Master's thesis

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Paint it Green

A Game for Increasing Your Physically Activity

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

This thesis is a part of the Game Technology for Health (GT4H) Network and contributes to NTNU's research on exergames. A sedentary lifestyle increases the probability of health issues such as type 2 diabetes and heart attacks. Simultaneously, games and other forms of digital entertainment have cemented their place in everyday culture in the industrialized world. The project's research goal is to discover, analyze, develop and test a new exergame concept and prototype which motivates people to increase their physical activity levels.

A prestudy was performed to gain knowledge on exergames, used technologies, game design, and research on exergame health effects. Choices of genre, concept, exercise scheme, and technologies were made using the knowledge from the prestudy, resulting in the exergame concept *Paint it Green*, a location-based mobile game based on exploring Trondheim and retaking the world from evil paint monsters.

A prototype was developed for Android smartphones and distributed to a group of 21 test subjects for an experiment lasting 19 days. The experiment aimed to learn how the prototype affected the subjects' physical activity levels and how enjoyable and motivating they found the game. Observations, interviews, questionnaires, and game usage data were used to produce quantitative and qualitative data.

An analysis of data showed that the game positively affected the number of daily steps the test subjects took. The data also showed an indication of an increase in how satisfied test subjects were with their own physical activity However, other metrics show less promising results on the effectiveness of the exergame prototype. The game returned varying feedback from different demographic groups, with gamers being more critical of the prototype and non-active test subjects perceiving a more significant effect on their physical activity levels.

In total, we deem the potential of exergames to provide health benefits to players as neither staggeringly low nor high. The prototype showed both encouraging and discouraging prospects. We estimate that a project with more resources and a broader scope for implementing the prototype could have had a major influence on the game's effectiveness.

Keywords: game development, exergames, physical health, location-aware games, pervasive games

Sammendrag

Denne oppgaven er en del av Game Technology for Health (GT4H)-nettverket og bidrar til NTNU sin forskning på treningsspill. En stillesittende livssil øker sjansen for helseplager som diabetes type 2 og hjerteinfarkt. Samtidig har spill og andre former for digital underholdning sementert stillingen sin i hverdagskulturen i den industrialiserte verden. Forskningsmålet for dette prosjektet er å *oppfinne, analysere, utvikle og teste et nytt treningsspillkonsept og en prototype som motiverer folk til å være mer fysisk aktive.*

Et forstudie ble gjort for å finne kunnskap om treningsspill, vanlige teknologier, spill-design, og forskning knyttet til treningsspills helseeffekter. Ved å bruke kunnskapen fra forstudiet ble kunnskapsbaserte valg av sjanger, konsept, treningsstrategi og teknologier tatt, og resulterte i treningsspillkonseptet *Paint it Green* (Mal det grønt), et lokasjonsbasert mobilspill hvor man skal utforske Trondheim og ta tilbake verden fra onde malingsmonstre.

En prototype ble utviklet for Android-smarttelefoner og sendt til en gruppe med 21 testsubjekter for et eksperiment som varte i 19 dager. Eksperimentets mål var å lære om hvordan prototypen påvirket hvor mye testsubjektene var fysisk aktive, samt hvor fornøyelig/gøy og motiverende de fant spillet. Observasjoner, intervjuer spørreskjemaer og spilldata ble brukt til å produsere kvantitative og kvalitative data.

En analyse av dataene viste at spillet hadde en positiv effekt på antall skritt testsubjektene tok daglig. Dataene viste også en indikasjon på en forbedring i hvor fornøyde testsubjektene var med egen fysisk aktivitet. Allikevel, andre målinger viser mindre håpefulle resultater på hvor vellykket treningsspillprototypen var. Spillet ga varierende tilbakemeldinger fra forskjellige demografiske grupper, hvor gamere var mer kritiske til prototypen og ikke-aktive testsubjekter oppfattet en større effekt på hvor ofte de var fysisk aktive.

Alt i alt, vil vi anslå potensiale til at treningsspill kan gi helsegevinster til spillere som hverken meget lite eller stort. Prototypen viste både oppmuntrende og nedslående potensiale, og vi estimerer at et prosjekt med større ressurser og et bredere implementasjonsomfang vil kunne ha en stor påvirkning på hvor vellykket spillet ble.

Nøkkelord: spillutvikling, treningsspill, fysisk helse, stedsbaserte spill

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Part I

Introduction

This part will serve as an introduction to the project and report. It begins with the motivation for the project, then details the project task and context. Further, the research questions and goal is defined, and the research method is presented. The part concludes with a reader's guide.

Chapter 1

Motivation

Games, gamification, and other forms of entertainment have cemented their place in everyday culture in the industrialized world. The global gaming market is estimated to have a value of 256.97 billion USD by 2025 [5]. Limelight reports that gamers spend more than six hours per week playing and that the mobile phone remains the primary gaming device [6].

Simultaneously, many people in the same demographics would like to and require more frequent physical exercise. The World Health Organization (WHO) reports that more than 1.4 billion adults worldwide are insufficiently active and that levels of inactivity are twice as high in high-income countries compared to low-income countries [7]. Furthermore, WHO reports that there has been no improvement in global physical activity levels since 2001 and that insufficient activity increased by five percent (from 32% to 37%) in high-income countries between 2001 and 2016.

Spoken freely, one can say that many people like to play games, utilize other digital media, and do not get enough exercise. Game concepts trying to exploit this observation have existed for many years already (see Section 7.2). However, there could still be room for games that motivate people to improve their physical health by exercising more. Such games, known as exergames, could benefit many people's health, as reported in a systematic literature review of the health effects of playing the popular exergame, Pokémon Go [8]. Its main conclusion is that Pokémon Go positively affects the players' physical, mental, and social health. However, this effect only lasts as long as the player plays the game.

Thus, games that make physical exercise fun, immersive and engaging are an exciting approach to improving many people's physical health.

The authors of this master thesis are both computer science students who have specialized in software development. They have some experience in game development but also a prolonged and affectionate interest in video games. Their motivation is to create a fun game that could make exercise a little bit easier for people in their everyday life, in addition to the exciting venture game development is in itself.

Chapter 2

Project Task and Context

The task given to us was the following:
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. The prototype will be evaluated and tested in the third and final phase.

This report is written as a master's thesis in computer science. The thesis follows work that was done as a part of the course TDT4501 - Computer Science, specialization project at The Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. Both authors specialize in software development. According to NTNU, the master thesis is meant to give insight into how knowledge, services, and technology are created and reported within the student's master's specialty area and understanding of advanced theory and practice within this topic. The course is also supposed to teach awareness of essential principles of research ethics, and academic honesty [9].

The project is also part of NTNU's Game Technology for Health (GT4H). GT4H 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 within and outside NTNU who develop or use game technology for health to deliver high-quality research and advance our knowledge at the best possible value [10].

Chapter 3

Research Questions and Method

This chapter presents the research questions and briefly describes the methods used to produce this paper.

3.1 Research questions

The research approach used in this project will be based on the Goal Question Metric (GQM) [11]. The GQM approach separates the desired knowledge, which we hope to attain, into three levels. On the conceptual level, there is the overall goal for the research. The research questions are more specific on the operational level, and their aggregated answers will resolve the research goal. Lastly, on the quantitative level, there are metrics to help answer the research questions.

Our chosen research goal:

Discover, analyze, develop and test a new exergame concept and prototype which motivates people to increase their physical activity levels.

Following GCM, the research goal has been decomposed into research questions (RQs) [11]. The research goal is only achievable if the developed exergame is successful. If no one plays the game, meaningful empirical studies of health benefits are unfeasible. Making the exergame successful depends on many factors, like reach, implementation of physical activity, and player enjoyment. The research questions produce answers which, in sum, could guide and inform better decisions when designing a successful exergame, thus achieving the research goal.

The research questions are:

RQ1: What is the best way to create an effective, enjoyable, and motivating exergame?
Answer metric: Summative evaluation based on reviewing existing exergame technology, exergames, research papers, survey, and experiment results.

The purpose of RQ1 is to help us, and other exergame developers figure out how to best create an exergame that would be enjoyable to play, engaging, and motivates the player to be more physically active. Our efforts will be mostly centered around user-oriented technology issues such as sensors, platforms, and other equipment for appropriating movement, and less around developer-oriented technology issues like software architecture, game engine usage, and further detailed inspections. Game development processes are also beyond the scope of this project. RQ1 is divided up into four sub-research questions:

RQ1-1: What platforms are most suitable for an exergame?
RQ1-2: What technologies are mostly used in exergames?
RQ1-3: How can an exergame make the players more physically active?

RQ1-4: How can an exergame be made enjoyable and motivating for a player?

RQ2: To what degree are people interested in using exergames to increase their physical activity level?
Answer metric: Survey data, findings from literature review, and experiment results.
RQ2 is a prerequisite for almost the entire project, as there is no purpose in designing an exergame if it would not make a player want to increase their physical activity level.

RQ3: What were the players' affective reactions to playing the exergame?
Answer metric: Experiment results.

The purpose of RQ3 is to find out whether the players enjoyed the developed exergame prototype. The research question will explore what parts of the game motivated players and who enjoyed the exergame. The question is divided into the following sub-research questions:

RQ3-1: How motivating and enjoyable did the players find the exergame?
RQ3-2: What motivated players to play, and what features were used the most?
RQ3-3: What demographics enjoyed and were motivated by the exergame the most?

RQ4: Does the developed exergame affect the players' physical activity levels?
Answer metric: Experiment results.

The purpose of RQ4 is to examine whether the developed exergame prototype affected the players' physical activity. The question is divided into the following sub-research questions:

RQ4-1: How did the players' physical activity levels change during the experiment?
RQ4-2: What type of physical activity did players perform while playing?
RQ4-3: Did people play the game instead of doing a sedentary activity or did playtime replace other exercise?

3.2 Research method

This section describes the research method which is used in this project. The specific research activities are more in-depth described in Chapter 27, as this section will focus more on the research process model, serving as the foundation of and structuring the performed research activities in this project.

This project's research process model follows that of Oates', et al. *Researching Information Systems and Computing* [1]. The model is visualized in Figure 3.1, where each square represents components that constitute Oates' research process model. The model suggests creating a set of research questions (and a conceptual framework) based on the researchers' experience and motivation and a literature review. These components lead to and influence research strategies to answer the research questions, data generation methods for empirical data, and finally, data analysis.

The selected components (squares in Figure 3.1) for this project are highlighted with a green border and detailed further below.

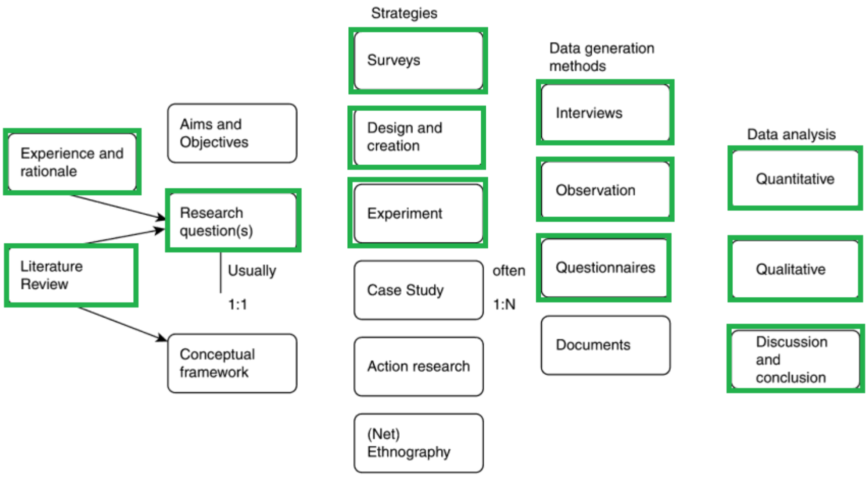

Figure 3.1: The research process model from [1]. Squares with green borders show what components are used in this project.

3.2.1 Prestudy components

The experience and rationale (motivations)

There are many reasons to do research. The first question one must ask oneself is why they are doing it. Experiences and motivation with factors like likes, dislikes, strengths, and weaknesses are instrumental in forming research questions [1]. The research process started with the prestudy produced by the experiences and rationale and the task description.

Our motivation and experience for this project are covered in Chapter 1. In addition, both authors are interested in and motivated to contribute to exergame research.

Literature review

In every academic research project, the researchers have to review the existing literature in the chosen area of study, whether it is journals, articles, books, or conference papers [1]. The literature can be on previous studies or other artifacts like existing exergames and available exergame development technology. A literature review is also helpful to find out where there are gaps in the knowledge base, topics to be addressed, or in the *exergame market*, which helps the researchers to place their project in a context and guide the forming of research questions. The discovered literature also needs to be evaluated and analyzed for patterns and themes which can link different authors' work together [1].

The literature review results serve as guidance in decision-making when designing a new exergame and highlight where there is insufficient domain knowledge, nudging our research question in the direction of exploring less-visited themes within exergaming. A literature review can be used throughout the project, even after the research questions have been formed, to be updated with the most recent available literature relevant to the project.

For the performed literature review, we will look at accredited publications examining the potential health effects of existing exergames and some papers on exercise theory, game enjoyment, game development, game genres, and available technologies. We will also include some facts on existing exergames and the genre history. The information from the literature review will be commuted to knowledge relevant to the research questions and goal in the discussion part of this paper.

Web of Science, Scopus, and Google Scholar are digital libraries available for students and are used to discover research papers, books, and other relevant sources. Our supervisor was also influential in pointing us towards some valuable sources and previously performed literature reviews on the field. The literature review will be used and updated after the research questions are formulated, persisting to the end of the research project to include the latest and most updated knowledge on the field. The contents of the literature review are found in Part II. All used sources will be subject to critical evaluation on credibility, acknowledgment, peer review, and consistency against other sources.

The research questions

As stated in Section 3.1, the research questions make up fully or partially a research goal. The settled research questions are more specific to an issue within the research topic. They are motivated by the experience, rationale, and literature review, as Figure 3.1 suggests.

This suggestion is followed in part in this project as the research questions are partly answered by the literature review and not only by its product. RQ3 and RQ4 are based on our rationale and experiences and the literature review from Part II, while RQ1 and RQ2 were produced not from the finished literature review but answered by it.

The culminated research questions have been presented in the previous section. The research goal was in this project determined based on the motivation from Chapter 1 and the project task stated in Chapter 2.

3.2.2 Strategies

The research strategies are the overall approaches to answering the research questions. We have selected three strategies: survey, design and creation, and an experiment.

Survey

A survey is used to obtain standardized data from a larger number of people. The data can then be analyzed by looking at patterns using statistics, which hopefully can be extrapolated to a larger population than just the people who answered the survey [1].

The survey in this project will be a prospective one and part of the prestudy. It will be spread widely to students at NTNU and further to our social networks. The survey is based on the respondents' attitudes and beliefs about exercise and physical activity, video games, and exergames. See Chapter 13 for details on the execution and results.

Design and creation

This strategy is about developing new technology, a product, an artifact, an information system, an application, an intelligent device, or another form of a computer-based system. These artifacts can be divided into four types [1]: constructs, models, methods, and instantiations.

After concluding the prestudy, an exergame concept will be chosen from one of many produced new concepts. It will be subjected to some light feasibility testing before an exergame prototype is finally developed. The reviewed material will heavily influence the choice of concept and technologies used in the prestudy, such as game genres, existing exergames, and available technology. When developing the prototype, prominent game design theory will heavily influence the decisions that must be made. The developed prototype will be an instantiation artifact type, meaning implementing an IT system demonstrating ideas, genres, constructs, or models in IT [1].

The chosen concept is covered in Part III and the prototype is covered in Part IV.

Experiment

An experiment explores cause and effect relationships to test a hypothesis or prove or disprove a link between a factor and outcome. Experiments should also be performed in controlled environments, but if it is not, not all influencing variables can be controlled and accounted for. This is called a quasi-experiment [1].

This project tests the developed prototype on real test subjects. The design, execution, results, and more from the experiment/quasi-experiment are covered in Part V.

3.2.3 Data generation methods

Questionnaires

Questionnaires consist of questions given to a test subject/respondent. They are often a source of quantitative data, having the respondents provide numerical answers or category answers, but can also provide qualitative data by including free text questions. There will be sent out two questionnaires as part of the experiment; one before the experiment and one after. They are considered the primary data generation method as they prove helpful when researching profiling of situations to develop overall patterns and are integral in answering most relevant research questions [12]. The answers can be compared when presenting answers to the same question from both questionnaires.

The questionnaires will include questions about demographics, along with gaming, physical activity, and exergame habits. The post-experiment questionnaire also aims to determine whether the test subjects' physical activity habits changed and how they enjoyed and interacted with the prototype. A respondent ID will connect the two questionnaires by enabling us to link a pre-experiment questionnaire answer with an answer from the post-experiment questionnaire when the answer originates from the same test subject.

Interviews and observations

Interviews and observations are two data generation methods from Oates' model, mainly providing qualitative data.

During *observations*, a subject is watched while acting by an observer taking notes. The observer is key to increasing the data validity as it provides an external and more objective view of the test subject's actions and does not have the generated data be exclusively subjective from the test subject's perspective.

Interviews are a conversation consisting of questions from a researcher and answers from a test subject, where the researcher is mostly in control of the discussed topics. Interviews can discover more in-depth knowledge than what the respondent answers in the questionnaires. The questions should favor the test interviewee to reveal their thoughts and feelings about the prototype they just tried. Therefore, the questions should be open-ended and aim to make the interviewee feel comfortable and rewarded for accurately describing their thoughts and feelings on the prototype. The interviews should also be semi-structured to allow for new questions not thought of beforehand to be asked, in addition to the planned questions.

During the experiment, observations and semi-structured interviews will be performed jointly to get more qualitative data on how test subjects interact with the exergame prototype. Their feelings, thoughts, reactions, and actions while and directly after playing the prototype will be noted and presented in Chapter 29.

Further details on the performed data generation method activities are found in Chapter 27 and Chapter 28.

3.2.4 Data analysis

Quantitative data

When the generated data is numerical, it can be statistically analyzed and presented in charts and tables to look for patterns that can be used in discussions and conclusions. The quantitative data in this project consist of data from the two questionnaires, the survey, and game usage data from the prototype's server and database, describing the actual usage of the prototype.

Qualitative data

Qualitative data is data that is observed or describes a phenomenon. Suppose the generated data is text or consists of other non-numerical media. In that case, it needs to be interpreted by the researchers to find patterns or other notable observations that can help discuss and answer the research questions.

The qualitative data in this project consists of observations, quotes, and experience descriptions from the performed playtime observations, quotes from the interviews, and free text answers from the survey and questionnaires.

Discussion and conclusion

By having both qualitative and quantitative data, we can compare the patterns from the two sources to validate the data and the process. This validation is often called the triangulation method [13] [14].

If the qualitative and quantitative data suggest the same or similar conclusions, the conclusion can be drawn more confidently, even if the conclusion states that more research is required. This triangulation provides a better understanding of the discovered patterns by inspecting them from different viewpoints.

After the data is analyzed, the findings need to be discussed, and conclusions need to be drawn [1]. Researchers should contemplate how to interpret the analysis and the implications their interpretations would have on the current understanding and knowledge base. In addition to outlining the findings, the research questions and goal should be referred back to evaluate whether the research questions can be answered and if the research goal is met.

The discussion should also address research limitations, make recommendations for future research, and conclude to the best of the researcher's ability. This project's discussion and conclusions are found in Part VI.

Chapter 4

Reader's Guide

This section will overview the report's structure, detailing each part's contents. The report is made up of six main parts.

Part 1: Introduction The introduction begins with the motivation for the project, then details the project task and context. Further, the research questions and goal is defined, and the research method is presented. The part is suited for readers interested in the project's motivation and purpose.

Part 2: Prestudy The prestudy contains an introduction to exercise and physical activity and a walkthrough of the history of exergames. The part also gives a more detailed walkthrough of the most popular exergames and discusses research that has been conducted on these games. The part also contains a walkthrough of potential game genres and technologies for an exergame. Lastly, the part contains a review of game design elements and a summary of a survey exploring people's habits concerning games, exercise, and physical activity. The part is suited for readers interested in the exergames' theoretical foundation.

Part 3: Concept This part contains a discussion of the prestudy and information related to the development of the exergame concept. First, the most critical findings from the prestudy will be summarized and discussed. Different game features and potential concept ideas are then reviewed before giving a more detailed walkthrough of the chosen concept, Paint it Green. The chosen technologies are discussed before lastly reviewing the feasibility testing process. This part is suited for readers who are interested in the game concept and wants a thorough walkthrough.

Part 4: Design and Implementation This part focuses on the design and implementation of the prototype. It covers the development methodology and process through the implementation phase with design choices and sketches before reviewing the chosen requirements and architecture of the prototype. Further on, all significant features of the implemented prototype will be presented along with a closer look at some central aspects. Usability testing and evaluation of the prototype and requirements are also included. The part is based on the specialization project on exergaming written in the autumn of 2021, before this thesis. This part is suited for readers interested in the prototype's implementation and technical aspects.

Part 5: Experiment and Results This part focuses on the design and execution of the experiment. It explains how the experiment collected and generated data and how test subjects were recruited and given access to the prototype. The results are presented and analyzed before reliability and validity concerns are discussed. This part is suited for readers interested in how the research data was gathered and what the data showed.

Part 6: Conclusion and Discussion This part concludes the master thesis. It discusses the findings from the previous parts before a conclusion is presented. Finally, further work is discussed concerning the thesis and future exergame research. This part is suited for readers interested in the research results and what the results imply.

Bibliography

Appendix A: Survey - Questions and results Lists all questions and a graphical representation of the answers from the survey.

Appendix B: Pre-Experiment questionnaire Lists all question statements in the pre-experiment questionnaire.

Appendix C: Post-Experiment questionnaire Lists all question statements in the post-experiment questionnaire.

Appendix D: Experiment data processing and storage agreement Displays the consent form on data processing and storage, agreed upon by all test subjects in the experiment.

Appendix E: Approved NSD application The application sent to NSD for storage and processing of the data for the experiment.

Appendix F: Complete observation report Includes the full report with all notes taken during the four observations in the experiment.

Appendix G: All game dialogue States all dialogue in the implemented prototype's story.

Part II

Prestudy

This part details the prestudy of the project. The prestudy contains an introduction to exercise and physical activity and a walkthrough of the history of exergames. The part also gives a more detailed walkthrough of the most popular exergames and discusses research that has been conducted on these games. The part also contains a walkthrough of potential game genres and technologies for an exergame. Lastly, the part contains a review of game design elements and a summary of a survey exploring people's habits concerning games, exercise, and physical activity. The part is based on the specialization project on exergaming written in the autumn of 2021, before this thesis.

Chapter 5

Exercise and Physical Activity

Humans go back far. Remains of our human-like ancestors go back as far as 3.5-3.8 million years ago. Almost 4 million years of evolution produced the modern humans, Homo Sapiens, approximately 35.000 years ago. A million years ago, hunting and gathering was the way of life for human beings, a lifestyle with high energy expenditures several days a week. Even after domesticating plants and animals 10.000 years ago and the industrial revolution, most people still had a high energy expenditure compared to the end of the twentieth century. Human energy expenditure declined during the twentieth century, especially after World War II. The reasons for this decline include increased automotive transportation, sedentary activities becoming more popular, and jobs that previously had significant energy demands becoming less strenuous because of progress in mechanization and automation [15].

> ”From a genetic standpoint, humans living today are Stone Age hunter-gatherers displaced through time to a world that differs from that for which our genetic constitution was selected [16].”

Physical activity reduces the risk of dying from many chronic diseases and improves function. A study concluded that if the most unfit part of the population started walking 30 minutes per day or used the energy equivalent, they would see significant health benefits [15].

5.1 Current state of physical activity and exercise

The Norwegian Institute of Public Health states that children should participate in moderate to high-intensity physical activity for at least sixty minutes a day, referencing the Norwegian Directorate of Health [17][18]. They should also participate in high-intensity activities at least three times a week, including activities that increase muscle strength and strengthen the skeleton. They further see that for 6-year-olds, about 90% meet these requirements, while the number falls to 80% for 9-year-olds and 50% for 15-year-olds. In all age groups, the girls are less active than the boys.

For adults, the Norwegian Directorate of Health recommends being moderately active for at least 150 minutes a week, which means activities that result in a higher heartbeat than usual, such as quick walking. The recommendation would also be met by doing 75 minutes of high-intensity activity per week or combining moderate and high-intensity activity. According to their data, only about 30% follow this recommendation, with adults on average sitting still for nine hours each day. Among adults, they found no difference in activity levels between 20-year-olds and 64-year-olds. The average activity level fell after hitting 65 and had an ever steeper fall after 75.

They conclude that it is beneficial from a health perspective to reduce the time used for sedentary activities and increase the time used for physical activities with moderate intensity.

5.2 Consequences of inactivity

The World Health Organization has concluded that physical inactivity (defined as not following the daily activity recommendations) is one of the leading risk factors for noncommunicable diseases [19]. Some estimates show that if it is possible to eliminate physical inactivity from the population, it will estimate a reduction of nine percent of all deaths [20]. Data shows that physical inactivity affects early death (before the age of 70) due to cancer and cardiovascular diseases [17]. Further physical inactivity is also strongly related to higher risks of diseases like type 2 diabetes, high blood pressure, and brain stroke. Severe sedentariness is connected to an increased risk of becoming disabled for people over 60 living at home [21].

5.3 Defining physical activity and exercise

There is a difference between physical activity and exercise, and due to them being principal terms in this paper, explicit definitions should be made:

Physical activity is any bodily movement produced by the muscles that result in energy usage [22, p. 126]. Physical activities include mowing the lawn, driving a car, sitting down, or painting pictures. Sleeping is also a physical activity, although it is very sedentary [23]. However, *exercise* can be defined as doing some physical activity intentionally to either improve or maintain physical fitness with a planned, repetitive format [22, p. 126].

Further, physical fitness is divided into two groups; one is related to health, the other to skill. The health group contains components like cardiorespiratory endurance, strength, and flexibility. The skill group contains components like agility, balance, coordination, and reaction time, meaning that physical activity working on these components may include certain sedentary activities [22][23].

5.4 Different types of exercise

Exercising can be done in different ways for various health benefits. This section covers the four main types of exercise to distinguish the differences between them and the benefits of each one [24].

5.4.1 Aerobic exercise

Aerobic exercise speeds up a person's breathing and heart rate and is essential for many bodily functions, as it increases endurance by focusing the heart and lungs [25]. Aerobic exercise is any activity sustained over a more extended period, training how efficiently the muscles can take up oxygen [26]. Exercise types include activities like walking, running, swimming, and dancing. Aerobic exercise has several benefits, like helping relax blood vessel walls, lowering blood pressure, burning body fat, lowering blood sugar levels, boosting mood, and raising "good" HDL cholesterol. Aerobic exercise has several long-term benefits, like reducing the risk of heart disease, stroke, type 2 diabetes, and breast and colon cancer. A study found that as well as improving their aerobic capacity, aerobic exercise also helped female people reduce their depression [27].

Several exergames focus on aerobic exercise, primarily walking and running. Pokémon Go and other location-based games encourage walking around a player's local environment to progress in the game while Zombies, run! encourages the player to physically run to outrun a horde of zombies in the game. More details on these games can be found in Chapter 9.

5.4.2 Strength training

Strength training builds muscle mass. The exercises make the muscles work harder than usual, which increases the muscles' strength, endurance, size, and power [28]. It also helps stimulate bone growth, lowers blood sugar, assists with weight control, improves balance and posture, and reduces stress and pain in the lower back and joints [25]. Strength training is anaerobic, which means exercises that demand much energy in a short time. Meanwhile, the heart is not producing enough oxygen for the muscles; anaerobic exercises thus often have a short duration. Exercise types include lifting weights, body mass exercises like push-ups and pull-ups, lifting grocery bags, and doing heavy gardening.

Exergames focusing on strength training include Exermon, where players have to perform different strength exercises to train and evolve their exermon. Ring Fit Adventure features strength exercises focusing on different body parts, which the player must perform to defeat enemies and play minigames. More details on these games can be found in Chapter 9.

5.4.3 Flexibility training

Aging leads to reduced flexibility in tendons and muscles. As we age, the muscles shorten and stop functioning properly, which leads to an increased risk of muscle cramps, muscle damage, and joint pain. The reduced flexibility also hinders getting through everyday activities like bending down to tie shoelaces [25].

By stretching the muscles, they get longer and more flexible, increasing the range of possible motions and reducing the risk of injury and pain. Before doing flexibility training, one should warm up with some minutes of dynamic stretches, making blood and oxygen flow to the muscles, making them more amenable to change. Flexibility exercises include stretching, both static and dynamic. Static stretching means holding the stretching position for a certain amount of time, while dynamic stretching means doing the stretching movement actively [29]. Flexibility training also includes doing yoga.

Exergames focusing on flexibility include the Wii Fit series, which includes different flexibility activities and yoga. Ring Fit Adventure also features Yoga exercises the player has to perform to defeat enemies and play specific minigames. More details on these games can be found in Chapter 9.

5.4.4 Balance training

Balance training is essential as balance is a part of almost every movement made in an upright position. Balance training makes people more steady, helps prevent falls, and improves general health [30]. It involves doing exercises that strengthen the muscle groups assisting the body in keeping itself upright, including the legs and core [31]. Balance exercise types include exercises like standing on one foot, walking heel to toe, and doing yoga.

According to the WHO, 684 thousand people die each year globally from falling. People above the age of 60 have the highest risk of falling [32]. Balance training helps prevent falls and injury [30]. Balance is also crucial for anyone seeking to become an athlete, as balance is crucial in sports like snowboarding, skiing, and ice-skating. Finally, balance training can help prevent ankle sprain and improve the healing process when recovering.

Exergames focusing on balance include the Wii Fit series, which includes several balance activities and minigames, and features yoga. As mentioned in the previous subsection, Ring Fit Adventure features Yoga exercises the player has to perform to defeat enemies and play specific minigames.

5.5 Summary

Physical activity has several essential health benefits, and so does therefore exercise. There is, however, a difference between physical activity and exercise. While physical activity is any bodily movement produced by the muscles that result in energy usage, exercise is doing physical activity to improve one's fitness. Furthermore, there are four main types of exercise, each with its health benefits and different activities. All main types of exercise have been featured in different exergames. Finally, there are negative consequences of inactivity, and the Norwegian government finds that only 30% of adults follow their physical activity recommendations.

Chapter 6

Game Genres

Games exist across multiple genres of varying popularity. Note that separating games into a meaningful taxonomy of genres is not always straightforward, as genres usually overlap, and most games can fit into several genres. This section will briefly introduce some of the most common game genres, with examples of popular games in each.

6.1 Action games

Action is a genre of video games where players must battle enemies with their skills, weapons, and tools [33]. The player is usually in control of a character and must navigate a level while battling the enemies. At the end of each level or series of levels, the player must often fight a more challenging enemy, the boss. The boss enemy is often a primary antagonist in the game's story. Enemy attacks often lower the player's health, resulting in death should the player's health run out. Some action games put players against each other rather than enemies controlled by artificial intelligence (AI). A core element of action games is emphasizing physical challenges like hand-eye coordination and reaction time.

Famous action games include the God of War series (see Figure 6.1) and the Ninja Gaiden series.

Figure 6.1: Combining greek mythology with fast paced combat, God of War become a large franchise.

6.2 Role Playing Games (RPGs)

Role-Playing is a genre of video games distinguished by the player controlling the actions of one or more characters while being immersed in a well-defined game word. The genre often allows the player to develop their character as they play, either by affecting their character in the story by making choices or in gameplay by leveling up their character and selecting different skills to focus on [34]. The genre's origins can be traced back to table-top RPGs, Dungeons and Dragons being the most famous example [35]. RPGs are played offline as single-player games and online through the internet. Massively Multiplayer Online Role-Playing Games (MMORPGs) are a sub-genre of RPGs focusing on communication and social interaction, with up to thousands of players colocating in a shared virtual game space.

Famous RPGs include The Elder Scrolls V: Skyrim (see Figure 6.2) and World of Warcraft.

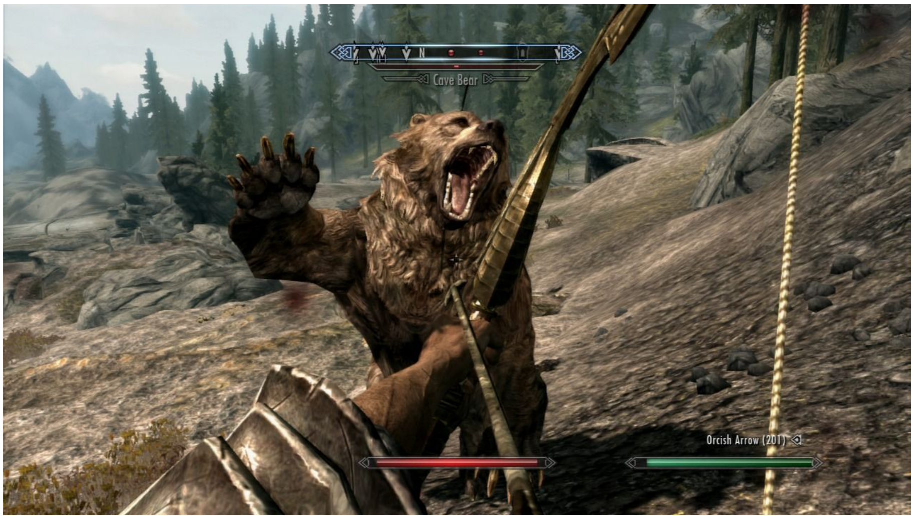

Figure 6.2: Skyrim puts the player in a massive world to explore.

6.3 Shooter games

Shooter games are distinguished by the player having to defeat several enemies using weapons given to them throughout the game. Most weapons are firearms of some sort, but these can often be used in combination with melee weapons, grenades, or other types of weapons [36]. Many shooter games require the player to keep track of their ammunition, with guns using ammunition as they are fired while the player can pick up ammunition throughout the game. Shooter games can be played as a single-player game, with the player playing against AI enemies, or multiplayer, either online or offline, with the player playing against other people. Many popular shooter games include a single-player and a multiplayer component, while other shooter games are specifically designed for one type of play.

Famous shooter games include the Halo series (see Figure 6.3) and the Call of Duty series.

Figure 6.3: Halo allows the player to either play a story alone or with another player, or multiplayer against other human players.

6.4 Strategy games

Strategy games are video games that focus on skillful thinking and planning for the player to win. The games often require tactical, economic, and strategic challenges, as well as exploration [37]. The player must plan their actions to win against one or several opponents, either AI-controlled or other human players. The goal is often to reduce the enemy forces or attack a key enemy location. Strategy games are often divided into two main categories, **turn-based** and **real-time**, depending on if the game's events unfold in a real-time or turn-based manner. Some strategy games are competitive, being played as e-sports with large prize pots and many spectators watching live games.

Famous strategy games include the StarCraft series (see Figure 6.4) and the Civilization series.

Figure 6.4: StarCraft 2 is a science-fiction real-time strategy game, letting players play against AI or each other.

6.5 Sports games

Sports games are a genre of games simulating real-life sports. Sports games try to simulate their real-life counterparts with varying grades of realism. Some games try to achieve a high grade of realism, while others go for an experience distinct from the actual sport [38]. An example can be seen with driving games, with the Gran Turismo series trying to simulate the driving experience more realistically, while the Need for Speed series adds extra gameplay elements that distinguish the gameplay experience from real-life driving. Sports games like Fifa (see Figure 6.5) emphasize playing the sport, while other games focus on management and strategy (games like Football Manager and Out of the Park Baseball). They have been based on sports like football, tennis, handball, and ice hockey. Several sports game series feature real-life athletes and teams, with annual updates to the series to reflect real-world changes [**?**].

Figure 6.5: The FIFA games ephasize playing football against AI or other players.

6.6 Puzzle games

Puzzle games are a genre of games that emphasize puzzle-solving. The games might test various skills, like logic, pattern recognition, sequence solving, spatial recognition, and word completion [39]. While other game genres, such as action games, often include some puzzle aspects, the puzzle game genre uses puzzle-solving as its main gameplay activity. Puzzle games often present players with multiple series of puzzles, each with its own theme. Completing puzzles often lead to more difficult ones.

Famous puzzle games include Tetris (see Figure 6.6) and Candy Crush Saga.

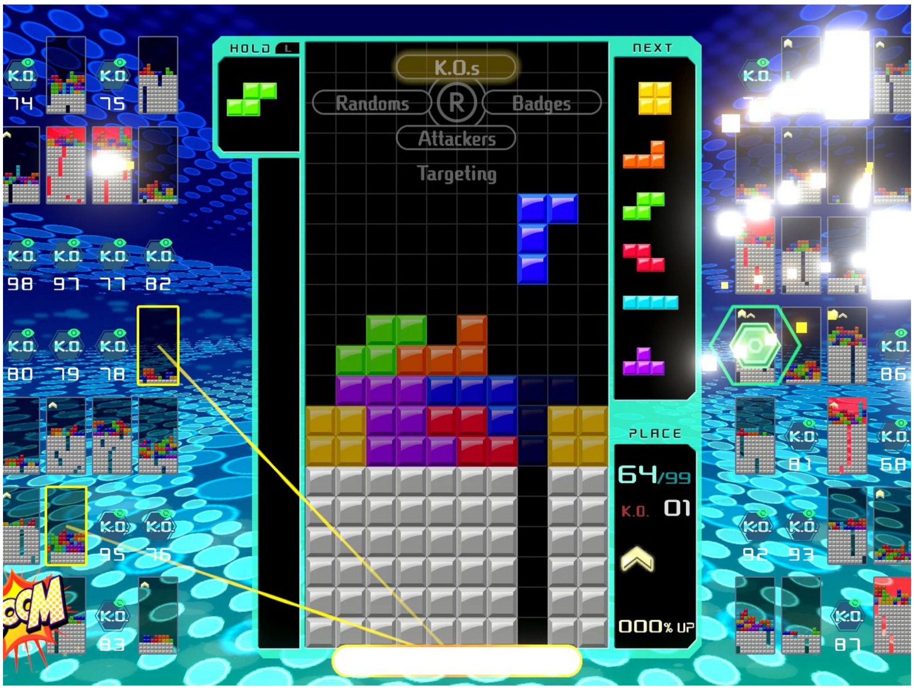

Figure 6.6: Tetris has become one of the most selling games of all time.

6.7 Adventure games

Adventure games are a genre where the player assumes the role of a character on an adventure, often participating in puzzle-solving and exploration [40]. The player is given the role of the protagonist in an interactive story. The genre often focuses on story, drawing from other narrative-focused media like film and literature. As a result, many adventure games are designed only for a single player, as a significant emphasis on the story makes designing for multiplayer complex. Adventure games rarely include combat elements, which distinguishes them from action games. However, many games borrow elements from action and adventure games, resulting in the action-adventure hybrid genre being one of the broadest genres in video games.

Famous adventure games include Telltale's The Walking Dead (see Figure 6.7) and the Monkey Island series.

Figure 6.7: The Walking Dead's focus on choices impacting the story led to it becoming a huge success.

6.8 Platforming games

Platforming games are a genre where the main objective of the game is to move a character between points in the game environment [**?**]. The level design of platforming games often features uneven terrain and platforms in the air that requires the character to use abilities like jumping or climbing. Games might also include other maneuvers like swinging and gliding through the air. Platforming games can either be presented from the side, using two-dimensional movement or in 3D, with different camera angles. Platforming games often include some form of combat with enemies, allowing the player to punch or jump on enemies.

Famous platforming games include the Super Mario Bros series (see Figure 6.8) and the Sonic the Hedgehog series.

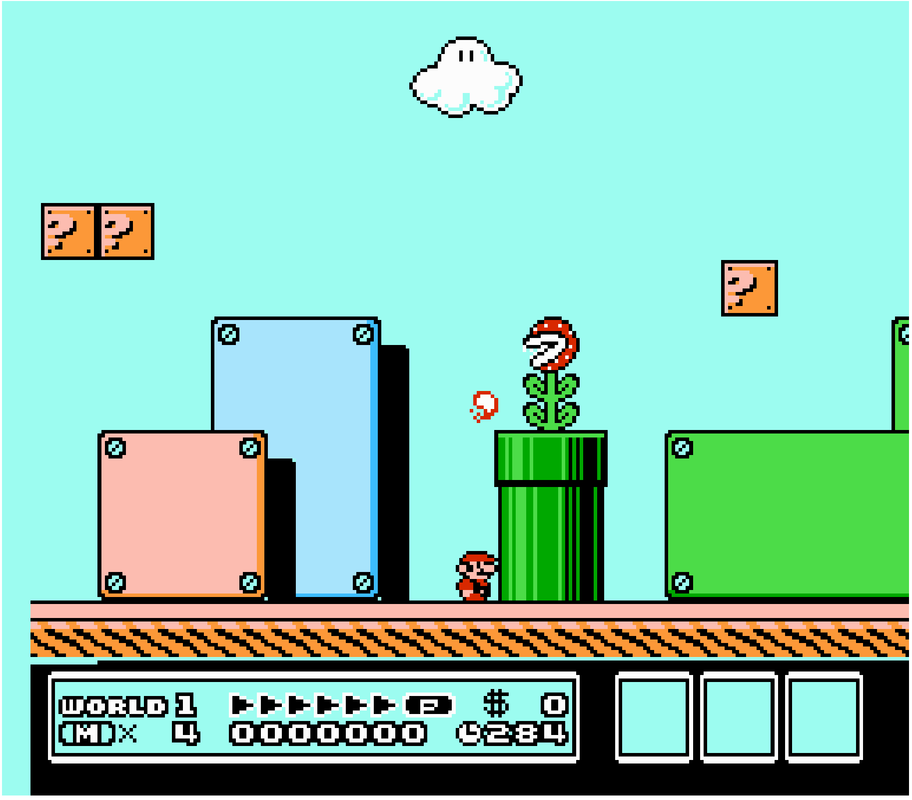

Figure 6.8: The Super Mario bros series led to Mario becoming one of the most iconic game characters.

6.9 Simulation games

Simulation games are a genre of games mainly designed to simulate real-life activities [41] accurately. Simulation games attempt to copy real-world activities like war, business, or family life. Often, there are no defined goals in the game, allowing the player to freely control the game's interactive elements.

Famous simulation games include the Microsoft Flight Simulator series (see Figure 6.9) and The Sims series.

Figure 6.9: Microsoft Flight Simulator allows players to fly across a simulated version of the real world.

6.10 Summary

Games exist across multiple genres, and while separating them into each genre is not always straightforward, some genres should be recognized. Action games are known for players battling enemies, while Role-Playing Games are distinguished by the player playing a character while immersed in a well-defined game world. Shooter games make players defeat enemies with firearms, unlike Strategy games, which focus on skillful thinking and planning. Sports games try to simulate real-life sports, while puzzle games emphasize puzzle-solving. Adventure games let the player assume the role of a character on an adventure, and platforming games focus on movement in the game environment. Finally, simulation games try to simulate real-life activities accurately. We feel like most of the genres would fit to create an exergame.

Chapter 7

Exergames

This chapter will discuss the concept of exergames, giving a definition and a history of exergames from the 1980s to the 2020s.

7.1 What are exergames?

One might believe that defining exergames is quite simple, but in reality, it is more complex than first thought. The word is a portmanteau of exercise and game, which encourages one to assume that the word means games that require exercise. However, the definition is not quite as straightforward.

Oh found that the term exergame perhaps started without considering the definition of exercise [23]. Most of the research literature quoted used the term to describe video games requiring physical activity to play. Even though the term exergames often refers to exercise, many researchers use the word interchangeably with physical activity [23]. As discussed in Chapter 5, this makes a difference, as physical activity and exercise are different.

