

27.3 Interviews

The multiplayer aspect of the game provides motivation. Playing together gave general motivation to continue and to have a higher intensity. The competition aspect was crucial for a few participants, and some commented on getting less motivated with the limited competition present. On the other hand, others mentioned that they got motivated by the cooperation aspect of the game. A couple also said they liked cooperation more than competing. Some subjects found it motivating that *Space Space Revolution* was both cooperative and competitive. One person stated that "*I found it motivating that you could choose if you wanted to play competitively or not*". In conclusion, most players got motivated by multiplayer, but there were differences in preferences of what type of multiplayer provides the most motivation.

Numerous participants mentioned collectibles when asked what motivated them to continue playing. Many said they were inspired by all collectibles, for example, "*It was motivating to collect everything*". One participant said they would have liked to have *trophies*. Both the stars and golden hearts were motivating, but multiple groups were confused about their purpose, and some said they would have been more motivating if they knew what they were. Coins caused motivation to buy items and collect more than the other player, but some groups forgot they could spend them. The shop was generally a motivator to continue playing. However, one test subject stated that the shop was not motivating because they had grown to like the first avatar and did not want to buy any new ones.

The motivation to continue playing came from curiosity and goals. Many participants said they wanted to continue playing because they were curious about new planets and mechanics. One player said that "*The game is very clear that there is more to come, such as levels, planets, and mechanics, which motivated me to progress further*". The level selector was also motivating due to portraying the player's progress. However, some would have liked even more information in the level selector about what you can receive from completing a level and some celebration when getting to a new planet. Players were also motivated to discover more about the story and mentioned that the cutscene at the beginning was the right length and provided a goal. One test subject stated that "*It would have been nice if the characters had a goal that was not to be physically active. Then it would have been more motivating*".

Levels were motivating, but having uncompleted levels was important as repeating previously completed ones was unmotivating. Some said they desired to try failed levels until they could finish them. It was unmotivating to die by running too fast. Having control issues was also unmotivating. Multiple test groups stated that they were motivated by having the first challenge level (P1C1) be very difficult, as they could retry it later. Being able to complete more challenging levels as their skills improved made the players want to continue. The score and statistics on the victory screen were motivating for some but ignored by most. One person said they were motivated by the music, and another commented on being motivated by the 25-minute play session time limit.

27.4 Summary

This chapter presented results on the players' motivation to continue playing the game. The overall desire to continue playing was positive, and everyone felt more motivated by playing together with another person. The game's collectibles and game progression were also motivating. Spaceship skins and scores inspired players the least. The motivation gained from skins was higher for subjects playing games regularly.

Chapter 28

Engagement Results

This chapter contains the results from the experiments related to the participants' engagement. It starts by providing results related to the questionnaire answers, followed by the outcome from the statistical analysis with low p-values for the group categories. Then it describes results from the conducted observations and interviews.

28.1 Questionnaire

Figure 28.1 shows the results from statements on engagement from the questionnaire (see Table 23.4). The responses were overall very positive regarding the game's engagement. The answers from S34 show that all participants agreed that they found themselves engaged while playing the game. Statement S38 about being emotionally involved in the game had the most disagreement.

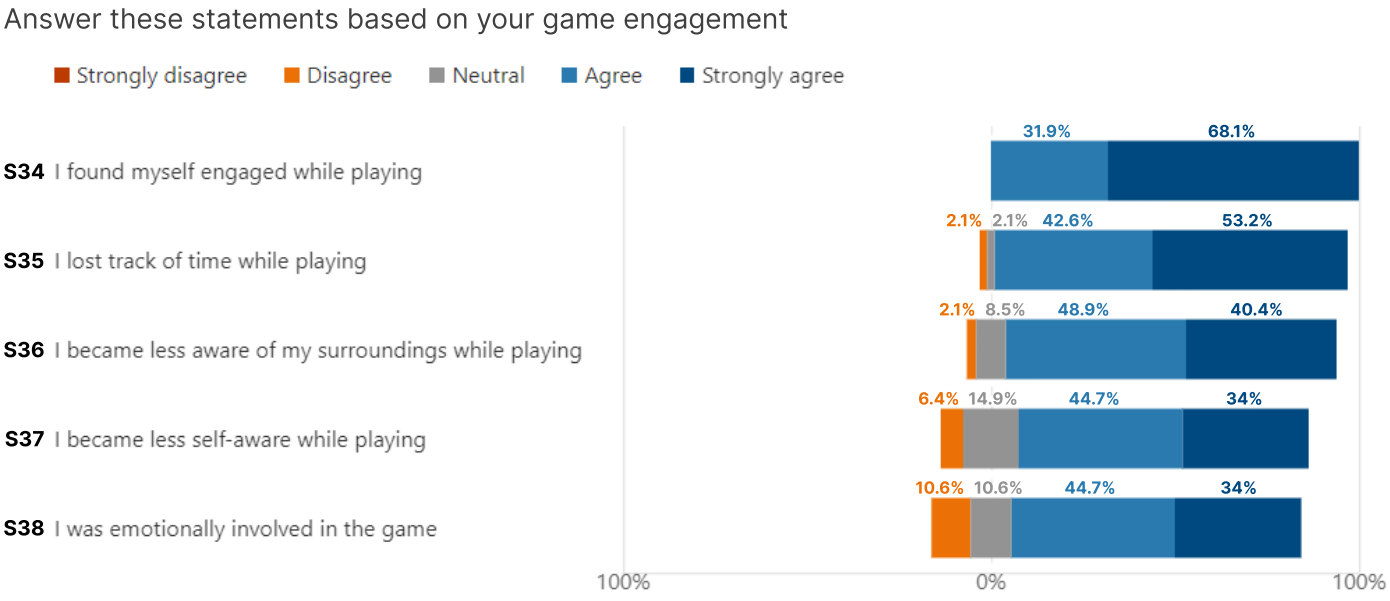


Figure 28.1: Engagement statements results.

Table 28.1 shows the statements on engagement from the statistical analysis of groups with low p-values (for the complete analysis, see Appendix Section D.4). The largest difference was found in the statement about being emotionally involved in the game (S38), where *Vigorous* participants were more engaged than *Not Vigorous*. The table also shows that *Vigorous* participants were more

engaged, and the female players became less aware of their surroundings while playing.

Table 28.1: Results of engagement statement analysis using the Mann-Whitney U test with $p < 0.10$.

ID	Statement	Group	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	P
S34	I found myself engaged while playing	Vigorous	0%	0%	0%	26%	74%	**0.0467**
		Not Vigorous	0%	0%	0%	60%	40%	
S36	I became less aware of my surroundings while playing	Male	0%	3%	13%	53%	30%	**0.0410**
		Female	0%	0%	0%	44%	56%	
S38	I was emotionally involved in the game	Vigorous	0%	6%	9%	43%	43%	**0.0112**
		Not Vigorous	0%	30%	20%	40%	10%	

28.2 Observations

The experiment participants showed signs of high engagement while playing the levels. We noted eleven groups that made loud exclamations during the gameplay, for example, shouting "*No!*" or "*Nice!*" according to events in the game. Players exhibited extra high engagement when getting past a difficult obstacle or almost dying. The highest engagement was observable when a group failed a level close to the finishing flag. At those times, people would often shout, for example, "*Oh my god! We were so close!*" while looking at each other, and a few would place both hands on their heads or sit down. This failure would often be followed by a player saying, "*Okay, now we got this!*" before trying the level again. One test subject said they got stressed when they only had one life left. Another participant said, "*I got really engaged now!*" while playing the final level on the Mars planet. We observed that players were focused on the game, only looking at the screen or the dance pad. One participant commented that "*It has been a long time since I have focused on something this much. I usually only play cozy games*".

We also observed player engagement outside of levels. Players showed high involvement in the victory screen right after completing a level. Here, almost all participants would make some victory exclamation such as shouting "*Yes! We did it!*" while looking at each other, smiling, and often performing a high five. We observed that the general engagement would rise throughout the play session as 15 minutes into the session, players talked more and ran faster in levels. The intro cutscene also provided some engagement as a few test subjects would say exclamations like "*Woho!*" on the last frame of the cutscene. We also observed that some got an altered sense of time, as when we announced that the play session was over, some would, for example, say "*Oh no already?*".

28.3 Interviews

During the interviews, participants said the game was engaging. For example, a test subject mentioned that "*I got so engaged that I ran more than I actually had to*" or "*It was surprisingly engaging because the game was so beginner-friendly. I do not usually play video games, but this was engaging*". A few people noted that the game was engaging initially, but it faded away after a while. The enthusiasm vanished due to getting tired and the game's lack of variation. Another player said they were engaged but that it might dwindle if they had to play the game weekly.

Many stated that they got excited by playing together with another person. Some got engaged by the game's competition aspects, for example, running in front of the other and obtaining coins and points. On the other hand, others said they got engaged by the game's cooperation. They got excited when the other person managed a jump because they shared their lives. Some participants said they got exhilarated by the balance between collaboration and competitiveness, as it created a friendly competition. As stated by numerous participants, the game would not be as engaging if

they were to play alone.

During the interviews, there were mentions of the game's immersion. People often said that they forgot they were working out, for example, saying that "*I got immersed into the game. I kind of forgot I was exercising*". Six groups also mentioned that time went fast or they lost track of time. One person noted about their focus that "*I liked that there was not too much to keep track of, it was intuitive and not too complex. This made it easier to focus on the game itself and have fun*".

The levels and controls were engaging. People mentioned that trying not to die and being close to death engaged them. Completing levels was also exciting, especially when they had previously failed it. The controls themselves provided engagement, as multiple participants pointed out that body movement and getting a higher pulse exhilarated them. One person noted that "*The controls were good enough to not be a hindrance for engagement*".

A few players were engaged by collectibles, as it was exciting to unlock new elements and buy characters. The music was also dominant for some, saying that "*The music was good and quick. I felt fast when I ran in the same tempo as the music*". A couple also mentioned that the story helped with their engagement.

28.4 Summary

This chapter provided the results related to players' engagement. The questionnaire got very positive results, where the lowest statement concerned participants' emotional involvement. The analysis shows that the *Vigorous* and *Female* sub-groups scored their engagement significantly higher than their counter groups. We observed excitement while playing levels and when completing a level. Interviews emphasize the importance of multiplayer and variation.

Chapter 29

Gameplay and Challenges Results

This chapter presents the results related to gameplay, game design, and challenges. The results presented are captured from the questionnaire, observations, interviews, and game-generated data.

29.1 Questionnaire

Figure 29.1 displays the responses to the statements on gameplay and challenges from the questionnaire (see Table 23.5). Most of the responses are mainly agree or strongly agree, with some neutral and disagree. One person strongly disagreed with statement S45: "*The game was good at tracking my moments*". All test subjects agreed that they liked the game. There was a 6.4% disagreement on how intuitive the menus were and the challenge levels' degree of variety (S41 and S44). In S46, almost 60% strongly agree that they liked receiving a score for each level.

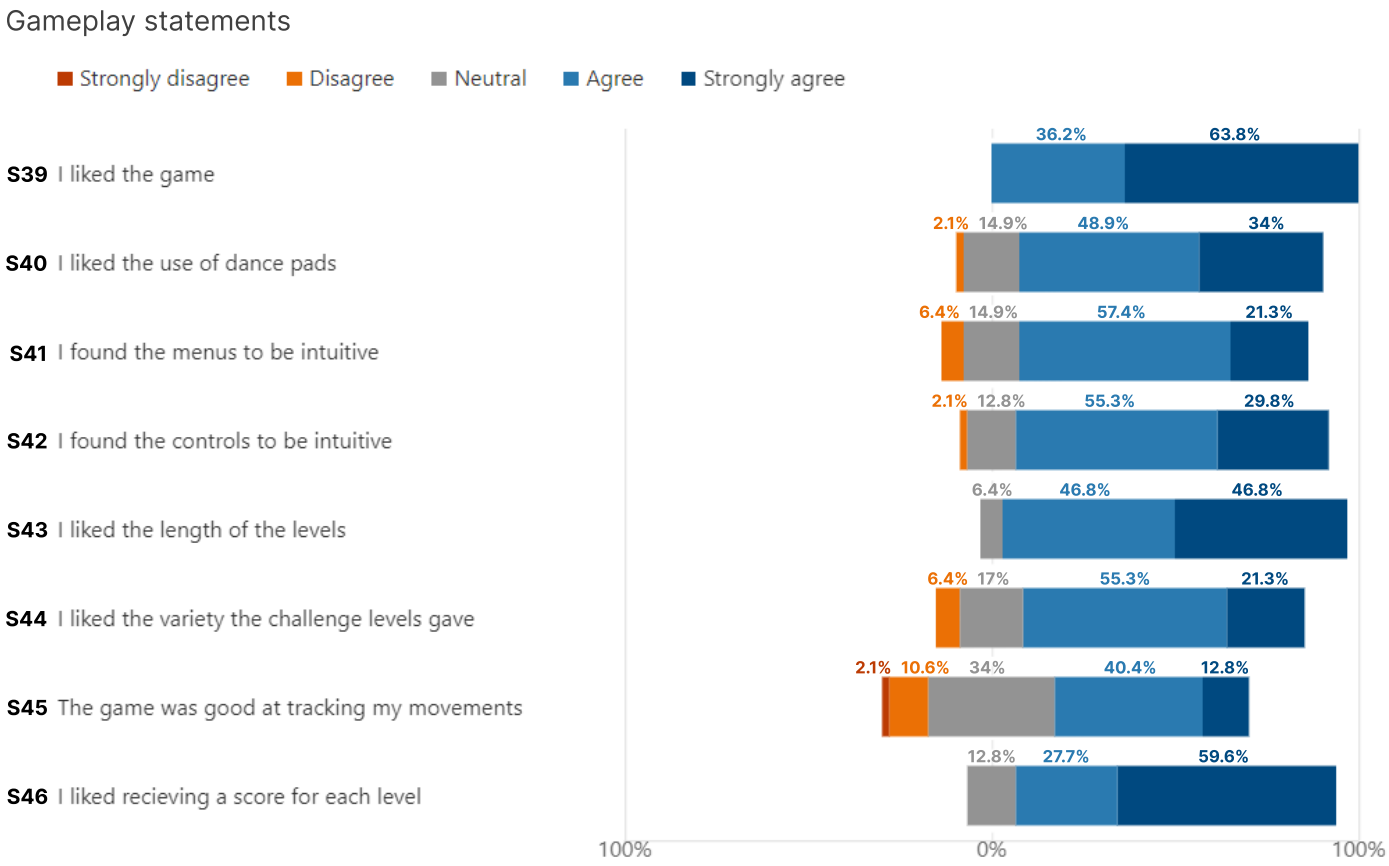


Figure 29.1: Gameplay statements results.

Figure 29.2 shows the result of the question "*How satisfied are you with the menus in the game?*", where the participants answered on a scale from 1 to 10. The result is positive, with an average of 7.94, a median of 8, and a standard deviation (SD) of 1.33. Figure 29.3 shows a similar result for the question "*How intuitive and enjoyable were the level controls?*", with an average of 8.15, a median of 8, and an SD of 1.40.

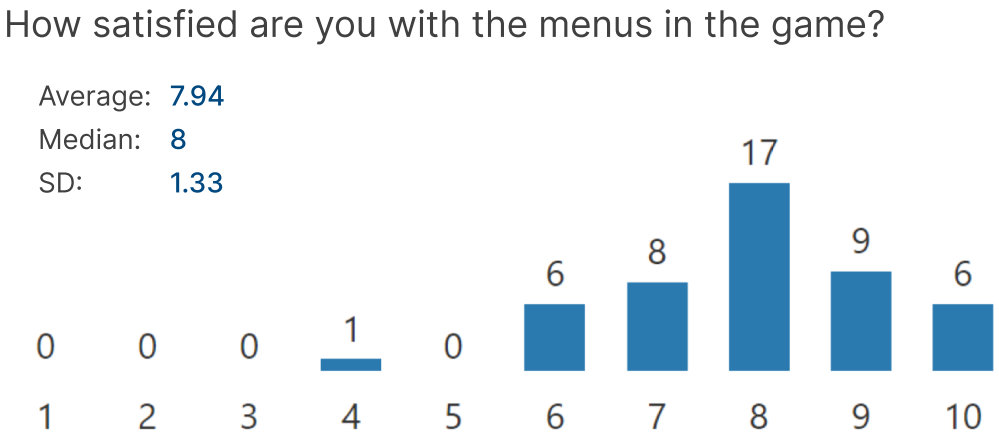


Figure 29.2: Player satisfaction with the menus.

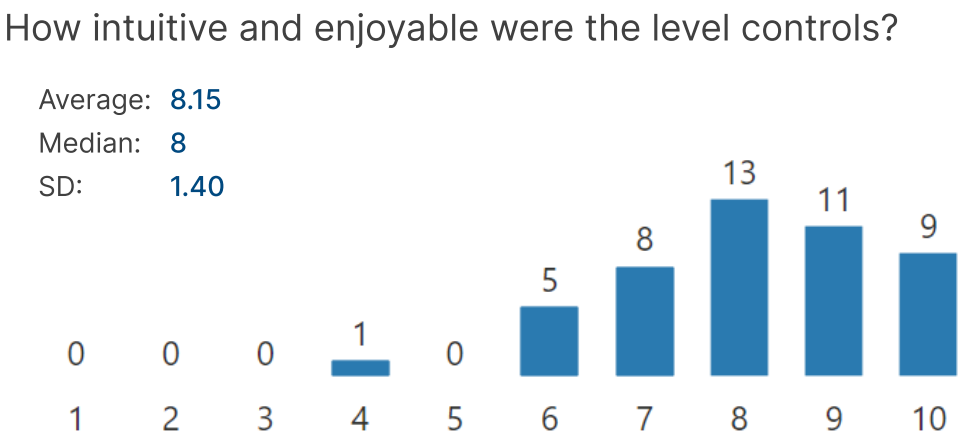


Figure 29.3: Player enjoyment with the level controls.