Using the definition of exercise explained in Section 5.3, exercise is doing some physical activity intentionally to improve fitness with a planned, repetitive format [22]. Using this definition, we know physical fitness consists of several components, two of which are reaction time and coordination. Using a definition of exergames that requires the player to exercise, and not just be physically active, might define playing a first-person shooter for hours sitting down as exercise. While playing a first-person shooter might improve coordination and reaction time, it is a sedentary physical activity, and considering games with this playstyle as exergames is not optimal.

Another issue is that for an activity to be an exercise, it has to be done intentionally to improve one's physical condition. If two people are playing, e.g., Just Dance together, one with the intention of losing weight and the other to have fun, just one of them is doing exercise, even though both of them are physically active in the same way and spend more energy than they would have by remaining sedentary. The person's intention thus matters when describing exercise.

If we instead consider exergames as games requiring moderate physical activity, there are more emerging issues, as the intensity of the activity has to be considered. If we assess the intensity in absolute terms, moderate to vigorous intensity is at least 3.0 metabolic equivalents (MET), where "a MET is the ratio of the rate of energy expended during an activity to the rate of energy expended at rest. [42, p. 54]". Walking at 3 miles per hour is equivalent to 3.3 METs, and would feel quite different for an obese person compared to an average-weight person in good physical condition. We consider this definition suboptimal, as it could lead to a game requiring that an obese person becomes exhausted to be counted as an exergame, while an average-weight person would not.

Instead, we can consider relative intensity. The 2008 physical activity guidelines used the simpler definition: “relatively moderate-intensity activity is a level of effort of 5 or 6 on a scale of 0 to 10, where 0 is the level of sitting, and 10 is maximal effort. Relatively vigorous-intensity activity is a 7 or 8 on this scale” [42] p55. If one tried playing Pokémon Go or Wii Fit to train one’s balance, the player would probably not meet this level of effort. Considering the energy expenditure is not optimal either.

Oh proposes a new definition of exergames and exergaming, which will be used in this report. The definition states: ”An exergame is a video game that promotes (either via using or requiring) players’ physical movements (exertion) that is generally more than sedentary and includes strength, balance, and flexibility activities [23].” Exergaming is an activity where playing an exergame is used to promote physical activity. The physical activity should not be sedentary and includes strength, balance, and flexibility activities [23].

7.2 Exergames history

This section discusses the history of exergaming. It briefly describes the most important exergames released during the last decades and some observations of patterns in the exergame industry throughout its history.

7.2.1 The 1980s

The most agreed upon inception of exergames was in 1980 when Atari released the JoyBoard as an extension for their Atari 2600 console [43] [44]. In Figure 7.1 one can see the JoyBoard as a balancing board, where the player controls the game by leaning in different directions. It was designed for use in a snow skiing game but was never a commercial success [44]. As with many early exergames, the physical exertion on the players was relatively primitive and only focused on a specific motor skill. As described later in this section, this prospect is due to change over the evolution of exergames.

Figure 7.1: The Atari JoyBoard

Not long after the release of the JoyBoard, Atari developed a project called *Atari Puffer* [45]. It was a system that would use a stationary bicycle where stepping on the bicycle’s pedals would influence the game being played in the Atari console, as showcased in Figure 7.2. Although the project was never released to the market due to internal changes within Atari, similar products followed [46].

Figure 7.2: The Atari Puffer

A study [47] reveals the rationale of the game development companies for investing their resources into exergames as trying to combine two of the most important markets of that era: video games and fitness. It states that a whole generation of children are not very attached to sports and physical activities, and at the same time, there is a vast market in the fitness industry. Many children were addicted to video games, and thus exergames could be seen as an aid towards a healthier lifestyle.

Later in the same decade, Nintendo released the Power Pad for their NES console, a plastic mat with sensors that could be stepped on [48]. It can be seen in Figure 7.3. Players would step on the different sensors to control the game being played. Several games were developed for the Power Pad, most of which focused on sports and dancing, but it never became a commercial success. A significant reason for this commercial failure was that the Power Pad's leading target group was athletes. However, it never became a success due to an inaccurate training system [43].

Figure 7.3: The Power Pad from Nintendo

In 1989, Nintendo released their Power Glove: a glove that contained motion sensors and was worn by the player, as can be seen in Figure 7.4 [49]. It was released for the NES console. The motion sensors could register the position and movement of the player's fingers. The Power Glove was successful for a short period of time, but it was only available commercially for the better part of a year [46].

Figure 7.4: The Power Glove from Nintendo

7.2.2 The 1990s

In 1992 the Tectrix VR Bike and VR Climber were released [43]. As can be seen in Figure 7.5, it was a bicycle game where the player controlled the game by stepping on the bike's pedals. It is considered the first virtual reality (VR) game because the machine blew air from the bottom of the screen towards the player to simulate outside cycling [43]. The Tectrix VR Bike and similar devices were never successful, mainly because they were costly. The virtual environments available were produced and stored on compact disks.

Figure 7.5: The Tectrix VR Bike

The early exergames never became great successes. Neither for home systems, in arcades, gym studios, or other environments, often due to the price of the machines [43]. However, in 1998, Dance Dance Revolution was released and became a massive success in arcades and later in homes and schools [50]. Dance Dance Revolution is described in more detail in Section 9.1.

7.2.3 The 2000s and 2010s

With the new millennia came more advanced and cheap technology. In 2002, Sony released the EyeToy, a small camera connected to the Playstation 2 console, showcased in Figure 7.6 [51]. The camera tracked the player's motions, and several games were available for the EyeToy. Thus, exergames could track movements of the whole player's body and not just what body parts were interfacing with the physical machine of the exergame. The EyeToy performed well commercially but never had a major blockbuster game release [46].

Figure 7.6: The Sony EyeToy with some Playstation 2 games

With the new opportunities from improved hardware and software, the exergames adopted more modern game theories, e.g., flow theory and immersiveness tactics [43]. In addition, exergames started adopting a broader approach to exerting players: Instead of focusing on the use of exergames to develop particular motor skills, the proposal was to present different interfaces, prototypes, and patterns where exergames were designed with the focus on an active living development against the typical sedentary style which was present in of the former video games. Active living is related to the search for the improvement of health and physical fitness through integrating physical activities in day-to-day life [43].

Thus, exergames encompassed a broader, more health-oriented approach compared to the strength-oriented machines of earlier exergames.

With the release of the Nintendo Wii in 2006 came the Wii Remote and nunchuck (see Figure 7.7), which could not only track the player's motions but also the acceleration of motions, to further improve the gameplay of exergames such as Wii Sports and Wii Fit [52]. Many Wii exergames also included features to promote active living, such as tracking calories burned, workout scheduling and reminders, and more. Helping players live healthier lives with more diverse exercises was prioritized over solely playing to step on sensors or bike pedals. Later exergames such as Fitness Boxing, Ring Fit Adventure, and Zombies, run! also share these features. See Chapter 9 for more details on these exergames.

Figure 7.7: The Nintendo Wii with the Wii Remote

In 2010 Sony and Microsoft released Playstation Move and XBOX Kinect to their consoles. Playstation Move used a handheld *wand* which tracked the player's movements, while the Kinect used only a camera, as can be seen in Figure 7.8 and Figure 7.9. The consoles Wii, Playstation, and XBOX now supported exergames with precise movement tracking of several body parts: arms, legs, head, waist, and feet.

Figure 7.8: Playstation Move wands

Figure 7.9: The XBOX Kinect

The quality and popularity of these consoles, especially the Wii, contributed to increased popularity in exergaming.

Coinciding with the evolution of smartphones, exergames for mobile units increased in availability and popularity. Improved software with better and more diverse sensors such as accelerometers and proximity sensors in the phones allowed for more diverse exergaming concepts [53]. Pokémon Go was released in 2016 and is perhaps the most significant success in exergame history. It is described in more depth in Section 9.5.

In later years VR technology has been further commercialized, which has opened new possibilities for exergames [54]. Today's VR headsets include Playstation VR, Windows VR, and Oculus Rift. See Figure 7.10 for what the Oculus Rift headset with its handheld controllers looks like today. VR technology especially allowed for improved player immersion because it takes up the entirety of the player's vision and lets the player visually navigate by physically turning their head. Beat Saber is an example of an exergame using available VR technology.

Figure 7.10: The Oculus Rift headset with handheld controllers

7.3 Summary

There are many considerations to consider when defining exergames for this research paper. The chosen definition of an exergame is a video game that promotes (either via using or requiring) players' physical movements, not including sedentary activities, but strength, balance, and flexibility activities.

Exergaming history starts in the 1980s and has undergone a significant technological and scopal evolution. From the Atari JoyBoard to VR Technology and smartphones, the software and hardware of exergames have improved massively. The focus of many exergames is not limited to enhancing and strengthening a specific motor skill of the player, but rather to encouraging active living and a healthier lifestyle.

Chapter 8

Theory on Game Design

This chapter will discuss designing an exergame to make it enjoyable and engaging. Several research papers will be examined and discussed to determine which game design elements should influence an exergame.

8.1 Challenge, fantasy and curiosity

This section will discuss the essential characteristics of good computer games, introduced in the paper "What Makes Things Fun to Learn?" [2]. The essential characteristics are divided into three categories: challenge, fantasy, and curiosity.

8.1.1 Challenge

The paper states that games must provide a goal whose attainment is uncertain for it to be challenging [2]. Several consequences can be drawn from this principle, the first being that a **goal** is essential in games. In another study, the author surveyed grade school children with previous computer game experience and found that the children preferred games with goals to games without goals. Another study found that fantasy made learning more interesting for children. The fantasy was designed to make the children use their learned knowledge to achieve a fantasy goal, rather than being the goal itself. It also made the goal a part of the fantasy. The study implies that video games may not be appealing, even with detailed environments, if they do not provide a goal for the player. The paper details four points related to goals:

- The goal should be obvious. The more obvious and compelling it is, the better. There are several ways to make a goal obvious or compelling, like using visual effects or fantasy.
- If the game does not have integrated goals, it should be easy for the player to create their own goals with appropriate difficulty. Programming is an example, as the programmer can start projects of appropriate difficulty.
- The best goals are based on fantasy or practicality, rather than on using a skill, like doing arithmetic problems in an educational game.
- A player needs to be able to tell when they are approaching the goal; this is called *performance feedback*.

The second consequence of the introductory principle is an **uncertain outcome**. A game is usually not fun if a player knows they will win, which is also valid for losing. There are four approaches to making the outcome of a game uncertain for players at various skill levels.

- **Variable difficulty level**. Video games should support different difficulty levels by automatically determining the difficulty based on player performance or letting the player choose it themselves. In multiplayer, where a player faces other human opponents, the opponent's skill determines the difficulty. Variable difficulty levels can be achieved in multiplayer games by putting the player against more skilled players the better they perform.
- **Multiple level goals**. Many video games have different goal levels. Players who easily succeed in reaching one goal level can still be challenged by another goal level. The game can achieve multiple level goals by including a basic goal, like getting the required level of points to unlock the next level in Angry Birds, and then introducing a meta goal, challenging the player to reach the basic goal optimally. An example of a meta goal is Angry Birds challenging the player to acquire enough points in each level to get three stars, as seen in Figure 8.1. The most common way of achieving multiple level goals is to utilize score-keeping, where the meta goal is to get as many (or few) points as possible, or speeded responses, where the meta goal is to achieve something as fast as possible.
- **Hidden information**. Games can hide information from the player and selectively reveal it to provoke the player's curiosity, making the game's outcome uncertain and contributing to the game's challenge.
- **Randomness**. Randomness makes outcomes uncertain, and while many gambling games use this to their advantage, it can also be used to make players more interested in other types of games. We see this principle used often in games with a loot mechanic, where players are motivated to kill or defeat certain enemies several times to get rare items that they have a chance to acquire by killing or defeating the enemy.

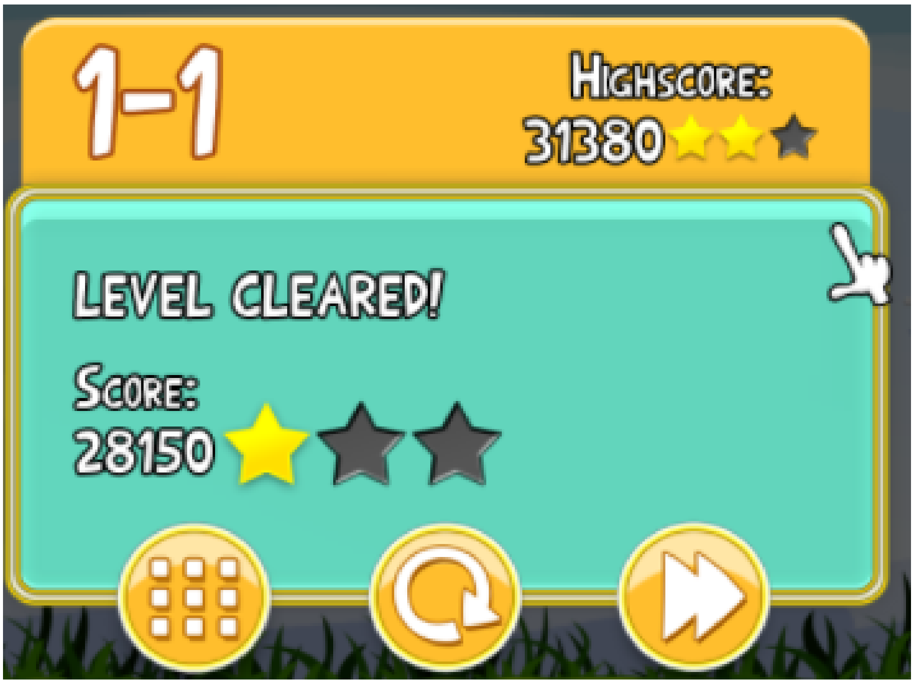

Figure 8.1: A player finishing the level but just getting one out of three stars in Angry Birds.

Finally, challenge in video games is interesting because it is relevant to the player's self-esteem. By succeeding in a game, the self-esteem is raised, but the opposite is also true, and if severe enough, it can make the player lose the desire to continue playing.

8.1.2 Fantasy

Fantasies can be utilized to make games more engaging. A relatively simple way to increase learning engagement is to overlay a test with a fantasy goal, like avoiding a man being hung in Hangman. In the example, the fantasy depends on the skill used, which is known as an extrinsic fantasy, contrasted by an intrinsic fantasy, where skill also depends on the fantasy, illustrated in Figure 8.2. Intrinsic fantasies present problems in terms of the fantasy world. The fantasy events depend on how the skill is used and how its use is different from the correct use. An example of an intrinsic fantasy is a game where the player must type in a number to throw a dart a certain distance to hit a balloon. If the dart misses, the player sees how far off the throw is and can adjust the distance accordingly. The problem is presented in terms of the fantasy, which is to hit a balloon, and the fantasy events depend on how far off the answer is; it is an intrinsic fantasy.

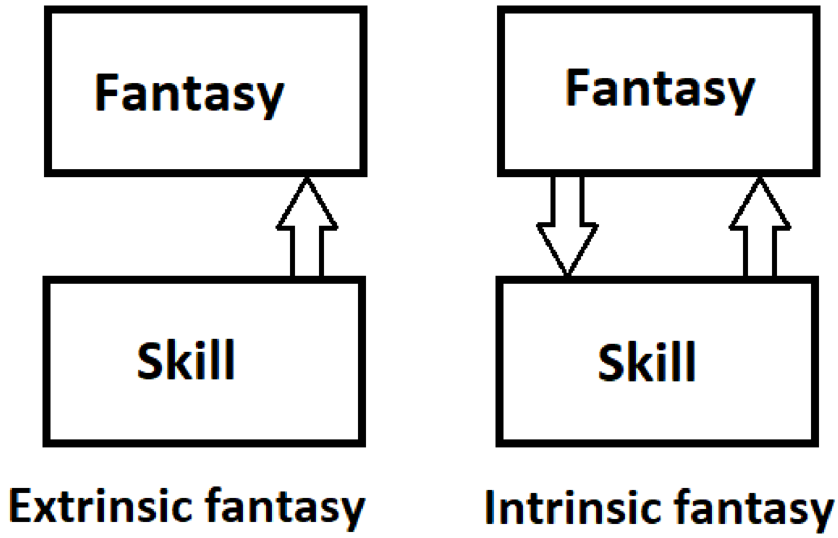

Figure 8.2: Logical dependencies in extrinsic and intrinsic fantasies [2].

An advantage of intrinsic fantasies is that they often indicate how a skill can be used to accomplish a real-life goal. Another advantage is that players can exploit analogies between the fantasy world and what they are learning; simulation games are examples of this (see Section 6.9).

Fantasies appeal to emotions, and some of their appeals derive from the emotional needs of those who play them. A consequence is that different people will find different fantasies appealing, like war games appealing to certain players, while others might prefer relaxing city-building games. If game designers can create different fantasies for different people, their games might have broader appeal.

8.1.3 Curiosity

Curiosity is a motivation to learn, independent from goal-seeking and fantasy-fulfillment. Games can evoke the player's curiosity by providing environments that are neither too simple nor too complicated, considering the player's existing knowledge. It is helpful to distinguish between two main types of curiosity: sensory and cognitive.

Sensory curiosity involves changes or patterns in light, sound, and other sensory-stimulating events that could attract a player's attention. Games can use audio and visual effects to appeal to the sensory curiosity of the player in several different ways:

- As decoration. Sound and graphics can be considered decorative when used independently of the player's actions.

- To enhance the fantasy. This is a particular case of decorative use that is not just captivating in its own right but also because of the fantasy associations it evokes.
- As a reward. Using sound or graphics as a reward for good performance can increase the salience of the goal and add to the challenge.
- As a representation system. Using sound and graphics to convey information more effectively than words is one of the most important uses. Modern games convey information through graphics alone, and sounds can give essential cues.

Cognitive curiosity is the desire to improve the form of one's knowledge structures. Players' curiosity can be engaged by presenting just enough information to make their current knowledge seem inconsistent or incomplete. The player is then motivated to learn more to improve their cognitive structures. An example is reading everything but the last chapter of a mystery book and then wanting to read the last chapter to bring completeness to the knowledge. Based on these ideas, two ways to make environments interestingly complex can be suggested.

The first is to engage a player's curiosity by making feedback surprising. An easy way to accomplish this is by using randomness. However, a more profound approach utilizes environments that seem surprising at first, but the underlying consistency is gradually revealed. The second way is to make feedback constructive. Feedback should help players see how to make their knowledge more complete, not just reveal that it is incomplete.

8.2 GameFlow

This section will discuss the GameFlow model, introduced in the paper "GameFlow: A Model for Evaluating Player Enjoyment in Games" [55]. GameFlow is a product of integrating existing heuristics of game design into a single validated and concise model to design, evaluate, and understand the enjoyment of games. The GameFlow model is based on the existing Flow model for an optimal experience and consists of eight elements, each including a set of criteria for achieving enjoyment [56].

8.2.1 Concentration

A player must be able to concentrate on the game for it to be enjoyable. The player's attention is completely absorbed when all relevant skills are needed to deal with a challenging situation. Games should grab a player's attention quickly and hold it throughout the game, which can be accomplished by providing something worth focusing on, like a complex game world. Maintaining the player's workload appropriately for cognitive, perceptual, and memory limits is essential. The game should not be filled with tasks that do not seem important, and distractions from game tasks should be reduced as much as possible. Reducing the game interface, like menus or heads-up displays, to prioritize game action is also a way to minimize distractions.

8.2.2 Challenge

Challenge is often seen as the most critical part of good game design. Games should match the player's skill level and provide a sufficient challenge at a proper pace. If a game's challenge level is greater than the skills of the player, it results in anxiety, and if the challenge level is lower than the skills of the player, the result is apathy [57]. Thus, games need to have an appropriate level of challenge.

Games must provide the player with a fitting series of unique and challenging situations calculated from thoughtful level and obstacle design. The game design should provide a positive experience that leaves the player wanting to play more. Player satisfaction in games comes from completing difficult tasks, challenging and defeating opponents, testing and mastering skills, reaching wanted goals, and coping with danger. Difficulty levels in games should also be variable to provide a correct level of challenge for all players. The difficulty should gradually increase as the player develops mastery to provide more challenge. Finally, the pace is important. The rate at which the games provide new challenges should be paced to provide tension and appropriate challenge levels. An appropriate pace pressures the player but does not frustrate them.

8.2.3 Player skills

Games should support the player's skill mastery and development to be enjoyable. Players must develop skills while playing the game to enjoy it, as their skills should match the game's challenge. Players can be taught how to play through absorbing tutorials or learn while playing, letting them learn the game at a measured pace.

Players should not need a manual to play; their current knowledge should be enough to start playing the game when turning it on. Games can assist the player while playing, but help should not be delivered through dialogue, as real-life elements attached to the game world might cause immersion breaks. Aside from direct methods of teaching players how to play a game, like tutorials, games can support player learning by being easy to use and learn. Game interfaces should follow the industry standard, and input devices must have a learnable button mapping. Games should use metaphors in the real world to help players understand how to interact with the game. An example of this is giving the horse a speed boost in The Legend of Zelda: Ocarina of Time, which uses the metaphor of giving the horse a carrot, shown in Figure 8.3.

Figure 8.3: Giving the horse a speed bost in Ocarina of Time uses the metaphor of giving the horse a carrot

8.2.4 Control

Players have to be allowed control over their actions to experience flow. They must be able to translate their intentions into the movement in the game and feel in control of how they explore the environments. The interface is also important, and players must experience control of it. The game controls should be simple enough to learn quickly and allow players to customize them to fit their play style. The game shell (the main menus) should be intuitively organized and easy to use to allow the players to explore the game how they want to. Game errors should be avoided to avoid players feeling a loss of control.

Players should feel an impact on the game's world, as though their actions co-create the world they are experiencing. Games with decisions that have significant impacts are more enjoyable to replay, as the player can experience another playthrough differently if making other choices. Games should not bother players with choices that do not feel important, as this would risk burdening the player.

A game that lets players play however they want puts them on the center stage. They are given freedom, a sense of agency, and greater control. Forcing the player to choose from a limited number of predefined options restricts the player's freedom. Players should feel control over their characters, and games should try to hide their linearity in structure. To immerse players emotionally, they need options for what they can do in the game. There should not be a single optimal way to win, but there should be a balance with multiple ways throughout the game and multiple paths to victory.

8.2.5 Clear goals

Games should have an objective or a goal, and this goal must be plain and comprehensible. The goal should be presented to the player early in the game. It is often done in an opening cinematic cutscene, establishing the story. During and after the introduction, the goal should be conveyed straightforwardly. If the game has different levels, they should each have their own goals, which can be presented through "briefings" at the start of each level.

8.2.6 Feedback

Players should receive fitting feedback at appropriate times. Feedback needs to be provided frequently to determine progress towards the goal. Players should also be given feedback when they lose to tell them if they are on the correct path. Games can use scores to encourage game mastery, and game interfaces and sounds can be used to provide feedback on the player's status. An example of the latter is in the Pokémon game, where a status-effect on a Pokémon is shown under their health bar, shown in Figure 8.4.

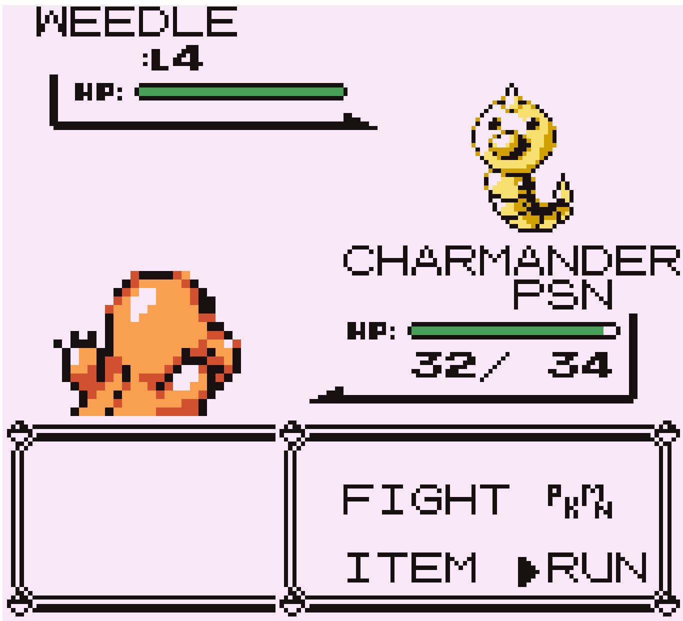

Figure 8.4: Pokémon Red uses text to give feedback to the player on the status of their Pokémon.

8.2.7 Immersion

Players should be able to experience a deep, effortless involvement in a game. This involvement can result in a player becoming less aware of their surroundings and experiencing a loss of time. Players are often emotionally invested in the games they are playing because of the time and effort they put into them. It leads to the game becoming the most critical part of their attention, and their emotions are affected by the game.

Players play games to experience emotions and thoughts not related to everyday life. Games are, by many, seen as an escape from real-life worries and allow the player to do things they might not have had the resources or skills to accomplish in real life. Games should make players forget that they are interacting with a medium and involve them personally and emotionally. Immersive games affect the players' senses through the audio and narrative, drawing them in. Both audio and narrative are essential for immersion, making the player feel like a part of the story and keeping them immersed in it.

8.2.8 Social interaction

Social interaction can interrupt game immersion, as other people provide a coupling to real life that can take them out of a fantasy game world. However, it provides much enjoyment because people play games for social interaction. Games should provide opportunities for players to compete, cooperate and connect to support social interaction. Experiences in the game should be created to improve player interactions and make these interactions enjoyable. Games should support interaction socially, either through a chat or online boards, as a large part of online games is a virtual community.

8.3 DualFlow

This section is about the DualFlow framework, as introduced in the paper "Exergame development using the dual flow model" [3]. The DualFlow framework is, like GameFlow, based upon the Flow model [56]. The DualFlow model considers two main factors critical for the success of an exergame.

8.3.1 Attractiveness and effectiveness

The first factor is *attractiveness*; it motivates people to play and continue playing. It is critical for an exergame that the game itself is fun to play. An example of an attractive exergame is Dance Dance Revolution, as detailed in Section 9.1. A study found that the main reason young adults kept playing the game was fun [58]. The DualFlow authors believe fun is crucial to making any exergame successful; a game will not be successful if gameplay becomes repetitive or boring.

The second factor is *effectiveness*, as one of the most important outcomes of an exergame is to improve the player's health. Motivating the player to do some physical activity is beneficial over sedentary activities. More factors should be considered to increase the benefits. An exergame should consider the combination of duration, intensity, and frequency if it wants to create the same benefits as an exercise program. These variables depend on the player's fitness level and must be tuned accordingly.

8.3.2 Flow and exergaming

One of the main elements of flow is balancing perceived skills with perceived challenge [56]. DualFlow encompasses the two main concepts, attractiveness and effectiveness, modeling them using the flow model, shown in Figure 8.5. Attractiveness balances the player's perceived skill with the perceived challenge, while effectiveness balances the player's fitness with the intensity.

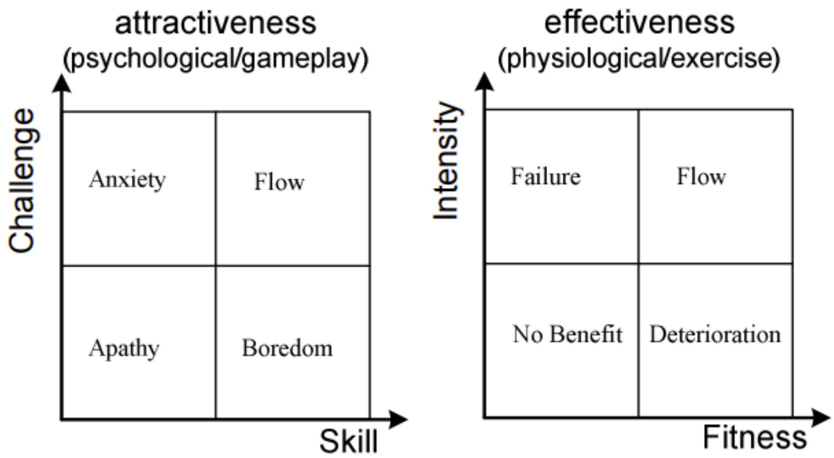

Figure 8.5: The Dual Flow Model for Exergaming [3].

The attractiveness figure in Figure 8.5 shows how boredom is reached if the skill is greater than the challenge, and anxiety sets in if the opposite is true. The player could feel apathy if there is a lack of skill and challenge. If the ratio is suitable, flow is reached. One way to ensure the attractiveness is in a state of flow is to ensure the challenge level is adapted to the player's skills, similar to what is discussed in Section 8.2.

The balance between intensity and fitness is similar. Flow is reached if the player's fitness level matches the intensity of the exergame, allowing the subject's fitness level to improve. If the intensity is higher than the fitness level, failure is reached. In contrast, if the fitness level is far greater than the intensity level, the player's fitness might deteriorate. Finally, if the player's fitness level is low and there is no intensity in the game, then there is no benefit to the player's fitness.

8.4 Scripting versus emergence

This section discusses the two contrasting approaches to creating game environments discussed in the paper "Scripting Versus Emergence" [59].

The first of the approaches is the one most commonly seen in games, known as scripting. Scripting requires developers to handcraft events and player interactions and involves a specific, low-level approach to designing game worlds. For developers, scripting involves substantial planning, testing, and implementation. It might also be hard to modify and extend a scripted game world. The scripted approach does, however, give developers complete creative control, as they always know how the system will behave.

The other approach is known as emergence. Emergent systems are easier to extend and modify, but the developers lose complete creative control. Emergence involves defining general, global, and interacting rules which lead to emergent gameplay. Emergent gameplay refers to game mechanics that change depending on the player's actions and state, allowing for more freedom for players and diverse gameplay.

The paper concludes that neither of the approaches is ideal but that there needs to be a compromise where both approaches are used in different parts of the game design [55]. Games should not be entirely scripted, but they should not be entirely emergent either. There might be advantages to a scripted approach for story and game objectives, as a game designer wants to give the player a clear goal and tell a story. For the main gameplay loop, an emergent approach could be advantageous to give the player more freedom and allow for emergent gameplay.

8.5 Player types

This section discusses parts of the paper Player Types A Meta-synthesis [60]. The paper focuses on player typologies to better understand potential customers for virtual goods in games. While selling virtual goods in-game will probably not be relevant for this project, it is still interesting to look at different player typologies to better understand different players of exergames.

There are four main categories of segmentation:

- Geographic segmentation. Dividing people based on geography, like country and cites.
- Demographic segmentation. Dividing people based on descriptive features like age, gender, and education.
- Psychographic segmentation tries to group people based on attitudes, values, and interests.
- Behavioral segmentation tries to find patterns in people's behavior.

The paper considers several typologies, but we have chosen to inspect three of them further to understand better who could be included in a potential target group for an exergame.

A common psychographic way to divide players has been to divide them into hardcore and casual players. Dividing players this way has been considered too simple but is used in literature as either segmentation or part of a more complex model. Compared to casual players, hardcore players can be seen as more dedicated, playing longer sessions and having more profound knowledge of the game [61]. Another perspective is hardcore players requiring more intellectually challenging games, preferring adventure and puzzle games [62].

A study looked at how players completed the adventure game *Tomb Raider: Underworld* and identified a behavioral segmentation divided into four unique styles with different patterns, solutions, and performance [63]. The players were divided into:

- **Veterans**, who do not die often and complete the game quickly.
- **Solvers**, who take some time to solve puzzles.
- **Pacifists**, who die mostly from enemies, not the game environment, but are fast at completing the game.
- **Runners**, who finishes the game very quickly.

Another player typology from Richard Bartle is based on observations from players in Multi-User Dungeons [4]. Bartle defines two dimensions to playing, acting vs. interaction and player-orientation vs. world-orientation. Comparing the two dimensions on a two-dimensional plane and finding out where a player would be on both axes could determine what player type a player fits in. The first type is the Achiever, who is world-oriented and likes action. The Killer also likes action but is player-oriented. An Explorer likes interaction over action and is world-oriented, while the Socialiser also enjoys interaction, but with other players. These player types are shown in Figure 8.6

Figure 8.6: Bartle's player types [4]

8.6 Summary

The models and theory discussed in this chapter help understand what makes games enjoyable and how we can create something a player would continue playing. The models present different requirements and categories that can be used during development to ensure the chosen concept is correctly trajected.

Several papers focused widely on the challenge aspect. If the player does not feel challenged by the game, they will not continue playing. Other concepts like curiosity and fantasy are essential to immerse players in the game world. Giving the player clear goals is vital to let the player feel motivated to continue. The paper on DualFlow discussed how this could be applied to an actual exergame and balance the game and exercise aspects. "Scripting versus Emergence" talks about two approaches to game world design, both of which should be used together for different aspects of the game. At the same time, the paper about player types provides a better understanding of who an exergame could be developed to target.

Chapter 9

Existing Exergames

This section gives a brief description of some existing exergames. Many exergames exist today, with a wide variety in their maturity, stretching over three decades. Some of the most popular exergames will be presented in short. Where applicable, relevant research findings related to the exergame will be discussed, and a brief description of the used technologies in question will be given.

9.1 Dance Dance Revolution (DDR)

DDR is a music and dance-oriented exergame, first developed and released in 1998 by Konami [50]. It is still widely played and is considered by many to be the first grandly successful exergame. The concept is that a player is standing in front of a monitor on a dance mat with four pressure plates resembling arrows. Arrow instructions will appear on the monitor, and the player must promptly step on the dance mat's corresponding arrow pressure plate. The arrow instructions are often rhythmically and conceptually related to a song playing simultaneously, providing the player with an experience of dancing. Initially, it was released as an arcade game with a monitor, speakers, and dance mat integrated into the physical arcade cabinet. However, it was later released for various platforms with a foldable and portable dance mat, as seen in Figure 9.1 and Figure 9.2. The player exercises aerobically by the quick and timed steps on the arrow pressure plates and is evaluated by receiving a score based on how well the movements correspond to the arrow instructions. Later versions feature estimated burned calories and workout modes.

Due to the numerous and diverse game versions, there is a great variety in the hardware and software used in the game. The arcade versions have a dual structure with the dance mat and the cabinet. The dance mat consisted of one or two sets of pressure pads, while the cabinet included a monitor, speakers, lights, and other decorative features. The portable console versions were released on platforms such as Playstation, XBOX, Nintendo Wii, IOS, and Android. The software was tailored to fit the console, and the dance mat was often made of plastic to make it foldable.

Some studies have explored DDR's effects on players' physical health. An international survey, [64] reports that playing DDR has a positive effect on players' physical health and social life, as it boosts endurance and muscle strength, and sense of rhythm. In addition, it was found that it creates a setting where new friends can be found.

Another study prospecting older people's health reports that DDR intervention is as effective as brisk walking in improving inhibitory control for elders. Therefore, DDR can be used as an alternative exercise to enhance cognitive function for elders [65].

However, some studies focusing on obese and overweight schoolchildren do not have quite as conclusive findings. Overweight and obese children were less physically active than normal-weight

children during the DDR intervention of the study [66].
The results indicate that although DDR did not boost physical activity levels, it may have helped to slow the decline in moderate to vigorous physical activity over time [67].

Figure 9.1: Arcade version of DDR

Figure 9.2: Console version of DDR used in a school for exercise

9.2 Wii Sports series

The Wii Sports games are sports simulating exergames developed and released by Nintendo for the Wii and Nintendo Switch between 2006 and 2022 [68] [69] [70]. The games use motion-tracking technology through the Wii Remote, Joy-Cons, and sometimes with controller extensions, as seen in Figure 9.3. All games in the series have sold well, with the entire series having sold over 100 million copies [68].

Wii Sports Resort was launched with the Wii Motion Plus expansion device for the Wii Remote, which allowed much more complex motion to be interpreted than previously possible by the Wii Remote. Nintendo Switch Sports was released on the Nintendo Switch. Unlike the previous two titles, Nintendo Switch Sports utilizes the Joy-Cons as controllers.

The games use the motion trackers to simulate sports such as tennis, bowling, boxing, and baseball. The latter is showcased in Figure 9.4. It is designed to be easy to learn and use for everyone, including children, elders, and casual exercisers.

A study on elders on an exergame program using Wii Sports found no significant improvement in physical activity level or perceived health after the intervention [71]. A study from 2016 tested energy expenditure in middle school children while playing Wii Sports and found that regardless of BMI category, given free choice, children will play games that require an increase in energy expenditure above the baseline [72]. Playing these games could help with overall energy expenditure if playing replaced sedentary activity.

Another study from 2010 had 15 children from age six through twelve put on a program playing exergames regularly [73]. The children mostly played games on the Wii console. The study found that although no change in daily activity or fitness levels after the Wii intervention was evident, there was an improvement in both motor skills and attitudes towards physical activity.

Figure 9.3: The Wii Remote with extensions

Figure 9.4: Wii Sports gameplay of baseball training.

9.3 Wii Fit series

Wii Fit is also developed and released by Nintendo and is estimated to be one of the most successful exergames ever made [74]. It is an exergame released for the Wii console in 2007. In addition to the Wii Remote, it also uses the Wii Balance Board, as seen in Figure 9.5. The balancing board tracks the player's center of balance and uses it in several exercises, including aerobics, yoga, balance, and strength. Nintendo released an enhanced edition of the game called Wii Fit Plus, released for the Wii in 2009. In 2013 Nintendo released a sequel, Wii Fit U, which was released for Nintendo's next console, the Wii U, in 2013. Wii Fit U, like its predecessors, utilized the Wii Balance Board, the Wii U's GamePad, and the newly introduced Fit Meter, an activity meter accessory.

A study on the physiological cost and enjoyment of Wii Fit adolescents, young adults, and older adults showed that all groups had higher energy expenditure. Their heart rate while playing the game was more significant than handheld gaming but lower than treadmill exercise, although group enjoyment rating was higher than treadmill walking and jogging [75].

Another study aimed at determining the effectiveness of the Nintendo Wii Fit as an occupation to promote weight loss in undergraduate students. Their results read that even though the sample size was small, the study's results suggest that the Wii Fit should be considered by occupational therapists as a potential occupation of weight control in undergraduate students when performed individually [76]. In contrast, a study on changes in physical activity and fitness after three months of home Wii Fit use reported a lack of significant changes in health-related fitness variables [77].

Figure 9.5: Wii Fit gameplay with the balance board and with the Wii U console.

9.4 Zombies, run!

Zombies, run! is an exergame promoting running, developed and released in 2012 by Six to start, and is available for Android and IOS units [78]. The point of the game is to survive a zombie apocalypse by running a course to escape the zombies and gather supplies, as showcased in Figure 9.6. While running, the player can listen to an audio narrative. The interactive audio motivates the player to run faster or slower depending on how "close the zombies are," which can simulate interval exercise running. The game uses the mobile phone's location sensor and accelerometer and measures time, speed, and calories burned to report to the player.

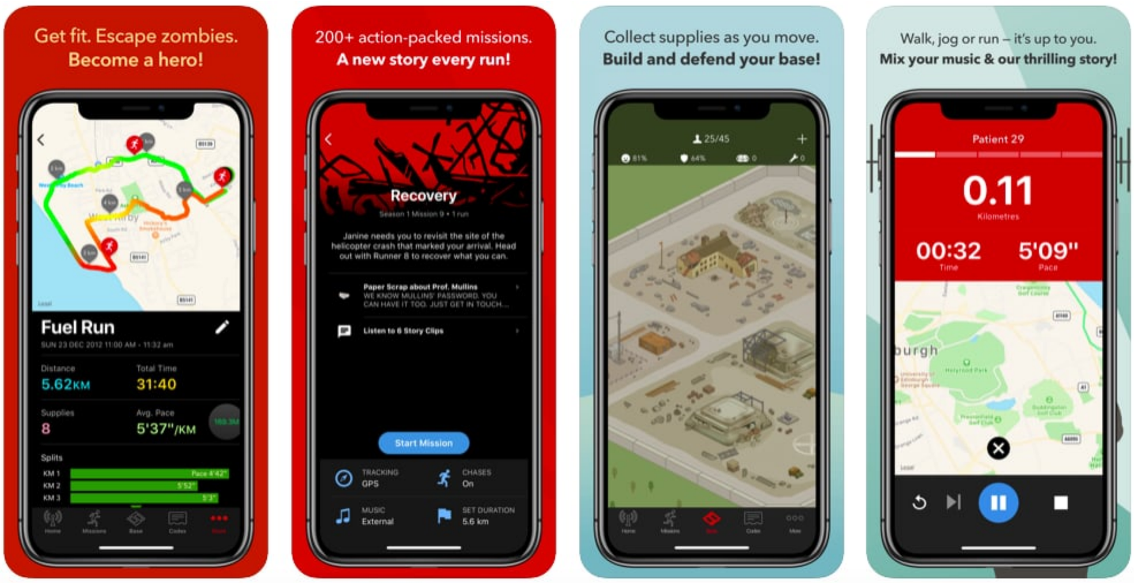

Figure 9.6: Gameplay of Zombies, run!

A study of Zombies, run! and another exercise app (Get Running [79]) measured the effects of the apps on cardiorespiratory fitness and physical activity levels in insufficiently active, healthy young people. The study was a 3-arm, parallel, randomized controlled trial conducted in New Zealand but concluded with no significant effect on the test subject's fitness [80].

Another study qualitatively analyzed the role of narratives in motivating people to exercise, using Zombies, run!. The study reports that features like tracking and goal orientation motivated players to exercise, as did narratives. However, their usage in well-being technology is still in its infancy. They also found that sharing the player's exercise with others was not a key motivator, as most participants did not want to/feel the need to share their exercise logs with other people or on online social platforms [81]. However, the study did have a small and relatively homogenous group of participants.

A third study interviewed Zombies, run! players to understand their motivation and experience using it [82]. It found that the game's story was the leading factor players found attractive in an augmented reality (AR) running exergame. It also found that Zombies, run! may engage players by modifying how they perceived physical activity through narrative, therefore dissociating them from the exertion effort.

9.5 Pokémon Go

Pokémon Go is a location-based, pervasive mobile game based on Nintendo's Pokémon franchise [83]. It was first developed and released in 2016 by Niantic, collaborating with Nintendo and the Pokémon Company. The game is based on collecting, trading, and battling Pokémon using the player's phone location sensor. The game map is based on the real world with streets, forests, and lakes. As the player moves around the map, catchable Pokémon, events, and loot stations appear. Players can catch Pokémon by throwing balls at them with the possible use of AR, as seen in Figure 9.7. There are some use cases for playing the game while sedentary, but the game strongly rewards players who walk around their environment and explore new locations. Some game elements also require the player to move, e.g., 5 kilometers for a reward. The location sensor measures how quickly the player travels to rule out motorized transportation as a way to explore more rapidly. The game is considered one of the most successful mobile games ever released, with over a billion downloads.

Pokémon Go is built using the Unity game engine, GPS, and AR technology. It is available for IOS and Android and uses a NoSQL database. Similar games have been developed like Harry Potter: Wizards Unite, Zombies run!, Ingress Prime, The Witcher: Monster Slayer, and Orna.

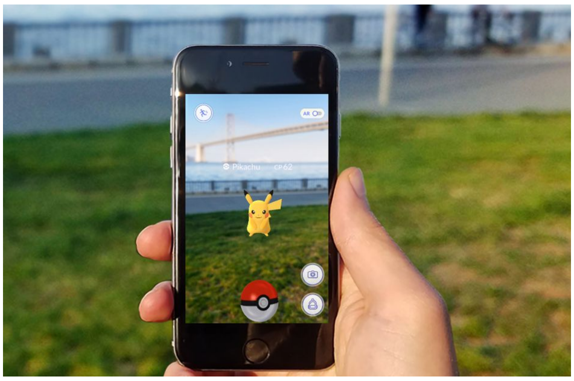

Figure 9.7: Pokémon go using AR while catching a Pokémon

There has been a substantial amount of research on the health effects of Pokémon Go [84]. A systematic literature review of 59 identified studies reports its central conclusion that Pokémon Go had an apparent positive effect on its player's physical, mental, and social health while they were playing the game. The motivations for playing Pokémon Go include having fun and an immersive experience, getting physical exercise, social reasons, and nostalgia related to the Pokémon universe. Players stopped playing the game because of technical challenges, slow progress, and a lack of variation and content.

The same literature review found that 60% of the studies showed an increase in the number of daily steps taken, whereas 30% of the studies found only short-term improvements, which declined soon after. The positive effects appeared more strongly on physically inactive individuals and were linked to playing retention. Furthermore, the results revealed that most data used in studies was from 2016, after which the game has drastically changed. Secondly, longitudinal studies spanning over a year are missing [84].

A second systematic review from 2021 with 36 included studies found that players had significantly greater physical activity levels than non-players in terms of daily steps and the number of days spent in moderate physical activity. Pokémon Go also improved players' social interactions. Findings suggest that playing Pokémon Go could promote meaningful improvements in walking behavior and psychological and social well-being [85].

Another study on the health and social impacts of playing Pokémon Go on various player groups reports that its most significant result is how Pokémon Go managed to motivate groups who are hard to motivate to be physically and socially active. It also found that Pokémon Go had a greater physical impact on females as they walked longer distances than the males.

9.6 Fitness Boxing

Fitness Boxing is an exergame for Nintendo Switch developed and released in 2018 by Imagineer, and Nintendo [86]. It uses the console's handheld controllers to scan the movements of the player's arms. The game's goal is to simulate a boxing workout with various punch and dodge maneuvers, showcased in Figure 9.8. This game focuses more on exerting the player rather than encouraging physical activity. There are also calendar features to set up exercise reminders and a virtual trainer to encourage the player. Manoeuvre sequence, complexity, and speed can be adjusted to fit the player.

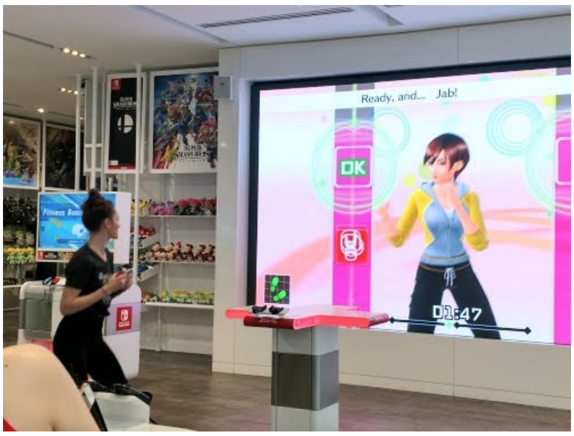

Figure 9.8: Gameplay of Fitness Boxing

No sufficiently relevant research papers were found on Fitness Boxing.

9.7 Exermon

Exermon is a strength exergame, developed for research purposes at NTNU in 2018 [87]. It is available for Android units and takes inspiration from Pokémon games and Tamagotchi. The game's goal is to perform strength exercises to evolve and maintain a fantasy character (an exermon). The exermon's appearance, stats, and survival lean on the player performing physical strength exercises, as shown in Figure 9.9. The mobile unit's proximity and accelerometer are used to measure the exercises. There are also features for fighting opponents generated by the game or friends' exermon. The opponents typically grow in strength as the game progresses, so the player has to keep exercising and further evolve their exermon.

Most of the source code is written in Java due to native/vanilla Android development being chosen over any frameworks. Exermon uses a client-server architectural pattern with a minimal server, deployed on Microsoft Azure's cloud service. The server provides a REST API for data storage and retrieval. The database used was ClearDB using data access objects (DAOs) [88].

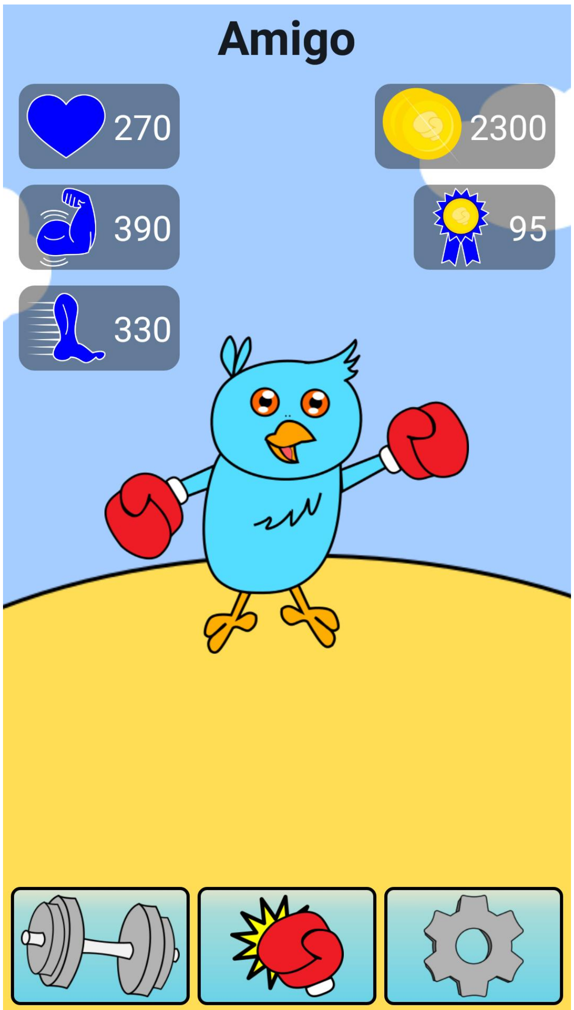

Figure 9.9: Gameplay of Exermon

In a study, the game was tested on 24 subjects over two weeks [87]. They found that more than 40% of the test subjects experienced improved strength and exercised more than before when playing the game, where most did 1-2 extra exercises per week and a few 3-4 extra exercises per week. The paper found cheating by making the used sensors believe the player was performing exercises and that the game primarily motivated the players interested in doing strength exercises in the first place. It also suggests that a tight coupling between the game concept and the actual physical exercises would be favored.

9.8 Ring Fit Adventure

Ring Fit Adventure is an adventure-RPG exergame developed and released by Nintendo for their Switch console in 2019 [89]. The game has the player, as a game character, use a ring to explore the game world, fight enemies, overcome obstacles, and eventually defeat an evil dragon. In addition to the two Joy-Con controllers used by the Switch, the game comes with two physical contraptions. The Ring-Con/Pilates ring and a leg strap. One Joy-Con is placed in each contraption and used to track the player's movements while the player runs, jumps, fights, and performs other actions by moving their body. Movements include running in place and stretching, pulling, and moving the Ring-Con. The game consists of many exercises, levels, and worlds and can also be adjusted to suit the exercise intensity of the player. In addition to the main gameplay story, just performing exercises is also possible.

Figure 9.10: Ring Fit Adventure

A 2021 study studied the effect of four weeks of interactive video games training, using Ring Fit Adventure, on the lower limb strength in the college students [90]. It reports that interactive video game training significantly can improve lower extremity strength quality and provide new options for physical activity exercises for the general public.

Another study investigated if Ring Fit Adventure had an effect on time running 1600m, cardiac force index, sleep quality, and mood disorders [91]. It found that test subjects who played Ring Fit Adventure significantly reduced their running time, while there was no significant reduction in the control group. No other significant differences were found considering the other factors.

9.9 Beat Saber

Beat Saber was developed and first released in 2019 by Beat Games and is available on Playstation 4, Microsoft Windows, and Oculus. It is a virtual reality (VR) game where players use VR motion controllers to hit or beat seemingly approaching boxes. The boxes are coupled to a song introducing a rhythmic dimension to the game. From the player's perspective, the VR motion controllers act as *sabers* to slice or hit incoming boxes in a surreal and neon environment, as seen in Figure 9.11. The boxes approach from various angles and can require the player to hit them from another certain angle, compelling the player to move their body and exercise similarly to energetic dancing. There are also obstacles to avoid. Similarly to Dance Dance Revolution, the player is given a score based on how many boxes were correctly hit. Beat Saber is compatible with Playstation VR and Oculus Quest. It is based on the game engine Unity.

Figure 9.11: Gameplay of Beat Saber

A study from 2019 found that Beat Saber can be considered a viable exercise form that is more engaging than treadmill running [92]. However, it should be noted that this study was performed with 20 young test subjects over two non-consecutive days.

9.10 Just Dance

The Just Dance series is a series of rhythm games developed and published by Ubisoft between 2009 and 2021 [93]. The games are released for a variety of platforms, and based on the platform the game is played on, it can be played with motion controllers, camera devices, or using a smartphone app.

Each game includes classic and modern songs with their own dance choreographies, as can be seen in Figure 9.12. Players must mirror the dance performed by actors on screen, following their moves and being rewarded for accuracy.

Figure 9.12: Gameplay of Just Dance

A study explored Just Dance 3's effect on 129 college students, compared to popular dance videos on Youtube. It found no significant differences in interaction effects on the participants' body movements, heart rates, blood pressures, step counts, or perceived psychological outcomes [94].

Another study compared the effects of playing Just Dance 2016 to dancing with a dance instructor [95]. The sample consisted of 30 physically active women with some dance experience. The study found no significant differences in heart rate and blood pressure between the Just Dance and dance sessions. It concluded that Just Dance might be a favorable option for individuals who wished to exercise at home.

9.11 Comparison of exergames

The presented exergames vary in genre, physical apparatuses required, price, success, exercise type, and many other factors. In Table 9.1, a comparison of the commercial factors of the exergames is presented. Immediately, Pokémon Go presents itself as the most successful exergame [96]. Ingress and the different Wii Games are also quite successful, although they have been commercially available for extended periods.

Table 9.1: Comparison of the exergames. Intensity: T-shirt sizes (S, M, L) indicates roughly how much intensity playing the game gives the player.

Exer-game	**Plat-form**	**Genre**	**Intensity** (S-M-L)	**Release year**	**Price**	**Downloads/ Sales**
DDR	Multi platform	Dance / Music	M-L	1980 - 2020	$\sim$ \$50– $\sim$ \$20000	>6.5 million
Wii Sports Series	Wii & Switch	Sports	S-M	2006-2022	Included in Wii $\sim$ \$50	$\sim$ 116 million
Wii Fit series	Wii & Wii U	Yoga/ Balance	M	2008	$\sim$ \$90	$\sim$ 44 million
Zombies, run!	IOS and Android	Adventure /Running	M	2012	Free	>1 million
Pokémon Go	IOS and Android	Adventure /Walking	S	2016	Free	>1 000 million
Ingress	IOS and Android	Adventure /Walking	S	2013	Free	>20 million
Fitness Boxing	Switch	Sports	M-L	2018	$\sim$ \$50	>1 million
Ring Fit Adven-ture	Switch	Adventure /RPG	M-L	2019	$\sim$ \$70	>11 million
Beat Saber	PS4, Win-dows, Oculus	Rythm/ Dance	M	2019	$\sim$ \$20 - $\sim$ \$70 (Game only)	>4 million
Just Dance Series	Multi-platform	Rhythm/ Dance	M	2009-2021	$\sim$ \$50	>40 million

9.12 Assessment of the research

Several research papers examine the physical activity effects these exergames can have on their players. The identified demographic groups of test subjects are the general public, schoolchildren, young adults, elders, and people with health impediments. This chapter has not examined research papers focusing on the latter group due to the project task described in Chapter 2.

Most of the research papers mentioned in this chapter have been short-lived studies with homogeneous or small groups of test subjects. While some studies are inconclusive on the health benefits of playing an exergame, most studies cited here have reported significant health benefits from their experiments. However, there seems to be a lack of results on the long-term benefits of exergaming. Many papers report increased energy expenditure and physical activity during and shortly after the experiment, but insignificant or no results on the long-term effects on the test subjects' lifestyle. Whether exergames can be a viable alternative solution to the vast health issues from a sedentary lifestyle is thus probably unclear.

Another reflection is that exergames have existed and been quite successful for several decades. Meanwhile, obesity and overweight are still reported as significant health issues in the western world, as elaborated on in Chapter 1 and Section 5.1. Exergaming has, so far, at least not solved this issue.

A study titled *Exergame effectiveness: What the Numbers Can Tell Us* surveys several quantitative exergame studies to define a general set of elements that make exergames effective from a physical standpoint [97]. It concludes with some admonitions for future exergame development. Even though the paper is from 2010, there are still some interesting considerations. The most relevant findings are listed below:

- The exergame activities should use larger muscles in the body, like the leg muscles.
- To avoid cheating, the sensor systems should be able to tell what the whole body is doing.
- To acquire more long-term health benefits, one must make long-term investments. The incentive elements of the game should provide long-term motivation (months and years).

The study also states that longer-term studies are needed to determine if incentive mechanisms work. The paper recommends measuring the utility value of an exergame by how much the player likes the game genre. If the player already likes first-person shooter (FPS) games, an FPS game would provide the most utility.

In addition, when looking at the activity level, no clear pattern of what type of players exergaming is best suited for has been found. Since the modern studies available are pretty limited, it is difficult and imprudent to make a direct comparison. Are exergames most effective for players who already have an active and healthy lifestyle and are interested in physical activity and exercise? Or is exergaming most suitable for those players with a sedentary lifestyle? The research papers discovered in this paper have not provided a clear and consistent pattern for conclusion on any questions on demographics for a potential target group. In Chapter 13, there is an attempt to shed some light on this matter.

Also notable is that where there are significant results for health benefits, it is often not only aerobic fitness or muscle strength that improves for the players but also social, motor, and cognitive skills.

9.13 Summary

Many varied exergames are available today, some of which have been presented in this chapter. Some exergames are particularly dependent on physical equipment to track and measure the player's movements. In contrast, other exergames are more software-based, only utilizing, e.g., a smartphone's GPS sensor to track the player's location.

Some research papers examine the physical activity effects these exergames can have on their players. The identified demographic groups of test subjects are the general public, schoolchildren, young adults, elders, and people with health impediments. This chapter has not examined research papers focusing on the latter group due to the project task described in Chapter 2.

Chapter 10

Mobile Phone Technology

This chapter will look at technologies found in modern smartphones that can be used to develop an exergame.

10.1 Augmented reality

Augmented reality (AR) is a system or experience where real-world elements can be viewed with digital elements.

> "AR can be defined as a system that incorporates three primary features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects [98]."

AR can be created using several different technologies. However, for gaming, there are three main ways: using head-mounted displays, using images projected on real-world surfaces, and using hand-held devices, where the latter might be the most relevant for this project [99].

There are several examples of mobile games and applications using AR technology. Snapchat's digital filters go on top of a real-life face, while Pokémon Go's digital Pokémon are represented in a real-life environment, shown in Figure 10.1.

Figure 10.1: A digital Pokémon being represented in real life enviroments in Pokémon Go

The two main categories of AR applications are marker-based applications, and location-based applications [100]. Marker-based AR applications use black and white markers to assist the camera in knowing where to put the digital objects. When creating a marker-based application, the markers need to be hard-coded in the application to make them easier to detect. Location-based AR applications do not depend on markers. They instead utilize the phone's GPS, accelerometer, or digital compass to place digital objects on top of the physical ones.

Several development kits exist for AR phone development, supporting a wide range of platforms, including both Android and iOS.

10.2 Global Positioning System (GPS)

Location-aware games are games that use the entire world as their game board, requiring technology to track the player's position [99]. Some of the earliest location-aware games used short-range proximity sensors, but this is not ideal. Modern smartphones offer sophisticated GPS technology and an internet connection through either Wi-Fi or cellular networks. They are a good fit for a location-aware game.

There exist several technological tools to assist in creating a location-aware game. Both Apple and Google provide APIs to determine a device's location, using the phone's position sensors, detailed in Section 10.3. Apple uses Core Location [101] to provide location data, and Google uses Fused Location [102]. Google also provides the Google Maps Platform, which allows access to a 3D rendered version of the world map with customization options, shown in Figure 10.2. It comprises two components, a Maps SDK (software development kit), which includes a client SDK and a collection of assets for the Unity game engine, and a Playable Locations API which serves locations for use in games [103]. Other development kits focusing on location information includes Unity's Mapbox SDK. Mapbox provides a starting point for location-based games, using the device GPS to position the game map [104].

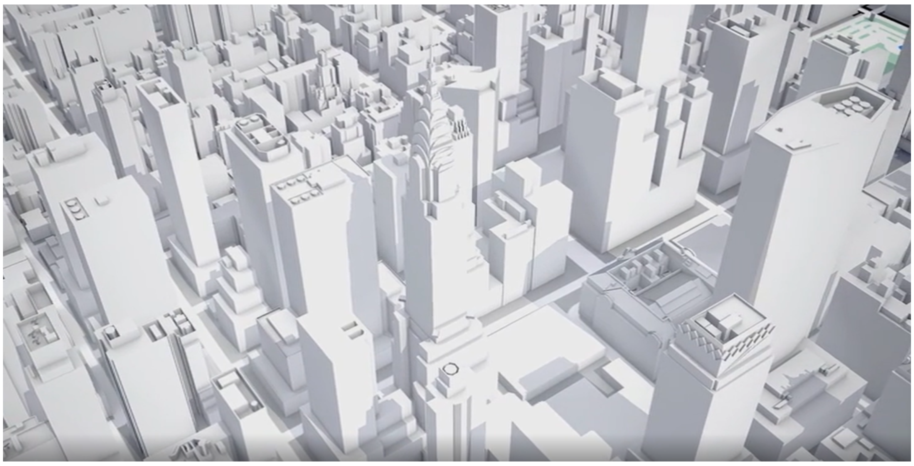

Figure 10.2: A 3D rendering of New York provided by Google Maps Platform

10.3 Sensors

Smartphones include a wide variety of sensors used to track their position and movement or detect changes in the phone's environment [105]. This section will present some of the different sensors. The sensors can be divided into motion, location, and environmental sensors.

10.3.1 Motion sensors

Motion sensors detect when the phone is moving and measures axle-based motion sensing like acceleration and rotational forces along three axes. This category includes the accelerometer, which detects changes in the smartphone's orientation. Popular features like flipping the phone 90 degrees to activate landscape mode, shown in Figure 10.3, use the accelerometer to detect when the orientation has changed [106]. The gravity sensor measures the intensity and direction of gravity, thus enabling it to find the relative direction of a device within a space. The accelerometer and gravity sensor combined allows for the use of navigation applications. Finally, the gyroscope is an advanced version of an accelerometer. It works with the accelerometer to detect the slightest change in orientation down to a single degree. When playing games, the gyroscope is what detects the changes in orientation depending on the player's actions. Some phones also come with a pedometer, another advanced accelerometer version, but used only to count steps. Counting steps can also be done with the accelerometer itself, but the results from the pedometer are much more accurate.

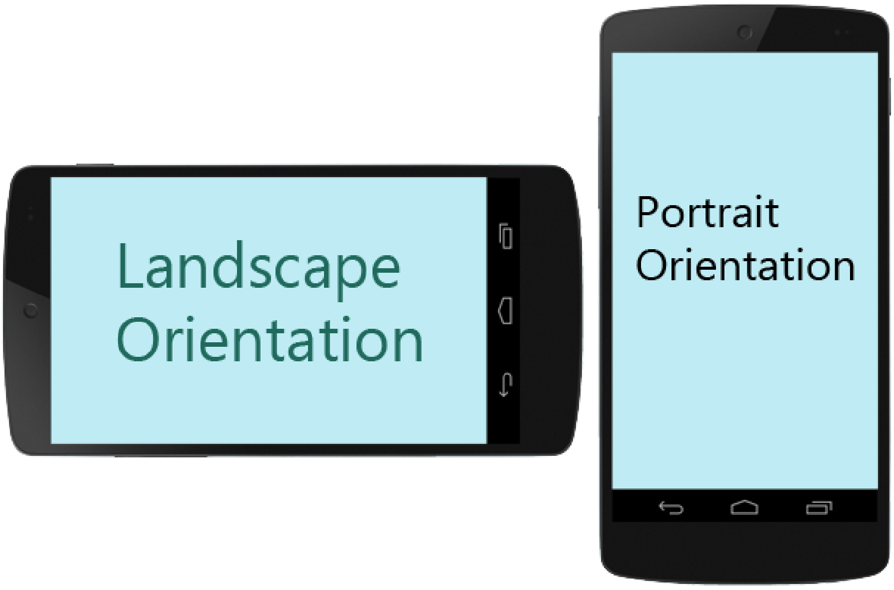

Figure 10.3: The different phone orientations illustrated

10.3.2 Environment sensors

Environmental sensors measure things like air pressure, temperature, and humidity. These sensors include the ambient light sensor, which detects the light in the device's environment, allowing phones to change the brightness automatically. Some phones include a temperature sensor, or a thermometer, to detect the environment's temperature. The barometer detects atmospheric pressure and can measure the distance to sea level from a device's position. It is used to help the GPS detect locations more accurately and be used by some fitness apps to track certain fitness activities.

10.3.3 Position sensors

Position sensors, or location sensors, measure a device's physical position and provide the data used to determine the player's position on the map, detailed in Section 10.2. This category includes a magnetometer, which measures the magnetic field to tell which direction is north. Together with the accelerometer, they can indicate a device's position relative to the north pole. Because of the magnetometer, a phone can be used as a compass. A proximity sensor measures the distance from a device to another object. For example, this sensor is, e.g., used to detect the distance to a face when being held up during a call.

10.4 Camera

Every modern smartphone comes with a camera, and most with two, one at the front and one at the back. The cameras can be used for AR-functionality, as mentioned in Section 10.1. Both Apple and Google provide APIs to use the camera in app development for iOS [107] and Android [108] platforms. These APIs allow for creating applications that use the camera to take photos or film videos.

10.5 Bluetooth and other accessories

Bluetooth is a technology for exchanging data between devices over short distances [109]. It is used to exchange files and connect phones to wireless headphones and other accessories. Today almost every phone supports connecting to other devices through Bluetooth, which allows for games utilizing external wireless accessories [110].

An example of a Bluetooth accessory used to complement gameplay is the Pokémon Go Plus, shown in Figure 10.4, and the Poke Ball Plus, which are accessories for Pokémon Go [111]. These accessories notify the player of the game's status without the player having to check their phone. Another example is using Bluetooth to connect a game controller to a phone, like an Xbox controller or another type of wireless gamepad created for phone use.

Figure 10.4: The Pokémon Go Plus accessory

Another popular Bluetooth accessory is the smartwatch. The smartwatch can be used to collect fitness data more accurately, or its display and eventual touch screen can be used for an exergame, either to compliment the phone display when doing physical activity or to provide the main display for the game [112]. The latter example is often seen with the existence of a wide variety of smartwatch games [113]. Pokémon Go previously had a smartwatch app, which would complement and work with the app running on a phone while also logging fitness data [114].

10.6 Fitness data

As mentioned in the previous section, smartwatches can collect fitness data. In addition to smartwatches, fitness trackers are also commonly used for this purpose. The smartphone itself is also able to track some data. Phones are usually not as accurate as a fitness tracker or smartwatch and can usually not track specific data like heart rate. Both Google and Apple have development platforms focusing on fitness data, like Google's Fit [115] and Apple's HealthKit [116]. HealthKit allows for creating apps that can read and write from the player's health and activity data if they permit it. This data can be used in an exergame. Fitness trackers and smartwatches can be used with these services, as the data collected by the devices update the fitness services on the player's device.

10.7 Summary

Modern smartphones come packed with technologies that can be utilized in game development. Modern sensors make it possible to track data about physical activity, like where a player is positioned and how many steps are performed. Together with the sensors, the camera allows for merging digital and physical realities through AR, and technologies like Bluetooth make it possible to connect a large variety of accessories to a phone. Fitness data can be collected by phone or accessories, and it is possible to use this data in games developed for phones.

Chapter 11

Other Exergame Technologies

This chapter will examine technologies other than those found in mobile phones, which can be used to create an exergame.

11.1 Virtual reality

Virtual reality (VR) is a simulation of a virtual environment that immerses the players to such a level that they feel like they "are there" [117]. VR has been available since the 1960s, but the high equipment cost and low quality have been barriers to broad adoption [118][119]. In modern times, however, consumer-grade VR headsets for gaming and entertainment have become more affordable [120] and VR is also becoming more popular within other industries, like healthcare and petroleum.

Focusing on gaming, VR is available on multiple platforms. HTC's Vive is compatible with high-end PCs, while Facebook's Oculus Quest, shown in Figure 11.1, provides VR without using separate hardware. Sony's Playstation VR provides VR for Playstation 4 consoles. VR is also available for phones through several different accessories, like Google Cardboard, a simple VR headset using the player's phone as a screen. Google provides an open-source Cardboard SDK, which allows for the development of immersive cross-platform VR applications for Android and iOS [121].

An example of an exergame using VR technology is Beat Saber, where the player has to hit approaching boxes matching the rhythm of the music in VR. See Section 9.9 for more details on Beat Saber. As VR games on platforms other than mobile often use motion controls and track body movement to a certain degree, VR is a platform that can be utilized well for creating an exergame.

Figure 11.1: The Oculus Quest VR headset

11.2 Motion controllers

Motion controllers are a type of game controller which uses different sensors to track motion and provide input [122] to the software. Motion controllers became more popular after the release of the Nintendo Wii in 2006. The Wii used the Wii Remote as its main controller, which used an accelerometer and optical sensor technology to support pointing and gesture recognition [123]. The Wii remote with different extensions is shown in Figure 9.3. The Wii remote was followed by Sony's Playstation Move for Playstation 3 systems. The Playstation Move motion controller functions similarly to the Wii remote but uses a glowing orb at the head of the controller together with the Playstation Eye camera to track the position of the controller [124]. The Playstation Move motion controllers were also used with Playstation VR on Playstation 4 systems. The main gamepad used by the Playstation 3, first the Sixaxis, then the Dualshock 3, also included motion-sensing functionality, which was included later in both the Dualshock 4 and the Dualsense controllers for Playstation 4 and 5 systems, respectively [125]. Nintendo also followed the Wii remote controllers with the Nintendo Switch Joy-Cons, shown in Figure 11.2, which can be used as a traditional gamepad or motion controller. Most VR systems also use motion controllers, like the Playstation VR and Oculus series of VR headsets (See Figure 11.1 for the controllers of the Oculus Quest headset).

Figure 11.2: The Nintendo Switch Joy-Cons

Many different exergames can be found across these different platforms that all use motion controllers. The Wii Sports series uses the Wii Remote, Fitness Boxing uses the Joy-Cons, and Beat Saber uses different VR motion controllers. See Chapter 9 for more information about these games. One observation to note is that motion controllers are used for various exergames, but they are also used for games that we do not consider exergames. A study examined young adults playing sedentary games with either traditional or motion-based controllers. The study found that motion controllers are unlikely to produce moderate-intensity physical activity on their own but that some games produce a small but insignificant increase in energy expenditure [126].

11.3 Gesture recognition accessories

While many games use physical controllers to track motion and pointing, some games try to use accessories to perform gesture recognition to allow players to use their bodies to interact with the game without physically touching any controller. One of the early examples of this is Sony's EyeToy camera, mentioned in Section 7.2.3, which was mainly used with the EyeToy line of games, developed by Sony and others [127]. Some of the more popular games were the EyeToy Play line, all of which were collections of minigames players could play using their bodies. In the game EyeToy: Play, the game recognized pixel changes in the video image and compared the proximity of the change to other game objects [128]. In the sequel, EyeToy: Play 2, the camera detected the speed and force of motion and was more accurate.

Another use of this type of technology is Microsofts Kinect, shown in Figure 11.3. The Kinect was released as a competitor to the Nintendo Wii and originated as a means to eliminate the game controller from the Xbox video game systems [129]. It first launched on the Xbox 360 and was bundled with some versions of Microsoft's next console, the Xbox One. Most of the games released on the Kinect were family-friendly titles, like one of the most popular games, Kinect Adventures, which featured 20 minigames like river rafting and track-and-field [130].

Figure 11.3: Two players playing a game on the Kinect

11.4 Summary

A wide range of technologies and accessories can be used to create an exergame on platforms other than mobile phones. Virtual Reality allows the player to be completely immersed in the game world. Motion controllers supplement the immersion by the player having to move their body to interact with some games. Motion controllers are also used outside of VR to point or interact with the game world in other ways. Some technologies allow movement-based interaction with the hardware without needing a controller, as seen with Microsoft's Kinect.

Chapter 12

Game Development Technologies

This chapter briefly reviews the most used and relevant game development engines and frameworks. Choosing technologies is an essential task in game development. With limited experience in game development, it can be challenging to make a choice, as numerous proprietary and open-source game engines are available, [131] with various targeted platforms.

There are also considerations beyond what technology best suits a specific exergame. Some of the main concerns are listed in the following list.

- What programming language is used for scripting
- How comprehensive is the documentation
- How large is the community using the technology
- Are there any costs to using the technology
- How easy is it for an inexperienced game developer to use

There are very few research papers written after 2018 on comparing the different game engines and frameworks. Since this chapter is just a short, surface-level overview of the most relevant game engines and frameworks, various articles, blog posts, and forum discussions were reviewed [132] [133] [134] [135] [136]. Where there was a clear pattern of similar experiences and assessments of a certain engine or framework, it will be presented below.

12.1 Game engines

Many different game engines can be used to develop a video game. This section looks at some popular game engines to determine their suitability.

Unreal Engine is a game engine developed by Epic Games and is one of the most popular game engines used today for cross-platform game development [137]. Many of the most prominent games released use Unreal Engine, and its strengths are scalability, performance, powerful graphical abilities, and VR support. It also has a marketplace with free assets for game developers but is possibly best suited for large team projects rather than a short-term project with limited resources.

Unity is a cross-platform game engine with a large amount of features [138]. With its all-in-one integrated development editor, it has a large user base and is a game engine for both large and small projects. Although not quite as performant as Unreal Engine graphics-wise and an extensive program to run, it has many strengths, including being free for small projects, VR support, having a significant assets store, and supporting practically any game type. Unity uses C# as the scripting language.

Amazon Lumberyard is a flexible game engine for making 3D games for Playstation, Xbox, PC, iOS, and Android [139]. It is feature-rich and free to use but is tightly coupled with Amazon Web Services, which can bring costs if the large scale and high performant multiplayer is an important aspect of the game at hand [140]. A beta preview was released in May 2021 and is regarded as a successor to CryEngine.

GameMaker: Studio 2 is a mostly 2D-based game engine from Yoyo Games. It has visual scripting and drag and drop features, enabling a game to be developed without requiring the developer to use any programming language [141]. It is cross-platform and is known for being a good fit for new game developers. However, it is not free to use, and its 3D features are limited compared to other game engines.

CryEngine is a free, cross-platform game engine from CryTek for 3D games [142]. Its strengths are graphic capabilities, VR support, and an asset marketplace. CryEngine is especially capable of rendering outdoor environments and first-person shooters well. However, it is not as scalable as other game engines, and the community is smaller than that of Unity and Unreal Engine [143]. It is known for powering the first FarCry games.

Godot is a free and open-source game engine for both 2D and 3D games [144]. Despite being open-source, the community is not as large, and the documentation is not as extensive as with bigger game engines. It is known to be flexible and well organized, with a passionate community fixing defects and answering forum questions. However, it uses a custom programming language for scripting, GDScript, forcing new Godot developers to learn another language.

Cocos2d-x is another open-source game engine for cross-platform development [145]. Many regard Cocos2d-x as easy to use with an intuitive interface, and even though it supports 3D games, it is best suited for games in 2D. It is also known to be fast but is more limited feature-wise. It is perhaps not as suited for large projects in big game development studios.

12.2 Game development frameworks

Frameworks are different from game engines and are more of a support structure or foundation on which one can build a game. This section glances over a few game development frameworks used today.

LibGDX is a cross-platform game development framework for Java [146]. It is open-source and has a unified API that works across all supported platforms. The documentation of LibGDX is not as comprehensive as other game engines. LibGDX is not an engine but a framework, giving the developer more control but requiring them to write more code and implement more features themselves [147]. It reportedly works better on Android devices than iOS devices, even though both are supported.

React Native Game Engine is an NPM package for the React Native framework [148] [149]. It can create simple games oriented more around menus and state transitions over heavy animations and complexly designed game scenes. It is not the most supported game engine documentation-wise, making it more difficult for developers unfamiliar to React Native [150]. It is not suited for graphics-heavy or otherwise large game projects but is easy to learn for React, JavaScript, or TypeScript developers.

12.3 Vanilla Android/iOS

Not using a game engine or a framework is possible if a game for a mobile unit is at hand. If the game developer wants the game to be available for Android and iOS units, the game would naturally have to be implemented twice. Using Android Studio and Android Game Development Kit for Android users, and Xcode and Swift on a Mac for iOS users [151] [152]. Although not using a framework or engine gives the developer more control to customize their game, it does introduce a lot of overload and more code for implementing basic features.

12.4 Summary

Most games developed in the last years have been made using a game engine. There are many different engines and frameworks for game development with a great variety in scope, targeted platform, scripting features, funding requirements, and performance. This chapter has given a short, surface-level review of the most relevant ones for this project.

Chapter 13

Prospective pre-game concept survey

This section will discuss the survey spread to collect information for technology and game concept choices. The purpose of the survey was also to gain some potential knowledge about a possible target group for an exergame and to collect data on the general public's habits, preferences, and opinions on the subject. The actual form is found in Appendix A.

13.1 Dissemination

The survey was an online form with 17 questions prompting data on demographic traits, habits, and attitudes on exercise, physical activity, games, and exergames. The questions were outlined to answer the research questions, especially RQ2 (see Chapter 3) and to discover demographic patterns on who is most likely to be a part of a possible user group. It was spread widely using our social media networks and other domains. The form was open for two weeks, and had received 187 individual answers at the end of the time period, where 186 were accepted for analysis.

To encourage more people to respond to the survey, two universal gift cards, each valued at 100 NOK, were promised to two of the respondents. After the form was closed, two respondents were randomly selected and sent their gift cards. All answers were decoupled to the contact information in separate forms so no answers could be tied to any sensitive or identifying information.

13.2 Demographics of the respondents

The assortment of respondents varies in demographic traits such as age, gender, and geographic location but seemingly disproportionately comprises urban students and working young adults.

Of the respondents, 71% were in their 20s, compared to the Norwegian population (using [153]), where 12% are between 20 and 29 years of age. Furthermore, 62% of the respondents were also between 20 and 25, indicating a dominance of people in their early 20s. The most probable explanation for this overrepresentation is that the survey was spread through social media, and urban students in their early 20s also dominate our networks.

While 36% of the respondents chose *working* as the most fitting situation, there was a heavy dominance of students in higher education institutions: 55%, compared to the percentage of Norwegians who are students, around 6%, students are over-represented.

79% of the respondents chose a large city with over 50 thousand inhabitants as their domicile category. There are ten towns in Norway with a population of over 50 thousand, and together these ten towns make up 41% of Norway's population as of the 1st of January 2020. Thus, urban people are also overrepresented in this survey.

Looking at the most significant living status categories, 20% of the respondents live alone, while 32% live in collective residences, and 28% live with a spouse or cohabitant without children.

The gender distribution was pretty even with 51% male, 46% female, and thus 3% with another gender identity or who did not want to input their gender.

13.3 Results

This section examines the results of the remaining survey parts.

13.3.1 Exercise and physical activity

Inspecting the results from the answers given by the respondents, there is a vague pattern of an exercise deficit. 23% of the respondents reported that they exercise zero times a week, while 33% reported a frequency of 0.5, once or twice a week.

The survey distinguished between exercise and physical activity, whereas the latter included low-intensity activities such as walking. The respondents were prompted to freely write how much time they spent doing physical activity on a *regular day*. Like most other questions, the respondents answered in a text input field and not by selecting one or more options. The sectioning was done later during the analysis. As seen in Table 13.1, 61% of the respondents were physically active for one hour or less.

Table 13.1: How many minutes the respondents reported to be physically active on a regular day.

Physical activity-time (minutes)	**Percentage of the respondents**
0-19	12%
20-39	15%
40-60	34%
61-80	4%
81-100	13%
>100	21%

All respondents were also asked whether they disagree, partially disagree, are neutral, partially agree, or agree to the following claim: "I wish that I was exercising more than I am currently exercising." The same prompt was done for physical activity. The two sets of answers are very similar and convey a clear majority of those who would like to exercise more and be physically active more often. In fact, 72% agree or partially agree with the claim about exercise.

Rounding off the survey section about exercise, the respondents could choose one or more answers (or add their own) to why they were not reaching their exercise and physical activity goals. The most selected reason was a lack of time (54%). Exercise not being fun (28%) and the need for someone else to nudge them into exercising (25%) were also popular reasons.

13.3.2 Games and gaming habits

The respondents were asked whether they enjoy playing digital games (games on mobile units, gaming consoles, and PC). Very few reported that they did not like digital gaming and 69% of all respondents chose the "agree" or "partially agree" option. When asked what platform (PC, mobile, or console) they enjoyed playing on the most, PC was the most popular (40%), although not by far. Mobile and console were relatively equally selected with 25% and 26% respectively.

When asked how much time they spent playing digital games on a regular day, 36% chose the lowest tier: 0-15 minutes. About half of the respondents (50%) chose tiers ranging from 15 minutes to two hours, while 14% reported more than two hours of daily digital gaming.

A question about what game genre the respondents liked was also included. The question was a multi-select of prominent game genres, but they could also add their own answers. The most selected genre was strategy and puzzle games, with 68% of the respondents choosing this joint category. Other popular genres were action/shooters, RPGs, and adventure. Some genres which were not very popular were sports/racing and platformers.

The respondents were also prompted to choose one or more answers (or add their own) to what was vital for them to enjoy a game. The most popular option was "Fun/Engaging gameplay," with 83% choosing this option. All other options were pretty similar and not selected by very many. The least selected element was music and achievements/awards.

13.3.3 Games and exercise

The last survey section was about exercise and games combined. The respondents were given a list of major existing exergames and asked to select what games they had played during the last six months. The majority of respondents (55%) said they had not played any of them for the last six months. The most played exergames were Pokémon Go/Wizards Unite/Ingress (19%), Just Dance (17%), Beat Saber (12%), and Wii Sports/Wii Sports Resort (12%).

Lastly, and perhaps most importantly, the respondents were prompted to agree or disagree with the following claim: "I would like to use games to come closer to my exercise/physical activity goals." About half (47%) said they agreed or partially agreed, 27% were neutral, and 26% disagreed or partially disagreed.

13.4 Filtered results

The reported results above indicate a potential target group's habits, attitudes, and beliefs. However, a more interesting approach would be to filter the given answers on whether the respondents agreed to the claim of being interested in using games to get closer to their exercise/physical activity goals and compare it with the complete/unfiltered set of answers. Thus, two filtrations were made. The first only includes answers where the respondents have said to disagree or partially disagree with the claim in focus. We will call this set N (for negative), and it consists of $n = 48$ answers. The opposite filtration only included the answers of those who agreed or partially agreed to the claim in focus. We will call this set P (for positive), and it consists of $n = 88$ answers. Let us call the complete and unfiltered set of answers A (for all), and it naturally consists of all $n = 186$ answers. The answers are mostly similar after analyzing both N and P and comparing them with A. However, the questions with significant differences will be commented on below. For a more compact and readable comparison of N, A, and P, see Table 13.2.

Table 13.2: Comparison of some notable results with the filtered results on whether the respondents was interested or not in using an exergame to help them reach their goals for exercise/physical activity (N - negative, A - all and P - positive)

Question	**N**	**A**	**P**
Exercise - How many times a week	3.40	2.48	1.89
Physical activity - How many minutes a day	78.00	79.52	77.78
I wish i exercised more - Mean (1=disagree, 5=agree)	3.25	4.00	4.39
I wish i was more often physically active more - Mean (1=disagree, 5=agree)	3.44	4.01	4.30
I like digital games - Mean (1=disagree, 5=agree)	3.02	3.84	4.11
I play digital games between 15 and 120 minutes a day (% of all in the group)	31%	50%	53%
Last 6 months - Percentage of respondents in group who have not played any of the presented exergames	79%	54%	34%

N seems to be a bit more active than A. Regarding weekly exercise, N has a mean of 3.40 compared to 2.48 in A. N also agrees less with the claim that they wished they exercised more than they currently are. With 1 meaning "Disagree" and 5 meaning "agree," N has a mean of 3.25 compared to 4.00 in A. A similar difference is found in the similar question about physical activity. N has a higher concentration of respondents who report that they dislike digital games, with a mean of 3.02, compared to A's of 3.84. The last notable difference is that N has fewer respondents reporting that they play digital games for 15-30, 30-60, or 60-120 minutes a day.

Hence, there is a vague pattern of N exercising more and liking games a bit less.

Inspecting P, the opposite trend is faintly apparent. P has a lower weekly exercise frequency with a mean of 1.89 compared to A's 2.48 times a week. The difference in physical activity is similar but barely noticeable. P has a mean of 77.78 minutes of physical activity daily compared to A's mean of 79.52. There is also a higher concentration in P of respondents who wished they exercised more than they currently are. The prompt is whether the respondents agree or disagree with the claim, with 1 meaning disagree, and 5 meaning agree. P has a mean of 4.39, while A has a mean of 4.00. A similar difference is found in the claim about wanting to be more physically active. P also has a slightly higher percentage of those who enjoy digital games. The mean is 4.11, while A has a mean of 3.84. A more significant concentration play digital games for 15-30, 30-60, or 60-120 minutes a day in P than in A. Furthermore, while still being dominated by "Fun/Engaging gameplay," the question about what makes the respondent find a game enjoyable, P has a more diverse set of answers than A. More respondents chose, e.g., graphics, performance, and exciting plot in P than in A. Lastly, more respondents in P have played one of the selectable exergames than in A.

Looking at what platforms are most promising for an exergame, two other filtrations are interesting. Mobile phones were the most selected favorite platform for respondents who strongly agreed that they wished they exercised more often than they do today. Another filtration excludes everyone but the respondents who, on average, play digital games more often than two hours a day. These respondents almost exclusively choose PC and console as their preferred platforms. These two observations indicate that the *hardcore gamers* (those who play a lot) do not enjoy mobile games as much and that the people who are most unsatisfied with how often they exercise could be more likely to enjoy a game for a mobile phone.

13.5 Summary

The reader should remember that young urban students and working people disproportionately dominate the survey answers. However, the results indicate that many people (about half of the respondents) could be interested in using games to exercise and be physically active more often. A majority of the respondents do not exercise as much as they would like due to a lack of time, and a reasonably large majority report that they like playing digital games. Most of the respondents play less than two hours a day, and strategy is the most popular genre, while Pokémon Go and similar games were the exergames most people had played recently.

Some faint patterns are recognizable when inspecting a filtered set of answers. The respondents who disagree or partially disagree with being interested in using games to help them reach their exercise and physical activity goals seem more physically active and like digital games a bit less. The opposite trend is vaguely apparent when doing the opposite filtration. Those who would like to use games to reach their exercise and physical activity goals are already less active and like gaming more. Also, the people who play the most are possibly not as likely to enjoy a mobile phone exergame. In contrast, the people who fully agree to not being satisfied with their exercise frequency are perhaps more likely to enjoy a mobile game.

Part III

Game Concept

This part contains a discussion of the prestudy and information related to the development of the exergame concept. First, the most critical findings from the prestudy will be summarized and discussed. Different game features and potential concept ideas are then reviewed before giving a more detailed walkthrough of the chosen concept, Paint it Green. The chosen technologies are discussed before lastly reviewing the feasibility testing process.