Table 29.1 shows the results of the statistical analysis for statements on gameplay for various groups with low p-values (see Appendix Section D.5 for complete analysis). The only difference for groups found was that *Vigorous* to a larger degree said they liked the game compared to the *Not Vigorous* group (p=0.0193).

Table 29.1: Results of gameplay activity statement analysis using the Mann-Whitney U test with $p < 0.10$.

ID	Statement	Group	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	P
S39	I liked the game	Vigorous Not Vigorous	0% 0%	0% 0%	0% 0%	29% 70%	71% 30%	**0.0193**

Figure 29.4 shows the results of the participants' experienced technical and gameplay issues. Only five reported no problems, while the rest had at least one. Almost everyone found it challenging to stand correctly on the dance pad and felt that the game did not register their steps or jumps. 19 of the 47 participants (40%) had trouble with both players pressing a button simultaneously when navigating, but only a few pressed a button unintentionally. The one person that responded with "Other" in the questionnaire wrote "*Inconsistent jumping when close to edges*".

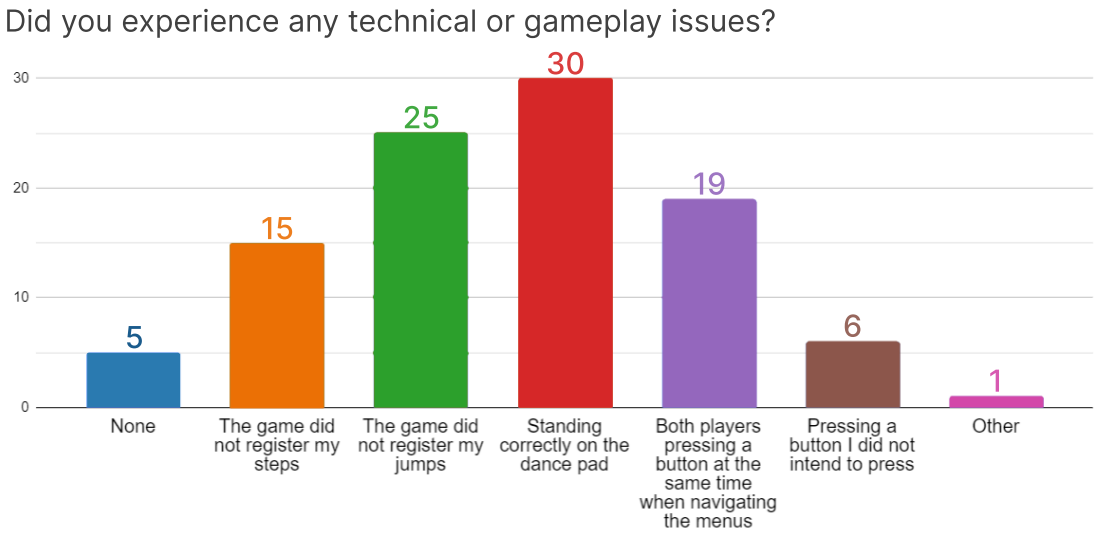
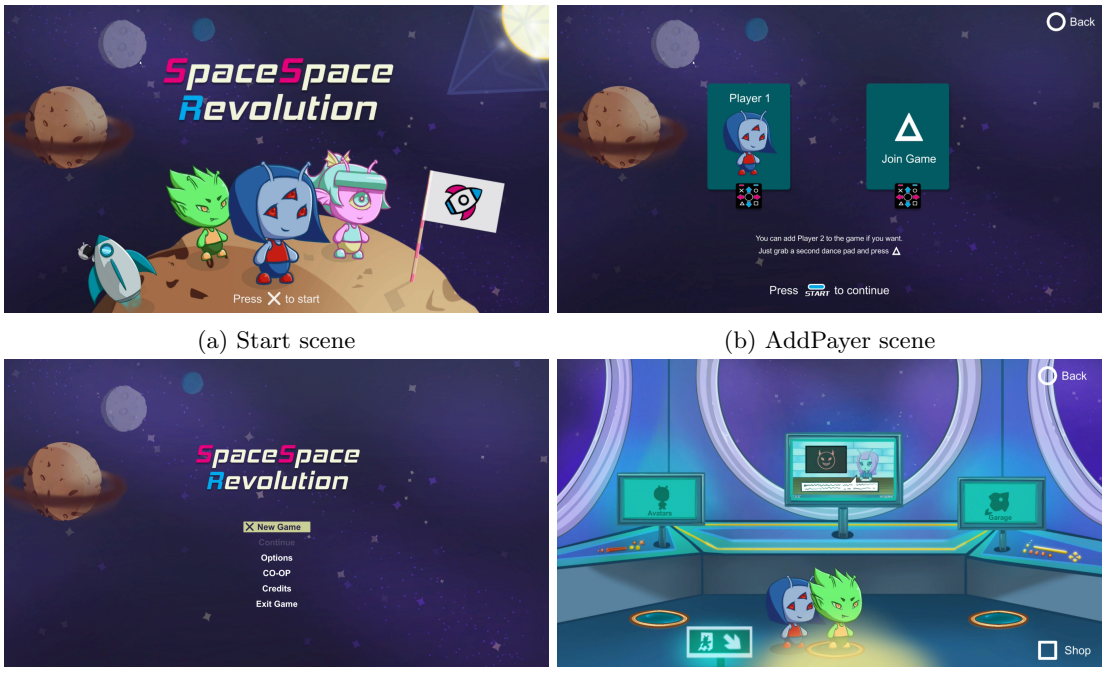


Figure 29.4: Experienced technical or gameplay issues.

29.2 Observations



(a) Start scene

(b) AddPayer scene

(c) Main menu scene

(d) Spaceship scene

Figure 29.5: Relevant screenshots from SSR.

The game starts in the `Start` scene (Figure 29.5a), where one player presses X to start and join the game. After pressing X, the players are navigated to the `Add Player` scene (Figure 29.5b), where the second player can choose to join and then press the start button to continue to the `Main menu` (Figure 29.5c). We observed many areas of improvement regarding the gameplay and game design. Some players struggled to understand how to start the game with two players. Seven players wanted the possibility to change their avatar in the `Add Player` scene, and several seemed surprised that it was not possible. Afterward, the player is navigated to the main menu, where

some of the options are *New Game*, *Continue*, and *CO-OP*. Some players were confused about how to start a new game and thought that they had to press *CO-OP* to start the game with two players. After doing so and realizing that it only allows you to add or remove players, they went back to the main menu and correctly pressed *New Game*.

There were some challenges with navigating the menus correctly. In the game, *X* is always *Confirm/Select* and *Circle* is the back button. Even though this is the standard mapping with PlayStation controllers and the dance pads use the PlayStation buttons, several players were confused in the beginning about how to select elements and how to navigate back. In most menus where you can navigate back, it says in the top right corner that you can press *Circle* to go back (see Figure 29.5d). However, we have not implemented it in every possible menu, and the contrast is often too low, which added to the confusion. The shop proved challenging to leave, and one group decided to return to the main menu and then go back into the game to exit the shop. After playing around with the menus, everyone eventually figured it out. There were also some issues with both players trying to navigate the menus simultaneously, causing unintended navigation and surprise. One player said that he would have expected that only one of the players should be able to navigate.

If you want to buy an avatar or spaceship, you have to open the shop and buy the desired item. Afterward, if you would like to equip it, you must navigate to the Spaceship (see Figure 29.5d) and select it. This flow created confusion, and several bought new items and started a new level without equipping what they purchased. Most people understood it immediately, and everyone figured it out at some point during their play session. The spaceships are only aesthetic and are not very visible in the game. Some expressed hope for it to be used in the levels, and others were confused about its purpose.

The jumping mechanic is the most challenging aspect we discovered during the observations. As previously described in Section 14.2, you jump by standing on both side arrows at the same time and then jump straight up and land back on them. You jump when you release the side arrows on your way up, and your jump duration determines the avatar's jump height. The tutorial describes the controls, but we observed that it does not explain them well enough for most players. Several jump into the middle of the dance pad, which ruins their run flow. Others believed that the avatar jumped when they landed on the dance pad, causing their avatar to take short jumps, making the levels more difficult. Almost everyone figured it out after playing less than 10 minutes, but some struggled with it the entire session. There is also a short delay from you jumping to the avatar is jumping in-game. This delay force the player to time their jumps to get over obstacles and holes. In the beginning, most struggled with the jump timing and jumping high enough, but they generally improved rapidly.

As described in Section 14.2, the player needs to repeatedly step back and forth on the side arrows to make the avatar run, and the player's step frequency determines its speed. When the tutorial shows the running controls, it generally causes some confusion, but almost everyone figured it out by the tutorial's end. Some stepped back into the dance pad's center for each step instead of running on the side arrows, which makes it much more cumbersome to run. They figured out what was wrong, and some of them also got help from the other player.

The use of dance pads proved to be a challenge for the players. Many of them commented that they had never tried it before or that it was around 15 years since they last used one. Standing on a dance pad button is equivalent to holding down a key on your keyboard. After finishing a level, some players stood on the side arrows without realizing it and tried to navigate the menus while pressing another button. They quickly understood what they were doing wrong, but it kept happening for several of them even though they were aware of it. One player said that "*I need to learn to stand in the middle*". It is also a common problem to drift on the pad when playing a level. The players generally walk slightly backward for each step they take, causing them to eventually not hit the side arrows when trying to run or jump. Many realized it and expressed frustration about going backward. The others got annoyed at the game for not registering their jumps or steps correctly because they believed they stood on the side arrows. Those who were more accustomed to dance pads did not drift to the same extent.

There was a significant variation in the different players' difficulties. The ones that understood

the running and jumping mechanics early on did well, and it was maybe a bit too easy for some of them. They finished many of the levels on the first try. The ones who struggled with figuring out the mechanics also did it with the gameplay, especially in the beginning, and failed many times on the same level. One said that "*This is really difficult!*", and another asked: "*Are we this bad?*". The majority was in-between, struggling at the start but quickly progressed throughout the game. The third level on the first planet (P1L3) proved difficult for many of them, and they were surprised about the steep learning curve. Several commented that the following ones were more manageable and suggested that we should change their order. The first challenge level was particularly challenging, and only one group completed it. Most players that tried it gave it a few tries before realizing that it was a waste of time to continue trying.

We observed some challenges with the level gameplay, but it mostly went well. The progress bar, showing how much the players have left, was understood by everyone. It caused exclamations such as "*Look how close we were!*" and "*Wow! We can do this!*". However, it is only visible when you die or when you open the menu, and several said it would be nice if it were always visible. The flag at the level end was understandable for everyone, but some stopped right before it thinking they had reached it. Many also tried to jump high into the flag because they believed it would give them more points, which it does not. Most liked the coins and stars, especially since the coins often indicate the better route. But, there was some confusion about the stars' purpose, which only is to be a collectible and give you points. There was also an issue that the respawn mechanic sometimes respawns the player on top of a hole, making the player lose another life.

The game supports both competition and cooperation between the two players. Several groups were very competitive, while the majority focused on teamwork. You can compete by trying to get the highest score and best statistics. Some of the quotes from the competitive players are: "*I am gonna get there first!*", "*Ha ha, I got the star!*", and "*Yes, I had more steps than you!*". Several said they were motivated to go faster and be better than their opponent. The players cooperated in many different ways. They encourage each other, notify each other about upcoming challenges in the track, discuss strategy to collect every collectible, and tries to run at the same pace. Some of their quotes are: "*Remember that there is a high jump soon.*", "*No you are too fast!*" "*Ah sorry!*", and "*Should we try to separate next time the track is dividing?*". There was some confusion about whether or not the game was competitive or cooperative. Initially, many think it is only competitive, but they cooperate more when they understand they share lives. A few got annoyed that the camera followed the slowest player, and one exclaimed: "*Why can I not run away from you?*".

29.3 Interviews

The majority were impressed by the game and its quality and uniqueness. Several players said they had never tried anything similar before and that it was "*unique and impressive*". One group said that they "*Feel that the game's quality equated to indie games they played in their childhood and not something two students have pieced together*". One participant said he probably would not play this game further on.

Several participants said they were confused about if the game was supposed to be cooperative or competitive. Several groups concluded that it was more teamwork than rivalry. Despite the confusion, they generally liked choosing how to play it themselves. One group said that it was "*Very fun when it was either a lot of cooperation or competition.*" and others said they preferred to work together. Some suggested letting the camera follow the fastest player to facilitate more competition.

Many participants said it was hard to keep their orientation on the dance pad and not slowly drift backward. The dance pad does not give any tangible feedback, forcing you to look downward to re-align yourself. Some stated that the drifting was mainly because of inexperience with dance pads and that you would quickly get used to it. Several said that their game experience would be better if it had a higher quality and were usable with shoes. One player said that "*I often had to look down because I am unaccustomed to dance pads*".

There were many opinions about the jumping mechanic, both positive and negative. According to some, the tutorial did not explain the mechanic well enough. It was hard to read and understand its information boxes because they were too focused on walking correctly, which caused many to jump incorrectly. Several said it took time to understand the jump's timing and jumping high enough, and some never figured it out during the play session. It was also a problem that people did not feel like every jump got registered. This issue was mainly caused by drifting off the side arrows. One player said: "*I felt it registered my jumps except when I missed the buttons*" and that it is annoying when it happens. Several said they enjoyed the mechanic and its implementation. One said that it took some time to get used to, but when he understood how it worked, it was very intuitive, and another one said that he "*liked the jump's timing and that you can jump higher*".

The participants found the menus and navigation intuitive, but there were some areas for improvement. It could be more clear that *X* was Confirm, and several said that "*it took some time before understanding that X was Confirm*". The *Circle* button navigates to the previous screen, but it is not apparent enough. Several commented that the text showing that you could press it to navigate back often had low contrast and was missing in some places. Especially leaving the shop was troublesome, and several participants said it was unintuitive and had a poor UI. On some screens, there is also a back button you can select and press *X* to navigate back. People said they did not realize that it was a button and got confused because it appeared that they could use both *X* and *Circle* to navigate back in some circumstances. Some also said it was challenging that both players could navigate the menus simultaneously but that they preferred it this way.

Many liked the level design and the game mechanics. Several players commented that the level's complexity was perfect and not too overwhelming. Others asked for more variation because they found them too repetitive. One person said that "*I like that it is harder to run uphill than downhill.*" and another said that "*I like that we need to cooperate to stay together. I also like that you can die by running too fast and that it is harder to know what is coming in the track if I am in the front part of the screen".* Several said it was frustrating that you sometimes respawn into a hole, and it was too easy to run too fast. A bug causes the players to get stuck on an edge sometimes. One of the few that encountered this bug said: "*It feels unfair when you get stuck on an edge. It would improve enjoyment if you resolved it*". Some commented that the final level on each planet was disappointing. They expected it to be a boss fight or something else to stand out from the other ones. The difficulty was adequate, and the participants said that the game had a good progression.

Some participants commented that the story could have played a more substantial part in the game. The only information about the game setting and your mission against the spuds is the cutscene at the beginning of a new game save. They want story elements between planets to show the spuds' reaction to you reconquering it and what happens next. One said it would also be nice if the spuds played a role in the levels, e.g., chasing you or destroying parts of the path in the final level of each planet.

29.4 Game-Generated Data

Table 29.2 shows the results from the game-generated data. It shows the aggregated data for each level's duration, success rate, and attempts. The success rate is the number of completed attempts divided by the total. The results show that most of the levels have a good difficulty, requiring the players to take several attempts to complete them without being unfeasible. The exceptions are *P1L3* and *P1C1*. P1L3, the third level on the first planet, has a significantly higher number of attempts and a lower success rate than the neighbor levels. It shows that it was too difficult for the players this early in the game. P1C1, the first challenge level, is intended to be challenging, but a success rate of 1% and 369 attempts shows it was too difficult. Note that each player's attempt is tracked, which means that if two players are playing together, the game counts each level they start as two attempts. We also sometimes played during the interviews to explain or discuss parts of the game, which caused the results to be slightly off.

Table 29.2: Results from the game-generated data.

Level	Duration (min)	Success Rate	Attempts
P1L1	24.2	87%	61
P1L2	47.8	60%	81
P1L3	115.2	14%	208
P1L4	74.0	42%	97
P1L5	25.2	71%	42
P1L6	58.3	39%	95
P1L7	30.2	74%	61
P1L8	96.0	34%	127
P1C1	15.5	1%	369
P1C2	23.4	44%	54
P2L1	63.5	24%	153
P2L2	25.8	89%	35
P2L3	23.3	29%	51
P2L4	17.1	35%	31
P2L5	13.5	12%	43
P2L6	5.0	27%	11
P2L7	12.2	17%	18
P2C1	4.2	62%	21
P2C2	2.2	60%	5
P2C3	3.7	36%	14

29.5 Summary

This chapter has presented the results related to gameplay, game design, and challenges, which included quantitative data from the questionnaire and qualitative data from the observations and interviews. Lastly, the chapter presented the results from the game-generated data. The results show that the participants liked the gameplay and concept, but there are many areas for improvement. Especially the use of dance pads and the jumping mechanic proved challenging to master.

Part VII

Discussion

Part VII is the discussion of the results. It starts by discussing the game's physical aspect before reviewing the enjoyment, engagement, motivation, and game design results. Lastly, it discusses factors that may affect the validity and reliability of the data generated in the experiment.

Chapter 30

Discussion of the Physical Activity

RQ3: *What level of physical exertion does the exergame give its players?*

This chapter will discuss the results of the physical activity data from the experiment. It answers research question 3 (RQ3) by examining the physical outcome of playing SSR and its ability to help players reach or go beyond WHO's recommendations for general physical activity.