Chapter 14

Most Pertinent Findings From the Prestudy

This chapter summarizes the most critical findings from the prestudy in Part II. The important outtakes will be any points that could impact the game concept or technology choices. The findings are organized into four groups, each looking at analyzing and developing a new exergame concept.

14.1 Health perspective

Many people in Norway and the western world do not get enough exercise and physical activity. Children's activity levels decline with age, and adults' activity levels are fixed at a low level from the age of 20 to 64, but then they start to decline again. Many health organizations have recommendations for physical activity on different intensity levels, but a large portion of the population does not follow these. However, these recommendations are often relatively moderate. For instance, the Norwegian Directorate of Health recommends being moderately active for at least 150 minutes weekly. If many people were to spend some time exercising with moderate intensity or a small amount of time exercising with high intensity, the recommendations for a healthy lifestyle would not be too cumbersome to achieve. Introducing a simple, convenient exercise opportunity for the general public could help many people increase their activity levels.

There are various research papers on the most prevalent exergames existing today. They cover diverse demographic groups as their test subjects. Unfortunately, there was no apparent conclusion on what demographic groups have the most significant health benefits from exergaming. The results of the experiments are sometimes inconclusive. However, many papers report some health benefits from playing an exergame, although long-term improvements towards a healthier lifestyle have not been uncovered thus far. Also pertinent; usually, there is not only a direct benefit to the muscle group in use from playing the exergame, but other benefits are also often reported related to cognition and social skills.

Regarding what type of exercise and the intensity of physical activity the exergame requires, there is no assertive conclusion to be made from the prestudy. The existing exergames vary from light walking to high-intensity boxing to yoga sessions on a balance board. The research on the exergames also has no plain pattern to be gestured at. There are, however, three notable perspectives to keep in mind. Firstly, as described in Figure 8.5, the intensity and challenge of the game have to be balanced with the skill and fitness level of the player to achieve flow. Secondly, as seen in Table 9.1, low to medium-intensity games such as Pokémon Go, Ingress, and Wii Sports have been the most commercially successful exergames. Encouraging players to be physically active with a slight increase in energy expenditure seems more meaningful than working on, e.g., a specific muscle group or solely on aerobic fitness. Lastly, one paper recommended exergames to use large muscle groups in the exergame activities.

Although without a solid, empirical foundation, we are cautiously inclined towards developing a low-intensity exergame that provides a low threshold for everyday physical activity with long-term incentives to keep playing the game. A low-intensity exergame could appeal to a broad audience which perhaps consists of the people who are not the most physically active and would like an easy and fun occasion to exercise or be physically active.

14.2 Genre and gameplay content perspective

In the prestudy, we found that an adventure game, puzzle game, or a platforming game would be a good fit for an exergame. This decision was based on the review of all major game genres. Otherwise, there are no prudent findings in the existing literature of what genres are best suited for an exergame. One research paper claims that a player is more likely to get a more significant utility value from an exergame if the exergame is in the same genre as the player liked before. The survey found that strategy and puzzle games were the most popular genres, creating a potential issue. The genre may be less suitable for an exergame due to the gaming context and the difficulty of finding a solid and easily understandable mapping between relevant physical exercise activities and in-game puzzles, which the mentioned study on Exermon in Section 9.7 found was important. This issue will have to be considered when choosing a concept.

Exergames have evolved from focusing on specific muscles or motor skills to have a more holistic approach to the players' health. Many modern exergames use fitness data such as heart rate and calories consumed and burned to encourage players to live a healthy and active lifestyle.

Lifestyle has a broader perspective than just the exercise in a given session; physical activity must also be considered over an extended period. Modern exergames thus endeavor to increase player retention and provide long-term incentives to prevent players from playing the game and returning to their previous sedentary lifestyle, as the literature reports often is the case. None of the experiments reported any substantial, long-term health benefits after an experiment or an exergame intervention. Any potential benefits occur while playing the game regularly. This observation encourages future exergames that intend to provide a healthier lifestyle to include long-term incentives to boost player retention. The incentives should have a perspective of months or years, or at least keep in mind that the health benefits are probably directly proportional to how long the player, at least semi-regularly, plays the game.

Other notable findings from the prestudy:

- A strong mapping between the actual physical activities performed while playing the game and the fantasy elements of the game is perhaps an advantage. If the player kicks while playing the game, something similar to a kick should occur in the game.
- As stated in Section 8.2.8 and Section 9.4 social interaction in exergames can both have positive and negative implications for the game experience. It does not appear to be a key motivator for exercise and can disrupt the game immersion. However, it can also provide enjoyment for the players by introducing competition, cooperation, and connection while playing.
- When designing a new exergame, the content of Chapter 8 should always be kept in mind.
- From the survey, *Fun and engaging gameplay* was by far the most selected option of what made the respondents enjoy a game. While fun and engaging gameplay is perhaps not the most tangible and meaningful metric, it is more important than music, graphics, and achievements.

14.3 Technical perspective

When choosing a game concept, one should also consider the technical feasibility. Are there suitable game engines or frameworks available? Is it possible to measure or track the player's physical actions? How mature are the technologies, how big is the community, and how much high-quality documentation exists? How easy is it to disable cheating? Fortunately, there is an assemblage of available engines, frameworks, sensors, and other technologies today for creating all kinds of exergames. However, all of them have their strengths and weaknesses, and the development team's experience with the technology should also be considered.

Since the exergame to be developed is also to be tested, the testability of the concept should be considered. Should the exercise form be walking around a large area, it is relatively easy to use a GPS tracker to measure the player's movement. Amount of steps and heart rate are also relatively simple to test. However, if the game measured amounts of push-ups or mindfulness, it would be difficult to precisely measure the activities and avoid cheating. GPS trackers and fitness data seem to be fine choices given the contemporary technology.

Also noteworthy, the most commercially successful existing exergames use GPS trackers or motion controllers to track player movements.

14.4 Reach and target group perspective

The survey's last question asked the respondents if they would be interested in using a game to help them reach their exercise and physical activity goals. Only 26% said they disagree or partially disagree with wanting to use a game for this purpose. Thus, if an engaging exergame were to be implemented, there would possibly be a potential to engage many people to reap its health benefits. From our assessment, the potential is neither staggeringly high nor low but substantial and worth further exploration.

Another notable finding from the survey is that a distinct majority would like to exercise and be more physically active than they are today. Many people do not reach their goals due to a lack of time, exercise not being sufficiently motivating and fun, or needing a nudge from an external agent to exercise more. In addition, few respondents reported spending much time on video games.

If one were only to inspect the respondents who are (partially) interested in using video games for exercise and physical activity, these people like video games slightly more and exercise slightly less. Inspecting the opposite segment: the people not very interested in using video games for this purpose, the opposite pattern emerges. Also apparent from the survey was that people who play a lot of video games are less likely to enjoy a game for a mobile device. People who fully agree to not being satisfied with their exercise frequency are perhaps more likely to enjoy a mobile game. If we were to make the prototype for the experiment a mobile game, it would probably be more challenging to reach the *hardcore gamers*, but easier to reach a broader audience who are more likely to want to exercise more than they are currently.

There is no eminently apparent target group visible after reviewing the prestudy. Exergames can have positive health benefits for children, teenagers, adults, and elders. However, for research purposes, it would perhaps be easier to test an exergame on a younger demographic due to two reasons:

1. Since the project is of small scale, the prototype testing group will probably primarily be populated by people in our social vicinity, thus people in their 20s living in Trondheim.
2. According to Statistics Norway, younger people and people with higher education have stronger digital skills [154].

It would be sensible not to limit the scope to a specific target group in the early phases to keep a younger but otherwise diverse demographic in mind.

14.5 Summary

This chapter has provided a distillate of the most critical findings from the prestudy. The chapter has been organized to present the findings from four perspectives: health, genre and gameplay, technical, and reach & target group.

Looking at the health perspective, the findings encourage us to develop an exergame with low-intensity physical exercises and long-term incentives to boost player retention. The low intensity helps focus on the players' long-term health benefits and lifestyle changes instead of playing the exergame a lot for a short time and then losing interest. The genre and gameplay perspective's most significant findings also encourage the previous point.

From the technical perspective, a discouragement towards strength exercises and an inclination to use the GPS tracker and fitness data are found. The potential usage of the exergame is not seen as notably high or low. However, there is a substantial prospect that it could tap into potential players' feelings about not reaching their physical activity and exercise goals.

Chapter 15

Concept Ideas

This chapter will present different ideas for the exergame prototype to be implemented for the experiment. The focus of the game concept ideas is to be enjoyable, inspired by game development theories in Chapter 8, and make the players more physically active, as elaborated on in Chapter 5. To reiterate the research goal of this project: *Discover, analyze, develop and test a new exergame concept and prototype which motivates people to increase their physical activity levels.* The chapter presents five game concepts deemed exciting and somewhat suitable for a prototype implementation and testing in an experiment. The concept chosen for development was naturally exposed to extension and change as the implementation phase progressed. The project's time restrictions and limited resources would result in some decisions in the design and implementation phase. Also, some game features would have to be changed or dropped to accommodate the short time span of the project, but the main game concept would be somewhat final and not subject to change. This concept is examined in Chapter 16. The following concepts will be evaluated on five parameters: reach potential, feasibility, exercise factor, fun factor, our motivation to make the concept, and testability.

15.1 Row Till You Bleed

Row Till You Bleed is a game concept idea using a rowing machine as input to a game being played on a screen near the rowing machine. The idea is inspired by the Playpulse exercise bike and can be played in both single-player or multiplayer [155]. The game allows the player to select different game modes. The first is a single-player campaign mode, which tells the story of a soldier rowing an old warship and puts the player in several naval war scenarios. The player can set the gameplay difficulty to suit them. The second game mode is a time trials mode, which allows the player to replay scenarios from the campaign again, with the single goal of completing the scenarios as fast as possible. The scores would be posted in a shared high score list, and players could compare their scores with their friends and other players. The third game mode is multiplayer, where players cooperate on rowing a single boat together through various levels as fast as possible by rowing synchronously. This mode would require several rowing machines.

The Rowing Crew activity in Wii Fit U is a somewhat similar concept, shown in Figure 15.1. Like in Wii Fit U, the player would row quicker in the game if they followed the correct rhythm. The optimal rowing rhythm would change depending on the scenario to ensure the player could not just row in the same rhythm for the entire game.

Figure 15.1: Gameplay of the rowing crew activity in Wii Fit U

The campaign mode gives the player clear goals, and the naval war setting can give the game a fantasy element by, for instance, being set in a medieval time. The campaign aims to further evoke the player's curiosity to motivate them to continue playing. These factors would hopefully engage players and create a fun experience while exercising. The game would focus on aerobic exercise, as the player would be rowing for more extended periods. The intensity of the campaign mode would increase as the player progresses, trying to achieve the correct intensity, as discussed in Section 8.3.

15.2 Neighborhood Warfare

Neighborhood Warfare is meant to be played on a smartphone with other people. The idea is inspired by the capture the flag and domination game modes in shooter games like Call of Duty and Battlefield, as well as the gym and portal capture mechanic in Pokémon Go and Ingress. The game is a location-based game, using the smartphone's GPS sensor to track the position of the players. The game is match-based, perhaps having between two and ten players per match, divided into two or more teams. One player has to create a lobby, taking the role of a host. When a match starts, the game creates control points or camps within a certain radius from the host. The host can change the radius and amount of control points. An example of a map from Call of Duty: Modern Warfare 2 with three control points can be seen in Figure 15.2. The two teams then compete to capture the control points and hold them to gain the most points throughout the match. The host can change the match duration to either a time limit or a score limit. A control point will gradually be captured if more players of a specific team are close to the control point. The players of the capturing team would then need to be standing close to the control point for a certain amount of time to capture it fully. If two players on opposing teams run into each other, they can battle each other by having to shoot the other player by tapping their phone screen as fast as possible. The loser is disabled for control point capturing purposes for 30 seconds, allowing the other player to capture a control point freely. The game would allow players to strategically choose perks before starting, like disabling other players faster, capturing a control point faster, or a balance between both.

Figure 15.2: A domination map in Call of Duty: Modern Warfare 2 with 3 flags.

Hopefully, the game would be enjoyable by being a group-based physical activity where the group can focus on competing for a fixed amount of time, similar to, e.g., a laser tag match. The game would be an activity where groups of players could play as an organized activity, but probably not something they would play all the time. The game's goal is something most players should be familiar with, as capture the flag is seen in many other games, both digital and non-digital. The game would focus on aerobic exercise, but unlike Pokémon Go, where the focus is on walking, the game would encourage people to run to get to the control points faster. The game would heavily focus on social interaction and competitiveness between players.

15.3 Arrow Party

Arrow Party is a VR game played with motion controllers. The idea is inspired by archery games using motion controllers like Wii Sports Resort, shown in Figure 15.3 and The Legend of Zelda: Skyward Sword, as well as Beat Saber. The game is a rail shooter, meaning that the player automatically moves in the game and has to focus on shooting oncoming enemies with a bow and arrow. The game would be themed around Greek mythology, with the player taking the role of an archer on a chariot. Enemies would be swarming the player from land, sky, and sea, depending on the level. The enemy pattern would be the same on every play of the same level, allowing players to master levels. Some obstacles require the player to duck down physically or cross their arms to block enemy projectiles. The game would feature several levels, allowing players to see their score for each level and compare it to their friends and other players.

Figure 15.3: Gameplay of archery in Wii Sports Resort

Like Beat Saber, the activity from the game will come from the player moving their arms quickly and precisely to hit all the oncoming enemies. The player must also move their body to duck and block enemy projectiles, adding an anaerobic aspect to the physical activity. The player could choose a difficulty for each level, hopefully hitting the perfect level of challenge, as discussed in Chapter 8. Players can also compare their scores to friends online, which would serve as another motivation for playing.

15.4 Idle Workout

Idle Workout is an idle strategy game for smartphones. The idea is inspired by idle games like AdVenture Capitalist, shown in Figure 15.4, and Clash of Clans and Exermon. Players can perform strength exercises, walk or run to acquire different currencies. Each type of workout would give the player a different type of currency. Currency can be traded to acquire worker units, which can gather different resources, such wood, rock, and clay. The units will continue to gather resources for a certain amount of time after the player has stopped actively playing. This period can be extended by doing a certain amount of daily workouts. At the start of the game, the player can only access the most basic units, which produce the most basic resources. As the player gets currency, they would be able to access higher-level units that can gather more expensive resources, giving the player motivation to continue playing to progress further.

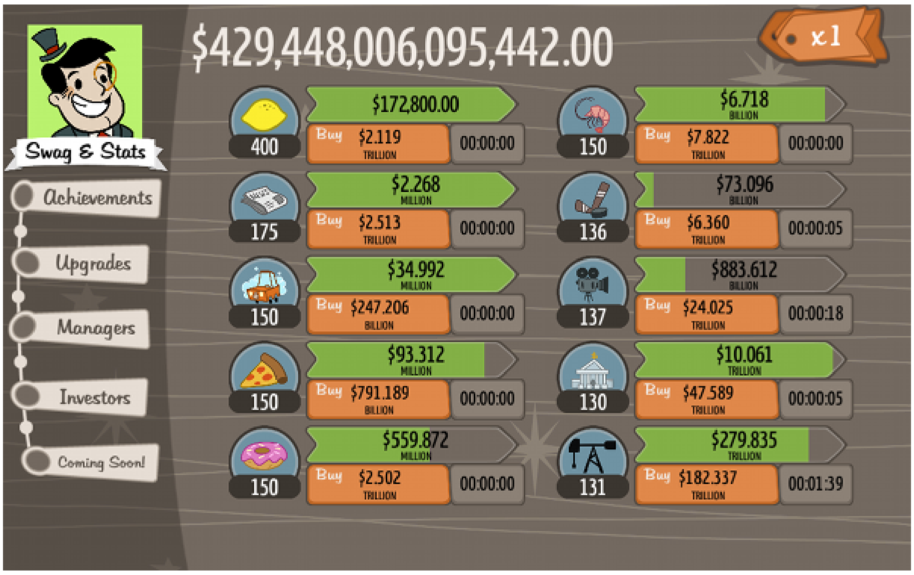

Figure 15.4: Idle game AdVenture Capitalist focuses on getting an absurd amount of money

The game would encourage the player to be physically active in many different ways, allowing them to choose if they want to do strength exercises or walk to gather currencies. By doing various exercises and not just focusing on the same exercise type, the player would be able to get a variety of currencies, which would benefit the player.

By spending the resources gathered by the working units, the player can acquire soldier units that can be used in battle or upgrade the player's city. Different soldiers and buildings would cost different currencies. The soldiers can attack other players' cities, or cities controlled by non-player characters, to steal resources, where the player would win or lose depending on the units chosen to attack. Each time the player wins a battle while attacking, they receive science points, which a player can use to choose different perks or upgrades. This game mechanic, alongside the attacking mechanic, would hopefully add a strategy element to the game, engaging players. The game would only allow players to attack players within their power level to prevent stronger players from attacking weaker players. The game would also set a cooldown timer after a player victory to prevent the same players from getting attacked repeatedly.

Another game variant would not include strength workouts, as focusing on low-intensity physical activity seems preferable, as mentioned in Chapter 14. This variant would only include one primary currency type acquired from walking, possibly allowing the player to get a bonus if walking more often, faster, or running.

15.5 Paint it Gray

Paint it Gray is a location-based game for smartphones. The idea is based on the concept of Pokémon Go and scratch maps, shown in Figure 15.5, where a person marks the places (streets and areas) they have been by scratching, with the game keeping a permanent record of all the places they have visited. The name Paint it Gray is a play on The Rolling Stones' song *Paint it Black*.

Figure 15.5: A scratch map of the worlds countries

Like an actual scratch map, the game would keep track of the places a player has visited while playing the game and display them on a digital map. A scratch map metaphor could encourage the player to *complete* a bounded location such as a city or another kind of area by having visited all available locations related to that area. An example could be to have walked on all streets of a city. The map would have different levels of detail, allowing the player to "zoom" between them to adjust their traveling scope. The map could show countries, regions/counties, and city districts. Players would at any point be able to compare their maps to other players to see who has explored the most. The player can revisit each area daily, and a leaderboard will track which player has visited each area the most. As the player physically moves, they are shown a map representation with their character or an avatar moving on the map correspondingly to their movements, like in Pokémon Go and Ingress. When visiting a street, its color on the map would change, indicating that the street has been visited. Every time a new area is explored for the first time, the player would get a large number of experience points (XP), and every time the player explores an area for the first time that day, they would get a medially amount of XP.

To make the game more engaging, it could include a fantasy element. The fantasy could be about evil paint blobs coloring the world with toxic paint. The player would be encouraged to remove the blob's paint trails by visiting different areas on the map and cleaning the areas, which would make the color change of a visited area make sense regarding the fantasy. While the game keeps track of each visited area, the blobs would retake the world daily, encouraging the players to keep exploring. Every day, there would be some particular marked areas with a higher blob concentration, encouraging the player to visit those specific areas. While the player walks, blobs would spawn around them at random intervals, requiring the player to tap on them a certain amount of times to defeat them, rewarding the player with XP. Leveling up would reward the player with more tapping power, being able to defeat the blobs faster.

15.6 Evaluation

Each game concept idea has been evaluated on reach potential, feasibility, exercise factor, fun factor, our motivation to make the concept, and its testability. The results can be seen in Table 15.1. Arrow Party and Row till you bleed were deemed to have the lowest potential reach, as they require specific, expensive hardware apparatuses to play, and the motivation to make these are also relatively low. Idle Workout and Paint it Gray have the highest reach potential as these mobile phone games can be played with a single player. In contrast, Neighborhood Warfare has a lower reach as it requires several players to play simultaneously. We are highly motivated to make all three latter games, but Paint it Gray seems the most feasible for implementing a prototype, based on advice from our supervisor. We also estimate Paint it Gray to have a high level of engagement, together with Neighborhood Warfare and Arrow Party. We estimate all of the concepts to have a high grade of testability. We chose to move on with Paint it Gray based on these criteria.

Table 15.1: The concept ideas rated based on several criteria. Each criteria is rated on a scale of low (L), medium (M) and high (H).

Concept	**Reach**	**Feasibility**	**Exercise**	**Engagement**	**Motivation**	**Testability**
Row till you bleed	L	L	Rowing	M	L	H
Neighborhood Warfare	M	L	Walking or running	H	H	H
Arrow Party	L	L	Body movement	H	L	H
Idle Workout	H	M	Walking or strength exercise	M	H	H
Paint it Gray	H	H	Walking or running	H	H	H

Chapter 16

Chosen Concept: Paint it Green

This chapter will give a detailed walkthrough of the chosen concept for the game, Paint it Green. The chapter will overview the concept, the core gameplay mechanics, and how the exercise aspect of the exergame will function. The chapter will also discuss how the game design is planned to fulfill the guidelines introduced in Chapter 8. The concept began as Paint it Gray, detailed in Section 15.5, but evolved into Paint it Green.

16.1 Game overview

This section provides an overview of the game as a whole. It will include general information about the concept, gameplay mechanics, and other critical aspects of the game design.

16.1.1 Game concept

Paint it Green is a pervasive game, defined as a game no longer limited to the virtual world and integrates parts of the real world [99]. Further, the game is a location-based/location-aware pervasive game, which can be regarded as a game using the entire world as a game board [99]. As mentioned in Chapter 15, the game concept will be developed for smartphones.

The game places the player in a version of the real world that has been overtaken by evil paint monsters (blobs) led by the evil paint bucket Paintavaggio (a play on the Renaissance painter Caravaggio). The story and gameplay mechanics are explicitly placed in the city of Trondheim, Norway. This decision was mainly made due to technical constraints and scoping issues in the development phase. However, it also provides a more homely and tailored experience to the test subjects detailed in Section 29.2.1 since the experiment will take place in Trondheim. More details about this choice can be found in Section 16.5.1.

The player can explore the in-game map by physically moving around in their environment. Geolocation data like visited addresses and city districts (equivalent to postal codes) will be saved on a server to track all areas visited by all players. Players can compare their progress in exploring each city district with other players.

The player can retake and repaint city districts that have initially been colored gray by Paintavaggio. When moving to a city district, it will get a new color based on how much the player has visited them. Visiting a city district for the first time will reward the player with a lot of exploration points (XP). Acquiring certain amounts of XP will cause the player to level up, which will cause new and stronger blobs to spawn and occasionally prompt a boss battle with Paintavaggio.

While the player is physically and virtually moving, blobs will spawn randomly on the virtual map near the player. There are many different types of blobs, with each type coming in different versions with varying size, appearance, and health points. Blobs are defeated in various ways, depending on their type. Small blobs are defeated by tapping one or more times, while bigger blobs must be defeated in a separate combat mode by launching paint missiles or throwing paint grenades. Defeating a blob will reward the player with small amounts of XP. The design of the paint blobs is inspired by the Amoeboid from the Ratchet and Clank series, shown in Figure 16.1.

Figure 16.1: Amoeboid from Ratchet and Clank

Once reaching the last story level (level 20), the player will battle Paintavaggio for the last time and finish the story, even though the game can still be played like before, even after completing the story.

16.1.2 Genre

Paint it Green is a location-based exergame with segments from action games and the RPG genre. The game's location-based nature is evident as it tracks the player's position, places a player avatar on a map of the natural environment in the player's proximity, and uses it as a core mechanic. The RPG and action segments hail from the player acting as a character on a quest to retake the world from an enemy and defeat said enemy and his minions in action-filled battles.

16.1.3 Graphics

The game will feature simple 3D graphics as impressive visuals are not the main priority of a small scoped smartphone exergame. The choice to use 3D graphics instead of 2D graphics was made as we wanted to provide a more immersive and realistic experience by strengthening the mapping between the game and real-life due to the in-game map representing the actual environment around the player. The game will utilize map data platforms to generate a representation of the real-life world at runtime. The game will represent both the player and enemies as simple 3D sprite models in the game world. All models in the game will come from free libraries or be manually created by us, as the project has minimal economic resources.

16.1.4 Story

The player will take the role of a green paint-can named after each player's username. The player is tasked with retaking and repainting the world by fighting the evil Paintavaggio and his blobs. Throughout the story, the player is assisted by a 2D companion character named Brushy, who is shaped like a paintbrush. The story is conveyed through text dialogue messages at the game's start and when the players level up to certain levels. The player should always identify as the story's protagonist, gradually taking the world back from chaos and progressing towards their given goal. When reaching key levels, the player will face Paintavaggio in a boss battle, who will reveal more of the story to the player each time he is defeated through dialogue. After battling Paintavaggio for the last time at level 20, the game's characters will, through assertive and dramatic dialogue, try to profess the player as no different than the villain, painting over the world just with a different color but also committing mass blob murder while doing it. The game's main story will end with Paintavaggio finally defeated and Brushy denouncing and condemning the player. However, the player can keep playing if they want.

See Chapter 22 for the implemented game with its features, and Appendix G for all story and tutorial dialogue.

16.2 Gameplay and game mechanics

This section will provide more details on the gameplay and game mechanics.

16.2.1 Coloring the map of Trondheim

The main gameplay of Paint it Green features the player walking around in Trondheim. The main gameplay view will look similar to the map view from Ingress, shown in Figure 16.2. Paint it Green will also feature a mini-map view of city districts, which can be reached by pressing a button with a globe icon in the main gameplay view. This map will show a topological map of Trondheim, divided into different city districts based on postal codes. Visiting and exploring different city districts will recolor them on the map. A city district will have a specific color if the player has never visited it, another color if the player has visited it but not on today's date, and a third if the player has fully explored the city district. To fully explore a city district, the player needs to have visited it for a certain amount of time, traveled a certain distance within the city district, and visited a certain amount of unique addresses within the city district.

Figure 16.2: Map view from Ingress

16.2.2 Battling blobs

When moving around on the map, blobs can spawn around the player. There are three types of blobs: small blobs, large blobs, and armored blobs. Each blob type will also have different versions with different sizes, health points, and appearances. At the start of the game, only small blobs spawn. Small blobs can be defeated by tapping them one or more times in the main view. As the player levels up, stronger blobs will spawn. Large blobs will take the player into a separate combat view, requiring them to throw paint grenades at them to defeat them. If the player runs out of paint grenades, they lose the battle and receive no XP. Armored blobs act similarly to large blobs but have shields in one of four positions, up, down, left, or right. The player will fire paint missiles by swiping their finger on the screen in four directions. The blob only loses health if the player successfully hits them, not the shield. Like the large blob, if the player runs out of missiles, they lose the battle. All blobs will have health bars indicating their remaining health points and will be animated to suit their state.

When the player hits crucial levels, like levels 5, 10, and 15, they will meet and battle the main villain, Paintavaggio, who is shaped like a bucket with a menacing face. These unique boss battles feature a mix of the game's two combat systems. After defeating Paintavaggio, the player receives a large amount of XP and some expositional dialogue from Paintavaggio and Brushy, revealing more of the game's story.

16.2.3 Double XP areas

Every day, five of the city districts become double XP areas. These districts will be marked with a light border in the map view to signal their importance to the players. Double XP areas reward the players with double the amount of XP for any action completed within that district. Which city districts that are double XP areas will change daily to nudge players to explore different parts of the city. However, an important aspect is that the double XP areas are the same for all players daily. By sharing which city districts give double XP between all players, we try to encourage more social interaction while playing the game by having players meet each other while playing.

16.2.4 Friends comparison

The game will feature leaderboards for each city district, where players can view the progression of the top players in that city district and compare their own scores to theirs. The leaderboards will only feature the scores of the five top players to avoid exposing players with low scores and potentially invoking unpleasant situations. However, all players can compare their own scores to those on the leaderboards. The leaderboards will only be available for city districts the player has visited at least once. Players can compare their progression on time spent in a city district, distance covered within that district, unique addresses visited, or all three combined.

16.3 Physical activity and cheating

The intensity level of the physical activity excerpted from Paint it Green is relatively low. The main physical activity will be players walking around in the city. However, it would also elicit fast walking, jogging, and running. Since the player would move faster on the in-game map when moving physically faster, they would progress quickly towards their goals by exercising more intensely. Thus, the game encourages players to increase the intensity while providing an adequate walking experience.

16.3.1 Aided movements

The primary purpose of this project is to create a fun and engaging game which motivates people to increase their physical activity levels. Cheating could mean playing the game and acquiring XP and goal progression without physically moving and exploring the area; playing the game while in a moving vehicle such as a car, a bus, or a motorized cycle would be an example. Implementing a player velocity tracking mechanism that triggers when the player moves noticeably quicker than usual walking or running and then remove or reduce the player's progress would be a possible solution to this kind of cheating.

16.3.2 Illegal server communication

Another example of cheating would be interacting with the global server illegitimately, such as directly setting one's or another player's level without acquiring sufficient XP to reach it. Several measures have been implemented to allow only legitimate server queries. The JSON web tokens generated at login will authenticate calls to the server [156]. Encrypted communication over HTTPS and removing all vital information from available endpoints also help counter this cheating.

16.3.3 GPS spoofing

Another form of cheating would be GPS spoofing: a player faking their in-game location to be somewhere they are not or moving in-game while stationary. There are some potential counter-measures to this type of cheating, but they are challenging to implement and would be limiting for players. An example of a countermeasure is to implement location verification in the game, like having them take a picture of a known landmark or otherwise easily recognizable structure that could be verified and authenticated on a server. A peer-based reporting mechanism could also be implemented if a player learned of another player spoofing their location. After confirmation of the cheating, the spoofing player could be banned or quarantined. This measure is also not a very effective control act against cheating. Due to the project's scope, which limits the volume of features, and what cheating safeguard measures can be made, some amount of GPS spoofing will probably have to be endured.

16.4 Use of game design theory

This section will discuss how the game concept fulfills the requirements detailed in Chapter 8. The section will go through each of the papers detailed in the chapter.

16.4.1 Challenge, Curiosity, Fantasy

Challenge, curiosity, and fantasy are essential aspects of a fun and enjoyable game. This section examines how the game concept fulfills the three aspects detailed in Section 8.1.

Challenge

Two main criteria are needed to provide challenge to a game: a goal and an uncertain outcome.

Paint it Green provides clear goals early on: defeat Paintavaggio and repaint Trondheim from gray to green. Furthermore, the goal can be reached by exploring the map, defeating blobs, and leveling up the player character. The goal is based on a fantasy, not just skill usage. The player should be able to tell that they are approaching the goal when they keep encountering more powerful enemies and lore as they level up. The player also has a level and XP counter with a progress bar visible in the main gameplay view. The goals and how to reach them are also conveyed through the dialogue, tutorial, blobs, and map view interactions.

Paint it Green provides an uncertain outcome through its battles. The player might lose the battle while battling large blobs, spiky blobs, and in Paintavaggio boss fights. Which variants of blobs that spawn are limited by the player's level and include some randomness. The game's double XP areas are also chosen randomly, providing the player an element of surprise every time they enter the game for the first time that day.

Fantasy

Paint it Green uses an intrinsic fantasy to motivate players to be physically active and explore their surroundings. The paint fantasy is intrinsic as the player walking around the map is tied to the actual fantasy, feasibly making the game more engaging than it would have with an extrinsic fantasy. The game aims to appeal to the player's emotions, primarily through the story and at the game's ending. The goal is to impact the player's sense of morality and make them question whether their actions were justified because they were introduced as the protagonist at the beginning of the game. The choice of a good versus evil paint fantasy was made to appeal to many players due to the theme of fighting enemies with evil minions, and contrasting paint colors would be understandable to almost everyone.

Curiosity

The game will use audio and visual effects as decoration and enhance the game's fantasy to appeal to the sensory curiosity of the player. It will also be used as a reward, playing a unique animation and sound effect when the player levels up, defeats blobs, or otherwise progresses in the game. New blobs with different appearances, animations, and abilities will also appear as the player progresses in the game.

To appeal to the cognitive curiosity of the player, the game will show the player a map of all the places they have visited, motivating the player to visit places they have not visited yet to complete the map to bring completeness. At the same time, the game features a story told in bits and pieces by unreliable and non-omniscient characters, teasing the player about the reveal that is to come, motivating the player to finish the game to find out how the story ends.

16.4.2 GameFlow

GameFlow consists of eight elements, each with its own criteria for achieving enjoyment. This section will discuss how Paint it Green meets these criteria.

Concentration: Concentration is a curious topic regarding location-based games as it is crucial for the player **not** to be too concentrated on the game. The player must mind their surroundings while playing to avoid walking into traffic or other people. Still, Paint it Green aims to capture some of the player's concentration with its game world. The game will not be filled with a plethora of tasks that are not important, and the interface will only show what is necessary for the player to see during play, to increase focus on gameplay.

Challenge: Paint it Green will aim to provide a sufficient challenge at a suitable pace. By introducing the player to stronger and tougher blobs further into the game, the player gets used to a somewhat increasing difficulty level. Boss fights will also be a little more brutal than standard fights. Consequentially, the player will become familiar with the core game features and the story while not being overwhelmed by too many features and gradually progressing through new features.

Besides the battles, the challenge will come from walking around the map and exploring new city districts, which can be done at the player's pace.

Player Skills: The game aims to develop the player's skills as they play by initially giving the player a minimal tutorial and by naturally developing the player's skills as they progress. By playing the game, the player will understand that the double XP areas are a good way of acquiring XP faster and that the same is valid for defeating blobs. The game will not inflatedly guide the player, providing an abundance of tutorials, but instead aims to be easy to use and learn and intuitive on its own. Furthermore, introducing more difficult blob types and battles as the player progresses through the game, the player's skills grow naturally.

Control: In the game, players are in control of their actions as they *are* the controller. As the character in the game moves when the player moves in real life and the in-game map resembles what the player sees, the controls should be both simple to understand and intuitive. The player can also rotate and move the in-game camera to view different map parts. The player is also in full control regarding what blobs they want to battle at what time. The game's tutorial is also repeatable, should the player want to rehash some dialogue or refresh the game's introductory story or mechanics.

Clear goals: Following the same reasoning as in Section 16.4.1, the game will provide a clear goal for the player.

Feedback: The game will provide the player with continuous feedback as they play. City districts on the map will change color as the player visits, and a progress bar will fill when the player acquires XP to show them that they are progressing. Notifications for events like acquiring XP, entering a new city district, leveling up, and more are also shown to the player. The story progression is also a kind of feedback indirectly telling the player that they are moving in the right direction.

Immersion: Immersion, like too deep concentration, is something a location-based game wants to avoid to a certain degree. The player needs to be aware of their surroundings while playing, but the game should still make the player feel like their walking does not require as much effort, or go quicker than before, to motivate them to play more and be more physically active.

Social Interaction: Paint it Green is a game that supports social interaction by providing players with opportunities to compete and compare their progress to other players. Players can compete by trying to achieve the highest score on the leaderboards for each city district. Players might also meet other players playing the game in the real world, as the double XP area feature motivates all players to visit the same areas.

16.4.3 DualFlow

Paint it Green attempts to reach flow in the attractiveness model (shown in Figure 8.5) using the same arguments as seen in the challenge paragraph in Section 16.4.2. Steadily increasing the challenge level to match the player's skill allows the attractiveness to stay in a flow state, never becoming so hard to make the player anxious but never becoming so easy it bores the player.

When it comes to effectiveness, everything is up to the players themselves. Players can choose the physiological intensity of their play session, hopefully choosing an intensity that leads to flow. As the game concept encourages low-intensity physical activity through walking, any form of physical activity while playing has some benefits, given that it does not replace higher-intensity physical activity.

16.4.4 Scripting versus emergence

Paint it Green tries to follow a balance between the scripted and emergent approach. The game's story is entirely scripted, with pre-written dialogue and story events triggering at pre-defined events in the game; this was done to give the players a clear goal while also giving us as developers creative control over the story itself.

A more emergent approach was taken for normal gameplay outside of story events. General rules were created to allow players to play how they wanted. The map is generated with the player's movements, blobs spawn randomly, and there is no hard goal except for earning XP, which the players can do in several different ways. If the players want to walk around just defeating blobs, recapturing paint stations, or trying to conquer the leaderboards is entirely up to them. It is not a completely emergent approach, but one very inspired by the freedom of emergent gameplay.

16.4.5 Player types

The first typology discussed in Section 8.5 was the hardcore vs. casual division. In Chapter 13 we made a loose definition of hardcore gamers as those who play more than two hours a day. These players often chose PC and console as their preferred playing platform, while most people who expressed a wish to exercise more than they do today chose mobile phones as their favorite platform for playing games. By targeting the platform of choice for non-hardcore gamers, it may seem that the choice of platform is targeting more casual gamers. Other than the choice of platform, Paint it Green was designed for smaller play sessions of around 20 minutes, something which casual gamers prefer, according to the paper [61].

It is more challenging to discuss the typology based on the Tomb Raider study, as there are no significant puzzles in Paint it Green. The game is designed to be played over a more extended period of time, not to be beaten quickly by skilled players.

The third typology is more relevant to the concept. Bartle divided players into killers, achievers, socializers, and explorers based on their preference of action vs. interaction and player orientation vs. world orientation. While Paint it Green features some limited social features, it is a game that favors world-oriented players. On the world-oriented side, the game supports action and interaction favored play styles. Players who prefer action can utilize combat actions to acquire XP, while people who prefer interaction can focus on interacting with paint stations and exploring city districts.

16.5 Limitations and scoping

The concept choice bears certain limitations, both in technological limitations based on our previous experience and skill level and the actual player group. The used technologies will be Unity as a game engine and Mapbox for the reverse geocoding and map generation API. It will be a game for mobile units using a GPS sensor and a client-server architecture. More details on the use of these technologies in Part IV.

16.5.1 Technical scope

A choice must be made on whether the game should be designed to be played globally or in a bounded area like a single city. As the available resources are somewhat limited, the game's scope has to realistically reflect the given limits for time and working hours available. One also has to keep in mind that the testing and exercise evaluation of the game is critical to the research dimension of the project, and creating feasible test scenarios is a significant priority. The considerations can be reduced to two alternatives:

- **Alternative 1: Implement the game for Trondheim, Norway only.** This would reduce the game's scope but could make the game appeal even more to the city's inhabitants. It would make it possible to manually divide the game's map into city districts. A much more comprehensive game experience could be provided to the Trondheim-based test subjects despite the static, manual work. The results could then be subject to induction and be used to evaluate a potential future game expansion.
- **Alternative 2: Make the game playable worldwide.** This would substantially increase the game's reach and give more diversified results, but regarding the scope of the project, it is highly uncertain if it is realistic to create a fun and engaging game with a global scope. Since city districts have to be manually created, this solution would mean not including the city districts with visitation, exploration, leaderboards, and double XP areas. This alternative would also produce issues like handling private areas, military bases, and other area restrictions. The game would also have to be balanced for rural areas where the concentration of different streets would be shallow.

Since both authors of this thesis live in Trondheim, the experiment and observations will probably be based in Trondheim in any case. Scoping the implementation based on Trondheim would warrant more features and design polishing to create a better overall experience for the player, which we deem more important to answer the research goal from Chapter 3. Thus, as already told in previous chapters, we have chosen alternative 1, as we believe it to be, all things considered, to be the best option, given the scopes of the master thesis project.

16.5.2 User group

Reach potential was an important factor when choosing the concept, and decisions were deliberately made to include a broad demographic group as the target audience. However, from the prestudy survey in Chapter 13, there is an indication that people who play a lot of video games (more than 2 hours a day) tend to have a lower probability of having mobile as their favorite platform. When choosing a mobile game with walking and running incentives, the *hardcore gamers* who prefer PC and console will probably not be as likely to be reached.

Another consideration is the exercise form, walking and running. Those who strongly prefer strength, balance, and anaerobic exercises are probably less likely to use the game to increase their physical activity levels.

Designing the game around Trondheim does, of course, also affect the player group. Even though Trondheim is a large, diverse city with urban, suburban, and rural areas, this limitation must be considered when analyzing the experiment results.

16.5.3 Technical limitations

As the game concept heavily features GPS technology, some issues must be considered. Based on input from our supervisor, GPS sensors are often somewhat slow and can be imprecise, especially if used indoors. If there were plans to add real-time multiplayer features to the game at some point, the heavy reliance on GPS sensors could be an issue.

As the game needs to be able to run on not just the newest smartphones, the game will have to be developed with performance in mind. We want the game to perform well, also on somewhat older phones.

16.6 Summary

The chosen concept for further development in this project is Paint it Green. The game is a location-based exergame focusing on walking or running as different types of physical activity. The game concept has been created with relevant game design theory in mind.

Chapter 17

Feasibility Testing

This chapter reviews the technical feasibility testing performed to confirm whether the chosen game concept and technology choices were realistic and suitable for the coming implementation of the prototype.

17.1 Testing aims

After making an initial choice of game concept and technologies, some feasibility testing was imminent. If a location-based exergame for mobile units using Unity and MapBox were deemed unrealistic, we would need to reassess some of the choices made with the project scope in mind. Thus, a minimal prototype, or a proof of concept (POC), was implemented to test the technical and conceptual feasibility.

We wanted to test if a location-based, game-like project with a player avatar on a map of the actual surroundings, spatially responding to the actual player moving around in their physical environment, was a realistic objective. In addition, we wanted to assess whether it was possible to run the project on a mobile device using Unity as a game engine and MapBox as a map API. To test out the MapBox API for in-game map generation, we would also observe if the virtual in-game map was a recognizable representation of the physical environment around the player.

17.2 Test execution

During arbitrary probing and searching of online forums, an extensive Youtube tutorial was found [157]. The tutorial was on creating a location-based, 3D game using Unity and MapBox, similar to Pokémon Go which also was an inspiring exergame for us in our choice of game concept. The tutorial was from 2018 but used reasonably modern versions of the technologies and was sufficiently detailed and wide-scoped to serve as an adept tutorial for creating the POC.

The POC was created while following the 29 video tutorials, and it was later tested whether the result was working on actual mobile units. After building and running the POC, it was played while moving physically around the Gløshaugen campus to observe if the player avatar would follow the physical mobile unit's spatial position. The generated map was also observed to determine whether it matched the actual buildings, roads, and other environmental features around the mobile unit. Other tutorial features like XP token gathering, droid battling, and enemy spawning were also tested.

17.3 Test findings

The tests returned positive results in all fields of interest. The POC was exported, built, and run on our mobile phones. The features of map generation and in-game GPS-based movement were tested and verified. A screenshot of the POC can be found in Figure 17.1. The dark buildings in the figures are similar in shape to the actual buildings. The camera and the player avatar were also observed to follow the player's physical movements. Other tutorial features were also observed to work acceptably and could serve as a good base for in-game features for later implementation.

Figure 17.1: Gameplay of the POC

Following the findings from the small-scale feasibility testing, we were confident with the choices made and that it is feasible to proceed with designing and implementing a prototype for the experiment.

17.4 Summary

This chapter was about performing some small-scale feasibility testing to ensure confidence in the choice of game concept and used technologies. Following an extensive online tutorial, a minimal prototype/POC was implemented and tested for essential attributes like player movement, following the mobile unit's GPS tracker, and in-game map generation matching the actual environment around the player. The POC functioned sufficiently well to be confident in moving on with the chosen concept and technology.

Part IV

Design and Implementation

This part focuses on the design and implementation of the prototype. It covers the development methodology and process through the implementation phase with design choices and sketches before reviewing the chosen requirements and architecture of the prototype. Further on, all significant features of the implemented prototype will be presented along with a closer look at some central aspects. Usability testing and evaluation of the prototype and requirements are also included.

Chapter 18

Development Methodology

This chapter will address the development methodology, consisting of the project's progress throughout the time period and some central tools and activities used to develop the Paint it Green prototype.

18.1 The project's progress and development phases

This project formally started in January of 2022 but leans notably on a Specialization Project from the Fall semester of 2021, starting in August [158]. As previously stated, Part II is based upon the work of that specialization project, which also was written by the same authors as this thesis. Thus, one could argue that the project started in August 2021. Part II and Part III were naturally revised and updated with new studies and alterations to the existing studies and the developed concept during the later stages of the project to make sure the literature review included the latest research on the subject of exergames.

In any case, the fall semester mainly consisted of producing the theoretical groundwork for the prestudy on which we would base most of our decisions. As seen in Figure 18.2, the other phases of the project took place in December of 2021 and throughout the spring semester of 2022, which is the period of this Master's thesis.

Before implementing the game, several activities had to take place. Several game concepts had to be conceived and evaluated before one of them was chosen and feasibility tested. The choice of game concept is covered in Part III, and took place from around November 2021 through January 2022.

Next came formulating functional and quality requirements, described in Chapter 19 and Chapter 20. After establishing the requirements, the architecture and game art design phase began. The architecture is discussed in Chapter 21, and a sketch from the game art design is provided in Figure 18.1. There was no rigorous user testing or extensive wireframing as the design was continuously evaluated and discussed among ourselves and our supervisor. These activities happened in rapid succession and were finished at the end of January to begin the implementation phase quickly.

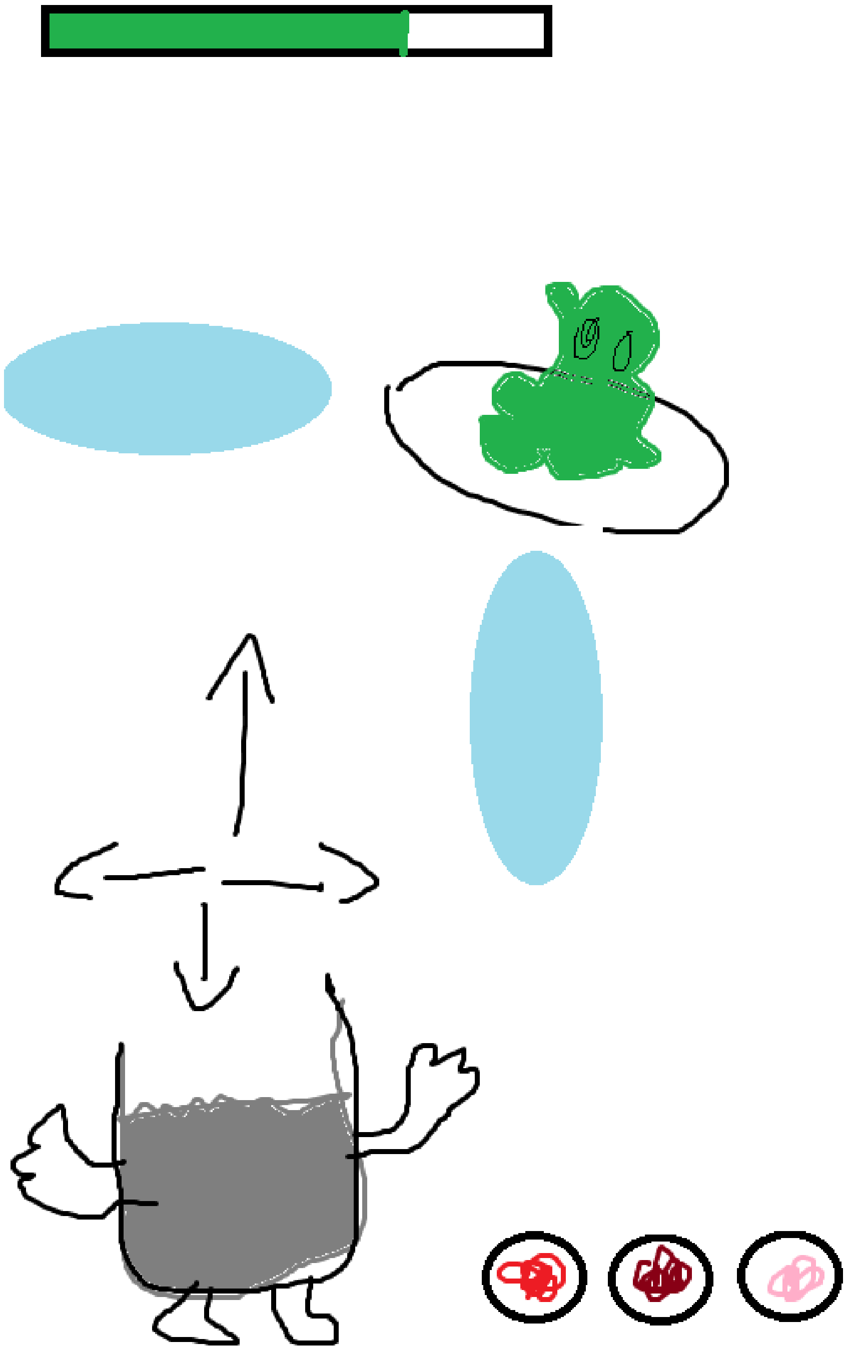

Figure 18.1: An early sketch of the game's combat.

During the implementation phase, designs and features were continuously and manually implemented, tested, evaluated, and possibly revised in an agile-like manner. Demonstrations of the game's current state were shown in an almost weekly manner to our supervisor. User/Usability testing was performed after finishing the last main features but before the experiment to fix bugs and small usability issues in the game. See Chapter 24 for more details on this testing phase. Finally, the requirements could be evaluated against the prototype, and the experiment could begin. See Chapter 25 for more details on the requirements evaluation.

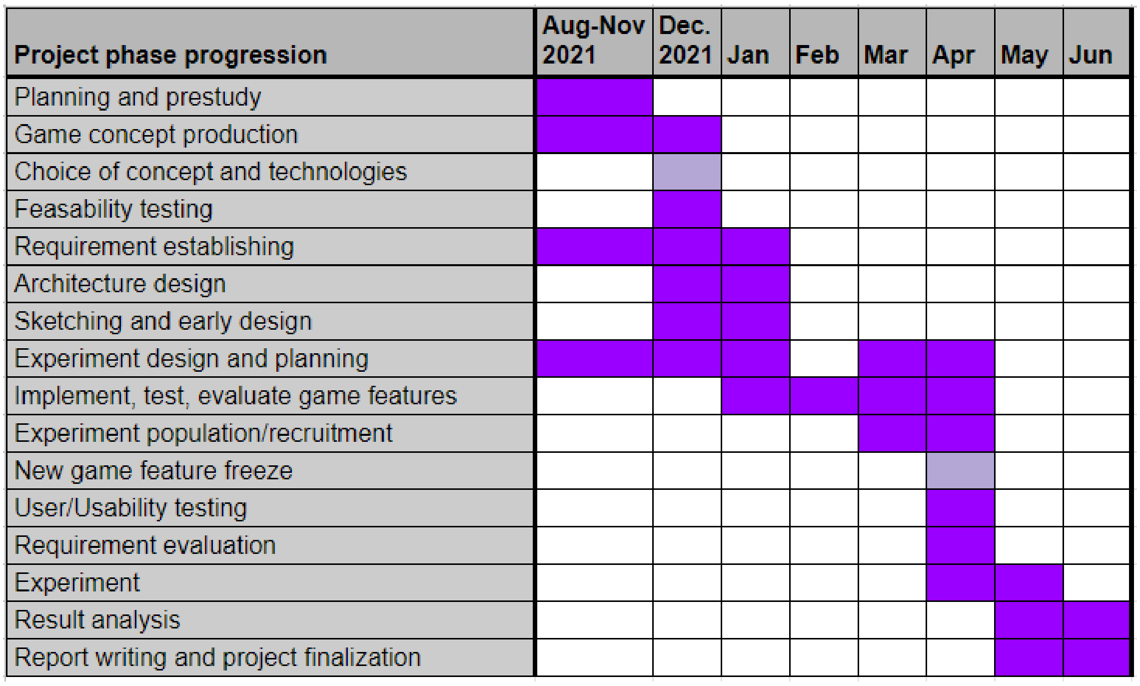

Figure 18.2: A coarse overview of the phases from planning and prestudy until project finalization.

18.2 Process tools and activities

For version control, Git was used diligently during the implementation phase. The code, which would be compiled by Unity and then run on the client (the actual code for the game), and the code for the central server were kept in separate repositories. This multi-repo strategy was utilized to ensure independent library versioning and independent feature releases and to enable autonomous work on the client and server repositories.

Our branching strategy for both repositories was scaled trunk-based development with one main branch and several short-lived feature branches, as can be seen in Figure 18.3. Since only two developers would work on the prototype, there was no significant need to work with development or release branches. Each feature branch was principally devoted to a feature and one developer. Before merging the finished feature branch into the trunk (the "main" branch), the other developer was to perform a code review of the feature branch.

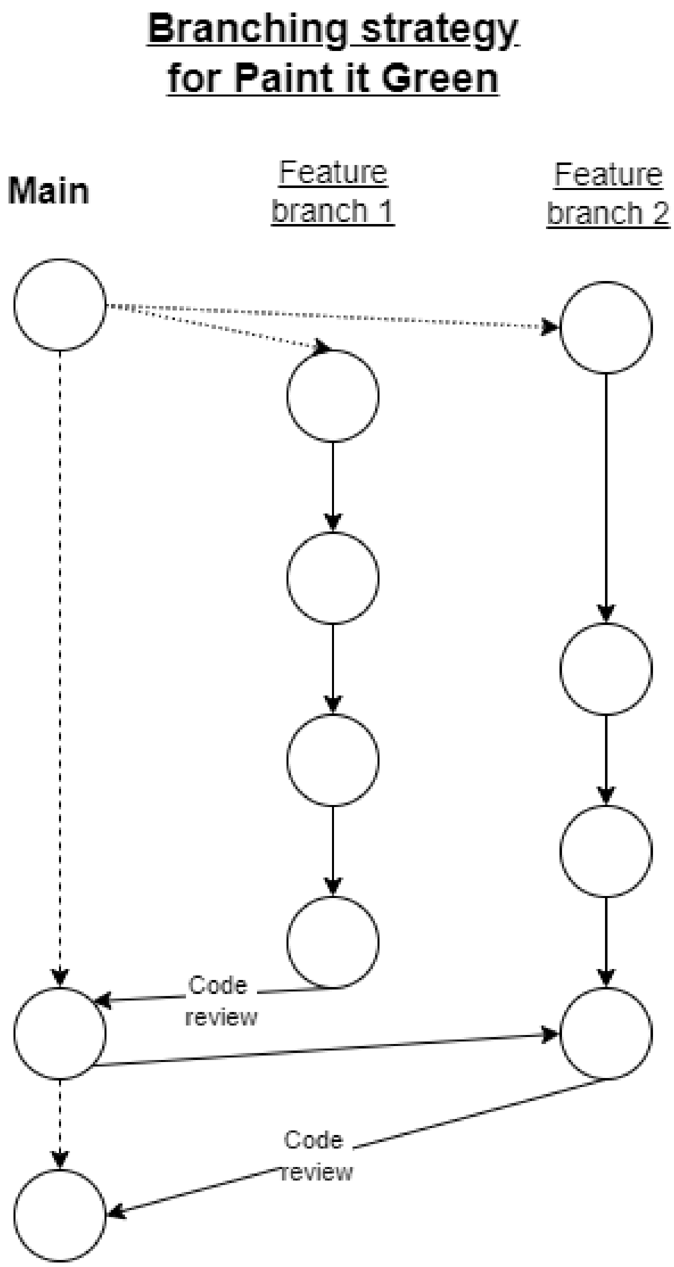

Figure 18.3: Scaled trunk based development

GitHub issues were also frequently used for small fixes and feature improvements, where updates to the requirements were not deemed necessary. Also, in addition to the mentioned agile practices, other activities like setting up continuous integration, daily stand-up meetings and pair programming were also performed during the implementation phase.

Lastly, we used Trello as a KanBan-inspired board to manage workflow. See Figure 18.4. Columns for "To Do," "Doing," "For review," "Review done, for issue-resolving," and "Done" was used to keep track of the status of each task (card).

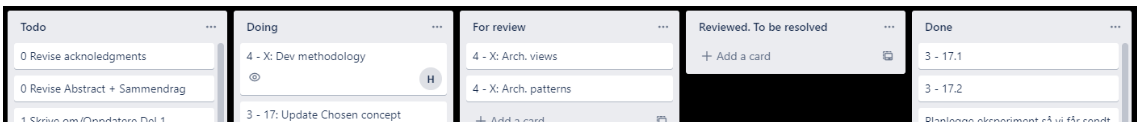

Figure 18.4: Trello board for report writing

18.3 Summary

The work on the master thesis started in January of 2022 but leans on a specialization project that started in August 2021. The prestudy was conducted primarily in the fall before a concept was chosen. The development of the concept took place in the spring of 2022. During the implementation, designs were continuously tested and demonstrated to our supervisor. Different tools were utilized throughout the implementation to make the process easier. Git was used for source control, and the frontend and backend repositories were hosted on GitLab and Github, respectively.

Chapter 19

Functional Requirements

This chapter covers the game's functional requirements, specified before the implementation phase began.

The functional requirements are mostly elicited from the game concept in Chapter 16 prior to the implementation phase. However, they are also somewhat influenced by learned theories from Part II and related courses about game design and game development. Each functional requirement has been prioritized, deeming it a high, medium, or low priority. These options are explained in Table 19.1.

Table 19.1: Explanation.

Priority	**Explanation**
H	High - Must have functionality
M	Medium - Features that should be implemented if there is enough time and resources, but after all features with high priority
L	Low - Nice to have functionality that is implemented if there is available time and resources

The priorities were used to select the functional requirements to implement before others. The priorities were also used to determine which requirements had to be dropped due to time and resource constraints. The complete overview of what functional requirements were implemented, partially implemented, or not implemented is presented in Chapter 25.

See Table 19.2 for the actual functional requirements.

Table 19.2: The functional requirements of the game.

ID	**Description**	**Priority**
FR1	**Track the player's movement on a real-world representation map**	
FR1.1	The game should display a map resembling the real world as the main gameplay view (World Scene).	H
FR1.2	The game should track the player's real-life movement on the in-game map in real-time.	H
FR1.3	The game should keep track of which part of the city the player is currently in. (Postal code/City district)	H
FR1.3.1	The address of which the player is currently in should be shown to the player in real-time.	M
FR1.4	The player should be able to view a minimap of all the city districts the player has visited, explored, and not visited, marked on the map.	H
Continues on the next page		

Table 19.2 – continued from previous page

ID	Description	Priority
FR1.5	The player should be able to rotate the map around the player avatar in the world scene.	M
FR1.6	The player should be able to zoom in and out in the world scene.	M
FR2	**Player account and data storage**	
FR2.1	The player should be able to create an account with a username and password, which is persistently stored and can be used to log in to their account.	H
FR2.2	The player's progress (XP and location history) should be persistently stored remotely on a server and updated frequently.	H
FR2.3	The player's leaderboard scores should be stored and updated regularly on a remote server.	M
FR2.4	The player should be able to delete their account and all stored data on it.	L
FR3	**Fighting enemies (Blobs)**	
FR3.1	The player should be able to battle and defeat small blobs by tapping on them (one or more times, depending on their strength) on the world map.	H
FR3.1.1	If the small blob is so strong that it requires several taps, a health bar indicating how many taps/how much health is left should be visible.	M
FR3.1.2	When a small blob is defeated, it should explode/die with an animation and a sound effect.	M
FR3.2	The player should be able to fight large blobs and enter battle mode by tapping them.	H
FR3.2.1	Battle mode should vary depending on the blob's strength and type.	M
FR3.3	Blobs should spawn randomly around the map when the player moves around.	H
FR3.4	The player should be met by boss fights when reaching levels 5, 10, 15, and 20. Boss fights are similar to large and armored blob battles but with a stronger enemy with a custom sprite and sound effect.	M
FR3.5	After defeating a boss, more of the story should be conveyed to the player.	M
FR3.6	Spawned small and large blobs should despawn after a certain amount of time.	M
FR3.7	The player should have a paint meter that can be depleted and refilled. Battling blobs uses paint and depletes the meter. Visiting city districts, tapping POIs, or acquiring special items refills it.	M
FR3.7.1	If the paint meter is empty, the player is unable to battle blobs and progress in city district exploration.	M
FR4	**Game setting and story progression**	
FR4.1	The player should easily identify a paint bucket as the player avatar in the player's physical location.	H
FR4.2	The player should be greeted by an introduction to the concept and game setting when playing the game for the first time.	M
FR4.3	The player should be introduced to a tutorial of the game when playing the game for the first time.	H
FR4.4	The tutorial should be repeatable.	L

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Table 19.2 – continued from previous page

ID	Description	Priority
FR4.5	The setting and concept of the game should include information about the evil Paintavaggio and give the player an objective to retake the world by coloring it from gray to green.	M
FR4.6	The game should have an ending where the player learns that they are just as bad as Paintavaggio. And then the player should still be able to play, but the story is finished.	M
FR4.7	The story of the game should be displayed through text dialogue messages at the start of the game and after defeating bosses, by a friendly companion/avatar (a paintbrush).	M
FR4.8	The player should meet the final boss (Paintavaggio) when reaching level 20 and, after defeating him, should be told the ending of the story.	M
FR4.9	After reaching the end of the story, the player should be able to continue as before with normal gameplay, just without the story elements.	M
FR5	**Exploration points, Levels and skill progression**	
FR5.1	The player should acquire exploration points (XP) through defeating enemies and exploring map areas and POIs around the city.	H
FR5.1.1	The player should see a notification message each time a game event like acquiring XP or entering a new city district happens.	M
FR5.2	The player should level up when acquiring a certain amount of XP.	H
FR5.2.1	Leveling up should take progressively more XP (and thus playtime) as the player reaches higher levels.	M
FR5.3	The player should receive large XP bonuses when doing something for the first time (battle enemies, enter a new city district, walking on a street)	M
FR5.4	The player's battling abilities should become stronger as the player levels up, but the bosses and medium enemies should progress faster to make battling harder as the game progresses.	M
FR5.5	The player should receive and be able to see their acquired badges when reaching milestones like levels 5, 10, and exploring 50 areas.	M
FR5.6	The player should be shown their level and progress towards the next level.	M
FR6	**Social interactions**	
FR6.1	The player should be able to compare their all-time progress in XP, map exploration, badges, and others to other players in a leaderboard per city district.	M
FR6.1.1	Each city district should also have daily, weekly and monthly leaderboards.	M
FR6.2	The player should be able to add other players as friends in the game.	L
FR6.3	The leaderboards should display the global top 5 players of that city district and the logged-in player.	M
FR7	**Replayability/Repeating game events**	
FR7.1	Some city districts should be highlighted each day/for some part of the day and have all actions happening in them rewards double/triple rewarded XP (Daily double XP zones)	M

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Table 19.2 – continued from previous page

ID	Description	Priority
FR7.2	The map areas (city districts) should have different colors on whether the player has: • Never visited it • Visited it but not that day/week • Visited it that day/week • Explored it And whether it is a double XP zone at the given time.	H
FR7.3	Daily login-streak-functionality should be implemented and reward the player with XP.	M
FR7.4	Every new day, the player should get a new quest/mission, rewarding the player with XP if the daily quest is completed.	M
FR8	**Other miscellaneous game features**	
FR8.1	The application should include music and sound effects.	M
FR8.2	The player should have access to an in-game menu with settings and other navigation options.	M
FR8.3	The player should have access to settings to adjust the volume for music and sound effects.	M
FR8.4	Actual POIs in the real environment should appear on the map and give XP when tapped.	M
FR8.4.1	POIs should have a cool down period where they can't be tapped while in cooldown.	M
FR8.5	The player should have access to a log of their actions (defeated blobs/bosses, XP acquired, city districts explored, etc.)	L
FR8.6	The player should be able to customize their player avatar's appearance.	M

Chapter 20

Quality Requirements

This chapter details the chosen quality attributes (QA) and the quality attribute scenarios for the game. The primary and secondary QAs will be presented and justified. Each quality attribute scenario is presented with the following boilerplate:

- **Source of stimulus:** The scenario trigger.
- **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.

20.1 Chosen quality attributes

Our chosen primary QA is *usability.* Usability is about the user's ability to understand the application and how it works. Users should be able to understand how to play the game quickly. Usability is almost always an important critical QA in software development. The main goal of this project is to create an enjoyable and engaging exergame to motivate and help people be more physically active. Having usability as the primary QA is thus deemed an appropriate decision. If the usability is lacking and the game is frustrating or complicated in an undesirable fashion, the player's motivation to play the game would quickly fade.

Our secondary QAs are *performance* and *availability.* Performance is about how well the game/system is performing and the timing at which the player can perform actions. When events occur, the system (including the remote server), or some system element, must respond to them in due time. Availability means that the game's software is *present* and ready to perform and do its task when needed. Fundamentally, availability is about minimizing service outage time by mitigating faults.

A common frustration among players, especially in online gaming, is poor performance while playing, informally known as *lagging.* A smooth player experience with low server latency and a consistently high rate of frames per second while playing the game is necessary to create an enjoyable and engaging exergame. Thus, we have chosen performance as a secondary QA.

Also, if the game were to not be playable at all times, there would be a loss of playing time for the players, and the perceived quality of the game would likely drop drastically. One of our findings from the prestudy, as stated in Chapter 14, is that we should aim for low-intensity physical exercise to try to reach those who want to exercise when it casually suits them. People should be able to play the game whenever they want, and if that is not always possible, the threshold for starting a playing session would likely increase. Therefore, we have also chosen availability as a secondary QA.

20.2 Quality attribute scenarios

The quality attribute scenarios state what response and response measure is expected of the finished game and are coupled to the chosen QAs [159]. They describe the game's non-functional properties, which ensure its quality for the stakeholders. As described in Chapter 21, architectural patterns and tactics were used to ensure that the game met these requirements. Each QA has several scenarios related to them.

20.2.1 Usability scenarios

U1: 80% of users understand how to play the game. See Table 20.1.

Table 20.1: Usability scenario - Understand how to play the game

ID	U1
Source of stimulus	User
Stimulus	The user plays through the introductory tutorial.
Artifact	Application
Environment	Run time
Response	The user has a sufficient understanding of how the game works and how to interact with it.
Response measure	80% of the users understand how to play the game after playing the introductory tutorial (2 minutes)

U2: 80% of users report that the game had clearly defined goals. See Table 20.2.

Table 20.2: Usability scenario - Clear goals

ID	U2
Source of stimulus	User
Stimulus	The user plays through the introductory tutorial.
Artifact	Application
Environment	Run time
Response	The user has a sufficient understanding of the game's goals.
Response measure	80% of the users report that the game's goals are clearly defined after playing the introductory tutorial (2 minutes)

U3: 80% of the users felt they were in control of their player avatar's movements. See Table 20.3.

Table 20.3: Usability scenario - Control of the player avatar

ID	U3
Source of stimulus	User
Stimulus	The user plays the game while walking.
Artifact	Application
Environment	Run time
Response	The player avatar's movements directly correlate to the player's real-life movement.
Response measure	80% of the users feel that they are in control of their player avatar's movement.

20.2.2 Performance scenarios

P1: There is no more than 7 seconds delay from opening the application to the gameplay in the world scene (+ time for login). See Table 20.4.

Table 20.4: Performance scenario - Delay from opening the application to being in normal gameplay

ID	P1
Source of stimulus	User
Stimulus	Starts the application
Artifact	Application and Mapbox API
Environment	Run time
Response	Application starts and the local map is correctly rendered in the world scene.
Response measure	Less than 7 seconds from opening the application

P2: The leaderboards of a city district are fetched and displayed with less than 3 seconds delay. See Table 20.5.

Table 20.5: Performance scenario - Sees the leaderboards of a city district with less than 3 seconds delay.

ID	P2
Source of stimulus	Client
Stimulus	Tries to enter leaderboard of a city district by clicking on the city district in the map view.
Artifact	Application and server
Environment	Run time
Response	Application fetches leaderboard data and leaderboard is displayed correctly
Response measure	The response is reached in less than 3 seconds from pressing the leaderboard button

20.2.3 Availability scenarios

A1: The clients and server are both running with at least 95% uptime. See Table 20.6.

Table 20.6: Availability scenario - 95% uptime objective

ID	A1
Source of stimulus	User
Stimulus	The player uses application
Artifact	Application (clients and server)
Environment	Run time
Response	The application starts and plays without crashing the client or the server
Response measure	>95% uptime.

20.3 Summary

In this chapter, the quality attribute scenarios have been presented. All quality attribute scenarios have been presented following the same boilerplate. *Usability* was chosen as the primary quality attribute for the project, while *performance* and *availability* were chosen as secondary quality attributes. Six quality attribute scenarios were presented, focusing on these three quality attributes.

Chapter 21

Software Architecture

This chapter presents the software architecture of the game prototype used in the experiment. The chapter will show some architectural views, present some architectural drivers and stakeholders, and discuss architectural patterns and tactics used.

21.1 Architectural drivers

Architectural drivers are requirements that significantly influence the system's architecture - meaning that the architecture could be very different without a specific requirement. This section briefly describes the requirements and their impact on the software.

21.1.1 Functional requirements

Tracking the player's movement on a real-world representation map

One of the most critical functional requirements details how the game needs to be able to track the player's movement and display it on a representation of the real-world map. This one requirement is a primary architectural driver. It means the game must be able to track the player's position, display a representation of the real-world map, and update the player's avatar relative to the map representation as the player moves in real life. The usage of an external API is all but required to take care of this, which affects the architecture.

Displaying a minimap of the city

Another essential functional requirement details how the game displays the map of Trondheim, divided into city districts. Each city district is colored differently based on how many times the player has visited each district and when the player visited last. This requirement was the main driver behind setting up a database and creating a backend for the game to store the player's movements and later display them on the map.

21.1.2 Quality attributes

This section presents all the quality attributes considered to be architectural drivers. For a more detailed rundown of the quality attributes, see Chapter 20.

Usability

Usability is crucial when making a game as we want to make the game easy to understand and learn. We want our game to provide much entertainment for the users yet be simple enough that they can easily navigate around the game and understand how to interact with it.

Performance

Performance is also essential when making a game, as we do not want users to be frustrated while playing the game. Therefore, the game must perform all the tasks the user expects it to perform in a short space of time. The user should not wait long to be logged in or enter battle mode.

Availability

Availability is vital as parts of the game not being available are another cause for frustration. Both the game running on a user's phone and the server must be available, as one of them being down makes it impossible to enjoy the game.

21.1.3 Business drivers

This section will present the business drivers of the architecture.

The game's development is constricted by the time frame of the master thesis. The time frame means that the game's development time is less than four months. Using only four months leaves sufficient time for testing and writing the final report. A significant consequence of this time dissection is that the game's scope can only be that of a prototype, not a complete game. The prototype must be large and polished enough that several test subjects can test it for 19 days without significant issues.

21.1.4 COTS

This section will present how the chosen COTS (Commercial off-the-shelf) products will affect the system.

Unity

Unity has been chosen as the main game engine, so it highly affects the game's architecture. Unity makes it simple to use the game loop and update patterns, as Unity's base classes come with an update function. This is detailed in Section 21.5.2. Unity also makes it easy to build the finished game and then ship the executable file.

Mapbox

The game utilizes the Mapbox SDK for its location services. The Mapbox SDK automatically obtains the player's location from the device and displays the player avatar on a representation of the in-game map. The Mapbox SDK also displays points of interest close to the player, which can be interacted with. The game also uses the Mapbox reverse geocoding API to fetch the player's address and post it to the server every 15 seconds to track the player's location.

Node and Express

The system's backend is created using the Node.js runtime environment and the Express web application framework. Node makes running and deploying the backend code easy, while Express makes it easy to create different REST endpoints for the API.

21.2 Stakeholders and concerns

This section will present the system's stakeholders, and their interests and concerns relating to the architecture will be discussed.

Table 21.1: Stakeholders and concerns

Stakeholders	Concerns
Experiment participants	Usability. Interested in the game being enjoyable. Wants to learn the system's functionalities to know how to best interact with the system.
Authors	System in its entirety. During development, modifiability is a significant. Wants to make test subjects engaged and motivated enough to increase their physical activity levels.
Supervisor	System in its entirety. Interested in the architecture being easy to understand to better give advice.
Grading Sensor	Finished thesis. Wants the architecture to be easy to understand when reading the master thesis.

21.3 The application's architecture at a glance

Paint it Green is developed using the Unity game engine for the client-side. The game is developed to run on Android phones. Because of the location-based game features, there was naturally a need to integrate with external map fetching and reverse geocoding APIs.

The Mapbox Unity SDK loads maps from the player's current position in the game world. Mapbox's Geocoding API fetches address data based on the player's position. A MongoDB database was set up on MongoDB's Atlas cloud platform to ensure persistently stored game data in the cloud. A REST API was created using Node.js, Typescript, and Express.js to serve the data to the game client from the database. The REST API was then deployed to Heroku's cloud platform. A specific manager class on the client-side, the DataManager, is responsible for communicating with the server's REST API and Geocoding API. An overview of the architecture is shown in Figure 21.1.

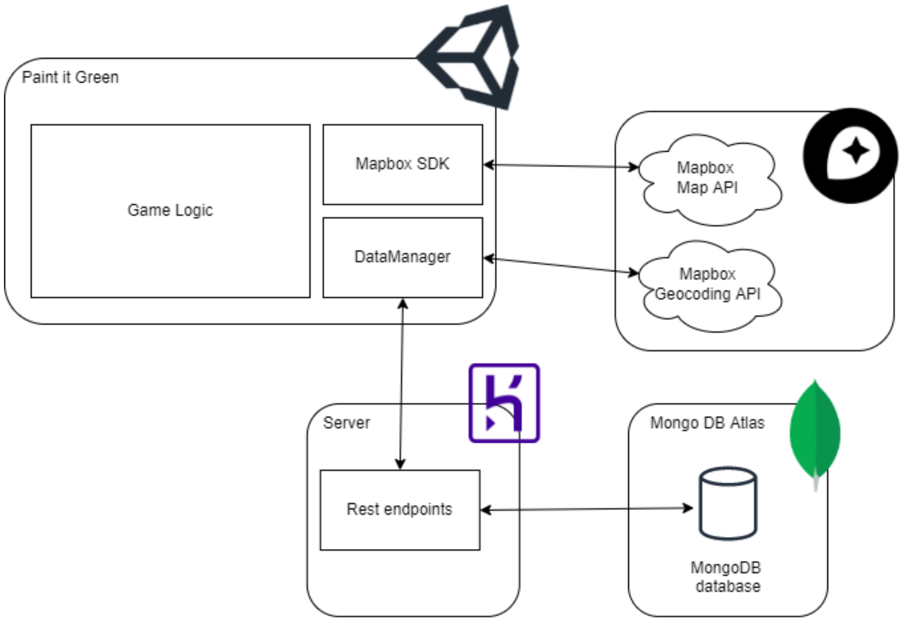

Figure 21.1: An overview of the application's architecture.

21.4 Architectural tactics

This section describes which architectural tactics have been utilized to realize the quality attributes. The tactics can be used to achieve the desired quality attributes.

21.4.1 Usability tactics

This section describes what usability tactics have been used. Usability has always been one of the main priorities while developing the game, and the following tactic has been kept in mind. While designing the user interface, design conventions like Don Norman's design principles [160] have been kept in mind.

Supporting user initiative

Supporting user initiative means providing the user with feedback on what the system is doing, allowing the user to respond appropriately. Canceling and undoing an action are examples of this. An example in the game is allowing users to skip dialogue by tapping the screen.

21.4.2 Performance tactics

This section describes what performance tactics have been used. Performance has also been a significant focus during development.

Increase Resource Efficiency

Performance latency will be kept as low as possible by striving to write optimal and fast algorithms. During development, there has been a constant focus on trying to optimize existing algorithms if possible.

Increase Concurrency

Unity allows for running coroutines in parallel, which has been done when handling asynchronous events, like sending and receiving network data.

Maintain Multiple Copies of Data

The game makes a local copy of the user's id when the user logs in. This id is then used for logging the user in automatically the next time the user opens the game.

Increase Resources

By setting a minimum Android API level of 24, the game will only run on Android 7 or newer. This demand comes with an expectation of processing power, as phones running Android 7 use modern hardware to a certain degree.

21.4.3 Availability tactics

This section describes which availability tactics have been used.

Exception Prevention

One way to make the system more available is by actively preventing exceptions. One way this is done in the game is by masking errors from the users and handling them without crashing the game.

Increase Competence Set

Another way to keep the system available is to design components to handle more faults as part of its regular operation. For example, components responsible for network communication handle many faults during runtime.

21.5 Architectural and design patterns

The prototype's architecture uses several architectural and design patterns to meet the requirements in Chapter 19 and Chapter 20. The patterns help organize the structure of the application and solve lower-level problems.

21.5.1 Client-Server

The client-server pattern is a network pattern where a server communicates with one or more clients [161]. A REST API built using Node.js, Express.js, and Mongoose hosted on the Heroku cloud platform serves as the game prototype's server. The API allows players to authenticate themselves and track their data, seeing which parts of the city they have visited and explored.

21.5.2 Game loop and update

The game loop and update patterns are sequence patterns concerned with updating multiple objects continuously [162] [163]. The game loop pattern allows for continuously processing player input, updating state, and rendering. The update pattern allows all game objects to have an update function called every frame in playtime. Together, they allow for updating the game objects continuously during playtime. Both patterns are established in Unity, as all scripts by default inherit from the MonoBehavior class, which includes the update function, which allows code to be run every frame.

21.5.3 Singleton

The singleton pattern is a design pattern that ensures a class can only have one instance and simultaneously provides a global point of access to that instance [164]. The patterns are used by several manager classes in the game, as it is essential only to have one instance at any time. It is also practical to provide a simple way of accessing it.

21.6 Architectural views

In this section, different architectural views will be presented. The views are graphical representations of the architecture and explain the system from different views. The views presented are logical, process and physical. A development view for this architecture would be almost identical as the logical view, and is thus not included here.

21.6.1 Logical view

In this section, the logical view of the system will be presented. The logical view illustrates key use-cases and functionalities for a player. A class diagram has been created to illustrate the structure of the application, shown in Figure 21.2.

The game consists of three different scenes, where one is active at all times. The player can go between the login and world scenes by logging in and out and switching between battle and world scenes by clicking blobs and winning or losing battles. Each scene has its own manager running in the background, while the world scene and battle scene also have unique managers responsible for managing the UI.

The game uses special singleton classes to handle particular parts of the game logic, utilizing the singleton pattern, detailed in Section 21.5.3. The BlobFactory class is responsible for spawning blobs in the world scene, and the SceneTransitionManager is responsible for switching between scenes. The GameManager is responsible for managing important data which needs to be accessed from different scenes, while the DataManager is responsible for network data transfer.

The game spawns different game objects the player can interact with within different scenes. The player avatar is moving in the world scene. The BlobFactory spawns blobs of three different types in the world scene. In the battle scene, the player can throw paint projectiles which are either paint grenades or paint missiles, depending on the blob type they are battling. Finally, paint stations spawn at points of interest on the map.

The location logic is handled by the Mapbox SDK [104]. The two main objects that make this work are the location provider, which provides the location of the player's phone, and the map, which displays a real-world map depending on the data from the location provider. The map object also automatically moves the player and spawns the paint stations at local points of interest.

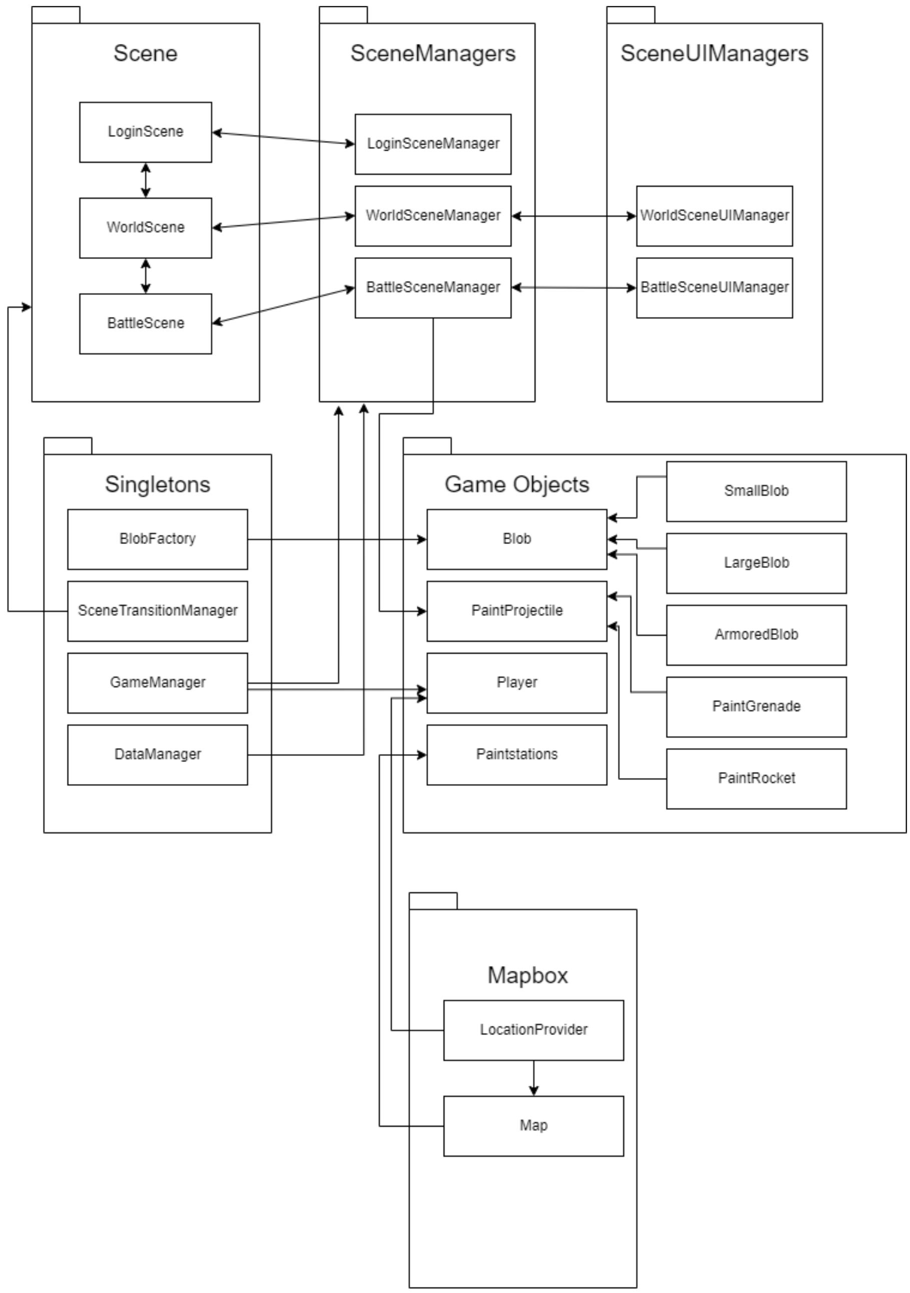

Figure 21.2: Logical view of the game prototype.

21.6.2 Process view

The process view shows the system at runtime, describing how a player might interact with the system. Two different diagrams have been created to show the process view of the system. First, a state diagram can be seen in Figure 21.3. The player starts in the login screen if it is their first time launching the game, or they are automatically logged in if they have played before. In the world scene, they can enter battle by tapping on large or armored blobs, and battles can be won or lost. Either way, the player is returned to the world scene. The player can enter the map view through a dedicated button or the main menu. The player can enter the city district view from there, which consists of a status overview and a leaderboard view. The player can log out or enter the settings in the main menu.

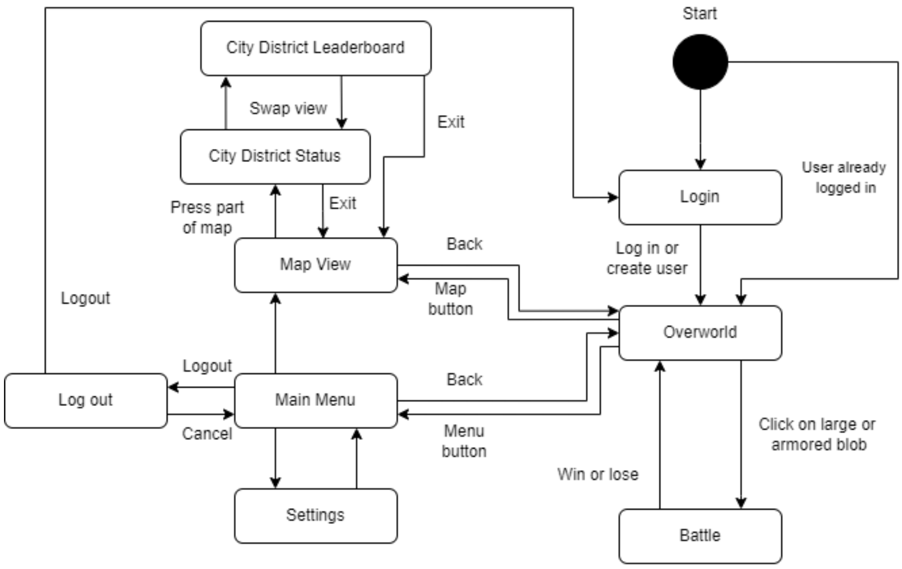

Figure 21.3: State diagram of the game prototype.

A sequence diagram has also been created to help understand where different data types originate when the player logs in. It is shown in Figure 21.4. When the player logs in, a request is sent to the server. An OK response is returned with player data if the login attempt is valid. After the player has logged in, the game uses the coordinates of the player's real-life position and sends a request to the Geocoding API, which returns the player's address. At the same time, a request is sent to the Map API, which returns data to render the map while the player is playing. After the client receives the address, it is sent to the server and stored in the database.

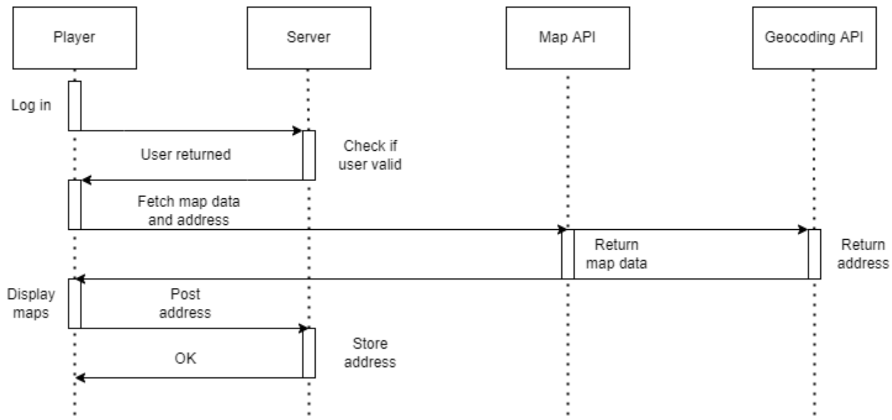

Figure 21.4: Sequence diagram of player login.

21.6.3 Physical view

The physical view gives an overview of how the different physical components interact. The physical view can be seen Figure 21.5. The game is built to run on Android phones and communicates with two different Mapbox APIs. The game also communicates with an API built with Express, Node, and Mongoose, running on a Heroku server (which runs the game's central logic), utilizing the client-server pattern, detailed in Section 21.5.1. The API then communicates with the Mongo DB Atlas database.