WHO recommends 150 minutes minimum of moderate-intensity aerobic physical activity or 75 minutes of vigorous aerobic activity per week. Additionally, people should do muscle-strengthening activities of moderate or greater intensity at least two times a week [213]. The experiment yielded physical exertion data from five different methods: heart rates from sensors, observations, questionnaires, interviews, and game-generated data. In the questionnaire, almost everyone answered that they got a good exercise from playing the game, and over 80% agreed that it could replace a workout session. The statistical analysis shows that the males felt they pushed themselves physically more than the females, but the heart rate data indicate that females had a higher average heart rate. The heart rate data also shows that the median stabilizes around 140 - 160 BPM after the players have warmed up. Almost 80% of the players reached a heart rate over 80% of their estimated BPM. Polar describes this intensity as " *You'll be breathing hard and working aerobically. If you train at this intensity, you'll improve your speed endurance. Your body will get better at using carbohydrates for energy and you'll be able to withstand higher levels of lactic acid in your blood for longer*" [153]. Ideally, we would have measured the player's oxygen consumption since it is a more precise measure of exercise intensity than heart rate, but using heart rate is sufficient to indicate the intensity level [57]. Thus, a session with SSR will provide a moderate or high level of physical exertion. The data from the five different methods indicate that, for the participants, the game provided enough exercise to count toward WHO's recommendations.

The questionnaire results show that the game facilitates a good exercise and motivates the players to do it. These results were also supported by the heart rate data, interviews, and observations. However, each group's play session only lasted 25 minutes, which is not enough time to know the game's long-term effects. For the game to be effective, it needs to be played regularly. Measuring the long-term effects is necessary if we want to know that the game will make the players regularly reach WHO's minimum recommended aerobic activity level and thus reduce the risks of the health problems caused by inactivity. A study of exergames' long-term effects gave inactive adults free access to a high-intensity exergaming platform (Playpulse). The participants decided when and how often they wanted to use it. The results showed that, despite the exergaming platform being high-intensive and enjoyable, the participants showed no significant health benefits over the 6-month intervention due to low exergaming frequency [16]. The study's results indicate that even with its high enjoyment and physical intensity, SSR may not have significant long-term effects on its users.

The Dual Flow model is a framework that builds upon the GameFlow and Malone's models [168]. According to it, the two main success factors for exergames are *attractiveness* and *effectiveness*.

The most important part of attractiveness is the correct balance between challenge and skill. 81% of the participants agreed that the game increased the challenge level according to their skill improvement through the play session. Additionally, 89% found the challenge level to match their skill. These results correspond to the interviews and observations, where a few commented that the first planet's third level and the first challenge level were too difficult. For effectiveness, the balance between intensity and fitness is the key component. 85% of the players felt that the game's exercise matched their fitness level, and they rated its physical intensity 6.79/10. During the interviews, many said that the game gave a good exercise and that they could use it as a regular exercise. Overall, the results show that SSR scores well in attractiveness and effectiveness, indicating that SSR can be a successful exergame.

Several participants compared SSR to other exergames, stating that it has a similar exercise level as *Ring Fit Adventure* and *Just Dance*. A study on 126 undergraduate students showed that *Just Dance* provides moderate levels of aerobic exercise by monitoring the participants' heart rates, blood pressures, and movements [107]. The study found *Just Dance* to have an average BPM of 109.2 (SD = 45.0), while our game's participants had an average of around 140 - 160 BPM throughout the game. *Ring Fit Adventure* has proved to be an effective exergame with an average energy expenditure higher than *Dance Dance Revolution* [29]. Studies of *Dance Dance Revolution* show that it can be a replacement for exercise and reaching the recommended amount of physical activity [65][212][62]. For instance, Whitehead et al. [212] surveyed six quantitative *Dance Dance Revolution* studies and concluded that it gives an average energy expenditure of 8.5 kcal/min, and the study provides a general estimate of expenditure according to heart rate. According to the paper, an exergame with a heart rate between 140 and 160 BPM has an expenditure of 6 - 8 kcal/min. Their results imply that SSR is slightly less effective than *Dance Dance Revolution* because it has an energy expenditure of around 7 kcal/min. The comparisons and results indicate that SSR provides a moderate to high energy expenditure and can be used to reach WHO's recommendations. However, the game lacks movement variation compared to other exergames, which several participants expressed in the interviews. They said it would be nice to use more body parts, including one person who said that a crossover with *Beat Saber* would be great. Our results indicate that SSR's physical intensity is comparable to the mentioned exergames, but we should note that they have a larger variation in their exercise activities. For instance, *Ring Fit Adventure* provides aerobic, strength, balance, and flexibility activities [29]. Thus, even though SSR provides an adequate physical exertion level, it should ideally incorporate more variation.

SSR's physical activity consists of spot running with the legs spread apart. You run in the same place, meaning you do not use any muscles to run forward as with regular running. A study examining the effects of spot running found that it had a significant effect on cardiovascular endurance for college boys [102]. However, it does not mention any potential side effects. Running in place does not use the muscles the same way as in classic running and may cause heightened strain on muscles or joints. Several of our participants complained about leg strain due to running on the spot and with their legs far apart. It is difficult to find any studies investigating the benefits and disadvantages of spot running relevant to SSR. Further work on the game should include a study to examine its positive and negative effects on joints and muscles.

Space Space Revolution provides enough exertion for the participants to count towards the recommended physical aerobic activity recommended by WHO. The majority's intensity is also high enough to count toward 75 minutes of vigorous aerobic activity. The results show that almost everyone felt they got a good exercise, and nearly 80% reached a heart rate over 80% of their estimated BPM. Several also compared the game to other exergames that have proved to be a replacement for regular exercise. The ability to provide long-term effects is crucial for exergames to contribute to public health, and our experiment is not sufficient to conclude about SSR's long-term effects. More research is needed to study the game over time and its positive and negative impacts on the body. Ideally, the game should incorporate more exercise variations to activate other body parts. The majority agreed that the game increased the challenge level according to their skill improvement and felt that the game's exercise matched their fitness level, which shows that SSR scores well in Dual Flow's attractiveness and effectiveness. In conclusion, SSR provides a moderate or high intensity, but more work is needed to study its long-term effects.

Chapter 31

Discussion of the Enjoyment, Motivation, and Engagement

RQ4: *How does the exergame affect the player?*

This chapter discusses the user perception of the game based on the experiment's results on enjoyment, motivation, and engagement. It answers research question 4 (RQ4), where each section addresses a sub-question.

31.1 Enjoyment

RQ4.1: *How is the player's enjoyment affected by the exergame?*

The questionnaire got very positive answers regarding the game's enjoyment, which overlaps with the observations and interviews. The results show that the participants enjoyed the game, as everyone agreed on the statement "*I found the game enjoyable*". One of the most enjoyable aspects was the artistic design, often mentioned in observations and interviews, and 94% and 95% agreed that they enjoyed the game's graphics and audio, respectively. The questionnaire analysis also shows that all the female subjects enjoyed the game's characters, compared to 83% for males (17% neutral). The interviews show the importance of multiplayer and GameFlow's *social interaction* element [181] for enjoyment. Participants mentioned that multiplayer increased their enjoyment immensely, and one stated that they would not have bothered playing the game alone.

We used the game enjoyment model GameFlow [181] as a basis when designing the game to enable a flow state for the players. We added at least one question per GameFlow element to the questionnaire to evaluate our success in using the model and indicate the game's enjoyment. Table 31.1 displays the calculated GameFlow score, where the overall score was 4.14 out of 5. This is regarded as a high score since, for example, *Warcraft 3* has 4.8 [181], *James Cameron's Avatar iOS* has 3.8 [182], and *Rayman 2: The Great Escape iOS* has 2.8 [182]. *Space Space Revolution* also scored higher than an unnamed platformer exergame, which got a mean flow score of 3.83 [95]. A high score may indicate that players entered a flow state while playing. However, the elements do not have all criteria present, which means that the scores are not completely accurate, but it is an indicator. Score computation mapped "Strongly agree" as 5 to "Strongly disagree" as 1. This calculation shows that the top three most successful elements were *concentration*, *player skills*, and *clear goals*. These all had only one statement to be represented, making them more inaccurate. Even so, people mentioned in interviews that the game was not too complex, making them able to focus and have fun with the game. Players having clear goals were also present in both observations and interviews. The *player skills* element could probably be better designed, as the player skill's increase could have been more accurate. The tutorial was mentioned as nice but

had problems regarding the text and should have explained the jumping mechanic better.

According to the GameFlow criteria evaluation, the elements *control*, *feedback*, and *social interaction* had the most potential for improvement. *Control* got the lowest score with 3.91 points (see Table 31.1). It only had one statement as representation, but observations and interviews also show that level controls were an issue. People felt less in control of their character when having difficulty understanding or using the level controls correctly. Players also got frustrated and discouraged when failing a level multiple times because of control issues. Adding more *in-game breaks* might have lessened this frustration, as it could have provided the *spaced practice effect* while maintaining a flow state [150]. Getting a spaced practice effect could have made players more comfortable with the controls and heightened their skill level. There was also a lack of *feedback*, as the dance pads are simple and do not provide much physical feedback. Players got annoyed by not receiving any feedback about their dance pad placement. Lastly, *social interaction* got a low score on the GameFlow criteria evaluation. This low score is because of the statement "*The game supported competition between players*" since many players stated that they only viewed the game as cooperative. One can note that the *Not Gamer* sub-group found the game to be more competitive compared to *Gamers*. Making the controls easier to understand, adding more in-game breaks, providing more feedback about dance pad placement, and including more competitive aspects might have increased players' enjoyment and added higher chances of flow state. However, adding dance pad feedback requires a change in hardware, which is expensive and hard to obtain.

Table 31.1: Evaluation of *Space Space Revolution* according to GameFlow criteria.

Element	**Statements**	**Score**
Concentration	I was not overwhelmed with tasks	4.51
Challenge	I found the challenge level to match my skill The game increased the challenge level according to my skill improvement throughout the play session	4.06
Player skills	The game provided information on how to play	4.28
Control	I felt in control of my character	3.91
Clear goals	The game gave me clear goals	4.23
Feedback	The game provided feedback for my actions I was given feedback on my progress in the game	3.98
Immersion	I lost track of time while playing I became less aware of my surroundings while playing I became less self-aware while playing I was emotionally involved in the game	4.21
Social Interaction	The game supported competition between players The game supported cooperation between players	3.94
	Overall	**4.14**

We also used Malone's *challenge, fantasy, and curiosity* model [112] to make the game rewarding to play. *Challenge* in this model focuses on goals, uncertainty, and self-esteem. These elements seem to have worked as multiple sources mentioned clear goals and the uncertain collectibles. However, the time bonus, stars, and golden hearts were maybe too ambiguous as many players were confused about them. Our measure of keeping coins and getting a prompt to restart seemed to help with players' self-esteem. However, the difficulty level was too high for some, and observations show that after losing numerous times, they felt discouraged and maybe lost self-esteem. The *fantasy* was enjoyable for over half of the participants, as 62% enjoyed the story and setting (36% neutral). One can keep in mind that the analysis unveils that the *Active* sub-group enjoyed the story and setting significantly more than the *Less Active*. It is more important to make the *Less Active* group enjoy the game to heighten the general public's physical health. Creating a more compelling and unique fantasy might have made the game more rewarding and maybe made the *Less Active* sub-group enjoy the game more. The results indicate that the game managed to create stimulating *sensory curiosity* since the sound effects and graphics got high praise.

The Dual Flow model states that the two main success factors of exergames are *attractiveness* and *effectiveness* [168], and the *Vigorous* sub-group demonstrated the importance of *effectiveness* for

enjoyment. The analysis outcome shows that the *Vigorous* sub-group had higher enjoyment than the *Not Vigorous* group on multiple enjoyment statements. This difference may be due to the effectiveness of the game. The *Vigorous* group members reached a maximum heart rate of over 80% of their calculated BPM. This enjoyment difference might indicate that the game had the correct intensity according to participants' fitness, and they attained an effectiveness flow state. Reaching this flow state is a success factor for exergames. In other words, the reason for the *Vigorous* sub-group to have enjoyed the game significantly more than the *Not Vigorous* group can be because they managed to get into an effectiveness flow state.

Space Space Revolution had an adequate challenge level, but it could have been more difficult. *Challenge* is crucial for enjoyment and is present in all of the enjoyment models mentioned [181][112][168]. The dynamic camera movement is a significant factor in the game's challenge level and creates an adaptive challenge- and intensity level, which is essential for exergames [168]. In the game, the camera moves according to the player furthest behind. However, making the camera follow the player at the front may provide a better-suited challenge level. This movement change may also add more competition to the game. Another crucial improvable *challenge* element is the level design difficulty curve. Results show that players found the learning curve too steep and later levels too easy. This sudden difficulty spike may have lowered subjects' enjoyment since matching *challenge* and *skill* is essential for reaching a flow state. In addition, the level designs contain purely *static environmental obstacles*, such as platforms and pits, which are not as enjoyable as *intelligent obstacles* [119]. Intelligent obstacles change their actions according to player actions, for example, homing weapons. Adding intelligent obstacles into the level designs may increase both the enjoyment and the difficulty.

To sum up, participants found *Space Space Revolution* enjoyable, even though it has improvement potential. The game follows the theories of designing an enjoyable game, where elements such as *concentration* and *clear goals* amused players. However, players were frustrated about control issues, lack of dance pad feedback, and were confused about the social interaction. Making the story more interesting might make the game more enjoyable for players that are within the *Less Active* sub-group. Having a well-adjusted balance between fitness and intensity may drive more people to play *Vigorously*, which was more enjoyable. This adjustment can be implemented by, for example, increasing the challenge level by making the camera follow the player at the front, adding intelligent obstacles, and testing levels more to prevent steep difficulty curves. Even if the game had some improvement potential, players got a remarkably large amount of enjoyment from playing, as shown in the results and the GameFlow score.

31.2 Motivation

RQ4.2: *How is the player's motivation to continue playing affected by the exergame?*

The motivation to continue playing was overall high, and about three-quarters of the participants were more motivated to exercise with the game instead of normal aerobic exercise. However, the test subjects were motivated by different aspects of the game. The most important motivator was playing together with another person, as seen from the questionnaire and the interviews. The importance of multiplayer is also revealed in previous studies, showing that multiplayer is associated with greater playing time [89], and has been indicated to increase children's motivation to continue playing active games [149]. The *self-determination theory* (SDT) illustrates general human motivation through *competence, autonomy*, and *relatedness* [165]. This theory shows the importance of multiplayer because *relatedness* is about generating motivation by connecting with other people. It is notable that one paper found the platformer genre to have one of the lowest play hours and that non-portable platforms also had less playtime than handhelds [90]. The same paper also showed an extremely high increase in hours of play for multiplayer games compared to single-player. Having *Space Space Revolution* provide a multiplayer mode was probably crucial for its motivation on players. From the questionnaire analysis, one can see that all participants in the *Not Gamer* sub-group were strongly motivated to perform better by playing multiplayer. Another motivator was the ability to customize the avatars and the spaceship. This customization

provides intrinsic motivation related to *autonomy* from the SDT, which includes choice, control, and freedom [165]. Game customization helps satisfy autonomy, in turn increasing players' willingness to continue playing [187]. The customization also enhances the *fantasy* element of Malone's model [112], making the game's story and setting more personalized and compelling. The *Gamer* subgroup was more motivated than *Not Gamers* by having customization options. In summary, both multiplayer and customization were essential for motivation. The results show that a player's gaming habits may have a sizeable influence on what motivates them to continue playing the game, as *Not Gamers* were more motivated by multiplayer and *Gamers* were more motivated by customization.

The *fantasy* and *curiosity* elements from Malone's model were significant for the game's motivation. Many commented on being curious about what the other planets were like and new gameplay mechanics. This incomplete knowledge of what the game contains may have made the participants *cognitively curious*, motivating them to continue. One test subject's comment indicates that the game's fantasy might have been more *extrinsic* than intended. The participant stated, "*It would have been nice if the characters had a goal that was not to be physically active. Then it would have been more motivating*". Ideally, the game would have an *intrinsic* fantasy, where both the fantasy and skill are dependent on each other. However, making the game characters' goal to be physically active may have made the fantasy seem more extrinsic.

Goals provided motivation, but the *controls* and the *challenge* were unmotivating. The GameFlow model mentions the importance of *clear goals* with an overriding goal and intermediate ones. The game's goals were crucial as many mentioned they were motivated by the collectibles and desire to collect everything. Participants were also motivated by the goal of progressing through the game and completing every level. These goals provide motivation by satisfying SDT's *competence*, which contains challenge and impact [165]. The collectibles and progress provide the player with a feeling of impact and influence due to the goals providing positive feedback and requiring competence. However, the GameFlow elements of *control* and *challenge* showed potential for improvement. The controls themselves were exaggerated, which supports competence and provides motivation in general, in games, and exercise [105]. On the other hand, control issues were unmotivating, as dying sometimes felt unfair. Another potential issue was the lack of replayability and not having enough levels. A short game may not provide enough new challenges at an appropriate pace to keep the player motivated. By not providing enough challenge and feeling of mastery, the game loses motivation as the SDT's competence remains not fully satisfied. One possibility is to change the camera to follow the player at the front instead of the back, as this may create more overall challenge and provide a higher *Kohler Motivation Effect*. The effect makes the weakest of a group more motivated to perform better when their performance is indispensable to the group [115]. In conclusion, the clear goals were motivational, but the motivation was damaged due to control issues and maybe a lack of levels. The control issues can be difficult to improve, but adding more *replayability* to levels and having more *challenge* would increase motivation to continue playing.

The motivation to continue playing was generally high, but there was potential for improvement, and the long-term motivation is unknown. A crucial aspect of exergames is the ability to have long-term motivation since improving physical health takes a long time and must be maintained. It is noteworthy that many were more motivated to work out with SSR than regular exercise. The results show that the game motivated players with the multiplayer mode and customization options. These results indicate that the game was able to satisfy the self-determination theory's (SDT) autonomy and relatedness elements. However, a player's gaming habits influence to what degree these aspects motivate them. Using Malone's model helped generate motivation through cognitive curiosity, but the fantasy could have been more compelling and provided a goal different from being physically active to seem less extrinsic. The clear goals from GameFlow were realized through collectibles and progression, which motivated players by satisfying SDT's competence element. The control issues and lack of challenge and replayability severely damaged the motivation. These aspects made the SDT's competence element not meet its full potential. In conclusion, improving the controls and the challenge may be crucial for the general motivation to continue playing and the long-term motivation.