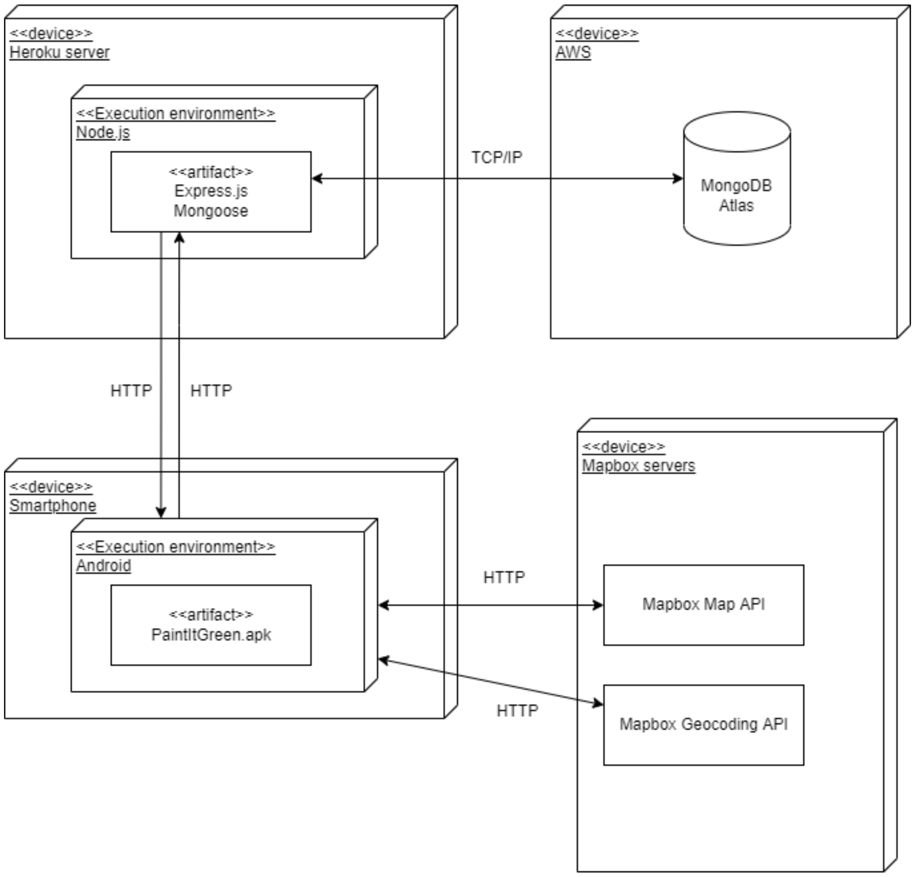

Figure 21.5: Physical view of the system.

21.7 Summary

Architecture is vital for a software system, just like a building. Many different aspects affect the architecture, like requirements and commercial software used. Paint it Green is created using the Mapbox SDK for location services in the Unity game engine. The game communicates with a Node and Express Rest API on the Heroku web service. The REST API communicates with a Mongo DB Atlas cloud database. Different patterns and tactics have been utilized to make the architecture as efficient as possible.

Chapter 22

Game Feature Review

This chapter will give a gameplay overview of the finished prototype used in the experiment. The most critical views/scenes and features will be shown and briefly explained to give the reader a better understanding of what the experiment participants were playing.

22.1 Login and registration

If the player has logged out or never logged in before, they are greeted by the login screen. They can create a new user or login with a current user. If they did not actively log out during their last play session, they are automatically logged in and moved directly to the world scene. The player will also be shown an error message if their login attempt was incorrect or the registration username is already taken. A status message is shown while evaluating the login/registration attempt on the server. The login screen is shown in Figure 22.1.

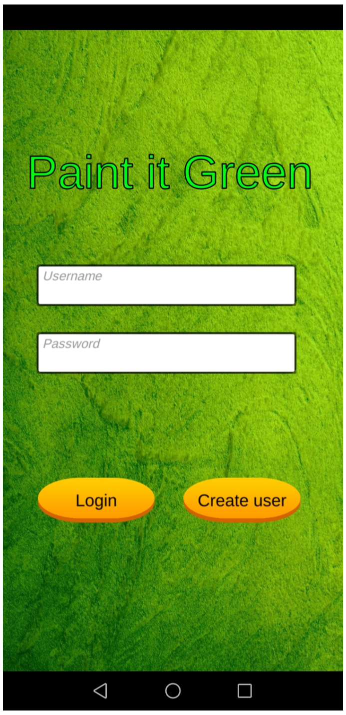

Figure 22.1: The login view

22.2 Game introduction and tutorial

If the player registers a new user, they are greeted by an introductory tutorial. They meet Brushy, an expositional and friendly character shaped like a paintbrush, used only in text dialogue messages, which is how the tutorial and story are portrayed. They are also introduced to themselves, or the player avatar, a green paint bucket with a name matching the player's username. The player can click on the screen to advance or skip through the text dialogue. The first line of dialogue is shown in Figure 22.2. All game dialogue can be found in Appendix G.

Figure 22.2: What the player sees when logging in for the first time.

The player is then introduced to the game's setting and the story, giving the player a mission to defeat Pantavaggio and repaint Trondheim. Further, Brushy tells the player about the basic game mechanics to move around the city, interact with paint stations, acquire XP, and battle Paintavaggio's blobs. The player is also warned that they will face stronger blobs as they level up and, at some point, battle Paintavvagio himself. The introductory tutorial can be repeated by pressing a button in the menu. A screenshot from the introduction is shown in Figure 22.3.

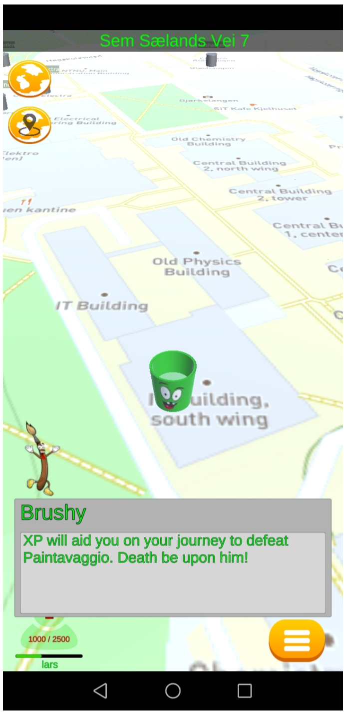

Figure 22.3: Brushy introducing the player to the world scene.

22.3 The world scene

The player's avatar is placed in the world scene, showing a map of their real-world surroundings. The in-game camera and player avatar follow the actual player's movements around the map in the world scene. The player can see their current address, a menu button, their current level and progress towards the next level, a shortcut to the city district map view, and a shortcut to the current city district status in their heads-up display (HUD). A notification can also be shown to the player if a particular event happens. A screenshot from the world scene with descriptions can be seen in Figure 22.4.

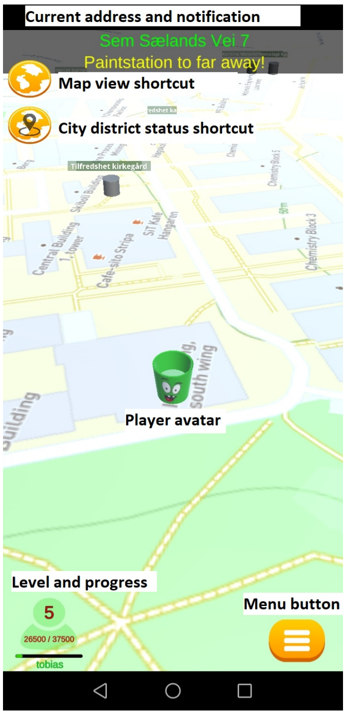

Figure 22.4: The world scene with explanations of the HUD elements.

In addition to the map details, player avatar, and spawned blobs, gray paint buckets called paint stations are scattered around the map. Paint stations correspond to points of interest (POIs), like statues or landmarks. If the player approaches and clicks on a paint station, they will get a notification telling them what POI they visited and get some XP. The paint station is then colored from gray to green and placed in a cool-down period of 15 minutes. If the player tries to click on it again, they will not be awarded XP and will get a notification telling them they just visited the POI. After the cool-down period, the paint station will be repainted gray and clickable again. If the player taps on a paint station too far away, they will not get any XP and get a notification that it is too far away, encouraging them to move closer to it. A screenshot showing a paint station mid-animation can be seen in Figure 22.5.

Figure 22.5: Paint stations

22.4 The blobs

The player will soon be met in the world scene by spawning blobs. There are three types of blobs: small blobs, large blobs, and armored blobs. Each blob type comes in three versions (S, M, L) with similar but varying appearances and abilities, giving the player nine different blobs to encounter during normal gameplay. In the first levels, only small blobs will spawn. All three types of small blobs are shown in Figure 22.8. The player is introduced to the small blobs and how to defeat them in the introductory tutorial. A screenshot of the small blob tutorial can be seen in Figure 22.6. The small blobs can be defeated by clicking on them one or more times in the world scene. A small blob being tapped is shown in Figure 22.7. The amount of clicks required to defeat a small blob depends on the version (S, M, L). A blob's health is indicated by a health bar. All blobs have simple animations linked to them, which are also responsive to player actions like being clicked on, dying, and attacking. When defeating a small blob, some gray paint effect is *spewed* out of the blob together with a dying animation.

All spawned blobs despawn after 120 seconds. They only spawn in a bounded, circular area around the player and never spawn within one another. If the player is standing still, no blobs will spawn. The amount of spawned blobs randomly varies when moving around, and the player's level determines what type and version of blobs can spawn.

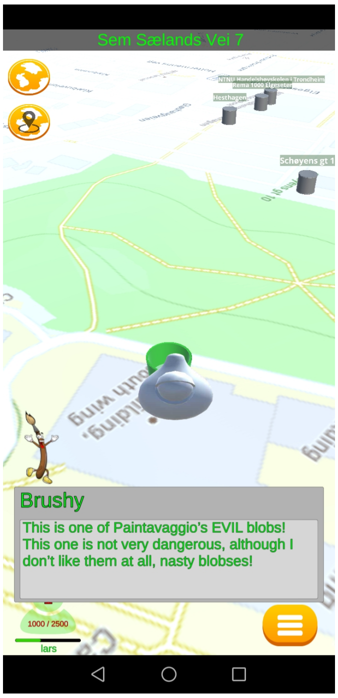

Figure 22.6: Brushy telling the player about the small blobs.

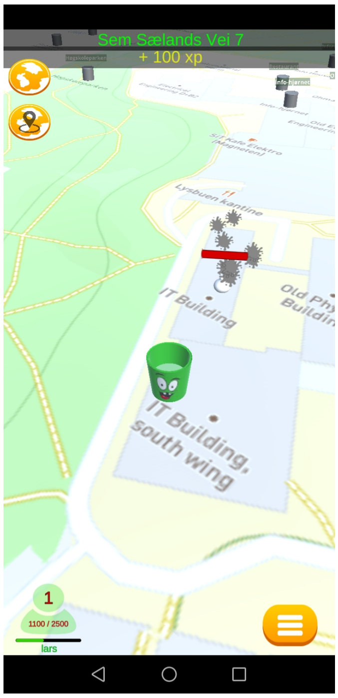

Figure 22.7: Battling small blobs.

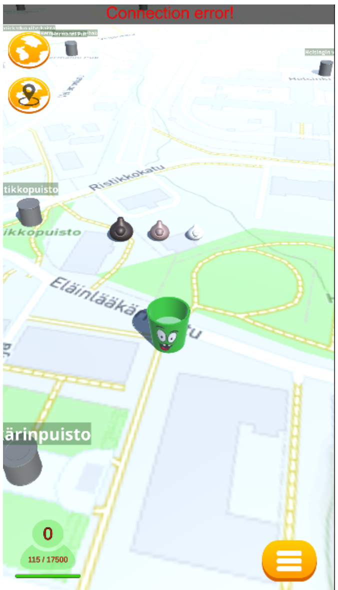

Figure 22.8: The three versions of small blobs.

During later levels, large blobs also start spawning. These look similar to the small blobs but are bigger and colored differently. Clicking on these blobs will not make them lose health or die but have the player enter battle mode. All three types of large blobs are shown in Figure 22.9.

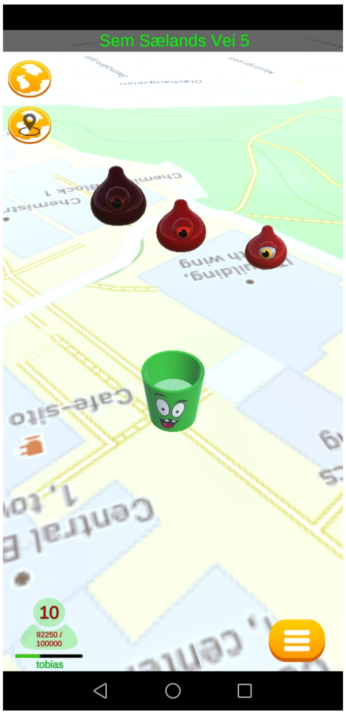

Figure 22.9: The three types of large blobs spawning in the world scene.

In battle mode, the tapped large blob will be placed directly in front of the player in a new scene, clearly separate from the world scene. When entering battle mode for the first time, the player will get a tutorial by Brushy explaining how to defeat the large blob. A yellow paint grenade will be directly in front of the player. The player has to throw paint grenades at the large blob. If a paint grenade hits the blob, it will lose life points. A screenshot of the player throwing a paint grenade is shown in Figure 22.10. If the player runs out of paint grenades, they will lose the blob battle, shown in Figure 22.12. However, if they reduce the large blob's life points/health to 0, they will win the battle and receive a chunk of XP, shown in Figure 22.11. After the player has seen the victory or defeat screen, they will return to the world scene from before the battle scene.

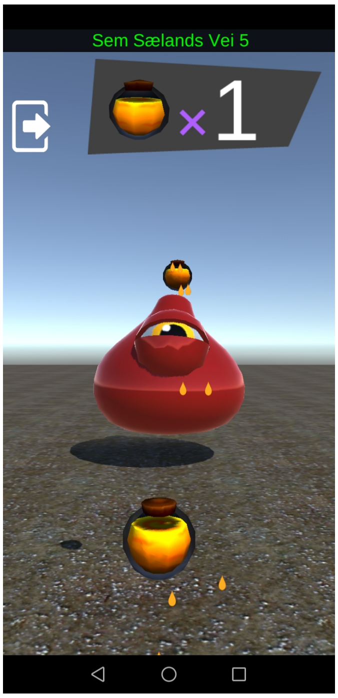

Figure 22.10: Throwing paint grenades.

Figure 22.11: Victory screen.

Figure 22.12: Defeat screen.

The third type of blob, armored blobs, will start spawning when the player reaches higher levels. These also come in three different versions, shown in Figure 22.13. When tapping an armored blob in the world scene, the player will again be taken into battle mode and have the armored blob be placed directly in front of the player. Like large blobs, Brushy will appear and give the player a tutorial. However, to defeat an armored blob, the player must launch paint missiles in one of four directions to hit the armored blob. Swiping up, down, left, or right will fire the missile in that direction. When a missile hits the armored blob, it will lose a life point. However, the armored blobs have rotating shields in front of them. The player must ensure their missiles do not hit any rotating shields to hit the armored blob. A screenshot from combat with an armored blob is shown in Figure 22.14. Like battling the large blobs, if the player runs out of missiles, they will lose, and if they reduce the blob's health to zero life points, they will win. Defeating or losing to an armored blob will return the player to the world scene.

Figure 22.13: The three versions of armored blobs spawning in the world scene.

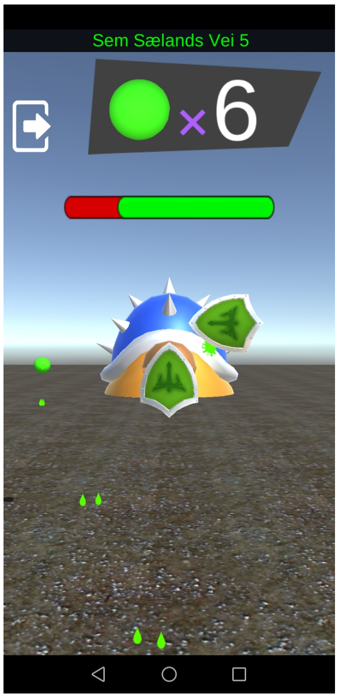

Figure 22.14: Launching paint missiles.

22.5 The city district map view

The city district map view is another integral game feature to encourage the players to be physically active and explore the city of Trondheim. It can be accessed directly from the world scene or the menu. The main menu is shown in Figure 22.15. It shows the different city districts (postal codes) of Trondheim with varying colors depending on their exploration status. All city districts are initially colored gray by Paintavaggio but are colored yellow if the player has visited them. Bright yellow if the player has visited it in the current day, and dull yellow if it has been visited but not that day. The bright color will become greener when the player explores a city district. The city districts outlined by turquoise are special city districts with double XP rewards. The map can be zoomed and panned for navigating the map further. The map is shown in Figure 22.16.

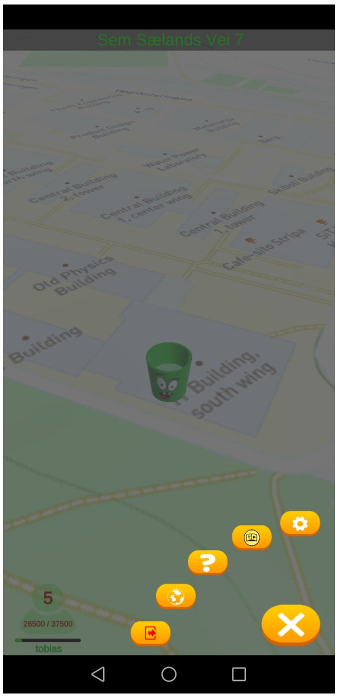

Figure 22.15: Menu screen.

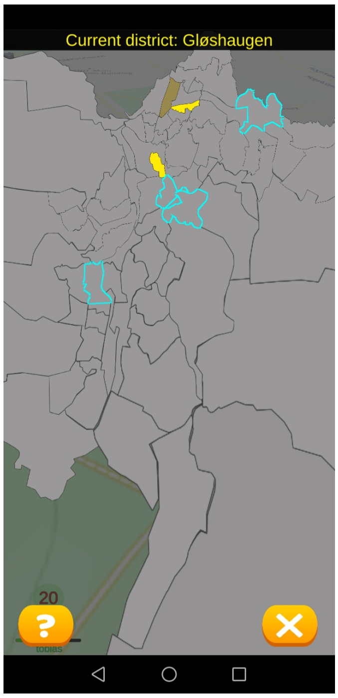

Figure 22.16: The city district map view.

By clicking on one of the city districts, the player can access two views: exploration status and leaderboards. In the leaderboard view, the player is shown the exploration score of the top five players of that city district and their own score. The score is calculated by combining time spent, meters traveled, and unique addresses visited in the city district. The player can also choose to see a leaderboard of only time spent, meters traveled, or unique addresses explored. The leaderboard is shown in Figure 22.17.

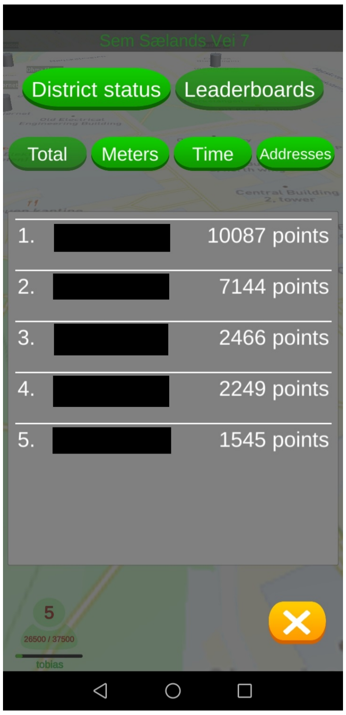

Figure 22.17: Leaderboards.

In the exploration status view, the player sees the city district's name, its current status (not visited, visited, explored, dominated, conquered), and the date of their last visit to the city district. Three progress bars can also be seen, measuring meters walked, unique addresses visited, and time spent. The bars indicate the player's progression in exploring (or dominating or conquering) the city district. This view is shown in Figure 22.18. If the player fills up all three bars, the city district will be regarded as explored (or dominated/conquered). A message will be shown if the player has not visited the city district yet. This message is shown in Figure 22.19.

The exploration levels correspond to how long the player has come on their way to retake Trondheim from Paintavaggio. If the three progress bars have never been filled up, the city district has a status of visited. Once they are completed once, the city district will be considered explored. When the bars are filled up, the thresholds for completing them increase, lowering the three progress bars. If they are all filled up a second or third time, the city district will get a status of dominated or conquered, respectively. When a city district gets conquered, the exploration status view changes to show the player that they have driven Paintavaggio out of that district, shown in Figure 22.21.

Reaching a higher exploration status will grant a lot of XP for the player, and the color of the city district will be colored a stronger green for each exploration level. A dominated city district is shown in Figure 22.20.

Brushy explains all mechanics in the introductory tutorial (which can be repeated due to the system's complexity).

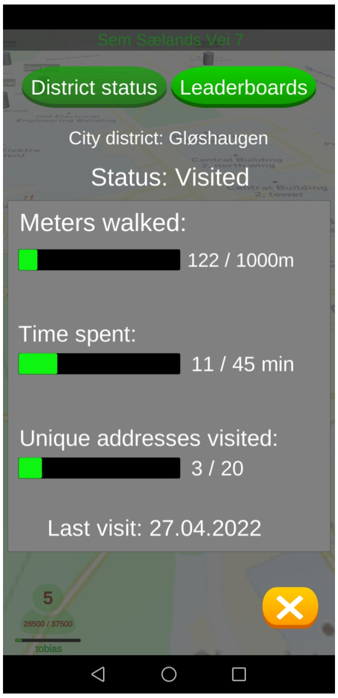

Figure 22.18: Exploration status.

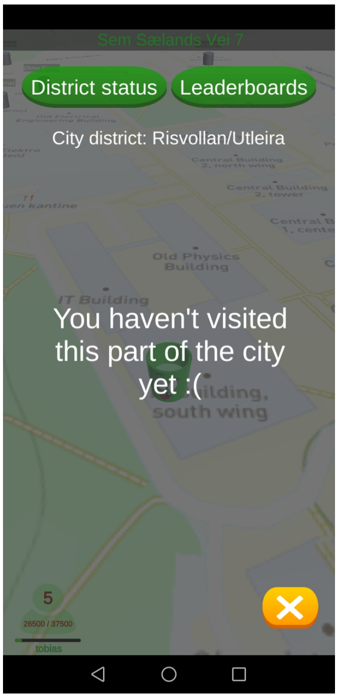

Figure 22.19: Not visited city district.

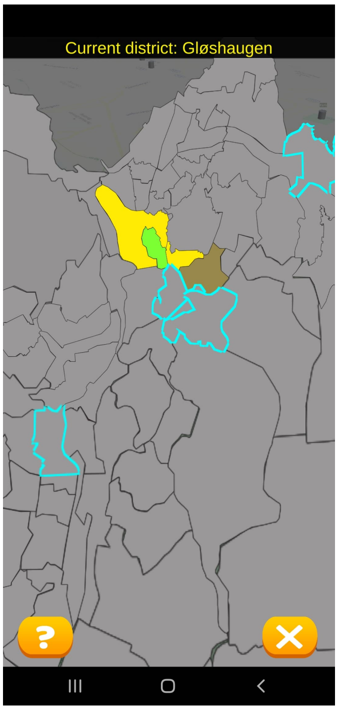

Figure 22.20: Dominated city district in city district map view.

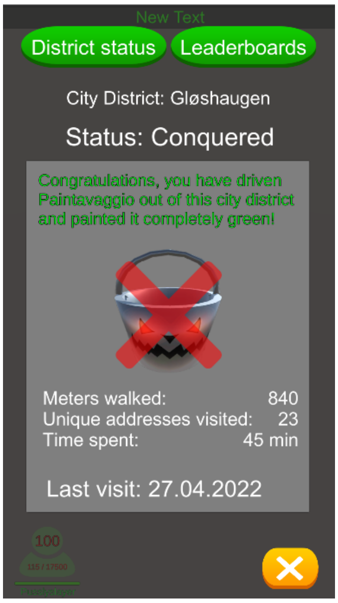

Figure 22.21: Conquered city district status

22.6 Story and boss battling

After the introductory tutorial, the player learns about the story when progressing to higher levels. At level 5, 10, 15 and 20, the player will get some expositional dialogue from Brushy and Paintavaggio, shown in Figure 22.22 and Figure 22.23, who appears for a boss battle at the four events. Paintavaggio appears in the world scene and will follow the player until clicked.

When clicked, the player will enter battle with Paintavaggio himself. The battling technique will evolve through the four encounters, and Paintavaggio will become harder to defeat. A battle with Paintavaggio is shown in Figure 22.24.

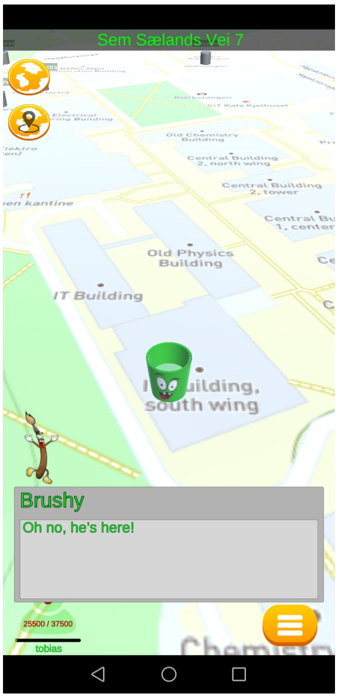

Figure 22.22: Dialogue Brushy

Figure 22.23: Dialogue and Paintavaggio appearing in the world scene

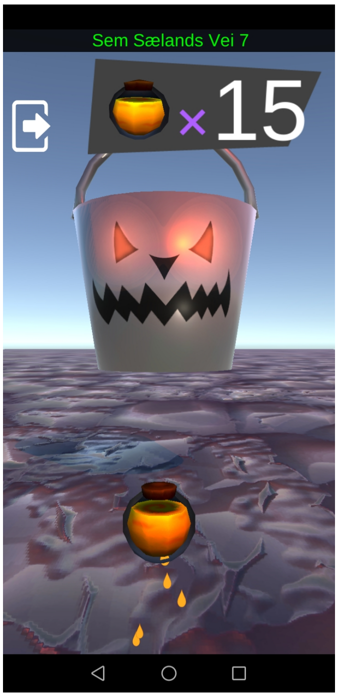

Figure 22.24: Battling Paintavaggio

If the player loses to Paintavaggio, Paintavaggio will taunt the player, and they will return to the world scene. The player can then click on Paintavaggio again for another try. If the player wins against Paintavaggio, some more expositional dialogue will be given to the player, and they will receive a significant XP bonus.

More of the story is conveyed to the player through the expositional dialogue. It mainly consists of banter and quarreling between the *good guys* (the player and Brushy) and the *bad guys* (Paintavaggio and his blobs). However, there are several small indications of the good and bad guys as two sides of the same coin, wanting to paint Trondheim in their own color. As mentioned, all dialogue can be found in Appendix G.

After defeating Paintavaggio for the fourth and last time, he will give his final concession to the player. Brushy will congratulate the player for defeating the villain and saying that the mission is finished. However, after a dramatic moment, the player character speaks for the first time and says that they are not finished, that every blob must be purged, and that every city district must be colored green. Brushy is startled and denounces the player, who spirals into more and more evil dialogue. The sprite of the player character is then changed to a darker green with a new, more sinister face, similar to the face of Paintavaggio. This transition is shown in Figure 22.25 and Figure 22.26.

Figure 22.25: The player about to turn evil

Figure 22.26: The player having turned evil

Afterward, the player can continue to play the game as before just now with the new player avatar, shown in Figure 22.27.

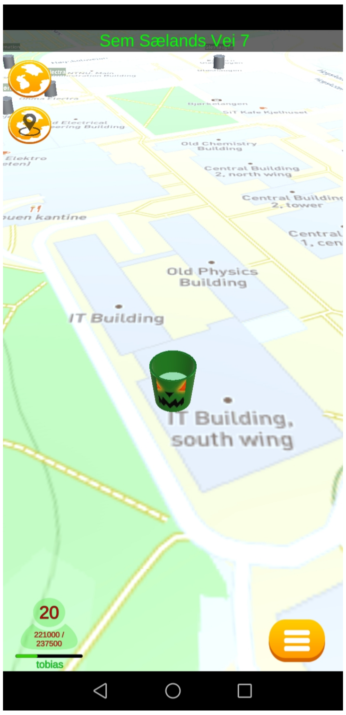

Figure 22.27: Evil player

The dialogue text is purposefully silly, goofy, and light-hearted. Due to the small scale of the game, we saw it unfit to create a somber tone we deemed unfitting for a prototype of an exergame. The dialogue is also packed with pop culture, nerd culture references, and jokes. While also maintaining the desired tone of the game, we hope it also serves as an incentive for the players to progress further in the story and play the game more, to uncover more of the dialogue.

22.7 Daily streaks and in-game notifications

Daily streak functionality has been implemented to improve player retention. Each day in a row, when the player logs into the game, they receive a pop-up box congratulating them with extending their streak and awarding them with progressively more XP. The pop up box is shown in Figure 22.28.

With every game event unrelated to the story, the player will get an in-game notification at the top of the screen, telling them what happened. Examples of notifications are acquiring XP, visiting a new city district, entering a double XP zone, losing internet connection, and moving too fast. An example of a notification is shown in Figure 22.29.

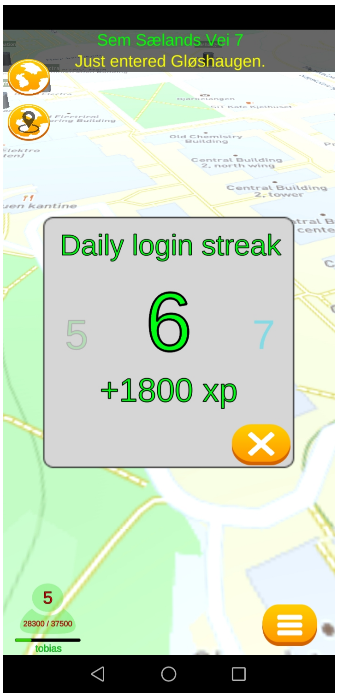

Figure 22.28: Daily streak

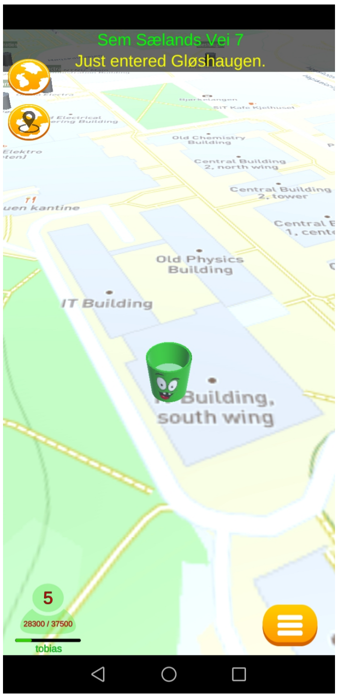

Figure 22.29: Notifications at the top screen

22.8 Summary

Paint it Green includes various features to appeal to different types of players. After registering and logging in, players are given an introduction to the game before they can explore features like the world, a map view, blob battle, and story progression. All these features have been detailed and shown with screenshots in this chapter.

Chapter 23

Implementation Details

This chapter is about a few selected subjects from the implementation phase, which are particularly interesting to this project and worth a closer inspection.

23.1 MapBox Unity SDK and reverse geocoding API

When researching what API to use to obtain map data and use geolocation services, there were three emerging alternatives: MapBox, Google Maps, and Open Street Map.

Open Street Map is free to use and is open source but has limited functionality and customizability. It is mainly community-driven and focused on obtaining and editing map data. Google Maps probably has the best and most reliable map data and feature assortment. However, its customizability features seem not as good as MapBox's. There is a generous free tier using the Google Maps API, but the payment plans are steeper and more unpredictable. Google Maps also by far has the most significant market share.

MapBox is cheaper than Google Maps and seems to be well documented. It is feature-rich and very customizable but perhaps has a steeper learning curve. Although not nearly as prominent in use as Google Maps, it is pretty popular and is regarded by many developers to have a good developer experience. There are also several Unity extensions available for integration with MapBox's APIs.

We have chosen MapBox because it is customizable and used in many similar projects.

Tracking the player's location is one of the game's key features. The game utilizes two of Mapbox's services for this purpose: their Unity SDK and Geocoding API.

Whenever the player is in the world scene, the SDK tracks their location and updates their position in-game to correspond to their real-life location. The SDK also renders the local map as the player moves. The map can be chosen from different presets or customized using Mapbox Studio, a web application for creating custom map styles. Paint it Green uses the Mapbox Outdoors style.

Another important use of the player's position is updating their exploration status on the minimap. The Mapbox SDK provides functionality that allows extracting the player's current position coordinates. Mapbox also offers a reverse geocoding API that takes in coordinates and returns the address and postal code matching the coordinates. The Geocoding API became the foundation for the entire city district map view. It provided a way to partition the map of Trondheim into disjunctive and exhaustive sections and let the game know which section the player was in currently. The reverse geocoding API only accepts 100.000 requests per month for a specific API key. The game only sends the player position to the API every 15 seconds to ensure that we would not exceed this limit during the experiment. Thus, every 15 seconds, the game receives the address as a response from the reverse geocoding API, displays it to the player, and then sends it to the server to be saved in the MongoDB database.

The map is displayed by querying the addresses for a player to check which postal codes they have visited and how much they have explored each postal code. Based on a single postal code, each city district is given a specific color based on what exploration requirement the player has met for that district. These exploration requirements are detailed in Section 23.4. A city district is colored yellow when the player has visited it once and gradually becomes greener when the state changes to "Explored" and "Dominated" before becoming a bright green when the status is "Conquered."

During development for rapid testing, MapBox also provided a script for mocking player position and movement to test the game. The script contained a set of predefined coordinates in Helsinki, Finland, to mock a player moving around in a realistic environment at a realistic pace. This script eased rapid testing in the development phase as we did not have to physically move around our environment while testing the prototype.

23.2 Blob spawning factory

One of the game's most intricate and logic-heavy classes is the class BlobFactory. When the world scene is active, the blob factory is running to determine the spawning of different blobs around the player's position. The factory makes sure the spawning of blobs follows the following set of rules:

- All blobs spawn within a maximum and minimum distance from the player's location.
- No blob should spawn within or overlap with another blob.
- The type and version of blobs to spawn should be random given the current level restraint.
- The player's current level should set restraints on what types and versions of blobs to spawn to ensure feature and difficulty progression. See the text and table below for further details.
- Every 7 seconds, a blob spawning tick happens. There is a 30% chance of blobs spawning at each tick.
- If the player is standing still, there should spawn no blobs.
- If the tick spawns blobs, the number of blobs should be between one and three blobs.
- Every blob should despawn if it has been active for more than 90 seconds or the player moves more than a certain distance from the blob.
- All active blobs should persist between scene transitions and only disappear when despawning, being defeated by the player, or defeating the player in battle mode.

We wanted not to overwhelm new players with too much functionality and have them experience challenge progression in difficulty as they leveled up. We also wanted to increase player engagement by appealing to their curiosity by *holding back* some blob types and versions until later levels, thus expanding the fantasy in parallel with the player progressing in the game. Only small blobs will spawn in the earliest levels, resulting in the player not being able to try (and receive a tutorial for) battle mode until level 4. The stronger and new blob types and versions are then progressively introduced as the player levels up. The smallest and weakest blob types are also removed on higher levels to remove easy XP sources from the player and enforce a greater difficulty. See Table 23.1 for the exact set of blob types and versions to spawn at what levels.

23.3 Blob animation state diagram

As described below, the foundations for the blobs were assets from the Unity Asset Store [165]. These assets included sprites, materials, meshes, animations, and more.

Table 23.1: What blob types (small, large and armored) and versions (S, M, L) spawn at what player levels.

Levels	Small blobs	Large blobs	Armored blobs
1-3	S, M		
4-6	S, M	S	
7-9	S, M	S, M	
10-12	S, M	S, M, L	S
13-15	S, M, L	M, L	S, M
16-18	M, L	M, L	S, M
19-30	L	M, L	M, L

In Figure 23.1 and Figure 23.2, two state machines are shown to exhibit the behaviour of the blobs. Some loops of animations should be determined and played based on player interactions like losing HP, winning or losing battle mode, and what scene is currently active. Each gray and orange state in the figures corresponds to a unique animation, and the arrows correspond to transitions between the animations. Transitions can be triggered by changing scenes, getting clicked on by the player, getting hit by a paint grenade, or others.

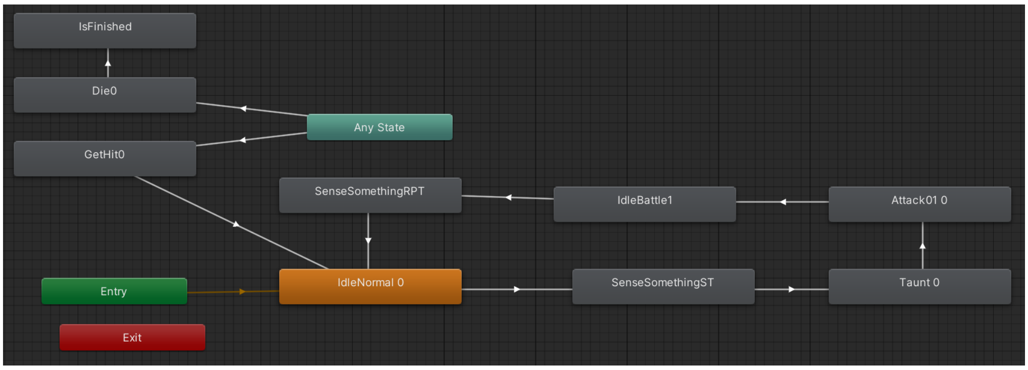

Figure 23.1: State machine for small blob animations

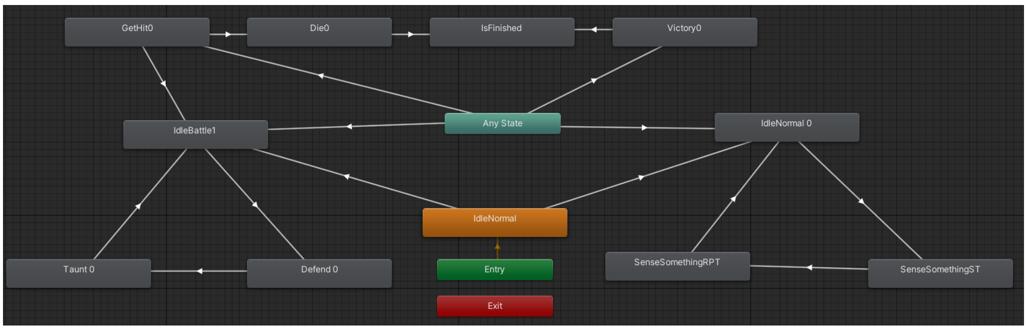

Figure 23.2: State machine for large and armored blob animations

23.4 XP, level and exploration requirement thresholds

Scaling the difficulty and required effort is paramount when making an enjoyable and engaging game, as elaborated on in Section 8.3. Most of the game features were designed and implemented to allow for a quick and agile change in numerical thresholds in the game. How much XP is required to reach the different levels, how much XP should be awarded for different actions, and how high the exploration requirements should be to explore, dominate and conquer a city district? These numerical values were set in a separate game constants file to have a *single source of truth* and a single place to test out different values being used several places in the code and make quick changes during testing.

Some selected game constant values are presented in Table 23.2 below. Also, since each blob type has a given XP reward and each version (S, M, L) has a multiplier, the actual XP reward of defeating each of the nine blobs is presented in Table 23.3. The exploration requirements for each normal city district are presented in Table 23.4. The small city districts with few unique addresses to visit, like Gløshaugen, have different and lower thresholds.

These values were tested and adjusted several times during testing before the experiment.

Table 23.2: Some game constants with their value used in the final prototype and where the constant is used.

Game constant	**Value**
Seconds between each server ping	15s
Defeating a small blob	100XP
Defeating a large blob	300XP
Defeating an armored blob	300XP
Blob version S multiplier	1.0x
Blob version M multiplier	1.5x
Blob version L multiplier	2.0x
First ever visit of a city district	1 000XP
First visit that day of a city district	500XP
Reached new exploration status of a city district	3 000XP
Visits a paint station	200XP
Daily login streak (N is the number of days in the current streak)	300XP $\times N$
Defeating Paintavaggio (Increases with 1 000XP for each victory)	1 000XP - 4 000XP
Max distance to not anull server ping	60m

Table 23.3: What blob types (small, large and armored) and versions (S, M, L) give what amount of XP when defeated.

	Small blobs	**Large blobs**	**Armored blobs**
S (1.0x)	100XP	300XP	300XP
M (1.5x)	150XP	450XP	450XP
L (2.0x)	200XP	600XP	600XP

Table 23.4: What exploration level requires in meters walked, time spent (in minutes) and unique addresses visited (for normal city districts).

	Meters walked	**Time spent**	**Unique addresses**
Explored	1 000	45	30
Dominated	2 000	90	40
Conquered	3 000	120	50

To motivate and ease the player's entry into the gameplay, the threshold for reaching the lower levels is relatively low, allowing them to reach level 5 and the first boss battle relatively quickly. After level 5, the requirements for reaching each level until the final boss battle is constant. Initially, the thought was to have the thresholds increase progressively. However, after realizing that the XP bonuses when visiting and exploring new city districts are strictly bounded by the available city districts within Trondheim/the proximity of each player, limiting their XP acquiring, we decided on more linear progress of the level thresholds.

After battling Paintavaggio for the last time and finishing the story, the required XP increases progressively, not linearly. Only the most motivated players are likely to continue playing long after the story is finished, and we thus wanted to give them a more significant challenge in reaching max level. See Table 23.5 for all level thresholds.

Table 23.5: Required XP for reaching each level.