31.3 Engagement

RQ4.3: *How is the player's engagement affected by the exergame?*

The engagement results are positive and imply that the GameFlow [181] elements *immersion*, *concentration*, and *challenge* increased players' engagement. The results show that many players got immersed in the game by, for example, mentioning their time alteration. The GameFlow score for immersion is very high and is quite reliable, as the questionnaire included four out of the five immersion criteria. The unincluded criteria related to players' visceral involvement, but players often mention their fondness for the artistic design. Being immersed in the game may be a reason for the positive engagement results, as immersion made players more involved and focused on the game. The realization of GameFlow's concentration may also have helped engagement since some players mentioned that they were able to focus on the game and that it was not too complex. The results indicate that keeping the players' attention can have made the game more engaging. However, the results show that the lack of variation over time damaged players' engagement. GameFlow's challenge element mentions the importance of adding new challenges at an appropriate pace. Including new challenges that add more gameplay variation may help maintain the engagement.

The GameFlow element *social interaction* was also crucial for players' engagement. The observations show that players often made exclamations regarding both themselves and the other player during levels, and finishing a level often made players show excitement by, for example, doing a high five. This immense positive effect that multiplayer had on engagement matches previous research papers. For example, one paper found that multiplayer increased players' engagement and immersion and that competitive, cooperative, and shared risk/reward gameplay increased group cohesion [125]. SSR's multiplayer creates cooperation between players through the interdependence of sharing lives, and such multiplayer is shown to increase social connection and closeness between the players [46]. Another important factor for multiplayer engagement was that the players were co-located. It has been demonstrated that playing games with another person in the the same room increases engagement [113] [86]. Therefore, *Space Space Revolution* might have increased engagement even more by having local multiplayer. In other words, providing multiplayer was essential for high engagement in *Space Space Revolution*. The game's cooperation, competition, interdependence, and co-location increased immersion, social closeness, and engagement.

The questionnaire data analysis shows that the *Vigorous-* and *Female* sub-groups were significantly more immersed than their counter sub-groups. The analysis results indicate that the players who reach a higher percentage of their maximum heart rate are more likely to be immersed in the game. These results can also be because of the Dual Flow effectiveness [168], as maybe the *Vigorous* players found the game's physical intensity and their fitness to be balanced. Making players reach high heart rates makes them more engaged and emotionally involved. One inference with a low p-value showed that *Females* became less aware of their surroundings, which is an essential aspect of immersion and engagement. The reason for *Females* being more immersed can be due to the co-location. A previous study that showed the high increase of engagement by being co-located also found that this effect was most prevalent for girls [86]. Therefore, the *Female* sub-group may have been more engaged because of having local multiplayer.

The questionnaire statement with the most disagreement was about players' emotional involvement in the game. The reason may be the story's low presence since the game only included a short cutscene when starting a new save file. Malone's model includes that fantasy should have emotional aspects to involve the players, and our results show that SSR could have added more emotional aspects to the story. It has been demonstrated that a game's narrative creates fun in serious games [48] [209], makes games more immersive [167], and increases player engagement [47]. However, a study on a two-dimensional platformer learning game found that the narrative did not have any significant effect on players' engagement [61]. The paper suggests that making the narrative more robust may increase player influence. Therefore, having a more well-designed plot with emotional aspects throughout the game might improve SSR's engagement, but it should be designed robustly to have an impact.

The results show that the participants found the controls themselves to be engaging, which may be influenced by the test subjects' age. A previous study researched player engagement in different game genres [157]. The paper found that exergames were the only game where the relationship between engagement and age curved upward instead of downward. It also showed that the peak engagement from exergames was at over age 20. All of the subjects that tested *Space Space Revolution* were over the age of 20, which may indicate that a reason for the positive engagement results was the participants' ages and that the game required physical activity. It is noteworthy that the *platformer* genre's engagement peaked at age ten and then curved downward. This engagement peak difference may indicate that younger players might get engagement from the platformer aspects of the game, while players over 20 may get more engagement from the controls.

In conclusion, *Space Space Revolution* increased players' engagement to a great extent while playing. The high engagement was most likely due to being a local multiplayer game with interdependence. Being co-located may be the reason for the *Female* participants being more immersed. Realizing GameFlow's immersion and concentration elements raised the engagement. Players were also engaged by the controls themselves, which might have been influenced by the test subjects' age. However, a lack of gameplay variation and minimal narrative decreased the players' engagement.

31.4 Summary

In summary, *Space Space Revolution* affected the player very positively. The results indicate that players' overall enjoyment, motivation to continue playing, and engagement were remarkably high. The most crucial aspect of the game was the ability to play *multiplayer*, as this had an immensely positive influence on all three of the evaluated variables. The GameFlow *concentration* impacted both the enjoyment and engagement of the players, and *clear goals* was consequential for enjoyment and motivation. We found that the *Vigorous* sub-group scored higher in both enjoyment and engagement. This result suggests that reaching a high heart rate relative to one's maximum can create a more positive player experience. What type of gaming habits a player had was found to influence which aspects of the game motivated them to continue playing. The narrative of the game could have been more compelling to enhance enjoyment and engagement more, and this might have increased enjoyment for the *Less Active* sub-group. The two most damaging aspects were the *control issues* and the *challenge level*, as those decreased the player experience substantially on all elements researched. There is little knowledge about the long-term motivation of the game, which is a fundamental aspect of exergames that should be tested and improved.

Chapter 32

Discussion of Game Design

RQ5: *How does the game design and gameplay contribute to the player experience?*
RQ6: *What are the challenges of playing the exergame?*

This chapter explores the results of the game design and gameplay from the experiment. It answers research questions 4 (RQ4) and 5 (RQ5) by reviewing which game elements affected the player experience and what challenges the players faced. The discussion also provides insight into different game design changes that can be implemented to improve the player experience.

All participants enjoyed *Space Space Revolution*, and many commented on the uniqueness of the game. Most players were fond of the use of dance pads, and many stated that the game had high quality. These results indicate that the game was generally well-designed and created positive player experiences. Test subjects that played vigorously also significantly liked the game more, which can be a result of *Vigorous* players maybe understanding the controls better and getting more engaged than the *Not-Vigorous*.

Controls and Levels

The level controls in games are crucial, and many participants experienced challenges with them. The questionnaire shows that the most dominant challenge was standing correctly on the dance pad, backed up by observation and interviews as players usually drifted backward on the dance pad during levels. One possible solution for the drift is to provide visual and audial feedback to players when they have moved off buttons, for example, checking if the two buttons below the left and right arrows are pressed during a level. In other words, provide feedback if players press the triangle or square buttons. This game response also realizes GameFlow's *feedback* element of providing players feedback about their status [181] and can contribute to a better player experience. The results also showed that players had trouble understanding and performing jumps. This misunderstanding indicates that the tutorial should explain the controls more clearly. The tutorial consists of text boxes that pop up when relevant, but players can run past them, making them unable to read the text in time. Adding illustrations or animations to the tutorial might help with the level controls' understandability [188]. Another potential solution is to be more strict in the tutorial, making players unable to continue unless they perform the correct input. This solution can, for example, be implemented by having the camera stop if players are stuck at an obstacle. In conclusion, many participants had control issues that negatively impacted their player experience, but providing feedback on the dance pad drifting and creating a clearer tutorial might lessen the problem.

The game lacked variation in gameplay and level design, but the level design length and complexity should remain about the same. The results show that the gameplay and levels were too repetitive, making a more monotonous player experience. A solution for adding more variation in the gameplay is to introduce new mechanics that utilize currently unused buttons, such as decelerating their speed by pressing the down arrow. However, it is essential to test new mechanics thoroughly to ensure fluent and intuitive controls. Level design variation can be added by, for example, including new level components. There are a total of five level component categories: *platforms*, *obstacles*,

movement aids, *collectibles*, and *triggers* [171]. There are currently only *static environmental obstacles*, adding other types such as *automated environmental-*, *intelligent-* or *interactive obstacles* such as enemies or falling objects creates more variation [119]. SSR already provides *movement aids* with the *jump power-up*, but new movement aids should be added at later planets. There are currently no *triggers* in SSR, but this is a well-fitting new addition to the game that creates variation. An example of this is a door that does not open until all players touch it. SSR's levels can also benefit from following the six 2D platformer design patterns: *guidance*, *safe zone*, *foreshadowing*, *layering*, *branching*, and *pace breaking* [96]. *Guidance* is provided by the placement of coins, and there are a few *branching* paths, but the other patterns are not presently implemented. Using these patterns can help create overall better and more varied levels, thus improving the player experience. For example, SSR can include a *boss battle* as the end of each planet to provide *pace breaking* for higher tension and to provide variation. Participants also noted their desire for a boss battle in observations and interviews. Although the level designs should incorporate more variation, according to the results, it is important to maintain the current length and complexity of the levels. Therefore, introducing new level design elements must be done slowly. In summary, variation in gameplay can be added by including new mechanics that utilize unused buttons. Level designs should retain the same length and complexity but slowly add variation by incorporating elements such as other types of obstacles, triggers, and boss fights.

Observations show that the difficulty level was slightly too challenging for some, especially if they had control issues. Finding the game too challenging decreases the player experience, but there are many ways we can make the difficulty more accurate for each player. The most important aspect is to make the tutorial clearer so that more players understand and use the controls correctly. Another addition can be an *easy* or *assist* mode, where players have an increased amount of lives in levels. Further, extra hearts can be placed throughout levels that refill lives. Additionally, players can be given an advantage after failing a level multiple times, for example, an extra life or a movement aid. Adding these elements will not significantly affect players that find the difficulty easy, as they will not lose that many lives or fail levels multiple times. The difficulty can also be changed by adjusting *scroll speed* and *target size* [211]. The results indicate that the *scroll speed* was adequate, as players could influence the speed. Having a dynamic camera speed makes the difficulty more adaptive, which the Dual Flow model emphasizes [168]. However, a few noted their frustration of dying by going too fast, so future work should test changing the camera to follow the player in front instead of the one furthest behind. The level designs should be reviewed according to their pits' difficulties, as the results show that the first challenge level (P1C1) and level three on the first planet (P1L3) were too difficult. A designer can adjust three aspects of jump-based obstacles: jump-start location, player options in-air, and safe landing locations [25]. Having a smaller *target size* makes the obstacle more difficult [211]. Therefore, these aspects should be examined in these two levels to make them easier. Level three (P1L3) should also switch placement with an easier level, such as level seven (P1L7) or level five (P1L5) since these had high success rates. In summary, the difficulty has the potential to match players' skills better. Improvements include having a clearer tutorial, adding additional lives for struggling players, trying to change which player the camera follows, rearranging the level order, and reviewing pits.

SSR's respawning has room for improvement. Players may currently get unlucky and respawn into a pit and die again, commented on in both observations and interviews. One possible solution is to have the player choose a time to respawn within a time limit. This solution makes it fairer for the player and can add gameplay variation since a new button or combination can be the respawn input.

User Interface

More information and breaks should be provided when failing a level. If a level is failed, then an overlay with a *Restart* and *Quit* button is presented. The number of coins obtained should be displayed since players keep coins from failed runs [119]. The game may benefit from making the screen shown when failing a level provide an in-game break, as that can create a spaced practice effect and a better player experience [150]. The failed level screen can, for example, display some suggestions for taking a break after players fail the same level numerous times. Alternatively, the game can include a specific number of times a level can be consecutively restarted, where players are then moved to the level selector when this counter hits 0.

Players appreciated the progress bar as it helped satisfy GameFlow's *feedback* element. An essential criterion is to provide the player with feedback about their status and progress towards goals [181]. Showing the progress bar when pausing or failing a level helped carry out this feedback criterion. However, the results show that players would have also liked to have the progress bar visible while playing a level. Displaying it throughout levels would enhance status and progress feedback. Therefore, this addition to the level UI should be implemented into the game, but it is essential to make it as minimal as possible not to clutter the screen.

Test subjects had multiple challenges with the game's menus, as it was not always intuitive or consistent. Generally, the menus were good enough, and the questionnaire shows this with a mean score of about 8 out of 10. Players' experiences improved by having the button placements match the button's physical location on the dance pad and the usage of PlayStation norms. However, the *CO-OP* button in the main menu was confusing to the majority, and the button should therefore either be renamed to, for example, "*Add Players*" or removed. Another problem was having both *Back* buttons and being able to go back with the circle (O) button. On some screens, there would be a *Back* button, pressable with the X button. Sometimes being able to navigate back by pressing X and other times O creates an inconsistency. Having inconsistencies in a GUI collides with Nielson's *Ten Usability Heuristics* [134] and negatively impacts users' experience in general systems [155] and in video games [188]. To keep the consistency of buttons on the screen matching the dance pad layout, the *Back* buttons that are pressed with X should be removed. The results also show that many participants bought skins and forgot to equip them. Therefore, SSR should include an overlay after buying a shop item, asking the players if they want to equip it immediately. In summary, the menus should rename or remove the *CO-OP* button from the main menu, remove any *Back* buttons, and include a prompt to equip items bought to remove menu challenges and enhance the player experience.

Social Interaction

The results show that players found the game's *social interaction* confusing, and there were mixed opinions on which social interaction type the game should provide. SSR is currently designed to emphasize cooperation between players due to their shared lives but has some competition with scores. Multiple participants commented on the possibility of having two separate modes where one is cooperative and the other more competitive. This solution might fulfill the players' desired type of social interaction, but it may require much work and hinder level design. A paper researching what effects different types of social interaction in exergames has on its players found that competitive play increased energy expenditure and cooperation enhanced players' motivation to continue playing, self-efficacy, and pro-social behaviors [115]. Cooperative gameplay in exergames also resulted in significant weight loss for obese and overweight adolescents. This paper's results indicate that SSR would benefit most from cooperative gameplay since SSR already provides a high amount of energy expenditure, and motivation to continue is one of its crucial elements for improving the general public's health. The questionnaire results from our experiments show that almost everyone enjoyed receiving a score, but they were not that motivated by scores. Therefore, the game should keep level scores but maybe make it a shared score, making the gameplay more cooperative. But, the game should provide some competition to accommodate every player's social interaction desire [115]. One possibility is to make the challenge levels more competitive, which sets a clear line between the cooperative main levels and competitive challenge levels. However, some participants liked SSR's current social interaction type.

Summary

In conclusion, the game design and gameplay provide an overall good player experience but have a few challenges to resolve. The game was very well received and got good scores on the questionnaire regarding the concept and how intuitive it was. Generally, players found SSR to be unique and high quality. However, many players had issues with the controls. This problem can be decreased with a clearer tutorial and by providing visual and audial feedback when drifting. The level gameplay lacked variation, which we can solve with new mechanics. The level designs were also slightly too difficult and lacked variation for some players. Adding an easy mode, more hearts, and in-game breaks may help struggling players. Levels must also be thoroughly playtested, as the results show that two had low success rates and should be reviewed and replaced. Future development of

the game should remove automatic respawning into pits and increase feedback and consistency of the GUI. Finally, SSR would most benefit from the effects of cooperative exergaming instead of competitive, but the inclusion of competitive aspects is still essential. One solution to this is to make the level scores shared and the challenge levels to be more competitive.

Chapter 33

Reliability and Validity

This chapter discusses factors that may affect the validity and reliability of the data generated in the experiment.

33.1 The Hawthorne Effect

The *Hawthorne effect* is the effect where people will modify their behavior because they know they are being observed [142]. As described in Subsection 4.3.2, our type of observation is overt, meaning that the participants know they are under observation. The Hawthorne effect might therefore influence our results. If this effect happens, we will receive more positive feedback and data than if the experiment was covert. Thus, we keep in mind that they might be affected by the Hawthorne effect. To help reduce this effect, we told the participants to behave as if we were not there. We asked the participants to imagine that one of them had invited the other person over to their house to check out a new game and behave accordingly.

One of the participants took a short water break to catch her breath during the play session but admitted that she probably would have taken a 5-minute break if she were alone without observers. It is plausible that this, or other changes in behavior, could also have occurred with other participants but without them mentioning it.

33.2 Personal Familiarity

As described in Section 22.2, we recruited participants through convenience sampling, meaning that the test population consists of friends and acquaintances. Since the test participants know us personally, it may influence them to answer questions and behave in a way that is favorable to us, thus hurting the validity of the experiment. To help reduce the effects of this, we told the participants to be as honest and neutral as possible during the observation, questionnaire, and interview. We also explained that the test's purpose is to test the game and its functionality, not the participants themselves. Despite taking these measures, we can not be sure the familiarity bias is not affecting our results.

33.3 User Group

The test population consisted of people between 20 and 30 years old, and most of them were students. To have a more generalizable result, we would need to have other user groups and demographics represented in our population. The experiment was sufficient to answer the research

questions, but we need a less homogeneous group if we were to do a more in-depth study. The results are valid for this age group, but we can not conclude that they are accurate for other ages.

33.4 Experiment Execution

The experiment for each group lasted for 45 minutes and included a 25-minute play session with observations, followed by a questionnaire and interview. This format is not enough time for the participants to play and exhaustively learn the game, which might decrease the result's validity. Ideally, they should have played the game over several weeks and at home. However, this was unfeasible due to time constraints, and most people do not own dance pads. According to our results, the game works great, but they do not say anything about its long-term effects, which is the most desirable aspect to measure with exergames. Ideally, we would also have used sensors to measure enjoyment, engagement, and motivation since a questionnaire could cause misinterpretation. However, it would be unfeasible for this project.

33.5 Summary

Several things might have affected the results and, therefore, lowered the reliability and validity. The participants might have changed their behavior because they knew they were under observation, and we recruited them using convenience sampling. The convenience sampling also resulted in a homogeneous user group of young adults. Ideally, the experiment duration should have lasted longer to let the players know the game better.

Part VIII

Conclusion and Further Work

Part VIII is the conclusion of the report. It starts by answering the research questions presented in Part I. Then, we suggest future research and development for the project.

Chapter 34

Conclusion

This chapter answers the research questions presented at the beginning of this thesis (see Chapter 5). The research goal of this project was to *create and evaluate a new exergame to assist in increasing the general public's physical activity level*, which we divided into six research questions. The first two questions were answered in the specialization project through a literature review and formed the basis for this thesis. Their answers resulted in *Space Space Revolution*, an exergame that combines a 2D platformer game with dance pads, where the goal is to conquer space by completing levels on planets. It is played by stepping and jumping on the dance pad, and the running mechanic consists of the player repeatedly stepping back and forth on the side arrows. The player must run fast enough to stay within the moving game level. To answer the remaining four questions, we conducted an experiment to evaluate the game. It gathered quantitative and qualitative data on the game's physical activity, enjoyment, motivation, engagement, and game design.

RQ1: *How can exergames motivate physical activity?*
There are many *game genres* suitable for creating physical activity motivation through exergames. Some already have many exergames, such as *rhythm games* and *sports games*. These two genres provide a natural link to exertion as dancing and sports already provide physical activity. Other genres that have successful exergames are *MMO*, *open world*, *role-playing*, *strategy*, and *survival* games. The rest of the genres are less used by exergames but provide opportunities for new and innovative exergame concepts.

We reviewed three different models for *game enjoyment*: *GameFlow*, Malone's *challenge, fantasy, and curiosity* model, and *Dual Flow*. Designing a motivating exergame will be more feasible by considering these models. It is not required to fulfill all their requirements to create an enjoyable game. However, being aware of the enjoyment components helps design a more fun game. One important takeaway is the importance of *challenge* since all three models mention how essential it is. Therefore, the new exergame concept should focus on having a good challenge for the players.

Existing *technology* to track the player's physical activity was reviewed and gave insight into how we can utilize them in an exergame. There are a variety of technologies able to track activity in an exergame, ranging from dance pads to full body tracking with Kinect. Other relevant technologies are smartphones, activity wristbands, virtual reality, and smart exercise equipment.

To promote the correct physical activity, we studied how and which activities an exergame should promote to give its players positive health effects. We found that the WHO recommends a minimal weekly exercise of 150 minutes of moderate-intensity aerobic physical activity or 75 minutes of vigorous aerobic activity to get significant health benefits, and aerobic exercise is the most efficient activity to increase the general public's health.

We studied *existing exergames* and reviewed their health impact. The review gave insight into which exergame types succeed in motivating physical activity. The games provide a variety of activity types and use several different technologies. Some of the games demand high energy ex-

penditure, for example, *DDR* and *Ring Fit Adventure*. Thus, they might be the most successful popular exergames in terms of exertion level. However, the immense usage of *Pokémon Go* also had a prominent influence on health, proving that games with a low energy expenditure also have the chance to impact the public's health.

RQ2: *What is a new enjoyable game concept that requires physical exertion?*
Space Space Revolution is the concept from our suggestions with the highest potential for enjoyment and physical activity. SSR is a PC exergame that combines a platformer game with dance pads, where the goal is to conquer space by completing levels on planets. It promotes aerobic physical activity by requiring the players to run and jump on the dance pad.

RQ3: *What level of physical exertion does the exergame give its players?*
The results show that the game provided enough physical exertion to count towards WHO's recommendation of 150 minutes minimum of moderate-intensity aerobic physical activity weekly for every participant. The intensity was also high enough for most players to be considered vigorous and count towards WHO's goal of 75 minutes of vigorous aerobic activity. When comparing SSR's results to other exergame studies, we found indications that its exertion level is between *Just Dance* and *Ring Fit Adventure*. Additionally, the game achieved high attractiveness and effectiveness from the Dual Flow model, matching the challenge- and intensity levels to the players' skill- and fitness levels. However, this question did not look at SSR's ability to provide long-term effects, and more research is needed to study its impact on the body over time. In conclusion, SSR provides a moderate or high intensity, but more work is needed to study its long-term effects.

RQ4: *How does the exergame affect the player?*
We found that SSR affects the player positively, with high enjoyment, motivation, and engagement. The game's multiplayer proved to be the most influential aspect of the user experience. The results also suggest that reaching a high heart rate zone is central to the player experience. The game narrative, control issues, and difficulty are areas of improvement to enhance the game's enjoyment, engagement, and motivation.

RQ4.1: *How is the player's enjoyment affected by the exergame?*
The results show that the participants found SSR enjoyable, and the game got a high GameFlow score of 4.14/5. Elements such as *concentration* and *clear goals* were executed well, but control issues and the social interaction caused some frustration. Making the story more prominent is also an area of improvement to facilitate more enjoyment. Overall, everyone found the game enjoyable, but some GameFlow elements could be improved.

RQ4.2: *How is the player's motivation to continue playing affected by the exergame?*
The motivation to continue playing was overall high, but the long-term motivation is unknown, and there is potential for improvement. The results indicate that SSR satisfies the autonomy and relatedness elements in the self-determination theory with the multiplayer mode and customization options. The game succeeded in using Malone's model to create motivation through cognitive curiosity, but the fantasy turned out too extrinsic. The collectibles helped provide clear goals, which motivated the players further. Control issues and a lack of challenge and replayability damaged the motivation and could also lower the long-term motivation. The majority stated that they felt more motivated to work out by playing the game than by regular aerobic exercise.

RQ4.3: *How is the player's engagement affected by the exergame?*
The experiment got positive engagement results and implied that the GameFlow elements immersion, concentration, and challenge increased the players' engagement. SSR is a local multiplayer game with a mix of cooperation and competitive play, which is likely to be vital to high engagement. Players were also engaged by the controls. More gameplay variation, a better narrative, and more competitive features are central to improving engagement further.

RQ5: *How does the game design and gameplay contribute to the player experience?*
The results show that the game design and gameplay provide an overall good player experience. Its uniqueness, use of dance pads, artistic design, and high quality contributed to the players' good impression of the game. The mix between competition and cooperative gameplay was confusing, but test subjects stated that it was fun and liked choosing how to play it themselves. People liked the story and cutscene when starting a new game save, but the story was not prominent, thus not contributing much to the experience. The levels' complexity was appropriate without overwhelming the players. However, both the levels and the gameplay would benefit from having more variation.

RQ6: *What are the challenges of playing the exergame?*
The experiment revealed several challenges, where the control issues and the jumping mechanic were the most prominent. They can be mitigated by having a better tutorial and more feedback. The difficulty level increased unevenly, which is solvable through testing and swapping some levels. Other challenges were the respawning mechanic, which sometimes spawned players into pits, GUI inconsistencies, and unintentional button presses.

Summary: The purpose and goal of this project were to *create and evaluate a new exergame to assist in increasing the general public's physical activity level.* The answers to the research questions show that *Space Space Revolution* is an enjoyable new exergame that succeeds in promoting physical exertion. A long-term study is needed to conclude its potential to impact the general public's physical activity level.

Chapter 35

Further Work

This chapter describes the future work for *Space Space Revolution*. The game has shown potential to be a successful exergame, but the concept needs to be developed further to become a complete game. First, the chapter describes the future research required to gain insight into the possibilities and limitations of SSR. Lastly, a list of future implementations based on the experiment and our ideas is presented.

35.1 Future Research

The experiment's test population consisted of people between 20 and 30 years old, and most of them were students. Research on other demographics is needed, for instance, testing its potential on children in after-school care or adolescents. It is also possible to study if the game can benefit the elderly after we implement difficulty adjustments in the game. Another research area is SSR's potential as a rehabilitation or physical therapy tool. With some adjustments, the game can be used by a diverse user group, and it is also possible to create alternative controls for users with cognitive or motor impairments.

Studying SSR's long-term effects is needed to study its physical outcome and game retention over time. Our results show that the game is enjoyable and provides physical activity, but Berg et al. [16] demonstrated that this is not necessarily enough to motivate the players to keep playing it. High game retention is essential for SSR's ability to help players reach or go beyond WHO's recommendations for general physical activity.

Several players complained about leg strain due to running on the spot with their legs far apart. Running in place may cause unwanted tension on muscles or joints, and there is a lack of studies investigating the benefits and disadvantages of spot running relevant to SSR. Therefore, more research is required to understand the game's positive and negative impacts on the body.

35.2 Future Development

Based on this thesis's results and discussions, new implementations can be added to the game to enhance the player experience. The game design changes revolve around improving the player experience and removing challenges. Future development of the game should focus on aspects like accessibility, long-term motivation, and challenge level balance. One of the crucial aspects is to provide the players with clear information, especially during the tutorial, to minimize control issues. Future development should also try out different combinations of cooperative and competitive gameplay. Possible future additions and changes are displayed in the bullet list below.

- Fix the respawn problem by having a three-second window where players can input when

they want to respawn.

- Remove any *Back* buttons so that only the O button can perform the "back"-action. The text "O Back" should be added to all applicable screens.
- Switch level locations according to results to have a better difficulty curve, for example, by swapping level 3 (P1L3) with level 7 (P1L7)
- Provide visual and audial feedback when players press triangle or square to indicate that the player might be drifting.
- Include an overlay after buying a shop item that makes it possible to equip the bought item immediately.
- Include the progress bar in levels so that it is always visible.
- Add more information about how to collect rewards, such as showing what is obtainable by completing a level when inside the level selector.
- Improve the tutorial by having more clear information, adding illustrations or animations to visualize the intended level controls, and requiring both players to perform the introduced mechanics correctly.
- Experiment with having the camera speed influenced by the player at the front instead of the one furthest behind.
- Experiment with different social interaction types, such as having more competitive challenge levels and shared level scores.
- Include a new type of collectible that only appears when replaying a level.
- Add more level design elements for more variation, for example, new types of obstacles, power-ups, and triggers.
- Change the fantasy so that the characters do not have a goal of being physically active.
- Add a story segment between unlocking planets right after completing a final level for the first time.
- Introduce new gameplay mechanics that utilize more of the dance pads, such as deceleration by pressing the down button.
- Add a boss fight against the Spuds at the final level of each planet.
- Create more planets and levels, optimally enough content to have players play the game regularly over multiple months.

35.3 Summary

There are several possible research options to gain insight into the possibilities and limitations of SSR, including studying its effects on other demographics and long-term effects. Based on the experiment results and our ideas, we also have many new features and changes that will enhance the player experience.

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Appendices

Appendix A

NSD Application

NSD NORSK SENTER FOR FORSKNINGSDATA

Vurdering

Referansenummer

719621

Prosjekttittel

Exergames - Play to get fit

Behandlingsansvarlig institusjon

Norges teknisk-naturvitenskapelige universitet / Fakultet for informasjonsteknologi og elektroteknikk (IE) / Institutt for datateknologi og informatikk

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)

Alf Inge Wang, alf.inge.wang@ntnu.no, tlf: 73594485

Type prosjekt

Studentprosjekt, masterstudium

Kontaktinformasjon, student

Ivar Nordvik Myrstad, ivarnm@stud.ntnu.no, tlf: 91608993

Prosjektperiode

01.03.2022 - 10.06.2022

Vurdering (1)

03.02.2022 - Vurdert

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet med vedlegg, og eventuelt i meldingsdialogen mellom innmelder og Personverntjenester. Behandlingen kan starte.

DEL PROSJEKTET MED PROSJEKTANSVARLIG
For studenter er det obligatorisk å dele prosjektet med prosjektansvarlig (veileder). Del ved å trykke på knappen «Del prosjekt» i menylinjen øverst i meldeskjemaet. Prosjektansvarlig bes akseptere invitasjonen innen en uke. Om invitasjonen utløper, må han/hun inviteres på nytt.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle alminnelige kategorier av personopplysninger frem til den datoen som er oppgitt i meldeskjemaet.

LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse som kan dokumenteres, og som den registrerte kan trekke tilbake.

Lovlig grunnlag for behandlingen vil dermed være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a.

PERSONVERNPRINSIPPER
Personverntjenester vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen om:

lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen

formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke behandles til nye, uforenlige formål

dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet

lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet

DE REGISTRERTES RETTIGHETER
Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18), og dataportabilitet (art. 20).

Personverntjenester vurderer at informasjonen om behandlingen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER
Personverntjenester legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

Ved bruk av databehandler (spørreskjemaleverandør, skylagring eller videosamtale) må behandlingen oppfylle kravene til bruk av databehandler, jf. art 28 og 29. Bruk leverandører som din institusjon har avtale med.

For å forsikre dere om at kravene oppfylles, må dere følge interne retningslinjer og/eller rådføre dere med behandlingsansvarlig institusjon.

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til oss ved å oppdatere meldeskjemaet. Før du melder inn en endring, oppfordrer vi deg til å lese om hvilke type endringer det er nødvendig å melde: https://www.nsd.no/personverntjenester/fylle-ut-meldeskjema-for-personopplysninger/melde-endringer-i-meldeskjema

Du må vente på svar fra oss før endringen gjennomføres.

OPPFØLGING AV PROSJEKTET
Personverntjenester vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!

Appendix B

Participant Agreement Contract

Informasjonsskriv

Vil du delta i forskningsprosjektet

"Exergames - Play to get fit"?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke den fysiske effekten av spillkonseptet Space Space Revolution (SSR). Gleden, motivasjonen og engasjementet man får fra spillet vil også undersøkes. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Formålet med prosjektet er å teste ut et nytt spill som krever fysisk aktivitet. Bakgrunnen for dette er at mange får for lite fysisk aktivitet i hverdagen. Dette prosjektet er med på å se hvordan videospill kan være med på å øke mengden fysisk aktivitet i folks hverdag.

Dette prosjektet vil evaluere spillkonseptet Space Space Revolution (SSR) ut ifra 5 aspekter:

- physical activity (fysisk aktivitet)
- enjoyment (glede/fornøyelse)
- motivation (motivasjon)
- engagement (engasjement)
- gameplay (spillstyring)

Vi skal også se på ulike utfordringer relatert til spillet.

Dette prosjektet er en del av en masteroppgave ved NTNU. Opplysningene brukes ikke til noen andre formål enn masteroppgaven.

Hvem er ansvarlig for forskningsprosjektet?

Prosjektet er en masteroppgave ved Institutt for datateknologi og informatikk, NTNU. Prosjektansvarlig er Alf Inge Wang (veileder for prosjektet og professor ved Institutt for datateknologi og informatikk).

Hvorfor får du spørsmål om å delta?

Utvalget av deltakere er tatt ut fra eget nettverk med interesse av å være med på eksperimentet.

Hva innebærer det for deg å delta?

Eksperimentet består av utprøving av spillet sammen med en annen deltaker under observasjon av oss. Etterpå vil det være et individuelt intervju og spørreskjema.

Hvis du velger å delta i prosjektet, innebærer det ca. 30 minutter med spilling av SSR sammen med 1 annen deltager. Under spillingen vil 2 personer observere og notere ned relevant informasjon, kommentarer og hendelser som er relevante for aspektene presentert under Formål.

Etter spilling vil ca. 15 minutter bli brukt på intervju og spørreskjema. Intervjuet inneholder spørsmål om deltakernes tanker og følelser rundt spillet de fikk prøve, der fokuset er på variablene presentert under Formål. Et eksempel på spørsmål under individuelt intervju er “Which parts of the gameplay did you enjoy the most?”.

Det individuelle spørreskjemaet er elektronisk via Microsoft Forms og anonymisert. Spørreskjemaet inneholder mer kvantitative spørsmål relatert til aspektene presentert under Formål. Et eksempel på spørsmål fra spørreskjemaet er “How many hours a week do you normally play video games?”. Av personopplysninger så samles kjønn og alder inn.

Det er frivillig å delta

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

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

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

Det er kun veileder Alf Inge Wang og studentene Turid Cecilie Dahl og Ivar Nordvik Myrstad som vil ha tilgang til dataene. Navn og epost vil erstattes med en ID som lagres på egen deltakerliste adskilt fra øvrige data. Deltakerliste, resultater fra spørreskjema og intervjunotater lagres i NTNUs SharePoint som sikrer kryptering og adgangsbegrensning.

Deltakere skal ikke kunne gjenkjennes i publikasjonen. Opplysninger vil brukes til for eksempel sammenligning mellom tidligere erfaring med exergames og opplevelsen av SSR.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?

Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 10. juni 2022. Listen over relasjon mellom personopplysninger og ID vil slettes etter prosjektslutt.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Norges Teknisk-Naturvitenskapelige Universitet (NTNU) har Personverntjenester vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine rettigheter

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

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

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

NTNU ved

- Alf Inge Wang - 73594485 - alf.inge.wang@ntnu.no
- Ivar Nordvik Myrstad - 91608993 - ivarnm@stud.ntnu.no

- Turid Cecilie Dahl - 97735141 - turidcd@stud.ntnu.no

Vårt personvernombud:

- Thomas Helgesen - 93079038 - thomas.helgesen@ntnu.no

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

· Personverntjenester på epost (personverntjenester@sikt.no) eller på telefon: 53 21 15 00.