Level	Additional XP required	Total required XP
1	0	0
2	2 500	2 500
3	5 000	7 500
4	7 500	15 000
5	10 000	25 000
6	12 500	37 500
7	12 500	50 000
8	12 500	62 500
9	12 500	75 000
10	12 500	87 500
11	12 500	100 000
12	12 500	112 500
13	12 500	125 000
14	12 500	137 500
15	12 500	150 000
16	12 500	162 500
17	12 500	175 000
18	12 500	187 500
19	12 500	200 000
20	12 500	212 500
21	25 000	237 500
22	25 000	275 500
23	37 500	325 000
24	37 500	387 500
25	50 000	462 500

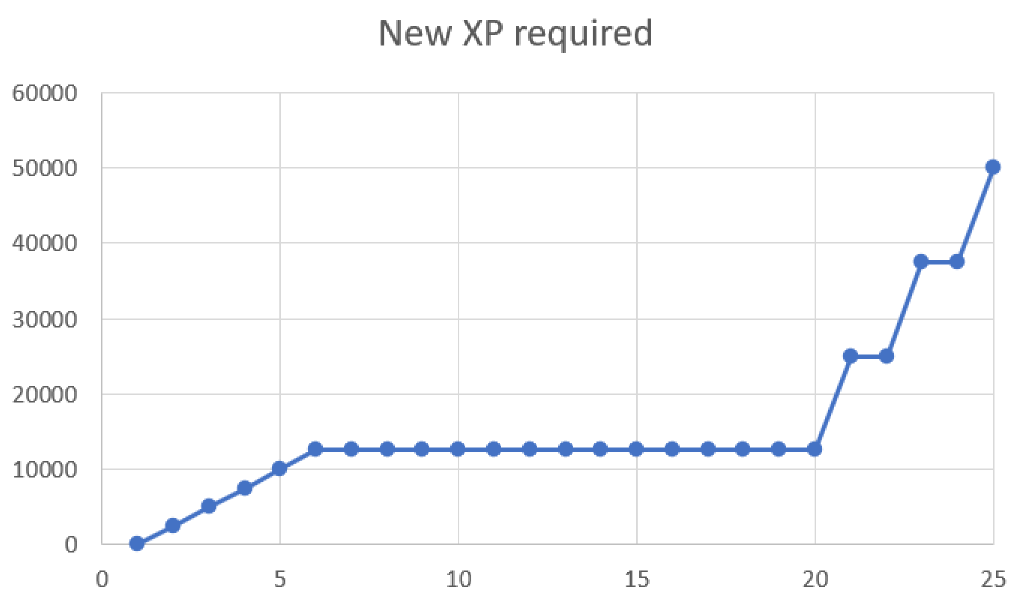

Figure 23.3: Required new XP to reach each level

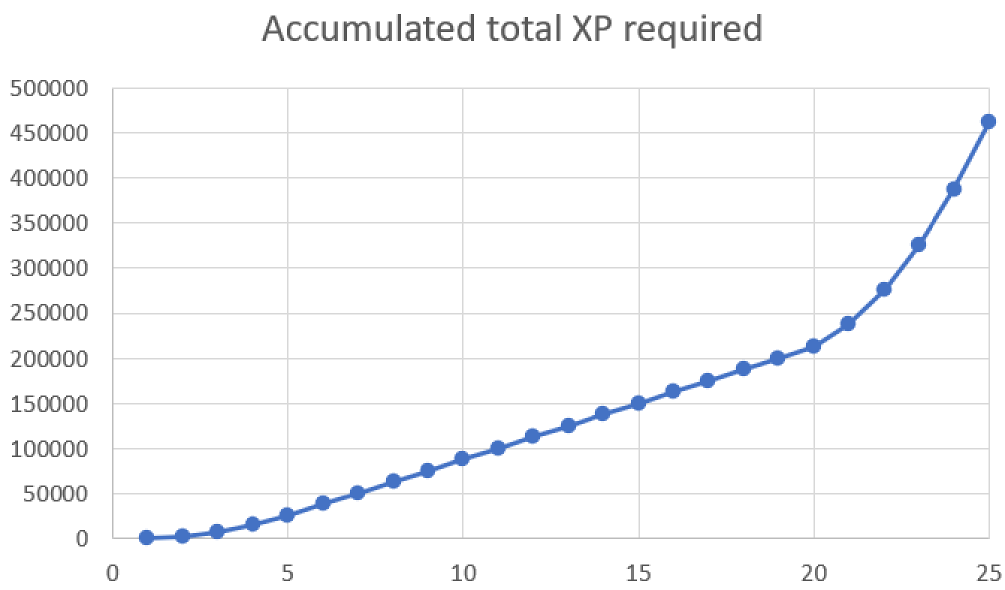

Figure 23.4: Accumulated required XP to reach each level

23.5 Summary

This chapter has focused on some parts of the implementation that we wanted to highlight, as they have been fascinating. Mapbox was used as a provider of location services, and their Unity SDK and Reverse Geocoding API were used in several of the game's primary gameplay elements, like tracking the player's movement and displaying their progress on the map. The BlobFactory class spawns all blobs in a very intricate way, while blobs are also animated based on state. Lastly, much thought was put into the values of XP rewards and requirements to ensure players leveled up at an optimal pace.

Chapter 24

User and Usability Testing

This chapter covers the limited user testing performed at the end of the implementation phase but before the experiment. The test preparation, execution, and takeaways are briefly reviewed.

24.1 Test motivation

The experiment will be similar to a very long user test, which raises the question of why user/usability testing should be prioritized in addition to the experiment. The purpose of this scarce usability testing is only to uncover usability issues and to *give the prototype some mileage* in a more realistic user environment to test performance on other mobile phones and have someone other than us test the prototype. In addition, usability is the chosen primary quality attribute, motivating us to improve the usability and the user experience as much as possible before the actual experiment.

Hence, usability testing and the experiment have different purposes. The experiment is to collect data in order to answer the research questions. The usability testing is done to improve and test the prototype's functionality. Performing usability testing on the prototype would make it less riddled with usability issues, bugs, and other issues that could affect the experiment data.

24.2 Test preparation, design and execution

The test subjects were four fellow students who would not participate in the experiment. Even though the target group for the game concept is not limited to students at NTNU, we saw early on in the recruitment process of subjects for the experiment (which took place in parallel with the usability testing) that fellow students at NTNU would dominate the experiment. Therefore, the usability test subjects should be similar to the experiment test subjects. Other than this consideration, we tried to have the test subjects and their user environment be as diverse as possible within the small scope of the usability testing. Four test subjects were recruited for a usability test in an ad-hoc fashion amongst our fellow students.

In preparation for the usability testing, we strove to provide a game prototype as close as possible to the prototype used in the experiment. All significant features were implemented, and as many bugs and other minor issues as possible were fixed.

No explicit usability tasks were prepared besides providing the test subjects with a quick introduction to the game and its purpose and then letting them try out the game.

All subjects played the game for 15-20 minutes during week 13 at Gløshaugen, NTNU. We followed and observed them and took notes on patterns, behaviors, problems, and questions. The test subjects were instructed to play freely but to think aloud, meaning to speak out questions and thoughts they were having while playing the game.Feedback and questions regarding the test execution were discussed, and further evaluative questions on the game's quality were asked.

24.3 Test takeaways

After performing the tests and analyzing the usability test results, the following concertized usability issues and bugs were evident. Other possible influential factors were also contemplated, such as the test subjects giving too positive feedback due to the friendly social relationships with one of the authors who observed them while testing. See Chapter 31 for a discussion on test reliability. The test findings are presented in Table 24.1.

Usability issue	**Solution**
Armored blobs were too easy to defeat	Introduced more randomness in the shield rotation speed and direction.
Some players forgot information from the tutorial and lost track of what to do, even though the tutorial is repeatable	Revised the amount of text in dialogue and added infoboxes with summaries of the game and its features.
Some loading issues and slow rendering in battle mode	Removed rendered 3D buildings in the background of battle mode.
Wanted a better overview of the world scene	Increased the maximum zoom out level
Some players wanted a shortcut to the status screen and leaderboards of the city district the player was currently in.	Added a separate shortcut button for that purpose.
Some players did not understand the purpose and role of the paint stations. Some also mistook the paint stations for other players.	Changed colors, added paint animations, and improved the explanation of the paint stations in the tutorial.
The player can not leave or quit in the middle of battle mode. One has to either win or lose against the blob.	Added an exit button in battle mode.
Players found the XP progress very slow. Some test subjects lost interest before exploring more of the features and story, which only come in later levels.	Increased the spawn rate of blobs and paint stations and decreased the lower level XP thresholds.
Several test subjects tried to press the level and XP icon in the bottom left of the world scene, expecting a profile view.	Made the icon more transparent to look less like a button and added the player's chosen username below it.
Players wanted to know the city district where they were currently	Added a text label in the map view, which always tells the player what city district they are in.

Table 24.1: Discovered usability issues and bugs from the usability testing, along with solution as a measure

When prompted for other game features the test subjects would have liked, there were a few suggestions that were deemed unsuitable or not implemented due to a lack of time and resources:

- More blob types with new battle modes
- Leave a green or yellow paint trail behind the player as they move around the map.
- Introduce achievements and or trophies
- Let the blobs fight back and be able to damage the player in some way

- Friend system/More social features
- Do a major overhaul of the game's visuals and assets to provide a recognizable and holistic look and feel

Elsewise, the overarching perception from the limited usability testing was positive, and all test subjects provided positive feedback. Specifically, the story with dialogue and blob fighting was highlighted. All test subjects reported the prototype as fun, engaging, and easy to learn.

24.4 Summary

Light usability testing was performed before the experiment to ensure the game's performance was acceptable and to fix any obvious usability issues. Four usability tests were performed on four fellow students. The tests revealed some usability flaws and bugs, which were quickly fixed. The tests also revealed some new features which the test subjects requested. However, these were not implemented due to the tests occurring towards the end of the development phase, with no time left to implement more extensive features before the experiment.

Chapter 25

Evaluation of the Implemented Prototype and Requirements

This chapter is about evaluating the implemented prototype of the game to be used in the experiment. The functional and quality requirements are tested, and the technology choices and architecture suitability will also be evaluated.

25.1 Test report on the functional requirements

This section will test and report all functional requirements (FR) from Chapter 19. All FRs that have only partially been implemented will be commented on below. Most FRs have been implemented and are marked green. The partially implemented and not implemented FRs are colored yellow and gray, respectively. See Table 25.1

Fully implemented (Yes)
Partially implemented (Partially)
Not implemented (No)

Table 25.1: Implementation status to color

Table 25.2: The functional requirements of the game together with their implementation status.

ID	Description	Priority	Implemented?
FR1	**Track the player's movement on a real world representation map**		
FR1.1	The game should display a map resembling the real world as the main gameplay view (World Scene).	H	Yes
FR1.2	The game should track the player's real-life movement on the in-game map in real-time.	H	Yes
FR1.3	The game should keep track of which part of the city the player is currently in. (Postal code/City district)	H	Yes
FR1.3.1	The address of which the player is currently in, should be shown to the player in real-time.	M	Yes
FR1.4	The player should be able to view a minimap of all the city districts the player has visited, explored and not visited, marked on the map.	H	Yes
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Table 25.2 – continued from previous page

ID	Description	Priority	Implemented?
FR1.5	The player should be able to rotate the map around the player avatar in the world scene.	M	Yes
FR1.6	The player should be able to zoom in and out in the world scene.	M	Yes
FR2	**Player account and data storage**		
FR2.1	The player should be able to create an account with a username and password which is persistently stored and can be used to log in to their account.	H	Yes
FR2.2	The player's progress (XP and location history) should be persistently stored remotely on a server, and updated frequently.	H	Yes
FR2.3	The player's leaderboard scores should be stored and updated regularly on a remote server.	M	Yes
FR2.4	The player should be able to delete their account and all stored data on it.	L	No
FR3	**Fighting enemies (Blobs)**		
FR3.1	The player should be able to battle and defeat small blobs by tapping on them (one or more times, depending on their strength) on the world map.	H	Yes
FR3.1.1	If the small blob is so strong that it requires several taps, a health bar indicating how many taps/how much health is left should be visible.	M	Yes
FR3.1.2	When a small blob is defeated, it should explode/die with an animation and sound effect.	M	Yes
FR3.2	The player should be able to fight large blobs and enter battle mode by tapping them.	H	Yes
FR3.2.1	Battle mode should vary depending on the blob's strength and type.	M	Yes
FR3.3	Blobs should spawn randomly around the map when the player moves around.	H	Yes
FR3.4	The player should be met by boss fights when reaching levels 5, 10, 15, and 20. Boss fights are similar to large and armored blob battles but with a stronger enemy with a custom sprite and sound effect.	M	Yes
FR3.5	After defeating a boss more of the story should be conveyed to the player.	M	Yes
FR3.6	Spawned small and large blobs should despawn after a certain amount of time.	M	Yes
FR3.7	The player should have a paint meter that can be depleted and refilled. Battling blobs uses paint and depletes the meter. Visiting city districts, tapping POIs, or acquiring special items refills it.	M	No
FR3.7.1	If the paint meter is empty, the player is unable to battle blobs and progress in city district exploration.	M	No
FR4	**Game setting and story progression**		
FR4.1	The player should easily identify a paint bucket as the player avatar in the player's physical location.	H	Yes

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Table 25.2 – continued from previous page

ID	Description	Priority	Implemented?
FR4.2	The player should be greeted by an introduction to the concept and game setting when playing the game for the first time.	M	Yes
FR4.3	The player should be introduced to a tutorial of the game when playing the game for the first time.	H	Yes
FR4.4	The tutorial should be repeatable.	L	Yes
FR4.5	The setting and concept of the game should include information about the evil Paintavaggio, and give the player an objective to retake the world by coloring it from gray to green.	M	Yes
FR4.6	The game should have an ending where the player learns that they are just as bad as Paintavaggio. And then the player should still be able to play, but the story is finished.	M	Yes
FR4.7	The story of the game should be displayed through text dialogue messages at the start of the game and after defeating bosses, by a friendly companion/avatar (a paint brush).	M	Yes
FR4.8	The player should meet the final boss (Paintavaggio) when reaching level 20 and after defeating him, should be told the ending of the story.	M	Yes
FR4.9	After reaching the end of the story, the player should be able to continue as before with normal gameplay, just without the story elements.	M	Yes
FR5	**Exploration points, Levels and skill progression**		
FR5.1	The player should acquire exploration points (XP) through defeating enemies and exploring map areas and POIs around the city.	H	Yes
FR5.1.1	The player should see a notification message each time a game event like acquiring XP or entering a new city district happens.	M	Yes
FR5.2	The player should level up when acquiring a certain amount of XP.	H	Yes
FR5.2.1	Leveling up should take progressively more XP (and thus play time) as the player reaches higher levels.	M	Yes
FR5.3	The player should receive large XP bonuses when doing something for the first time (battle enemies, enter a new city district, walking on a street)	M	Partially
FR5.4	The player's battling abilities should become stronger as the player levels up, but the bosses and medium enemies should progress faster to make battling harder as the game progresses.	M	Partially
FR5.5	The player should receive and be able to see their acquired badges when reaching milestones like levels 5, 10, and exploring 50 areas.	M	No
FR5.6	The player should be shown their level and progress towards the next level.	M	Yes
FR6	**Social interactions**		

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Table 25.2 – continued from previous page

ID	Description	Priority	Implemented?
FR6.1	The player should be able to compare their all-time progress in XP, map exploration, badges and others to other players in a leaderboard per city district.	M	Partially
FR6.1.1	Each city district should also have a daily, weekly and monthly leaderboards.	M	No
FR6.2	The player should be able to add other players as friends in the game.	L	No
FR6.3	The leaderboards should display the global top 5 players of that city district, and the logged in player.	M	Yes
FR7	**Replayability/Repeating game events**		
FR7.1	Some city districts should be highlighted each day/for some part of the day and have all actions happening in them rewards double/triple rewarded XP (Daily double XP zones)	M	Yes
FR7.2	The map areas (city districts) should have different colors on whether the player has: • Never visited it • Visited it but not that day/week • Visited it that day/week • Explored it And whether it is a double XP zone at the given time.	H	Yes
FR7.3	Daily login-streak-functionality should be implemented and reward the player with XP.	M	Yes
FR7.4	Every new day, the player should get a new quest/mission, rewarding the player with XP if the daily quest is completed.	M	No
FR8	**Other miscellaneous game features**		
FR8.1	The application should include music and sound effects.	M	Yes
FR8.2	The player should have access to an in-game menu with settings and other navigation options.	M	Yes
FR8.3	The player should have access to settings to adjust the volume for music and sound effects.	M	Yes
FR8.4	Actual POIs in the real environment should appear on the map and give XP when tapped.	M	Yes
FR8.4.1	POIs should have a cool down period where they can't be tapped while in cooldown.	M	Yes
FR8.5	The player should have access to a log of their actions (defeated blobs/bosses, XP acquired, city districts explored, etc.)	L	No
FR8.6	The player should be able to customize their player avatar's appearance.	M	No

42 out of 54 FRs are implemented, which is 78%. 3 FRs (6%) have only been partially implemented, and 9 FRs (17%) have not been implemented.

Below, in Table 25.3, is a more detailed description of the three FRs which were partially implemented.

ID	Comment
FR5.3	The player receives a large XP bonus then entering a new city district for the first time, but not when battling a new enemy for the first time or visit a new street.
FR5.4	The enemies do progress in strength and difficulty to defeat. But the player's battling ability does not increase with leveling up except for natural progression in battling skills which comes with more experience from playing the game while leveling up.
FR6.1	The requirement is implemented for map exploration (time, unique addresses and distance) but not XP or badges.

Table 25.3: FR6.1 - The requirement is implemented for map exploration (time, unique addresses and distance) but not XP or badges.

The following tables briefly explain why the non-implemented FRs were not prioritized.

ID	Comment
FR2.4	This FR was not implemented as we already had a way to delete accounts directly through the database interface. We, therefore, prioritized the implementation of other FRs, as users who wanted to leave the experiment could contact us to get their data deleted at any time during the experiment.
FR3.7	This FR was considered for implementation but was not due to time constraints and because battles already used some form of finite ammunition, making a paint meter non-critical.
FR5.5	Badges is something that would have taken much time to design and implement, but we were uncertain if it would have led to substantially more engagement and enjoyment from users. After a discussion with our supervisor, we decided to drop the FR and focus on other FRs more directly related to the concept and gameplay instead.
FR6.1.1	After implementing city district leaderboards, it would not require a great effort or take too long to implement the time-based variants. However, as players could already filter the leaderboard criteria (score, meters, time, and addresses), it was dropped so as not to clutter the UI too much.
FR6.2	Improving the social aspects of the game was never the highest priority for us, and the workload of creating a well-functioning friend system is formidable. It was therefore not implemented, and the social fun from the game focused on competing and comparing progress through the city district leaderboards instead.
FR7.4	One of the FRs we wanted to implement at the end but had to prioritize overall gameplay polishing instead. We saw it as a non-critical feature since we had reassurances from our supervisor that the prototype had sufficient gameplay features for the experiment. Also, the daily streak feature covered some of the calls for player retention tactics.
FR8.5	Another one of the FRs we wanted to implement. However, it was not prioritized as we deemed the functionality not to add much to most players' overall experience.
FR8.6	Just like the friend system, this FR would have taken much time and was not prioritized as the player was the only one that would have been able to see their own avatar customization. Had FR6.2 (friend system) been implemented, this FR might have been prioritized and implemented.

Table 25.4: Functional requirements that were not implemented.

25.2 Test report on the quality attribute scenarios

This section will test and report all quality attribute scenarios from Section 20.2.

ID	Expected response	Observed response	Evaluation
U1	80% of users understood how to play the game after playing the tutorial	81% of users understood how to play the game after playing the tutorial	Success
U2	80% of users report that game's goals were clear	76% of users reported that game's goals were clear	Failure
U3	80% of users report they feel in control of their avatar	90% of users reported that they felt in control of their avatar	Success
P1	Application and map loads in 7 seconds	Application and map loads in 9 seconds	Failure
P2	Leaderboard data is fetched and displayed in 3 seconds	Leaderboard data is fetched and displayed in 2 seconds	Success
A1	Game starts without crashing more than 95% of the time	Game started without crashing 100% of the time	Success

Table 25.5: Results of all quality attribute tests.

See Table 25.5 for a short report on the quality attribute scenarios. Two of the quality attribute tests failed: U2 and P1.

U2 failed due to not having 80% of the players agreeing to report that the game's goals were clear.

P1 failed due to the game not loading quickly enough.

25.3 Evaluation of the chosen technologies and of the architecture

The choice of technology influenced both the software architecture and the development phase. This section will talk about how we, after the implementation of the prototype, evaluate the technology choices made before development started.

One of the first significant choices was to develop the game for mobile phones, targeting both *iOS and Android* units. The decision was later altered to focus only on *Android*, based on feedback from our supervisor, as it was far easier to distribute the game to Android units for the coming experiment.

Unity was chosen as the game engine. While Unity had a somewhat steep learning curve, overall, its development has faired smoothly. Having tutorials to rely on in the beginning gave the development phase a smooth start, and all the online documentation was helpful whenever we felt stuck. Persisting data between scenes was also a little tricky, slowing development velocity somewhat.

Another important choice was to use *MapBox* as a provider for map services. In hindsight, MapBox worked nicely overall, especially positioning the player avatar at a map on their real-life position was surprisingly easy. Otherwise, we were somewhat limited by a lack of documentation from MapBox. An issue with using the points-of-interest (POI) feature was that the POIs did not include any unique ID for the POIs. When trying to save information about visited POIs (Paint stations), the POI name had to be used as an identifier.

Lastly came the choice to use a *client-server architecture*. A shared, external server for game usage data and central game logic was vital, as a lot of the game's functionality relied on data from other players. A Rest API was built with Node.js and Express.js, running on a Heroku web server and using a MongoDB database on the MongoDB Atlas cloud service. This server was simple to develop and use.

Overall, after implementing the prototype, we are mostly happy with all of our major technology choices and have no areas where we would have made different choices if we were to start over. A possible exception could have been to more thoroughly investigate Google Maps as a map provider

API since there were some issues with Mapbox. The other map APIs were never tested or analyzed more than the surface level.

25.4 Summary

At the very beginning of this thesis, we established our research goal: *Discover, analyze, develop and test a new exergame concept and prototype which motivates people to increase their physical activity levels.* This project aims to try to motivate people to increase their physical activity levels and health by playing a game. An exergame prototype was needed to be designed, implemented, and tested to reach the *develop and test* parts of the research goal. The prototype must be playable by many players, observable by us, the researchers, and include game features that nudge players to be physically active.

78% of the FRs were implemented, while 6% were partially implemented. Four out of six quality attribute tests succeeded, while two failed. While we would have liked to see all tests succeed, we deem it acceptable given the project's scope.

We are happy with the chosen technologies and with the architecture as a whole. The prototype scales well with tactics to support many players playing simultaneously daily.

Part V

Experiment and Results

This part focuses on the design and execution of the experiment. It explains how the experiment collected and generated data and how test subjects were recruited and given access to the prototype. The results are presented and analyzed before reliability and validity concerns are discussed.

Chapter 26

Experiment Population

This chapter examines the recruited test subjects for the experiment. The recruitment results and privacy issues will be assessed. The demographics of the recruited test subjects are covered in Section 29.2.1.

Thirty-one people registered for participation by filling out the pre-experiment questionnaire and agreeing to the data processing agreement, out of which 26 created an account after accessing the game. 21 out of the 26 players played the game for more than 30 minutes in total, which was deemed the minimal value of total playtime to be able to make a capable assessment of the prototype. Twenty-one people were thus included in the questionnaire data set.

26.1 Experiment population methodology

When considering who would be eligible for being a test subject, we set the scope to be quite large and did not have many restraints on who could participate in the experiment. The designed experiment is lightweight and thus more scalable, meaning it would not require much work to follow up on the test subject throughout the test period.

However, there were some restraints. All test subjects were required to:

- Situate themselves in Trondheim for at least most of the test period.
- Own and be able to use an Android smartphone with an Android version of at least 7.
- Own a phone with a reasonable amount of processing power, cellular data, and battery life to play the game while moving around Trondheim for a couple of minutes or hours at a time.
- Be at least 18 years old.
- Register and play the game at least once and preferably at least a couple of times.
- Agree to the data storage and processing agreement.
- Fill out two questionnaires: one pre-experiment and one post-experiment.
- Play the game for at least 30 minutes in total.
- Not purposefully and knowingly sabotage or otherwise undermine the project.

When recruiting/sampling test subjects, we considered the recommended randomized sampling method with control groups to avoid as much bias in our data as possible. However, our supervisor advised us that this was unnecessary, given the project's scope. We could thus turn to opportunity sampling [166].All communication after the recruitment phase, such as the distribution of the prototype, invitations to observations and interviews, and questionnaires, were done using email.

Opportunity sampling can be used when it is not deemed beneficial or necessary to use a sample representative of a broader population and does not strictly need to be generalized. For this project, even though we had no rigid limitations on the target group, the main goal was to determine if the game showed any potential to give health benefits to the test subjects. It was therefore regarded as adequate with a low applicable sample. At least 30 participants in the sample size are recommended for statistical analysis to be reliable [1], but our final 21 is under the limit. Even though the sample size is small, tests will still be performed to determine if our data is statistically significant.

26.2 Privacy concerns in the experiment

26.2.1 Data processing and storage agreement

Since the experiment would involve collecting data about the test subjects themselves, along with their opinions on and usage of the prototype, a formal data processing, and storage agreement was produced and distributed to all test participants. The actual document can be found in Appendix D No test subject would receive the prototype before agreeing to the data processing and storage agreement.

The agreement expresses what and how the data will be stored, the experiment's purpose, who was responsible for the experiment, what it would mean to participate in the experiment, why they were asked to join, and to what purpose the data will be used. All test subjects were explicitly informed that they could drop out of the experiment at any time and have their data deleted with no other consequences or adverse effects. They could also see what personal data was stored, should they wish to do that. They were provided, in the agreement, with information about what would happen to their data after the project was finished and how they could send a complaint to the Norwegian Data Protection Authority.

26.2.2 Data storage and access

All game usage data was stored locally on the test subject's devices or an encrypted server separate from all other experiment data. Only we had access to the data stored. Every registered player was assigned a random ID to their user to ensure anonymity and security. All REST API endpoints for login and posting usage data and otherwise tampering with other players' usage data were protected by web tokens to ensure data integrity and protect against cheating. There were also no endpoints that could map usernames to user-ID's. However, other players could see some usernames due to the leaderboard functionality. Since the players chose their usernames, it was up to each player if they wanted to choose a username that could identify them or not.

The other set of player data stored was gathered from the recruitment process, the two questionnaires, and the recorded data from observations and interviews. All persistently stored data from these origins were stored on a Microsoft NTNU SharePoint workspace. All data is secured, encrypted, and stored on non-personal hardware. No directly identifying information, like name, social security number, or any images on the test subjects were stored in any files on the workspace. In the recruitment phase, all test subjects had to provide their email address to enable communication with the authors during the experiment. Each email address was mapped to a random ID (separate from the one mentioned in the above paragraph). This mapping was stored separate from all other documents and deleted after the experiment ended.

26.2.3 Norwegian Centre for Research Data

To be allowed to perform this research project, we were required to apply for permission from the Norwegian Center for Research Data (NSD). An application including the planned experiment details and the plan for processing and storing personal data was sent to NSD early in the project phase. The approved application can be read in whole in Appendix E.

26.3 Summary

Out of 31 people registered to join the experiment, 21 were included in the questionnaire data. All test subjects filled specific criteria, like being at least 18 years old and living in Trondheim. Opportunity sampling was used to recruit test subjects, and as a result, most of them were from our social circles. Formal data processing and storage agreements were sent out to all test subjects, as personal data had to be stored. An application was also sent to the Norwegian Centre for Research Data to get permission to store sensitive data about our test subjects.

Chapter 27

Experiment Design

This chapter describes the planned experiment with the intent and design of its data-generating methods. These methods are pre-experiment and post-experiment questionnaires, game usage data, observations, and interviews. Research theory from *Researching Information Systems and Computing* was the inspiration in designing the research process, and is described in Section 3.2 [1].

27.1 Data triangulation

This project collects data both qualitatively and quantitatively to ensure data triangulation. The qualitative data originates from the literature review, observations, interviews, and free-text questions with open and inviting question prompts from the questionnaire and survey. The quantitative data is numerical and originates from the survey, questionnaires, prestudy, and usage data from the game server and database.

Using and comparing quantitative and qualitative data is often used to validate the research process and is referred to as the triangulation method [13] [14]. Qualitative and quantitative data are different and are gathered from different sources with different methods.

27.2 Experiment activities outline

Pre-experiment questionnaire The first data generation method was performed through the pre-experiment questionnaire, which collected data about the test subjects' demographics, gaming experience, and physical activity. This questionnaire was made using Microsoft Forms and sent to all test subjects as a prerequisite for participating in the experiment. Each test subject was given a unique ID to be stated as an answer to the first question. The ID's purpose was to be used again in the post-experiment questionnaire to be able to connect answers before and after the experiment. Some questions have dynamic effects on the rest of the form, based on the answers given. Thus, some questions only appear if they are relevant to the participant.

The format of the responses was mainly structured as a version of the Likert scale with the options "Disagree," "Partially disagree," "Neutral/No opinion," "Partially agree," and "Agree" [167]. There were also some text input questions and some multiple-choice questions. The post-experiment questionnaire had the same question formatting.

The actual questionnaire can be seen in Appendix B.

Three-week gameplay access After completing the first questionnaire, all test subjects were sent an email on the 25th of April, 2022, containing the game prototype for download (a .apk file), an installation guide, some practical notices, and our contact information for reporting bugs, issues, and questions.

The test subjects were given access to the game for 21 days and were told that they could play the game as much as they wanted, but were also given a yearning from us to *at least play it a little bit, to test it*.

If there were any bugs, issues, or other problems, the test subjects would receive a new version of the game, which would serve as a game update with just a few clicks required from the test subjects. As they were reported, we provided help and answers while monitoring the MongoDB Atlas cloud platform to oversee the players' progress and uncover potential issues.

Observation and interviews During the second and third weeks, four overt observations with semi-structured interviews following right after were performed. We wanted to observe a *regular playing session*, not the first time someone played the game and thus made the observations well into the experiment time frame. The observations and interviews were done with one test subject at a time and one observer/interviewer.

The chosen test subjects were told to meet one of us at Gløshaugen for a 15-20 minute playing session followed by a 20-minute interview. When the observation was to start, the test subject was told to *play the game, naturally* and pretend that they were not followed by an observer (one of us). The observer tried to interact with the test subject as little as possible and take notes on what the test subject said and what emotions were expressed during the observation. The test subjects were also told that they could interrupt the observation and interview at any time.

After the observation, the test subjects were led to an enclosed interview room at Gløshaugen, where the interview would take place. The interviews were semi-structured, meaning that in addition to the list of open-ended questions to be asked, there was room for follow-up questions and new themes that would emerge from the interview and not be thought of beforehand. Although, a semi-structured interview decreases the comparability of the generated data from the answers. The questions were asked in an informal tone to decrease tension between interviewer and interviewee. All interviewees were encouraged to take their time and respond with their own words. The interview questions were formulated to nudge the interviewees to provide more extended and reasoned answers. The purpose of the interview was to get a better impression of how the test subjects experienced the prototype by facilitating more detailed and reflected answers than the questionnaires.

The 29 pre-determined questions are all listed in Table 28.3. See also Section 3.2 for further details on observations and interviews.

Post-experiment questionnaire After 19 days of gameplay, all test subjects were sent a link to the post-experiment questionnaire. This questionnaire was made using Microsoft Forms and sent to all test subjects as a prerequisite for being eligible to win one of the two gift cards of 250 NOK. This questionnaire collected data on the test subjects' demographics, game usage, physical activity habits and attitudes during the experiment, motivation, enjoyment, engagement, and other themes. One of the first questions was prompting the respondents to answer whether they had played the game a sufficient amount to provide answers to the questionnaire (which was stated in the question text to be at least 30 minutes in total playtime). Only respondents who answered yes to that question were included in the final data set for the experiment. The questionnaire included some repetitions of questions from the pre-experiment questionnaire to see if there were any changes in the test subjects' physical activity levels or attitudes towards physical activity.

The actual questionnaire can be seen in Appendix C.

27.3 Summary

This project collects data both qualitatively and quantitatively. Qualitative data is based on sources like the literature review, while quantitative data is based on numerical data sources like the questionnaires. The experiment aims to generate data to help answer research questions 1, 4, and 5. The experiment will include several activities to answer these questions and collect data. First, the test subjects will answer a pre-experiment questionnaire before being given access to the game for 19 days. During the 19 days, four of the test subjects will be observed and interviewed. After the period is over, all test subjects will answer a post-experiment questionnaire. The data from the two questionnaires will then be compared and analyzed with the findings from the observations and interviews.

Chapter 28

Experiment Execution and Data Generation

This chapter covers the data generation methods from Oates' model (questionnaires, interviews, and observations) and the game usage data from the experiment. In the following chapter about results, the data will primarily be organized by themes related to the research questions and within each theme by data generation method, where applicable. In this chapter, the same organization is applied but reversed to bridge the path between experimental design and reporting results. Each data generation method will be presented with the relevant themes linked to each question or statement.

The relevant themes comprising the results section division are listed below:

- Demographics
- Physical activity
- Enjoyment
- Motivation
- Supplementary

28.1 Pre-experiment questionnaire

The pre-experiment questionnaire consisted of 19 relevant questions related to the themes *Demographics* (PrQ1-PrQ8.1) and *Physical activity* (PrQ9-PrQ17.1). They were mostly about getting to know the pool of test subjects and their habits and attitudes on gaming and physical activities. Each question has been given an index of *PrQX* where the *Pr* is short for pre-experiment, the *Q* is for question/statement, and finally, the number is for easy referencing in later chapters.

The questions are listed in Table 28.1. These include only the 19 relevant questions from the answered questionnaire. Some questions like the experiment ID and the data processing and storage consent questions have been removed to focus on the relevant questions for the research questions. A few questions have also had minor linguistically changes to improve readability. See Appendix B for the actual answered questionnaire. Twenty-one of the test subjects' answers have been considered. See Chapter 26 for why not all were included.

Table 28.1: The relevant questions and statements from the pre-experiment questionnaire

ID	Question/Statement text	Format	Theme
PrQ1	Age?	Number	Demographics
PrQ2	Gender?	Number	Demographics
PrQ3	How would you categorize your weight category (BMI)?	Multiple choice	Demographics
PrQ4	I like playing video games (mobile, PC, console)	Likert	Demographics
PrQ5	About how many hours do you play video games on a normal day?	Multiple choice	Demographics
PrQ6	What game genres do you prefer to play?	Multiple choice *	Demographics
PrQ7	What platform do you prefer?	Multiple choice	Demographics
PrQ8	Have you tried playing an exergame in the last 12 months?	Multiple choice	Demographics
PrQ8.1	Which exergames have you played in the last 12 months?	Multiple choice *	Demographics
PrQ9	How would you subjectively rate your physical fitness/shape?	Multiple choice	Physical activity
PrQ10	Roughly, how many times a week do you exercise?	Number	Physical activity
PrQ11	Roughly, how much time (minutes) do you spend being physically active on a normal day?	Number	Physical activity
PrQ12	Roughly, how many steps do you take on a normal day	Multiple choice	Physical activity
PrQ13	I wish I were more physically active than I am today	Likert	Physical activity
PrQ14	I wish I exercised more than I do today	Likert	Physical activity
PrQ15	What are the reasons you are not as physically active/do not exercise as you wish you were?	Multiple choice *	Physical activity
PrQ16	When you exercise, what kind of exercise do you do?	Multiple choice *	Physical activity
PrQ17	Do you go for walks/strolls/hikes in your spare time?	Multiple choice	Physical activity
PrQ17.1	Do you prefer to walk/stroll/hike in nature (rural areas) or in more urban areas?	Multiple choice	Physical activity

Question PrQ6, PrQ8.1, PrQ15, and PrQ16 are marked with * in their format cell to indicate that several answers could be selected in their multiple-choice format. Question PrQ8.1 and PrQ17.1 have an extra number to indicate that they were part of the dynamical behavior of the form and could only be answered if the respondent had answered *yes* to PrQ8 or PrQ17.

28.2 Game usage data

Although not a part of Oates' data generation methods in the research process model, the actual usage of the game from the experiment will support answering the research questions [1]. The quantitative data from the database will help strengthen or weaken any conclusions from the other data generation methods (questionnaires, observations, and interviews).

After the experiment, we removed all usage data that did not originate from the test subjects before fetching the usage data from the database. Table 28.2 will present the data queries, what question is answered by the query, and which theme each query relates to. All queries are also given an ID for easy referencing in future chapters.

Table 28.2: Game usage data queries with a related question each query tries to answer, with related themes.

ID	Query	Question	Theme
GU1	Amount of registered users in the database	How many player profiles were created during the experiment?	Supplementary
GU2	Amount of server pings to the reverse geocoding API	How much total time was spent playing the game by all players? (The server is pinged every 15 seconds)	Supplementary
GU3	Amount of server pings grouped by postal code	What postal codes (city district) were used the most?	Supplementary
GU4	All user objects' final level and XP values	What levels did the players reach?	Motivation
GU5	All users' story progress flags	How far did the players progress in the story?	Motivation
GU6	All users' paint station interactions	How much did the players use the paint stations?	Motivation
GU7	Server pings per day of the experiment	How did the total usage of the game progress through the experiment?	Motivation
GU8	Server ping time stamps	When during the day did the players play the most?	Supplementary
GU9	Location distance (in meters) between temporally adjacent server pings	How fast did the players move while playing?	Physical activity
GU 10	Location distance (in meters) between temporally adjacent server pings with no zero-results	How fast did the players move while playing when not being stationary?	Physical activity

28.3 Observation and interviews

Four observations and interviews were conducted as described in Section 27.2. The generated data from these activities will serve as a source of qualitative data and be used in conjunction with the questionnaire data as the main instrument for answering the relevant research questions. Answers from the interviews will be mostly subjective data, but observing the test subjects provides more objective data since the reported expressions, usage patterns, and behavior are perceived by someone other than the data origin person.

The observations were executed as planned, with the participants meeting us at Gløshaugen and playing while being overtly observed for a short session. The participants' actions and behavior, spoken and interpreted from body language and exertion, were noted. In Chapter 29, the observations related to each theme are summarized. These observations include what game features were used the most and how intense the *produced* physical activity was. In Appendix F, a full report on the four observations is available.

The interviews were also conducted as planned just after the observations. The pre-determined questions in the interview consisted of 29 questions related to all of the listed relevant themes from the chapter introduction. Each question has been given an index of *InQX* where the *In* is short for "interview," the *Q* is for "question," and finally, the number is for easy referencing in later chapters. See Table 28.3 for all of the pre-determined questions from the interviews.

Table 28.3: The pre-determined questions from the interviews

ID	Question/Statement text	Theme
InQ1	Age?	Demographics
InQ2	Gender?	Demographics
InQ3	Do you like playing video games?	Demographics
InQ4	Roughly how many minutes do you spend playing video games on a normal day?	Demographics
InQ5	Have you played an exergame in the last 12 months?	Demographics
InQ6	Roughly, how much time (minutes) do you spend being physically active on a normal day?	Physical activity
InQ7	What do you think of combining gaming and exercise/physical activity?	Physical activity
InQ8	How intensely physically active did the game encourage you to be?	Physical activity
InQ9	Do you think this game could replace a regular exercise session for you? Why/Why not?	Physical activity
InQ10	Do you think this game could replace some other physical activity? Why/Why not?	Physical activity
InQ11	In the time when you were playing the game, what do you think you would have been doing if you did not play?	Physical activity
InQ12	What do you think of the game?	Enjoyment
InQ13	Did you feel in control of your actions while playing?	Enjoyment
InQ14	For the most part, did you understand how to play the game?	Enjoyment
InQ15	Was there anything you liked about the game? What was it?	Enjoyment
InQ16	Was there anything you disliked about the game? What was it?	Enjoyment
InQ17	Were you aware of your environment and surroundings while playing?	Enjoyment
InQ18	Did any part of the game make you curious and wanting to learn more?	Enjoyment
InQ19	Was there any part of the game which made you feel satisfied/pleased?	Enjoyment
InQ20	What did you think about the graphics of the game?	Enjoyment
InQ21	While playing, what were your in-game goals?	Motivation
InQ22	What, if anything, motivated you to reach those goals?	Motivation
InQ23	Were the goals difficult to reach/achieve?	Motivation
InQ24	Did you experience progress toward your goals while playing?	Motivation
InQ25	Did you feel any skill progression, in that you got better at playing the game?	Motivation
InQ26	Do you feel that the game motivated you to be physically active?	Motivation
InQ27	Did you experience any technical difficulties or other complications while playing? If so, how did it affect your gaming experience?	Supplementary
InQ28	Is this a game you could imagine playing more of if it were further developed?	Supplementary

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Table 28.3 – continued from previous page

ID	Question/Statement text	Theme
InQ29	Do you have any other ideas or feedback you would like to tell us?	Supplementary

See Chapter 29 for the findings from the interviews.

28.4 Post-experiment questionnaire

The post-experiment questionnaire consisted of 45 questions related to the listed relevant themes from the chapter introduction. The data from this questionnaire is the primary source of quantitative data, which is the primary tool for answering the research questions RQ1, RQ3, and RQ4.

Each question has been given an index of *PoQX* where the *Po* is short for "post-experiment," the *Q* is for "question," and finally, the number is for easy referencing in later chapters.

The questions are listed in Table 28.4. These include only the 45 relevant questions from the answered questionnaire with minor linguistical changes for readability. See Appendix C for the actual answered questionnaire.

Table 28.4: The relevant questions and statements from the post-experiment questionnaire

ID	Question/Statement text	Format	Theme
PoQ1	Did you test the game? (At least 30 minutes in total) **	Binary (Yes/no)	Demographics
PoQ2	What kind of mobile unit did you use to play the game?	Text	Demographics
PoQ3	Roughly, during the experiment, how much time (minutes) did you spend being physically active on normal days?	Number	Physical activity
PoQ4	During the experiment, I still wish I were more physically active than I was	Likert	Physical activity
PoQ5	I was physically active more often during the experiment than I was before	Likert	Physical activity
PoQ6	The game helped motivate me to be physically active	Likert	Physical activity
PoQ7	I mostly ran instead of walked while playing the game	Likert	Physical activity
PoQ8	I forgot/became unaware that I was being physically active while playing the game	Likert	Physical activity
PoQ9	I would like to use this game instead of traditional exercise in the future	Likert	Physical activity
PoQ10	Using an exergame can make me more physically active than I am today	Likert	Physical activity
PoQ11	Roughly how many steps do you take on average during the experiment (in the last weeks)?	Multiple choice	Physical activity
PoQ12	Roughly, for how long (minutes) did you spend playing the game each play session?	Number	Physical activity
PoQ13	I found the overall gameplay enjoyable	Likert	Enjoyment
PoQ14	I enjoyed visiting and exploring the map parts (city districts)	Likert	Enjoyment

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Table 28.4 – continued from previous page

ID	Question/Statement text	Format	Theme
PoQ15	I enjoyed exploding the small battling blobs	Likert	Enjoyment
PoQ16	I enjoyed battling the large blobs	Likert	Enjoyment
PoQ17	I enjoyed battling the armored blobs	Likert	Enjoyment
PoQ18	Time felt like it went faster when playing the game	Likert	Enjoyment
PoQ19	The story and overarching goal/purpose of the game was clear and understandable to me	Likert	Enjoyment
PoQ20	I understood how to play the game after completing the tutorials	Likert	Enjoyment
PoQ21	I liked the graphics of the map, minimap, character, blobs, animations, etc.	Likert	Enjoyment
PoQ22	My goals were clearly defined when playing the game	Likert	Enjoyment
PoQ23	I felt in control of my player avatar's movements	Likert	Enjoyment
PoQ24	I liked the music and sound effects	Likert	Enjoyment
PoQ25	The game's difficulty was	Multiple choice	Enjoyment
PoQ26	I found this feature the most fun/enjoyable	Multiple choice	Enjoyment
PoQ27	Were there any game features which you did not understand how to play/use? If yes, what features?	Text	Enjoyment
PoQ28	What about the game did you enjoy the most?	Text	Enjoyment
PoQ29	What about the game did you enjoy the least?	Text	Enjoyment
PoQ30	I played mostly (alone or with others)	Multiple choice	Enjoyment
PoQ31	I played the game mostly in (rural og urban areas)	Multiple choice	Enjoyment
PoQ32	I repeated the tutorial after finishing it on the initial play session	Binary (Yes/no)	Enjoyment
PoQ33	The level and XP system was motivating	Likert	Motivation
PoQ34	The game motivated me to visit places/areas which I had not yet visited (often)	Likert	Motivation
PoQ35	Seeing leaderboards and competing against friends and other players was motivating	Likert	Motivation
PoQ36	Marking areas as explored, dominated, or conquered was motivating	Likert	Motivation
PoQ37	Battling small, large and armored blobs was motivating	Likert	Motivation
PoQ38	The story motivated me to finish the game and learn more	Likert	Motivation
PoQ39	During the experiment, I found it hard to motivate myself to use the game	Likert	Motivation
PoQ40	I completed the story and defeated Paintavvagio	Binary (Yes/no)	Supplementary

Continues on the next page

Table 28.4 – continued from previous page

ID	Question/Statement text	Format	Theme
PoQ41	I played the game even after completing the story	Binary (Yes(no)	Supplementary
PoQ42	Did you experience any technical problems? If yes, please describe the problems	Text	Supplementary
PoQ43	Did any other external factors prevent you from playing the game as much as you would like to? (Such as illness, poor weather conditions, etc.) If yes, please describe the factors	Text	Supplementary
PoQ44	Did you cheat during the experiment? If yes, how and why did you cheat?	Text	Supplementary
PoQ45	Do you have any last/departing comments?	Text	Supplementary

Question PoQ1 is marked with ** to indicate that the respondent was directed to the form's end if the answer was *no*. Answering *no* to question PoQ1 would mean that the respondent played the game for less than 30 minutes in total, which was less than the minimum amount of time playing the game to make a qualified assessment of the game. Therefore, the test subject could not be included in the final data set as stated in Chapter 26.