Med vennlig hilsen

Alf Inge Wang (forsker/veileder ved NTNU	Ivar Nordvik Myrstad (student, NTNU)	Turid Cecilie Dahl (student, NTNU)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *Exergames - Play to get fit*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- å delta i intervju
- å delta i spørreskjema
- å delta i utprøving av spillet under observasjon

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

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(Signert av prosjektdeltaker, dato)

Appendix C

Experiment Questionnaire

Norsk bokmål (Norge)

Questionnaire - Space Space Revolution

* Obligatorisk

Personal information and habits in regards to video games and physical exercise

1. User ID (provided by us) *

Verdien må være et tall

2. Gender *

- ◯ Female
- ◯ Male
- ◯ Other

3. Age *

Verdien må være et tall

4. How many hours a week do you normally play video games? *

Verdien må være et tall

4/19/2022

5. What kind of video games do you play? *

- [ ] I do not play video games
- [ ] Adventure
- [ ] Fighting
- [ ] First Person Shooters
- [ ] Massively Multiplayer Online (MMO)
- [ ] Platformers
- [ ] Rhythm
- [ ] Role-Playing Game (RPG)
- [ ] Simulation
- [ ] Sports
- [ ] Strategy
- [ ] Survival
- [ ] Other

6. Which of these exercise games have you previously played? *

- [ ] I have not played any exercise games before
- [ ] Beat Saber
- [ ] Dance Dance Revolution (DDR)
- [ ] Just Dance
- [ ] Pokémon Go
- [ ] Ring Fit Adventure
- [ ] Wii Fit
- [ ] Wii Sports
- [ ] Other

4/19/2022

7. How many hours per week do you normally perform physical exercise? *

Verdien må være et tall

8. What kind of physical exercises do you normally do? *

- [ ] I do not exercise
- [ ] Bicycling
- [ ] Dancing
- [ ] Running
- [ ] Skiing
- [ ] Soccer
- [ ] Strength exercise
- [ ] Walking
- [ ] Group classes
- [ ]

Annet

Gameplay

Your experience with the gameplay and the game design

9. Statements *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I liked the game	◯	◯	◯	◯	◯
I liked the use of dance pads	◯	◯	◯	◯	◯
I found the menus to be intuitive	◯	◯	◯	◯	◯
I found the controls to be intuitive	◯	◯	◯	◯	◯
I liked the length of the levels	◯	◯	◯	◯	◯
I liked the variety the challenge levels gave	◯	◯	◯	◯	◯
The game was good at tracking my movements	◯	◯	◯	◯	◯
I liked recieving a score for each level	◯	◯	◯	◯	◯

10. Did you experience any technical or gameplay issues? *

- [ ] None
- [ ] The game did not register my steps
- [ ] The game did not register my jumps
- [ ] Standing correctly on the dance pad
- [ ] Both players pressing a button at the same time when navigating the menus
- [ ] Pressing a button I did not intend to press
- [ ]

Annet

11. How satisfied are you with the menus in the game? *

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

12. How intuitive and enjoyable were the level controls? *

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Physical Activity

13. Statements *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The game motivated me to exercise	◯	◯	◯	◯	◯
I got a good exercise from playing the game	◯	◯	◯	◯	◯
I felt that the exercises matched my fitness level	◯	◯	◯	◯	◯
I forgot that I was working out while playing the game	◯	◯	◯	◯	◯
I pushed myself physically when playing	◯	◯	◯	◯	◯
The game can replace a workout session	◯	◯	◯	◯	◯
Going uphill required more physical effort	◯	◯	◯	◯	◯
Going downhill required less physical	◯	◯	◯	◯	◯
It was easy to keep up with the level tempo	◯	◯	◯	◯	◯

14. How intense do you feel the game's physical exercise was? *

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

Player experiences

15. Answer these statements based on your game enjoyment *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I found the game enjoyable	◯	◯	◯	◯	◯
I was not overwhelmed with tasks	◯	◯	◯	◯	◯
I found the challenge level to match my skill	◯	◯	◯	◯	◯
The game provided information on how to play	◯	◯	◯	◯	◯
I felt in control of my character	◯	◯	◯	◯	◯
The game gave me clear goals	◯	◯	◯	◯	◯
The game provided feedback for my actions	◯	◯	◯	◯	◯
I was given feedback on my progress in the game	◯	◯	◯	◯	◯
The game supported competition between players	◯	◯	◯	◯	◯
The game supported cooperation between players	◯	◯	◯	◯	◯
I enjoyed the game's music and sound effects	◯	◯	◯	◯	◯
I enjoyed the game's story and setting	◯	◯	◯	◯	◯
I enjoyed the game's characters	◯	◯	◯	◯	◯

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The game increased the challenge level according to my skill improvement throughout the play session	◯	◯	◯	◯	◯
I enjoyed the game's graphics	◯	◯	◯	◯	◯
I was curious to learn more about the game while playing	◯	◯	◯	◯	◯

16. Answer these statements based on your game engagement *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I found myself engaged while playing	◯	◯	◯	◯	◯
I lost track of time while playing	◯	◯	◯	◯	◯
I became less aware of my surroundings while playing	◯	◯	◯	◯	◯
I became less self-aware while playing	◯	◯	◯	◯	◯
I was emotionally involved in the game	◯	◯	◯	◯	◯

17. Answer these statements based on your motivation to continue playing *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The game was motivating	◯	◯	◯	◯	◯
Playing together is more motivating	◯	◯	◯	◯	◯
Playing against/with another person motivated me to perform better	◯	◯	◯	◯	◯
I feel more motivated to workout by playing the game than an aerobic exercise	◯	◯	◯	◯	◯
I was motivated having different characters to choose from	◯	◯	◯	◯	◯
I was motivated having different spaceships to choose from	◯	◯	◯	◯	◯
I was motivated by collectables (coins, stars, golden heart)	◯	◯	◯	◯	◯
I was motivated by scores	◯	◯	◯	◯	◯

4/19/2022

Appendix D

Full Analysis Results

All Likert statement tables have SD = Strongly agree, D = Disagree, N = Neutral, A = Agree, and SA = Strongly Agree.

D.1 Physical Activity

Table D.1: Full physical activity statements analysis results for the *Gaming habits* group category.

Statement	Group	SD	D	N	A	SA	P
The game motivated me to exercise	Gamer	0%	3%	11%	46%	40%	0.4571
	Not Gamer	0%	8%	8%	25%	58%	
I got a good exercise from playing the game	Gamer	0%	3%	0%	51%	46%	0.4269
	Not Gamer	0%	0%	0%	42%	58%	
I felt that the exercises matched my fitness level	Gamer	0%	6%	14%	49%	31%	0.2221
	Not Gamer	0%	0%	0%	58%	42%	
I forgot that I was working out while playing the game	Gamer	0%	0%	26%	49%	26%	0.4388
	Not Gamer	0%	17%	0%	42%	42%	
I pushed myself physically when playing	Gamer	0%	9%	9%	57%	26%	0.5381
	Not Gamer	0%	8%	25%	42%	25%	
The game can replace a workout session	Gamer	0%	6%	11%	46%	37%	0.9261
	Not Gamer	0%	0%	17%	50%	33%	
Going uphill required more physical effort	Gamer	0%	6%	0%	37%	57%	0.9889
	Not Gamer	0%	0%	8%	33%	58%	
Going downhill required less physical	Gamer	0%	0%	23%	43%	34%	0.2365
	Not Gamer	0%	0%	8%	42%	50%	
It was easy to keep up with the level tempo	Gamer	0%	17%	14%	54%	14%	0.4241
	Not Gamer	0%	8%	17%	50%	25%	

Table D.2: Full physical activity statements analysis results for the *Exercise habits* group category.

Statement	Group	SD	D	N	A	SA	P
The game motivated me to exercise	Active	0%	5%	11%	38%	46%	0.9661
	Less Active	0%	0%	10%	50%	40%	
I got a good exercise from playing the game	Active	0%	3%	0%	41%	57%	**0.0593**
	Less Active	0%	0%	0%	80%	20%	
I felt that the exercises matched my fitness level	Active	0%	5%	11%	46%	38%	0.5870
	Less Active	0%	0%	10%	70%	20%	
I forgot that I was working out while playing the game	Active	0%	3%	19%	49%	30%	0.7267
	Less Active	0%	10%	20%	40%	30%	
I pushed myself physically when playing	Active	0%	11%	14%	46%	30%	0.8529
	Less Active	0%	0%	10%	80%	10%	
The game can replace a workout session	Active	0%	5%	8%	49%	38%	0.4294
	Less Active	0%	0%	30%	40%	30%	
Going uphill required more physical effort	Active	0%	3%	3%	35%	59%	0.5518
	Less Active	0%	10%	0%	40%	50%	
Going downhill required less physical	Active	0%	0%	19%	49%	32%	0.2683
	Less Active	0%	0%	20%	20%	60%	
It was easy to keep up with the level tempo	Active	0%	16%	11%	57%	16%	0.8314
	Less Active	0%	10%	30%	40%	20%	

Table D.3: Full physical activity statements analysis results for the *Gender* group category.

Statement	Group	SD	D	N	A	SA	P
The game motivated me to exercise	Male	0%	3%	10%	43%	43%	0.6954
	Female	0%	0%	13%	38%	50%	
I got a good exercise from playing the game	Male	0%	3%	0%	50%	47%	0.4932
	Female	0%	0%	0%	44%	56%	
I felt that the exercises matched my fitness level	Male	0%	7%	10%	57%	27%	0.1605
	Female	0%	0%	13%	38%	50%	
I forgot that I was working out while playing the game	Male	0%	3%	20%	47%	30%	0.7466
	Female	0%	6%	19%	50%	25%	
I pushed myself physically when playing	Male	0%	7%	10%	43%	40%	**0.0219**
	Female	0%	6%	19%	75%	0%	
The game can replace a workout session	Male	0%	3%	17%	40%	40%	0.8514
	Female	0%	6%	6%	56%	31%	
Going uphill required more physical effort	Male	0%	7%	3%	37%	53%	0.2432
	Female	0%	0%	0%	31%	69%	
Going downhill required less physical	Male	0%	0%	30%	47%	23%	**0.0011**
	Female	0%	0%	0%	31%	69%	
It was easy to keep up with the level tempo	Male	0%	20%	20%	43%	17%	0.1494
	Female	0%	6%	6%	69%	19%	

Table D.4: Full physical activity statements analysis results for the *Heart rate zone* group category.

Statement	Group	SD	D	N	A	SA	P
The game motivated me to exercise	Vigorous	0%	3%	9%	34%	54%	**0.0432**
	Not Vigorous	0%	10%	20%	50%	20%	
I got a good exercise from playing the game	Vigorous	0%	0%	0%	43%	57%	**0.0248**
	Not Vigorous	0%	10%	0%	70%	20%	
I felt that the exercises matched my fitness level	Vigorous	0%	0%	11%	49%	40%	**0.0737**
	Not Vigorous	0%	20%	0%	70%	10%	
I forgot that I was working out while playing the game	Vigorous	0%	6%	17%	49%	29%	0.8361
	Not Vigorous	0%	0%	20%	50%	30%	
I pushed myself physically when playing	Vigorous	0%	6%	9%	54%	31%	**0.0074**
	Not Vigorous	0%	20%	30%	50%	0%	
The game can replace a workout session	Vigorous	0%	3%	9%	46%	43%	**0.0194**
	Not Vigorous	0%	10%	30%	50%	10%	
Going uphill required more physical effort	Vigorous	0%	6%	3%	31%	60%	0.4290
	Not Vigorous	0%	0%	0%	60%	40%	
Going downhill required less physical	Vigorous	0%	0%	17%	40%	43%	0.1812
	Not Vigorous	0%	0%	30%	50%	20%	
It was easy to keep up with the level tempo	Vigorous	0%	17%	9%	57%	17%	0.7883
	Not Vigorous	0%	10%	30%	40%	20%	

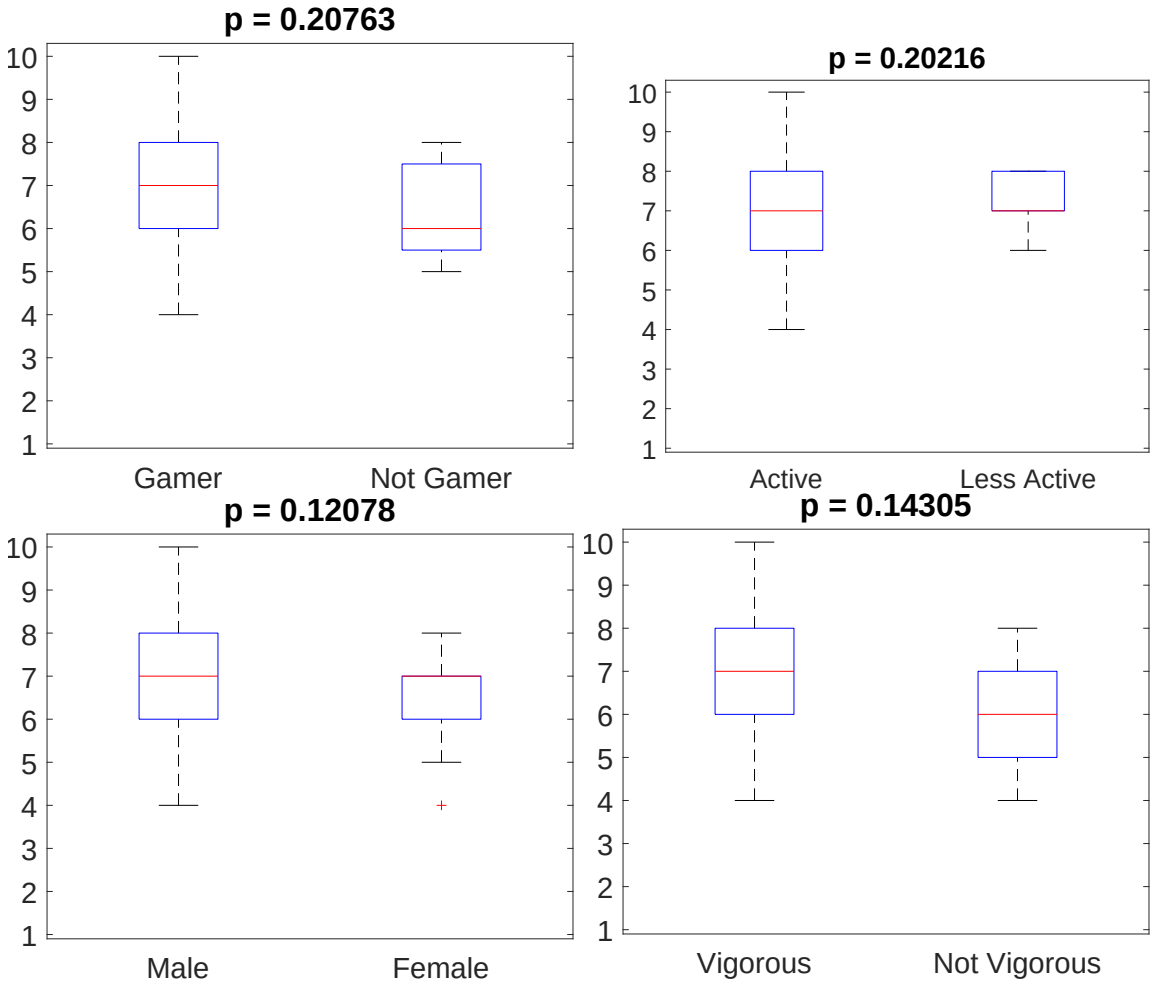

Figure D.1: Analysis of 1 to 10 rating of how physically intense the game was.

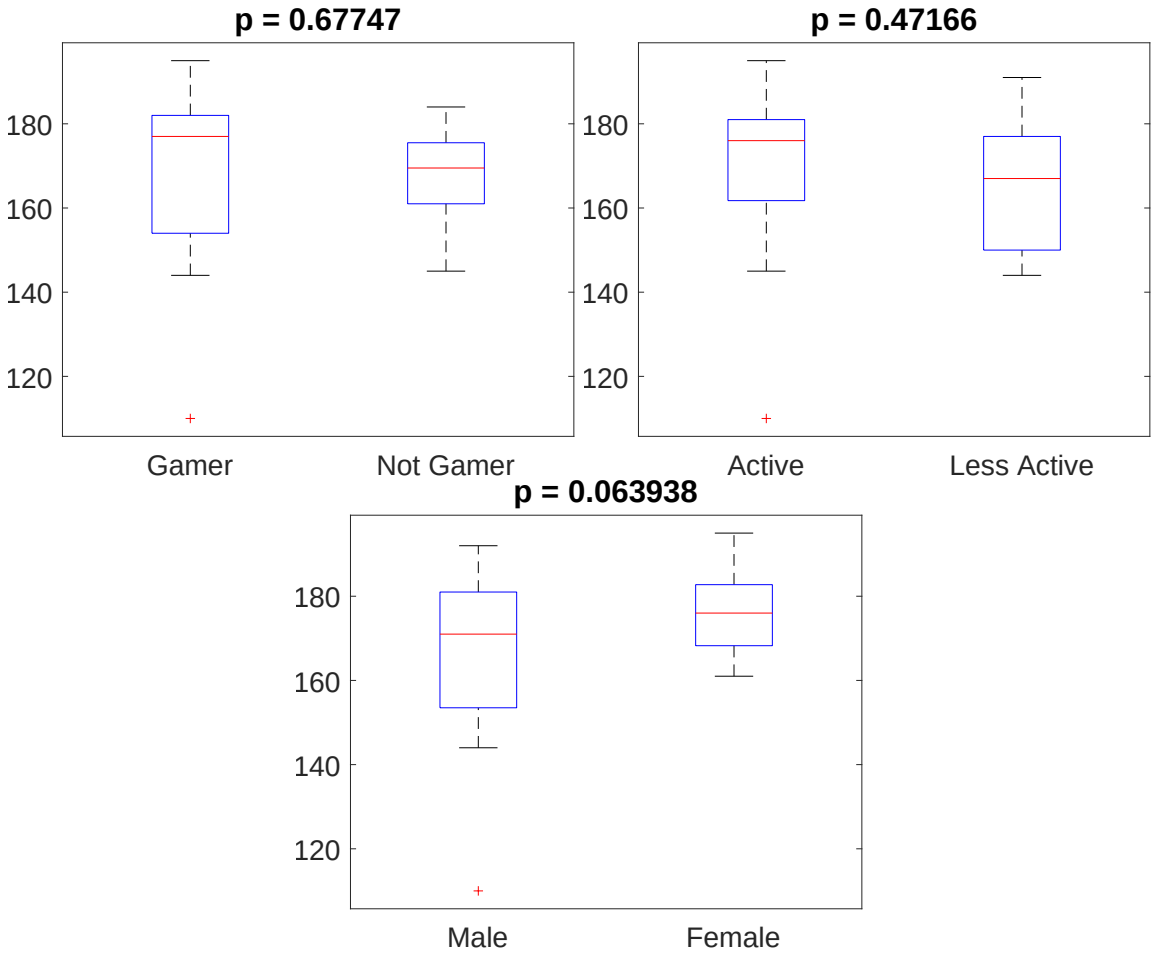

Figure D.2: Analysis of maximum heart rate measured.

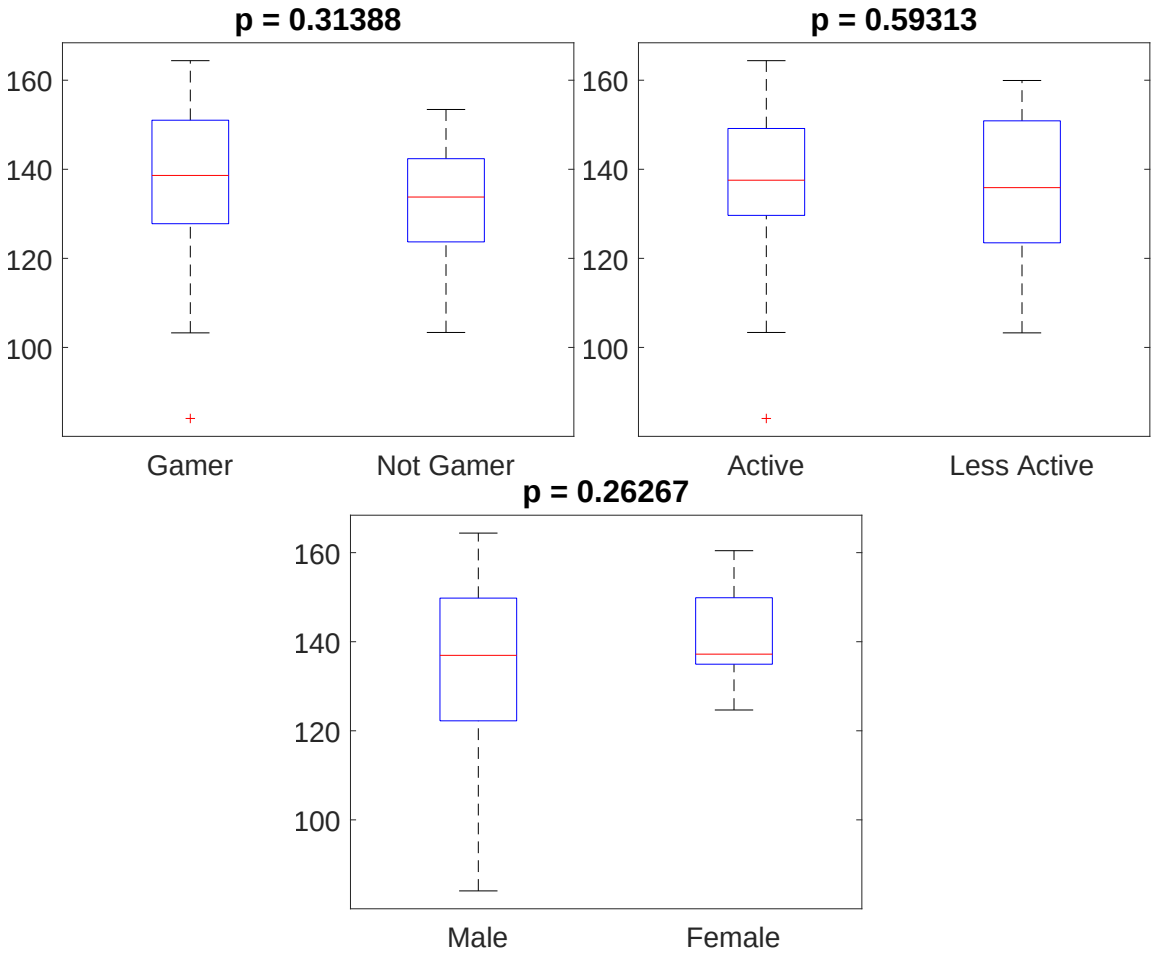

Figure D.3: Analysis of average heart rate measured.

D.2 Enjoyment

Table D.5: Full enjoyment statements analysis results for the *Gaming habits* group category.

Statement	Group	SD	D	N	A	SA	P
I found the game enjoyable	Gamer	0%	0%	0%	40%	60%	0.9314
	Not Gamer	0%	0%	0%	42%	58%	
I was not overwhelmed with tasks	Gamer	0%	0%	3%	37%	60%	0.2470
	Not Gamer	0%	0%	8%	50%	42%	
I found the challenge level to match my skill	Gamer	3%	0%	11%	51%	34%	0.6312
	Not Gamer	0%	0%	0%	67%	33%	
The game provided information on how to play	Gamer	0%	0%	17%	34%	49%	0.4101
	Not Gamer	0%	0%	8%	67%	25%	
I felt in control of my character	Gamer	0%	0%	23%	60%	17%	0.5997
	Not Gamer	0%	0%	42%	33%	25%	
The game gave me clear goals	Gamer	0%	0%	11%	46%	43%	0.1917
	Not Gamer	0%	0%	25%	50%	25%	
The game provided feedback for my actions	Gamer	0%	6%	23%	37%	34%	0.7047
	Not Gamer	0%	0%	8%	67%	25%	
I was given feedback on my progress in the game	Gamer	0%	6%	31%	31%	31%	0.6809
	Not Gamer	0%	8%	8%	58%	25%	
The game supported competition between players	Gamer	3%	26%	23%	37%	11%	**0.0242**
	Not Gamer	8%	8%	8%	17%	58%	
The game supported cooperation between players	Gamer	0%	3%	6%	37%	54%	0.5042
	Not Gamer	0%	8%	0%	50%	42%	
I enjoyed the game's music and sound effects	Gamer	0%	0%	0%	43%	57%	0.4106
	Not Gamer	0%	0%	17%	33%	50%	
I enjoyed the game's story and setting	Gamer	0%	3%	34%	40%	23%	0.9690
	Not Gamer	0%	0%	42%	33%	25%	
I enjoyed the game's characters	Gamer	0%	0%	14%	34%	51%	0.2728
	Not Gamer	0%	0%	8%	67%	25%	
The game increased the challenge level according to my skill improvement throughout the play session	Gamer	0%	11%	6%	57%	26%	0.5029
	Not Gamer	0%	8%	17%	58%	17%	
I enjoyed the game's graphics	Gamer	0%	0%	6%	40%	54%	0.8898
	Not Gamer	0%	0%	8%	33%	58%	
I was curious to learn more about the game while playing	Gamer	0%	3%	17%	46%	34%	0.5893
	Not Gamer	0%	0%	25%	50%	25%	

Table D.6: Full enjoyment statements analysis results for the *Exercise habits* group category.

Statement	Group	SD	D	N	A	SA	P
I found the game enjoyable	Active	0%	0%	0%	35%	65%	0.1642
	Less Active	0%	0%	0%	60%	40%	
I was not overwhelmed with tasks	Active	0%	0%	3%	41%	57%	0.6030
	Less Active	0%	0%	10%	40%	50%	
I found the challenge level to match my skill	Active	3%	0%	11%	51%	35%	0.8265
	Less Active	0%	0%	0%	70%	30%	
The game provided information on how to play	Active	0%	0%	19%	35%	46%	0.8986
	Less Active	0%	0%	0%	70%	30%	
I felt in control of my character	Active	0%	0%	27%	54%	19%	0.9428
	Less Active	0%	0%	30%	50%	20%	
The game gave me clear goals	Active	0%	0%	14%	43%	43%	0.2169
	Less Active	0%	0%	20%	60%	20%	
The game provided feedback for my actions	Active	0%	5%	16%	43%	35%	0.4275
	Less Active	0%	0%	30%	50%	20%	
I was given feedback on my progress in the game	Active	0%	5%	30%	32%	32%	1.0000
	Less Active	0%	10%	10%	60%	20%	
The game supported competition between players	Active	5%	27%	16%	30%	22%	0.1589
	Less Active	0%	0%	30%	40%	30%	
The game supported cooperation between players	Active	0%	5%	5%	38%	51%	0.8389
	Less Active	0%	0%	0%	50%	50%	
I enjoyed the game's music and sound effects	Active	0%	0%	3%	43%	54%	0.9054
	Less Active	0%	0%	10%	30%	60%	
I enjoyed the game's story and setting	Active	0%	3%	27%	43%	27%	**0.0450**
	Less Active	0%	0%	70%	20%	10%	
I enjoyed the game's characters	Active	0%	0%	16%	38%	46%	0.8530
	Less Active	0%	0%	0%	60%	40%	
The game increased the challenge level according to my skill improvement throughout the play session	Active	0%	14%	5%	57%	24%	0.9419
	Less Active	0%	0%	20%	60%	20%	
I enjoyed the game's graphics	Active	0%	0%	8%	32%	59%	0.4338
	Less Active	0%	0%	0%	60%	40%	
I was curious to learn more about the game while playing	Active	0%	3%	19%	43%	35%	0.6037
	Less Active	0%	0%	20%	60%	20%	

Table D.7: Full enjoyment statements analysis results for the *Gender* group category.

Statement	Group	SD	D	N	A	SA	P
I found the game enjoyable	Male	0%	0%	0%	43%	57%	0.4369
	Female	0%	0%	0%	31%	69%	
I was not overwhelmed with tasks	Male	0%	0%	0%	47%	53%	0.8427
	Female	0%	0%	13%	25%	63%	
I found the challenge level to match my skill	Male	3%	0%	10%	57%	30%	0.2955
	Female	0%	0%	6%	50%	44%	
The game provided information on how to play	Male	0%	0%	17%	37%	47%	0.7537
	Female	0%	0%	13%	50%	38%	
I felt in control of my character	Male	0%	0%	27%	63%	10%	0.1882
	Female	0%	0%	25%	38%	38%	
The game gave me clear goals	Male	0%	0%	13%	47%	40%	0.9293
	Female	0%	0%	13%	50%	38%	
The game provided feedback for my actions	Male	0%	7%	20%	37%	37%	0.9019
	Female	0%	0%	19%	56%	25%	
I was given feedback on my progress in the game	Male	0%	3%	30%	27%	40%	0.2442
	Female	0%	13%	19%	56%	13%	
The game supported competition between players	Male	3%	20%	20%	40%	17%	0.5117
	Female	0%	25%	19%	19%	38%	
The game supported cooperation between players	Male	0%	3%	7%	47%	43%	0.1310
	Female	0%	6%	0%	25%	69%	
I enjoyed the game's music and sound effects	Male	0%	0%	0%	47%	53%	0.6993
	Female	0%	0%	6%	31%	63%	
I enjoyed the game's story and setting	Male	0%	3%	40%	40%	17%	0.1030
	Female	0%	0%	25%	38%	38%	
I enjoyed the game's characters	Male	0%	0%	17%	47%	37%	**0.0516**
	Female	0%	0%	0%	38%	63%	
The game increased the challenge level according to my skill improvement throughout the play session	Male	0%	13%	7%	57%	23%	0.5932
	Female	0%	0%	13%	63%	25%	
I enjoyed the game's graphics	Male	0%	0%	10%	40%	50%	0.3146
	Female	0%	0%	0%	38%	63%	
I was curious to learn more about the game while playing	Male	0%	3%	20%	57%	20%	**0.0278**
	Female	0%	0%	13%	31%	56%	

Table D.8: Full enjoyment statements analysis results for the *Heart rate zone* group category.

Statement	Group	SD	D	N	A	SA	P
I found the game enjoyable	Vigorous	0%	0%	0%	37%	63%	0.2076
	Not Vigorous	0%	0%	0%	60%	40%	
I was not overwhelmed with tasks	Vigorous	0%	0%	6%	34%	60%	0.3736
	Not Vigorous	0%	0%	0%	60%	40%	
I found the challenge level to match my skill	Vigorous	3%	0%	6%	51%	40%	0.1314
	Not Vigorous	0%	0%	10%	80%	10%	
The game provided information on how to play	Vigorous	0%	0%	17%	40%	43%	0.7439
	Not Vigorous	0%	0%	10%	60%	30%	
I felt in control of my character	Vigorous	0%	0%	29%	49%	23%	0.6010
	Not Vigorous	0%	0%	30%	60%	10%	
The game gave me clear goals	Vigorous	0%	0%	11%	46%	43%	**0.0392**
	Not Vigorous	0%	0%	30%	60%	10%	
The game provided feedback for my actions	Vigorous	0%	6%	20%	43%	31%	0.6070
	Not Vigorous	0%	0%	10%	60%	30%	
I was given feedback on my progress in the game	Vigorous	0%	9%	23%	37%	31%	0.6756
	Not Vigorous	0%	0%	20%	50%	30%	
The game supported competition between players	Vigorous	0%	23%	17%	31%	29%	**0.0605**
	Not Vigorous	20%	20%	20%	40%	0%	
The game supported cooperation between players	Vigorous	0%	6%	3%	34%	57%	0.2627
	Not Vigorous	0%	0%	0%	70%	30%	
I enjoyed the game's music and sound effects	Vigorous	0%	0%	3%	40%	57%	0.5956
	Not Vigorous	0%	0%	10%	40%	50%	
I enjoyed the game's story and setting	Vigorous	0%	0%	31%	46%	23%	0.1715
	Not Vigorous	0%	10%	50%	20%	20%	
I enjoyed the game's characters	Vigorous	0%	0%	9%	40%	51%	**0.0422**
	Not Vigorous	0%	0%	30%	50%	20%	
The game increased the challenge level according to my skill improvement throughout the play session	Vigorous	0%	3%	9%	63%	26%	0.1288
	Not Vigorous	0%	30%	10%	40%	20%	
I enjoyed the game's graphics	Vigorous	0%	0%	9%	37%	54%	1.0000
	Not Vigorous	0%	0%	0%	50%	50%	
I was curious to learn more about the game while playing	Vigorous	0%	0%	14%	49%	37%	**0.0353**
	Not Vigorous	0%	10%	30%	50%	10%	

D.3 Motivation

Table D.9: Full motivation statements analysis results for the *Gaming habits* group category.

Statement	Group	SD	D	N	A	SA	P
The game was motivating	Gamer	0%	0%	11%	46%	43%	0.6568
	Not Gamer	0%	0%	8%	42%	50%	
Playing together is more motivating	Gamer	0%	0%	0%	26%	74%	0.5383
	Not Gamer	0%	0%	0%	17%	83%	
Playing against/with another person motivated me to perform better	Gamer	3%	3%	9%	23%	63%	**0.0160**
	Not Gamer	0%	0%	0%	0%	100%	
I feel more motivated to workout by playing the game than an aerobic exercise	Gamer	3%	6%	20%	31%	40%	0.7772
	Not Gamer	8%	8%	8%	42%	33%	
I was motivated having different characters to choose from	Gamer	0%	6%	14%	49%	31%	**0.0103**
	Not Gamer	17%	8%	33%	33%	8%	
I was motivated having different spaceships to choose from	Gamer	3%	23%	37%	26%	11%	**0.0848**
	Not Gamer	17%	25%	50%	0%	8%	
I was motivated by collectables (coins, stars, golden heart)	Gamer	0%	0%	6%	40%	54%	0.9447
	Not Gamer	0%	0%	0%	50%	50%	
I was motivated by scores	Gamer	6%	14%	31%	26%	23%	0.2466
	Not Gamer	0%	17%	17%	25%	42%	

Table D.10: Full motivation statements analysis results for the *Exercise habits* group category.

Statement	Group	SD	D	N	A	SA	P
The game was motivating	Active	0%	0%	11%	38%	51%	0.1474
	Less Active	0%	0%	10%	70%	20%	
Playing together is more motivating	Active	0%	0%	0%	24%	76%	0.7904
	Less Active	0%	0%	0%	20%	80%	
Playing against/with another person motivated me to perform better	Active	3%	3%	8%	19%	68%	0.1498
	Less Active	0%	0%	0%	10%	90%	
I feel more motivated to workout by playing the game than an aerobic exercise	Active	3%	8%	14%	35%	41%	0.4188
	Less Active	10%	0%	30%	30%	30%	
I was motivated having different characters to choose from	Active	5%	8%	22%	38%	27%	0.4479
	Less Active	0%	0%	10%	70%	20%	
I was motivated having different spaceships to choose from	Active	8%	19%	41%	19%	14%	0.3915
	Less Active	0%	40%	40%	20%	0%	
I was motivated by collectables (coins, stars, golden heart)	Active	0%	0%	5%	35%	59%	0.1646
	Less Active	0%	0%	0%	70%	30%	
I was motivated by scores	Active	5%	16%	24%	24%	30%	0.9572
	Less Active	0%	10%	40%	30%	20%	

Table D.11: Full motivation statements analysis results for the *Gender* group category.

Statement	**Group**	**SD**	**D**	**N**	**A**	**SA**	**P**
The game was motivating	Male	0%	0%	13%	47%	40%	0.4378
	Female	0%	0%	6%	44%	50%	
Playing together is more motivating	Male	0%	0%	0%	30%	70%	0.1953
	Female	0%	0%	0%	13%	88%	
Playing against/with another person motivated me to perform better	Male	0%	0%	7%	27%	67%	0.5500
	Female	6%	6%	6%	0%	81%	
I feel more motivated to workout by playing the game than an aerobic exercise	Male	3%	0%	20%	33%	43%	0.1322
	Female	6%	19%	13%	38%	25%	
I was motivated having different characters to choose from	Male	7%	7%	13%	47%	27%	0.9902
	Female	0%	0%	31%	44%	25%	
I was motivated having different spaceships to choose from	Male	10%	23%	33%	23%	10%	0.6635
	Female	0%	19%	56%	13%	13%	
I was motivated by collectables (coins, stars, golden heart)	Male	0%	0%	7%	37%	57%	0.5735
	Female	0%	0%	0%	56%	44%	
I was motivated by scores	Male	3%	17%	33%	20%	27%	0.3341
	Female	6%	6%	19%	38%	31%	

Table D.12: Full motivation statements analysis results for the *Heart rate zone* group category.

Statement	**Group**	**SD**	**D**	**N**	**A**	**SA**	**P**
The game was motivating	Vigorous	0%	0%	9%	46%	46%	0.5574
	Not Vigorous	0%	0%	20%	40%	40%	
Playing together is more motivating	Vigorous	0%	0%	0%	20%	80%	0.5193
	Not Vigorous	0%	0%	0%	30%	70%	
Playing against/with another person motivated me to perform better	Vigorous	3%	3%	6%	14%	74%	0.4931
	Not Vigorous	0%	0%	10%	30%	60%	
I feel more motivated to workout by playing the game than an aerobic exercise	Vigorous	6%	9%	11%	31%	43%	0.5553
	Not Vigorous	0%	0%	40%	30%	30%	
I was motivated having different characters to choose from	Vigorous	6%	0%	17%	49%	29%	**0.0826**
	Not Vigorous	0%	20%	30%	40%	10%	
I was motivated having different spaceships to choose from	Vigorous	9%	23%	37%	20%	11%	0.6896
	Not Vigorous	0%	20%	50%	20%	10%	
I was motivated by collectables (coins, stars, golden heart)	Vigorous	0%	0%	3%	40%	57%	0.5956
	Not Vigorous	0%	0%	10%	40%	50%	
I was motivated by scores	Vigorous	6%	14%	23%	23%	34%	0.3172
	Not Vigorous	0%	20%	40%	30%	10%	

D.4 Engagement

Table D.13: Full engagement statements analysis results for the *Gaming habits* group category.

Statement	Group	SD	D	N	A	SA	P
I found myself engaged while playing	Gamer	0%	0%	0%	31%	69%	0.9158
	Not Gamer	0%	0%	0%	33%	67%	
I lost track of time while playing	Gamer	0%	3%	0%	40%	57%	0.3245
	Not Gamer	0%	0%	8%	50%	42%	
I became less aware of my surroundings while playing	Gamer	0%	3%	11%	49%	37%	0.2625
	Not Gamer	0%	0%	0%	50%	50%	
I became less self-aware while playing	Gamer	0%	6%	17%	43%	34%	0.9062
	Not Gamer	0%	8%	8%	50%	33%	
I was emotionally involved in the game	Gamer	0%	9%	9%	54%	29%	0.7436
	Not Gamer	0%	17%	17%	17%	50%	

Table D.14: Full engagement statements analysis results for the *Exercise habits* group category.

Statement	Group	SD	D	N	A	SA	P
I found myself engaged while playing	Active	0%	0%	0%	30%	70%	0.5515
	Less Active	0%	0%	0%	40%	60%	
I lost track of time while playing	Active	0%	3%	0%	46%	51%	0.7901
	Less Active	0%	0%	10%	30%	60%	
I became less aware of my surroundings while playing	Active	0%	3%	11%	43%	43%	0.8517
	Less Active	0%	0%	0%	70%	30%	
I became less self-aware while playing	Active	0%	5%	19%	41%	35%	0.8671
	Less Active	0%	10%	0%	60%	30%	
I was emotionally involved in the game	Active	0%	11%	11%	43%	35%	0.8891
	Less Active	0%	10%	10%	50%	30%	

Table D.15: Full engagement statements analysis results for the *Gender* group category.

Statement	Group	SD	D	N	A	SA	P
I found myself engaged while playing	Male	0%	0%	0%	30%	70%	0.9423
	Female	0%	0%	0%	31%	69%	
I lost track of time while playing	Male	0%	3%	0%	40%	57%	0.4022
	Female	0%	0%	6%	50%	44%	
I became less aware of my surroundings while playing	Male	0%	3%	13%	53%	30%	**0.0410**
	Female	0%	0%	0%	44%	56%	
I became less self-aware while playing	Male	0%	7%	17%	43%	33%	0.9506
	Female	0%	6%	13%	50%	31%	
I was emotionally involved in the game	Male	0%	7%	10%	57%	27%	0.4485
	Female	0%	13%	13%	25%	50%	

Table D.16: Full engagement statements analysis results for the *Heart rate zone* group category.

Statement	Group	SD	D	N	A	SA	P
I found myself engaged while playing	Vigorous	0%	0%	0%	26%	74%	**0.0467**
	Not Vigorous	0%	0%	0%	60%	40%	
I lost track of time while playing	Vigorous	0%	0%	3%	43%	54%	0.8880
	Not Vigorous	0%	0%	0%	50%	50%	
I became less aware of my surroundings while playing	Vigorous	0%	3%	6%	46%	46%	0.1276
	Not Vigorous	0%	0%	20%	60%	20%	
I became less self-aware while playing	Vigorous	0%	3%	17%	40%	40%	0.2045
	Not Vigorous	0%	20%	10%	50%	20%	
I was emotionally involved in the game	Vigorous	0%	6%	9%	43%	43%	**0.0112**
	Not Vigorous	0%	30%	20%	40%	10%	

D.5 Gameplay

Table D.17: Full gameplay statements analysis results for the *Gaming habits* group category.

Statement	Group	SD	D	N	A	SA	P
I liked the game	Gamer	0%	0%	0%	34%	66%	0.6602
	Not Gamer	0%	0%	0%	42%	58%	
I liked the use of dance pads	Gamer	0%	3%	11%	51%	34%	0.6996
	Not Gamer	0%	0%	25%	42%	33%	
I found the menus to be intuitive	Gamer	0%	9%	14%	51%	26%	0.6820
	Not Gamer	0%	0%	17%	75%	8%	
I found the controls to be intuitive	Gamer	0%	0%	17%	49%	34%	0.5674
	Not Gamer	0%	8%	0%	75%	17%	
I liked the length of the levels	Gamer	0%	0%	6%	46%	49%	0.6615
	Not Gamer	0%	0%	8%	50%	42%	
I liked the variety the challenge levels gave	Gamer	0%	3%	20%	54%	23%	0.5985
	Not Gamer	0%	17%	8%	58%	17%	
The game was good at tracking my movements	Gamer	3%	14%	29%	43%	11%	0.6888
	Not Gamer	0%	0%	50%	33%	17%	
I liked recieving a score for each level	Gamer	0%	0%	11%	31%	57%	0.7274
	Not Gamer	0%	0%	17%	17%	67%	

Table D.18: Full gameplay statements analysis results for the *Exercise habits* group category.

Statement	Group	SD	D	N	A	SA	P
I liked the game	Active	0%	0%	0%	32%	68%	0.3177
	Less Active	0%	0%	0%	50%	50%	
I liked the use of dance pads	Active	0%	3%	11%	49%	38%	0.1970
	Less Active	0%	0%	30%	50%	20%	
I found the menus to be intuitive	Active	0%	8%	14%	57%	22%	0.9420
	Less Active	0%	0%	20%	60%	20%	
I found the controls to be intuitive	Active	0%	3%	14%	54%	30%	0.8052
	Less Active	0%	0%	10%	60%	30%	
I liked the length of the levels	Active	0%	0%	8%	43%	49%	0.8497
	Less Active	0%	0%	0%	60%	40%	
I liked the variety the challenge levels gave	Active	0%	5%	14%	57%	24%	0.1503
	Less Active	0%	10%	30%	50%	10%	
The game was good at tracking my movements	Active	3%	11%	30%	43%	14%	0.5357
	Less Active	0%	10%	50%	30%	10%	
I liked recieving a score for each level	Active	0%	0%	14%	24%	62%	0.6240
	Less Active	0%	0%	10%	40%	50%	

Table D.19: Full gameplay statements analysis results for the *Gender* group category.

Statement	Group	SD	D	N	A	SA	P
I liked the game	Male	0%	0%	0%	40%	60%	0.3211
	Female	0%	0%	0%	25%	75%	
I liked the use of dance pads	Male	0%	3%	17%	47%	33%	0.6071
	Female	0%	0%	13%	50%	38%	
I found the menus to be intuitive	Male	0%	7%	13%	53%	27%	0.3754
	Female	0%	6%	19%	63%	13%	
I found the controls to be intuitive	Male	0%	0%	17%	43%	40%	0.1911
	Female	0%	6%	6%	75%	13%	
I liked the length of the levels	Male	0%	0%	7%	53%	40%	0.1916
	Female	0%	0%	6%	31%	63%	
I liked the variety the challenge levels gave	Male	0%	3%	23%	53%	20%	0.4032
	Female	0%	6%	6%	63%	25%	
The game was good at tracking my movements	Male	0%	10%	37%	47%	7%	0.6691
	Female	6%	13%	25%	31%	25%	
I liked recieving a score for each level	Male	0%	0%	10%	37%	53%	0.5464
	Female	0%	0%	19%	13%	69%	

Table D.20: Full gameplay statements analysis results for the *Heart rate zone* group category.

Statement	Group	SD	D	N	A	SA	P
I liked the game	Vigorous	0%	0%	0%	29%	71%	**0.0193**
	Not Vigorous	0%	0%	0%	70%	30%	
I liked the use of dance pads	Vigorous	0%	3%	17%	43%	37%	0.7212
	Not Vigorous	0%	0%	10%	70%	20%	
I found the menus to be intuitive	Vigorous	0%	9%	11%	66%	14%	0.4441
	Not Vigorous	0%	0%	30%	30%	40%	
I found the controls to be intuitive	Vigorous	0%	3%	9%	60%	29%	0.5625
	Not Vigorous	0%	0%	30%	40%	30%	
I liked the length of the levels	Vigorous	0%	0%	9%	40%	51%	0.4177
	Not Vigorous	0%	0%	0%	70%	30%	
I liked the variety the challenge levels gave	Vigorous	0%	6%	11%	57%	26%	0.1227
	Not Vigorous	0%	10%	30%	50%	10%	
The game was good at tracking my movements	Vigorous	3%	11%	31%	37%	17%	0.4034
	Not Vigorous	0%	10%	50%	40%	0%	
I liked recieving a score for each level	Vigorous	0%	0%	17%	23%	60%	0.9507
	Not Vigorous	0%	0%	0%	50%	50%	

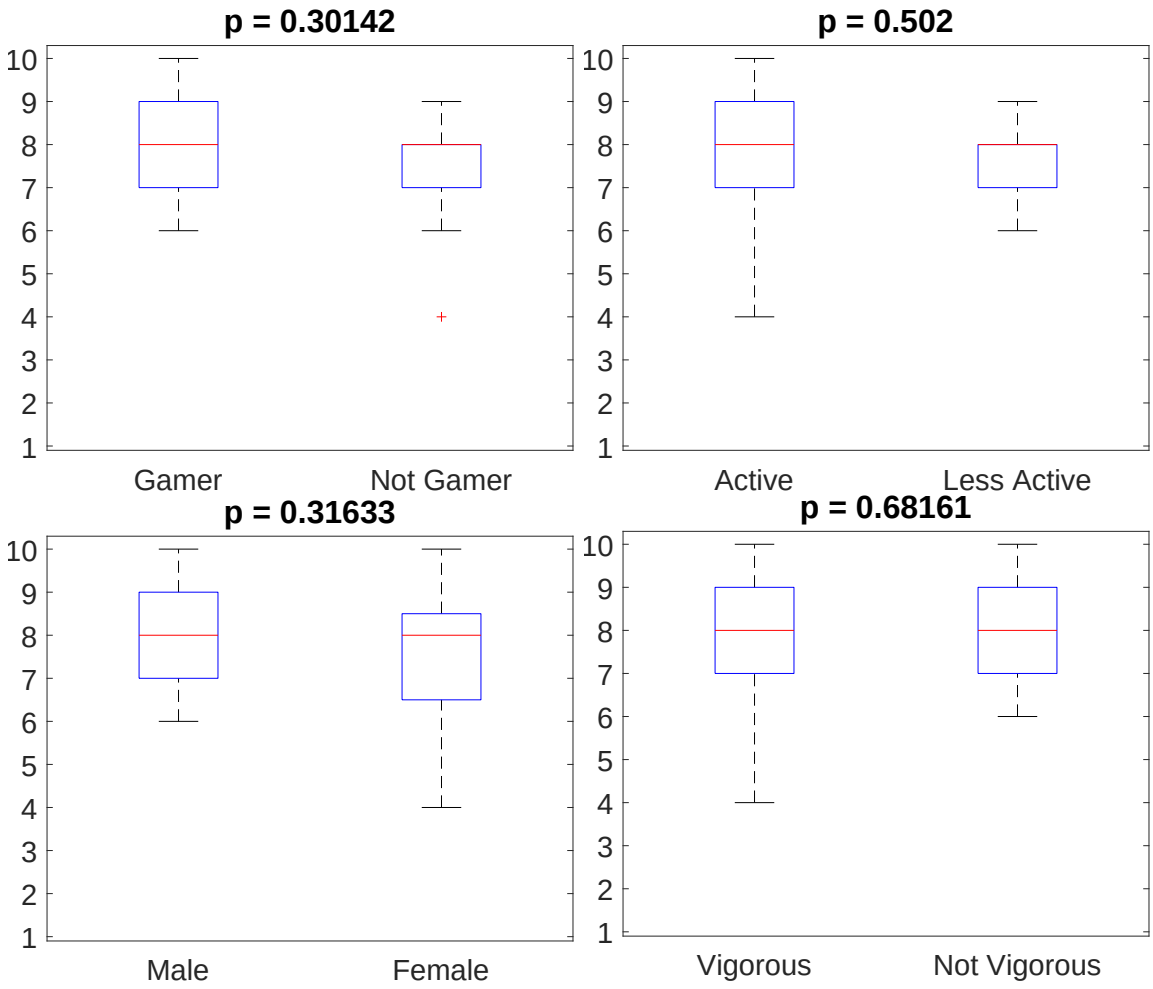

Figure D.4: Analysis of 1 to 10 rating of how intuitive the menus are.

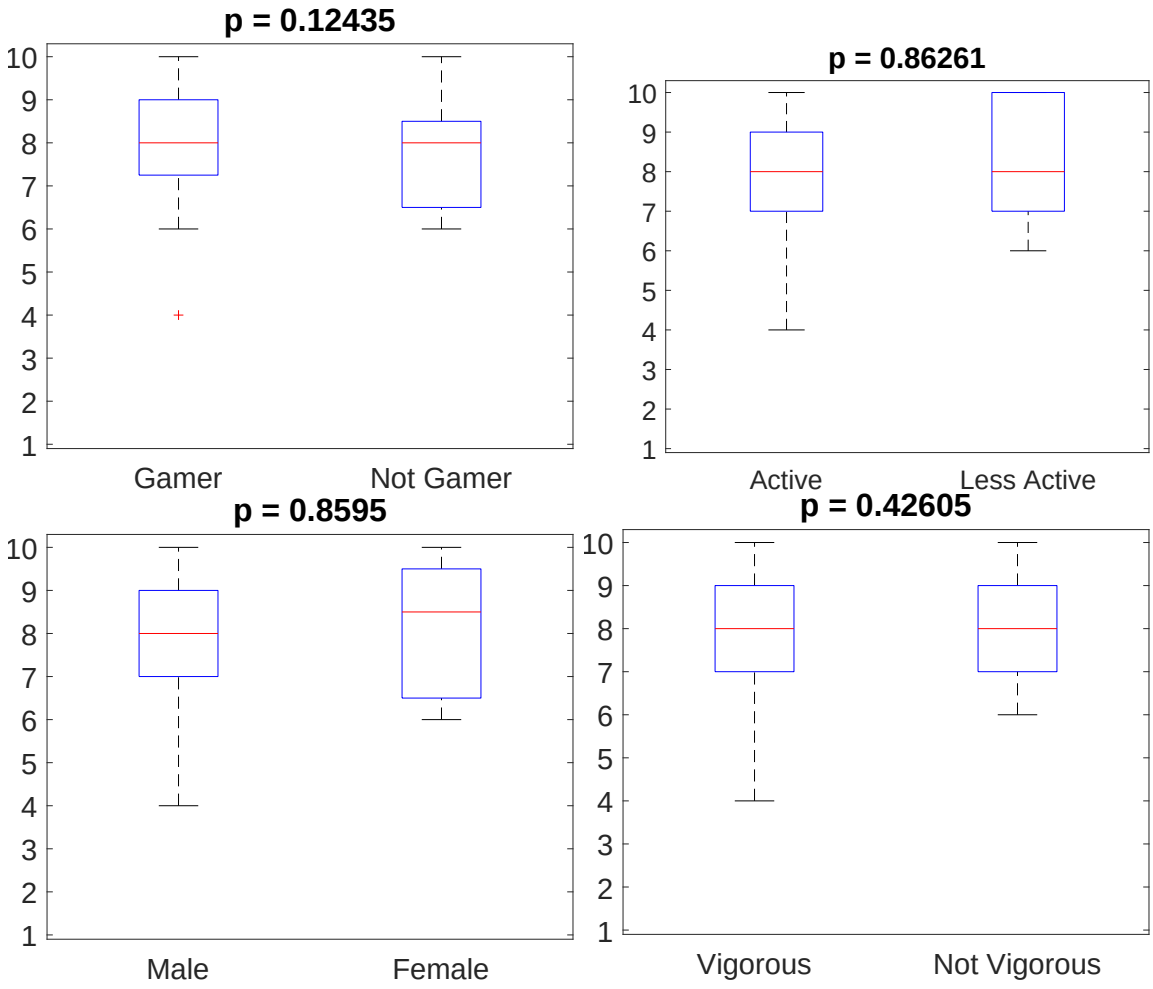

Figure D.5: Analysis of 1 to 10 rating of how intuitive and enjoyable the level controls are.

Turid Cecilie Dahl & Ivar Nordvik Myrstad

Space Space Revolution - Using Dance Pads in a New Exergame to Promote Physical Exertion

NTNU
Norwegian University of
Science and Technology