28.5 Experiment execution - Problem handling reported and handled

As mentioned in Section 27.2, all test subjects were given the contact information to both of us to use in case of any bugs, issues, or problems which kept them from playing the game as they liked. During the experiment, the test subjects were *left to themselves* during the experiment to play however and as much as they liked. A handful of bugs and issues were reported to us during the experiment. We, the developers, addressed and tended to these bugs and issues. After the initial version of the game (v1.01), two new versions, v1.02 and v1.03, were sent out to the test subjects to address various bugs. In Table 28.5, all reported bugs and issues are listed, together with what version of the game implemented the measure/fixed the issue (when applicable):

Table 28.5: All reported bugs and issues during the experiment and what version of the game included the fix/measure.

Bug/Issue	**Version**
The daily streak XP bonus was repeatable, leading to some players receiving lots of unearned XP	v1.02
The leaderboards showed the wrong amount of players	v1.02
The city district status view missed some text on some smaller devices	v1.02
The leaderboards showed the wrong unit on some exploration metrics	v1.02
Paintavvagio's size got too small when clicking the exit battle button many times in quick succession	v1.03
Paintavaggio's size sometimes became smaller than expected	-
One sometimes did not automatically lose a battle when having no more paint grenades/missiles	-

28.6 Summary

Data from each of the activities detailed in Chapter 27 will divided into five themes, *Demographics*, *Physical Activity*, *Enjoyment*, *Motivation* and *Supplementary*. Questions in the questionnaires and the interview have been mapped into these themes. Different data from the game database has also been mapped to the same categories. When the results are presented in Chapter 29, the data will be presented for each of these themes and hopefully be easier to understand after reading this chapter.

Chapter 29

Results

This chapter covers the results of the experiment. The result data originates from the two questionnaires, observations, interviews, and game usage data. After a short description of how the data will be analyzed, all results will be placed in a fitting theme. The five themes are demographics, physical activity, enjoyment, motivation, or supplementary.

29.1 Data analysis approach

The generated data from the experiment is both quantitative and qualitative. The quantitative data from the questionnaires is considered the primary means of producing knowledge. The qualitative data from the questionnaires, interviews, and observations, together with the quantitative game usage data, is also applicable but serves mainly to strengthen or weaken any conclusions from the primary data analysis and provide alternative perspectives.

A version of the Likert scale was used to format most of the questions and statements, enabling the data to be defined as ordinal data [168]. In the Likert-formated answers, alternatives can be assigned numbers to define an ordinal scale as seen in Table 29.1.

Likert option	Number
Disagree	1
Partially disagree	2
Neutral/No opinion	3
Partially agree	4
Agree	5

Table 29.1: Likert option assigned to number

The central tendency of the ordinal data will be illustrated by calculating the average numerical value (mean) and the midpoint of the ordered results (median). Where relevant, the standard deviation is also calculated.

A visual representation of the data from the numerically and categorically (multiple choice) formatted questions is also presented where relevant. The data will also be partitioned and grouped by some demographic traits and compared for a more in-depth analysis. See Chapter 30.

The text-format questions and statements from the questionnaires, together with the other qualitative data from the interviews and observations, will be interpreted and used in combination with the quantitative data.

29.2 Demographics

This section covers the demographic results from the questionnaires, observations, and interviews. Common demographic traits such as age and gender are noted but also more specific traits to this project such as relationship to gaming and recent exergaming habits.

29.2.1 Pre- and post-experiment questionnaire

Table 29.2 shows the related questions and statements from the pre- and post-experiment questionnaire for this theme (demographics). As mentioned in Chapter 26, 21 test subjects were included in the final data set. None of the 21 answers was deemed written in bad faith or otherwise unfit to be used in the data analysis.

Table 29.2: The relevant questions and statements from the pre- and post-experiment questionnaire

ID	Question/Statement text
PrQ1	Age?
PrQ2	Gender?
PrQ3	How would you categorize your weight category (BMI)?
PrQ4	I like playing video games (mobile, PC, console)
PrQ5	About how many hours do you play video games on a normal day?
PrQ6	What game genres do you prefer to play?
PrQ7	What platform do you prefer?
PrQ8	Have you tried playing an exergame in the last 12 months?
PrQ8.1	Which exergames have you played in the last 12 months?
PoQ1	Did you test the game? (At least 30 minutes in total)
PoQ2	What kind of mobile unit did you use to play the game?

Figure 29.1, Figure 29.2 and Figure 29.3 respectively shows the distribution of age, gender and reported BMI (Body Mass Index) category of the participants. The test participants are mostly between 24 and 25 years of age (62%) and male (71%). Normal/healthy weight and overweight people comprise about half of the test population. The mean age is 25.3, and the median age is 25.

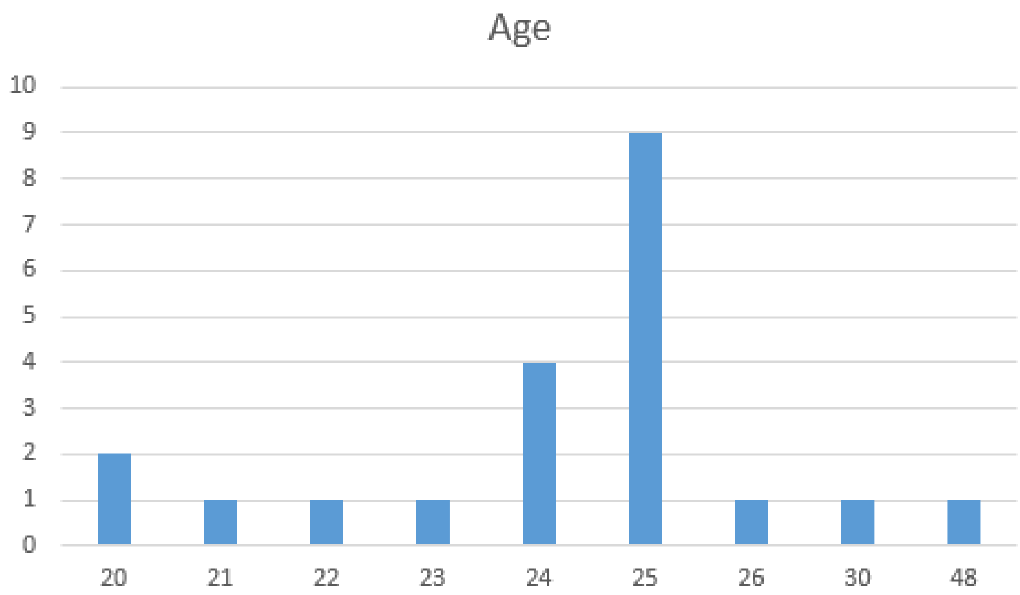

Figure 29.1: PrQ1 - The age of all participants

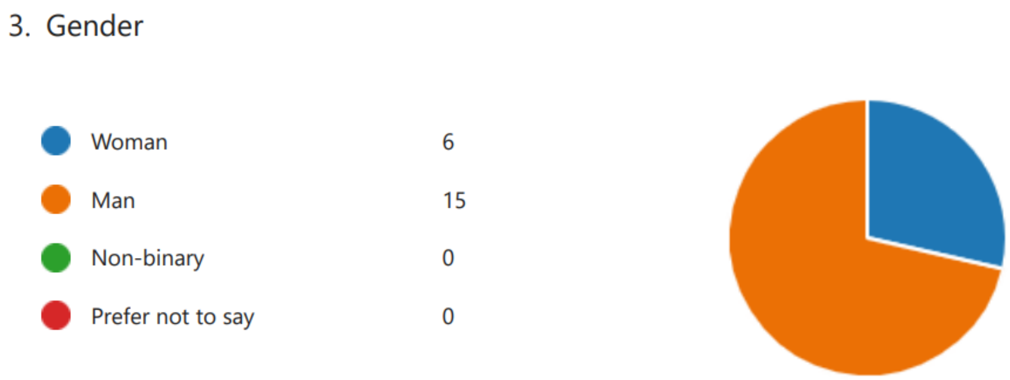

Figure 29.2: PrQ2 - The gender of all participants

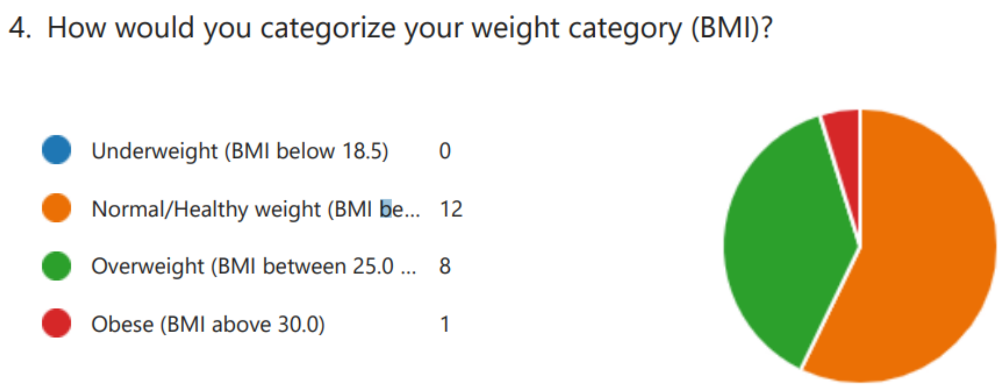

Figure 29.3: PrQ3 - The reported BMI category of all participants

To understand the test subject group a bit more before undertaking the experiment design, we want to examine how much the test subjects liked playing video games and if they have played an exergame within the last 12 months.

Habits, attitudes, and other relations to physical activity are also relevant to keep in mind when getting to know the test subjects' demographics. However, traits related to physical activity are covered in Section 29.3.1.

As can be seen in Figure 29.4, a large majority of test subjects like playing video games, with 86% agreeing or partially agreeing to the statement *I like playing video games*. However, Figure 29.5 shows that only about half of the test subjects (52%) report playing video games for more than an hour or more on a *normal day*.

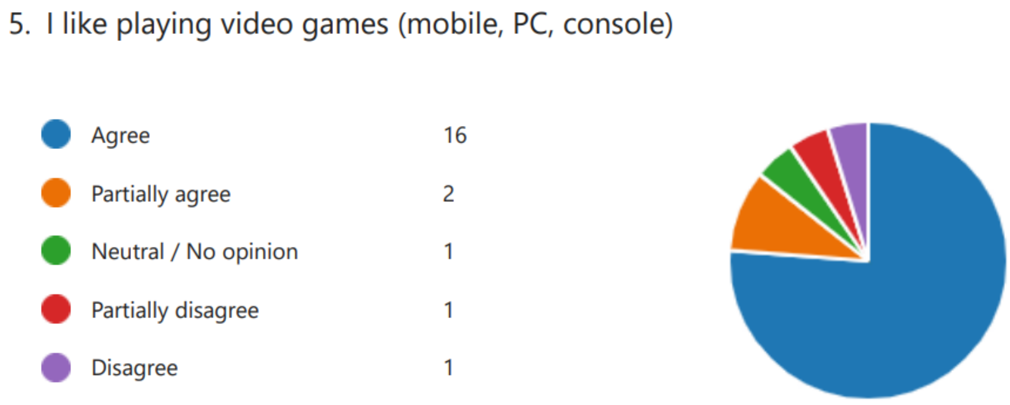

Figure 29.4: PrQ4 - How the participants likes playing video games

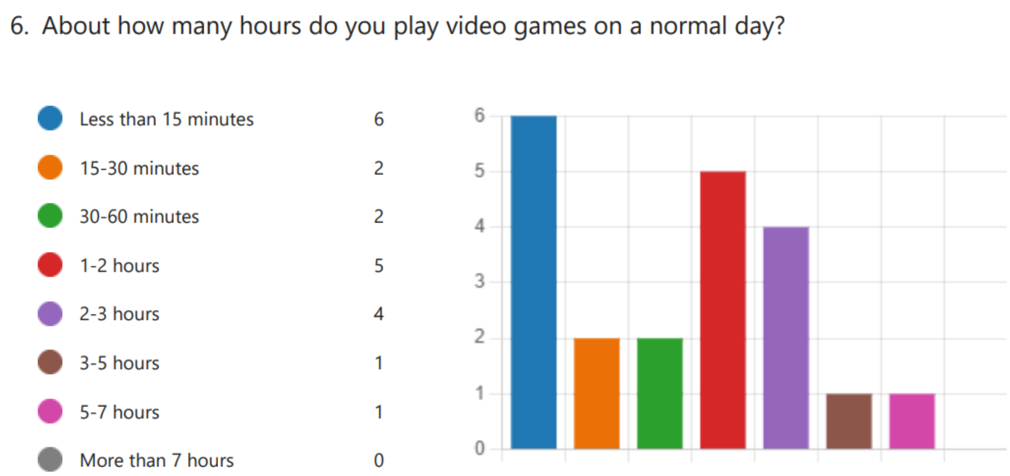

Figure 29.5: PrQ5 - How many minutes/hours the test subjects report to play on a normal day

Figure 29.2 shows that the most popular game genres were strategy games and RPGs, with a reasonably even distribution amongst all genre alternatives. No one reported preferring to play idle games. When prompted to choose their preferred gaming platform, 52% chose PC while 33% chose console.

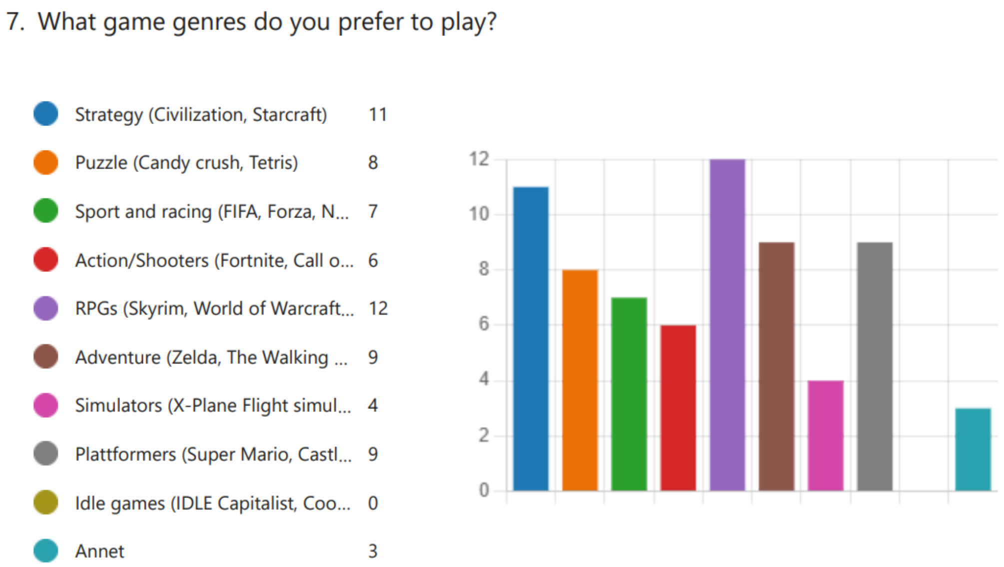

Figure 29.6: PrQ6 - What game genres the test subjects report to prefer when playing

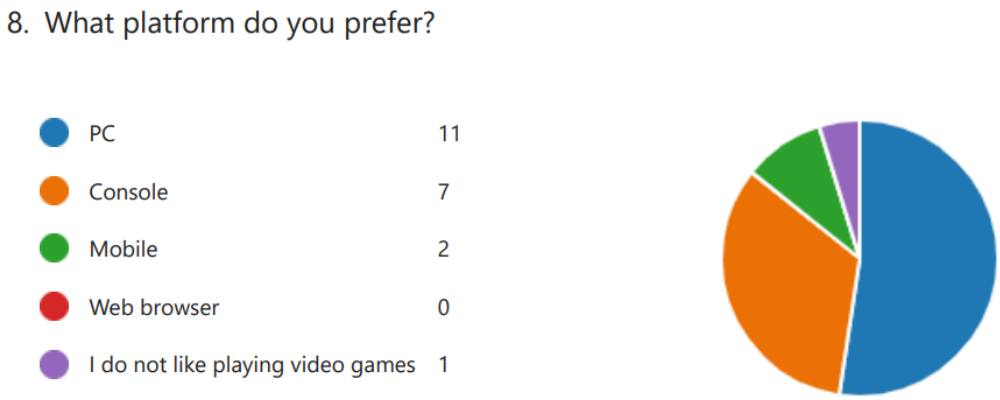

Figure 29.7: PrQ7 - The test subject's preferred gaming platform

Finally, 38% of the test subjects reported not having played any exergame in the last 12 months, as displayed in Figure 29.8. The remaining 62% varied fairly evenly between playing a little, some, or many exergames in the last 12 months. Most of the test subjects had played no specific exergames, but Pokémon Go was the most used, with 33% selecting it, as shown in Figure 29.9.

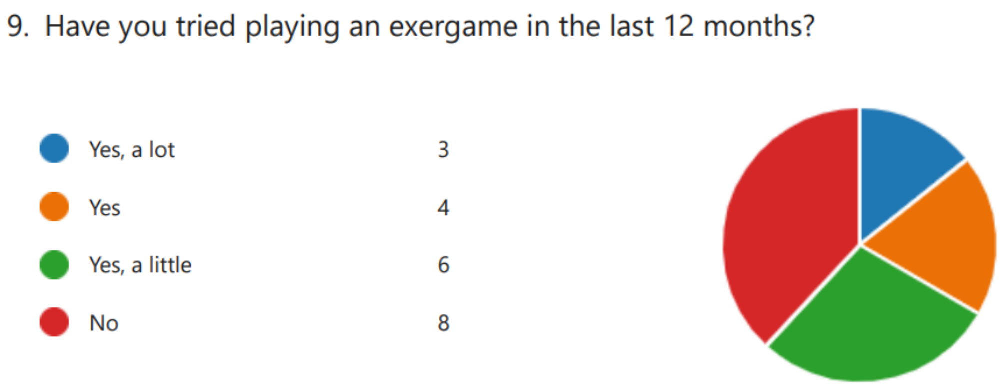

Figure 29.8: PrQ8 - The test subject's history of playing exergames for the last 12 months

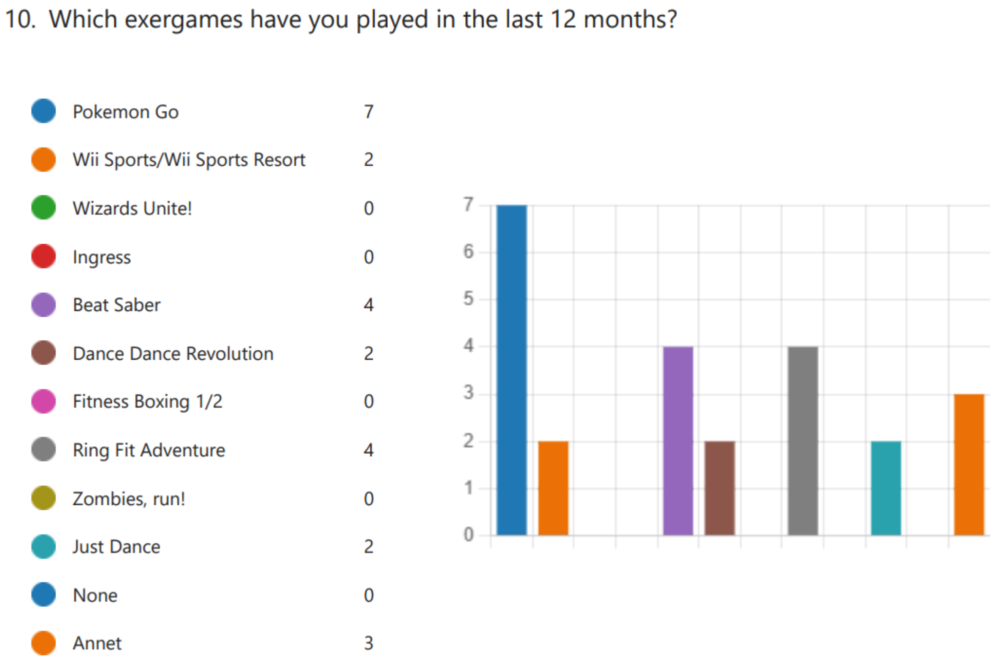

Figure 29.9: PrQ8.1 - What specific exergames the test subjects have played in the last 12 months, if any

However, the most important question related to this theme is whether the test subjects reported having played the game for 30 minutes or more. This question from the post-experiment questionnaire set a rigid exclusion limit where if the test subjects answered *No*, they were deemed unable to provide a capable verdict on the game. People who answered *no* were therefore navigated to the end of the questionnaire and had their response from the pre-experiment questionnaire removed. *21 out of the 29 people (72%)* who opened the post-experiment questionnaire answered *Yes* and were thus allowed to continue the form. h

When asked what mobile device they used during the experiment (PoQ2), 38% reported using a Huawei model, and 29% used a Samsung model.

29.2.2 Observations and interviews

Table 29.3 shows the related pre-determined questions from the interviews for this theme.

Table 29.3: The pre-determined questions from the interview relevant to demographics

ID	Question/Statement text
InQ1	Age?
InQ2	Gender?
InQ3	Do you like playing video games?
InQ4	Roughly how many minutes do you spend playing video games on a normal day?
InQ5	Have you played an exergame in the last 12 months?

Four test subjects were chosen for the observations and following interviews. The test subjects were chosen to recruit people of different genders, ages, and relationships to gaming. The demographic data for each test subject is listed in Table 29.4. e

Test subject	**1**	**2**	**3**	**4**
Gender	Female	Male	Female	Male
Age	24	48	23	20
Exercise sessions per week	3	0-1	2	0
Physical activity amount per day	30 min	30-60 min	45 min	30 min
Likes playing video games	Yes	A little	Yes	Yes
Average time playing video games per day	30 min	0 min	120 min	300 min
Has played an exergame in the last 12 months	Yes	No	Yes	No

Table 29.4: Key data for the four test subjects who participated in the observations and interviews.

Even though there are only four samples, there is a significant variation in age, gender, weekly exercise sessions, time spent playing video games, and relation to exergames, as seen in Table 29.4. All test subjects report being active for at least 30 minutes a day, and all like playing video games *at least a little bit.*

29.2.3 Summary of demographics results

This section summarized the result data related to demographics and the test subject's relationship to gaming and exergames. The test subject pool is quite diverse but with some preeminent patterns. The pool includes many males in their mid-20s and almost no underweight or obese persons. Most of them report liking playing video games, but about half play for less than an hour each day. Mobile is the preferred gaming platform for almost no one.

29.3 Physical activity

This section presents the data related to physical activity from the questionnaires, observations and interviews, and the game usage data. The section will begin with a reminder of all relevant questions from each data generation method before dwelling on the results. The questions and statements effectively equivalent in the pre- and post-experiment questionnaires will be compared to check for any changes in physical activity.

29.3.1 Pre- and post experiment questionnaire

Where applicable, some statistical analyses will be performed to check for indications of or statistically significant changes in the given answers from the pre- and post-experiment questionnaires. T-tests and Mann-Whitney tests will be the tools. All p-values lower than 0.05 will be regarded as statistically significant, while p-values between 0.05 and 0.15 will be regarded as an indication of a change.

After the comparable question results have been presented, all other results related to physical activity will be presented.

Table 29.5 shows this theme's related questions and statements from the pre- and post-experiment questionnaire.

Table 29.5: The relevant questions and statements from the pre- and post-experiment questionnaire

ID	**Question/Statement text**
PrQ9	How would you subjectively rate your physical fitness/shape?
PrQ10	Roughly, how many times a week do you exercise?
PrQ11	Roughly, how much time (minutes) do you spend being physically active on a normal day?
PrQ12	Roughly, how many steps do you take on a normal day
PrQ13	I wish I were more physically active than I am today
PrQ14	I wish I exercised more than I do today
PrQ15	What are the reasons you are not as physically active/do not exercise as you wish you were?
PrQ16	When you exercise, what kind of exercise do you do?
PrQ17	Do you go for walks/strolls/hikes in your spare time?
PrQ17.1	Do you prefer to walk/stroll/hike in nature (rural areas) or in more urban areas?
PoQ3	Roughly, during the experiment, how much time (minutes) did you spend being physically active on normal days?
PoQ4	During the experiment, I still wish I were more physically active than I was
PoQ5	I was physically active more often during the experiment than I was before
PoQ6	The game helped motivate me to be physically active
PoQ7	I mostly ran instead of walked while playing the game
PoQ8	I forgot/became unaware that I was being physically active while playing the game
PoQ9	I would like to use this game instead of traditional exercise in the future
PoQ10	Using an exergame can make me more physically active than I am today
PoQ11	Roughly how many steps do you take on average during the experiment (in the last weeks)?
PoQ12	Roughly, for how long (minutes) did you spend playing the game each play session?

Change in daily time spent being physically active

The test subjects were asked how much they agreed to the statement *I was physically active more often during the experiment than I was before* (PoQ5). To this subjective assessment of change in their physical activity level, 33% disagreed (chose *Disagree* or *Partially disagree*) while 43% agreed (chose *Agree* or *Partially agree*).

Figure 29.10 shows the statements with Likert-formatted answer alternatives related to the theme of physical activity. See the second statement in the figure for the answers to PoQ5.

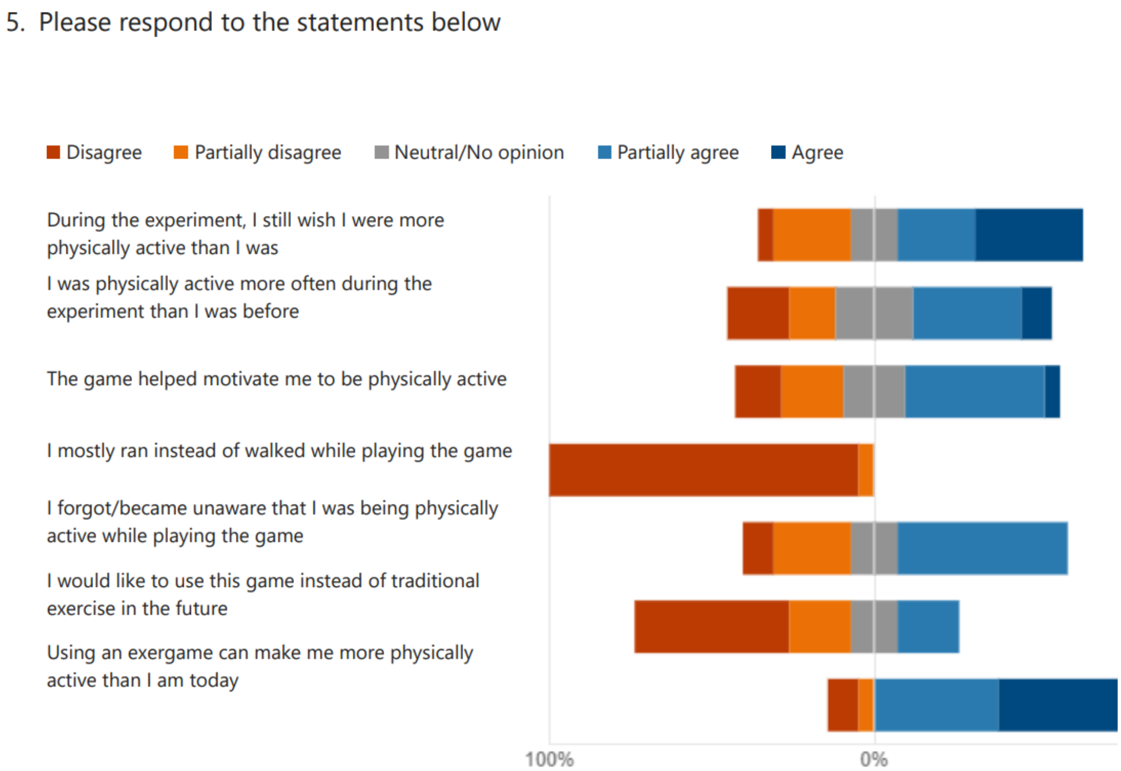

Figure 29.10: PoQ4-PoQ10 - Physical activity likert-statements from the post-experiment questionnaire.

All test subjects were also asked how much time they spent physically active on a normal day both before and during the experiment (PrQ11 and PoQ3). The pre-experiment question resulted in a mean of 52.1 minutes, a median of 40 minutes, and a standard deviation of 36.1. The post-experiment question resulted in a mean of 75 minutes, a median of 45 minutes, and a standard deviation of 97.8. In order to understand whether there is an actual change in time spent being physically active, a paired t-test was performed to find the relevant two-tailed p-value.

The test was performed with two paired samples of $n = 21$. The test resulted in a p-value of 0.2152, which is not regarded as statistically significant (< 0.05) or an indication of change (< 0.15).

When combining this data with the quite similar values in agreeing and disagreeing with a perceived increase in time spent being physically active, there is, for now, no evidence that the game increased physical activity levels.

See Figure 29.11 for the answers to PrQ11 and PoQ3.

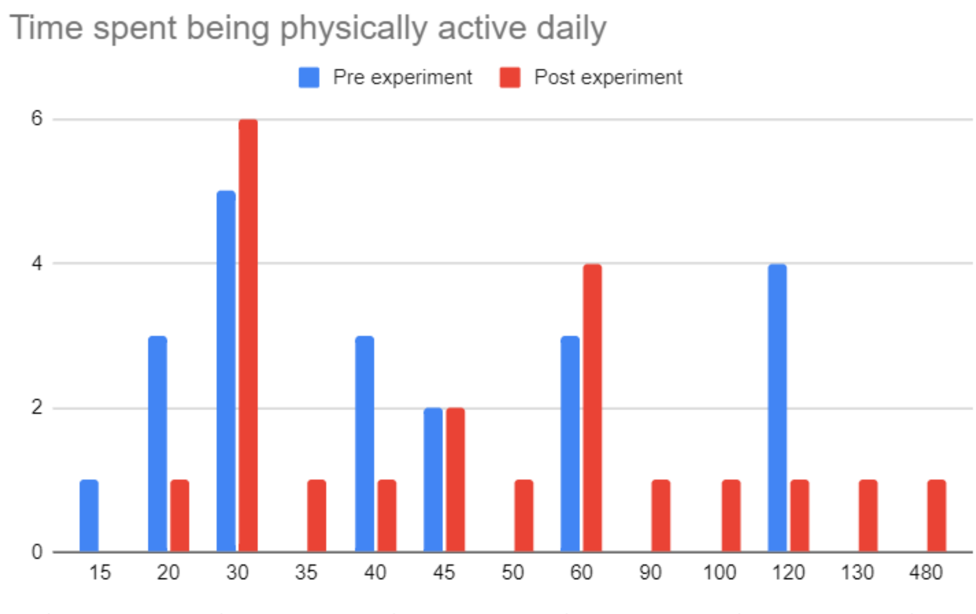

Figure 29.11: PrQ11 & PoQ3 - Roughly, how much time (minutes) do you spend being physically active daily

Change in daily step count

The test subjects were asked how many steps they took on average on a normal day both before and during the experiment (PrQ12 and PoQ11). The test subjects' answers are placed in categories of step count ranges, each with the size of 3 000 steps. The answers are shown in Figure 29.12. Each category is mapped to a number in the middle of the step count range to perform a meaningful test on the given answers, as seen in Table 29.6.

Table 29.6: The answer categories from the step count questions mapped to a numerical value in t-test

Answer category	Numerical value
0 - 3 000	1 500
3 000 - 6 000	4 500
6 000 - 9 000	7 500
9 000 - 12 000	10 500
12 000 - 15 000	13 500
15 000+	16 500
Don't know	N/A

Taking the answers from Figure 29.12 and mapping the answers to numerical values using Table 29.6, one can perform a paired t-test to check for any statistically significant change in steps taken before and during the experiment. The test was performed with two samples of $n = 19$ (due to two people answering *Don't know* in the post-experiment questionnaire and thus not being part of the test results). The test resulted in a p-value of 0.0010, regarded as statistically significant.

Using the same mapping, one can calculate the mean and median value for daily steps taken before and during the experiment. The mapped pre-experiment answers ($n = 21$) give a mean of 5 643 steps with a median of 4 500. In the post-experiment questionnaire ($n = 19$), the mapped answers provide a mean of 8 447 steps with a median of 7 500.

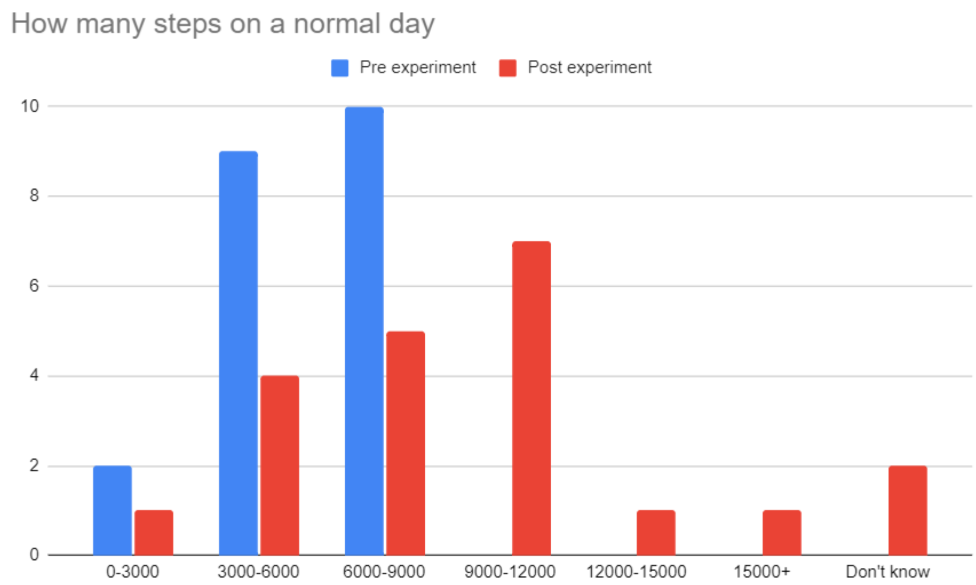

Figure 29.12: PrQ12 & PoQ11 - Roughly how many steps do you take on normal days?

Change in satisfaction with physically active

Also, on the subject of being satisfied with their physical activity levels, the test subjects were asked effectively the same question in both questionnaires on whether they wished they were more physically active than they were (PrQ13 and PoQ4). Both questions' answer alternatives were in the Likert format and can be mapped to a number between 1 and 5 as shown in Table 29.1.

The ordinal data from the numerically mapped numbers can be tested to determine whether there is a statistically significant change in the satisfaction levels before and during/after the experiment. Another Mann-Whitney test was performed with two equal samples of $n = 21$. The tests result in a p-value of 0.0688, regarded as an indication of change.

The median value of the pre-experiment question (PrQ13) was *Agree*. For the post-experiment question (PoQ4), the median was *Partially agree*.

See Figure 29.13 for the answers to PrQ13 and Figure 29.14 which shows the answers to PoQ5.

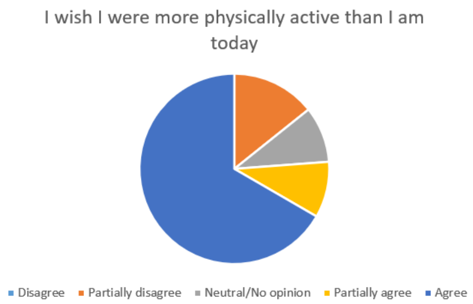

Figure 29.13: PrQ13 - I wish I were more physically active than I am today

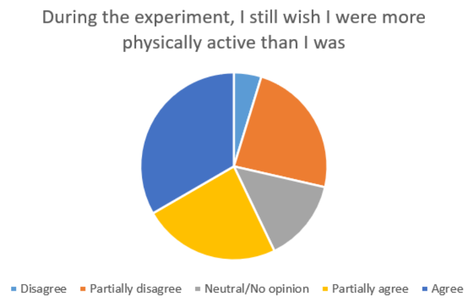

Figure 29.14: PoQ4 - During the experiment, I still wish I were more physically active than I was

Other physical activity results

Inspecting the rest of the statements with the Likert-answer format from Figure 29.10 and Figure 29.15 some results are apparent and presented in Table 29.7. For readability, the alternatives *Agree* and *Partially agree*, and *Disagree* and *Partially disagree* will be merged, like before.

ID	Question text	Disagree	Neutral	Agree
PrQ14	I wish I exercised more than I do today	14%	10%	76%
PoQ6	The game helped motivate me to be physically active	33%	48%	19%
PoQ7	I mostly ran instead of walked while playing the game	100%	0%	0%
PoQ8	I forgot/became unaware that I was being physically active while playing the game	33%	14%	52%
PoQ9	I would like to use this game instead of traditional exercise in the future	67%	14%	19%
PoQ10	Using an exergame can make me more physically active than I am today	14%	0%	86%

Table 29.7: The answers to the remaining statements about physical activity in the pre- and post-experiment questionnaire. See also Figure 29.10 and Figure 29.15.

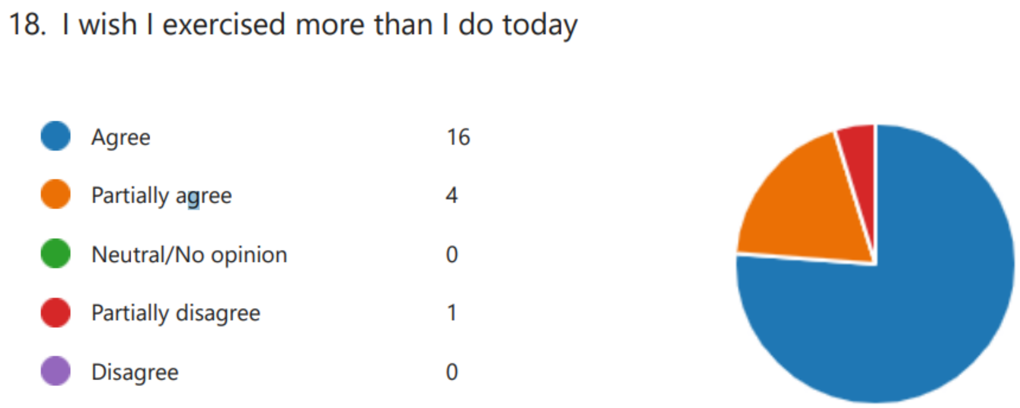

Figure 29.15: PrQ14 - I wish i exercised more than today

Table 29.7 shows that a large majority of the test subjects want to exercise more than they currently do and that walking was almost exclusively the physical activity performed while playing the game. Almost none would like to use Paint it Green to replace other exercises. However, a majority state the possibility of using an exergame to be more physically active than they are today.

Figure 29.16 shows a fairly even distribution in the reported satisfaction with the test subjects' own physical shape/fitness before the experiment (PrQ9). 24% rate their overall physical health or shape as good, 38% as all right/good enough, and 38% as not very good. None rated their physical shape as poor or excellent.

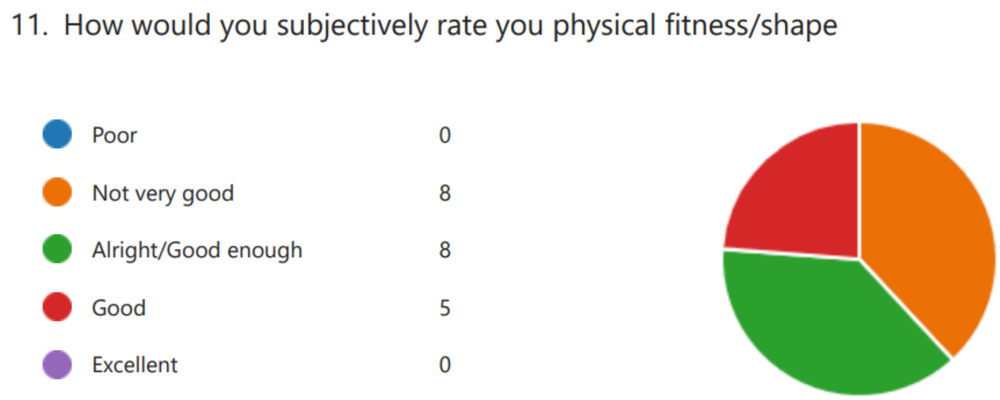

Figure 29.16: PrQ9 - How would you subjectively rate your physical fitness/shape?

PrQ10 asks the test subjects how many times a week they exercise. In the questionnaire, exercise was defined as *more intense physical activity than walking*. The mean answer was 1.7 weekly exercise sessions, and the median was 1. The standard deviation is 1.2. See Figure 29.17 for the answer distribution of PrQ10.

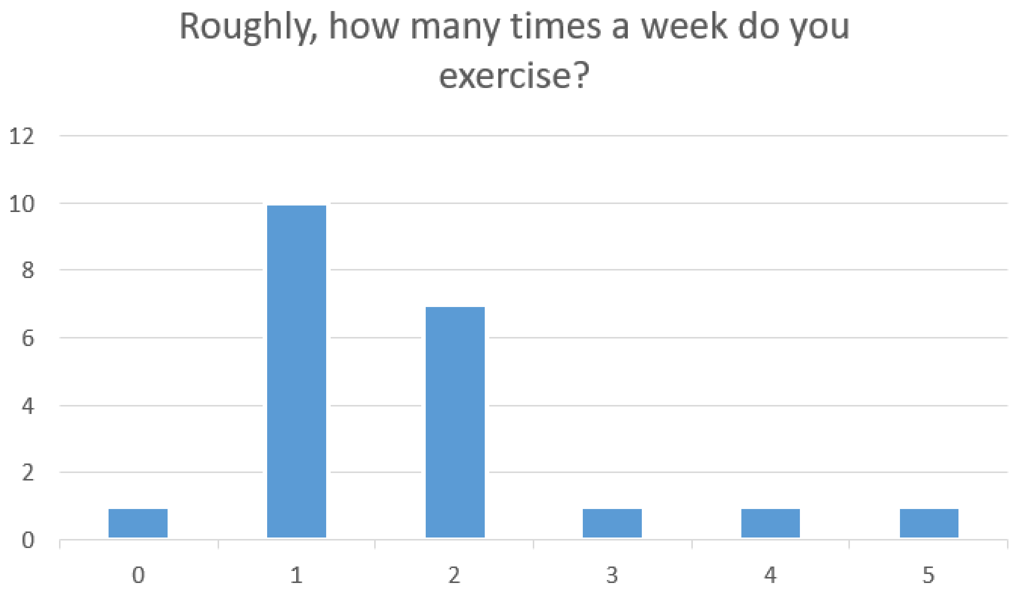

Figure 29.17: PrQ10 - Roughly, how many times a week do you exercise?

Figure 29.18 shows the reported reasons for not exercising and being physically active as much as the test subjects would like. Not enough time (67%), not finding exercise and physical activity fun or entertaining enough (57%), and needing someone or something to nudge them to exercise or be physically active (57%) are the most selected reasons.

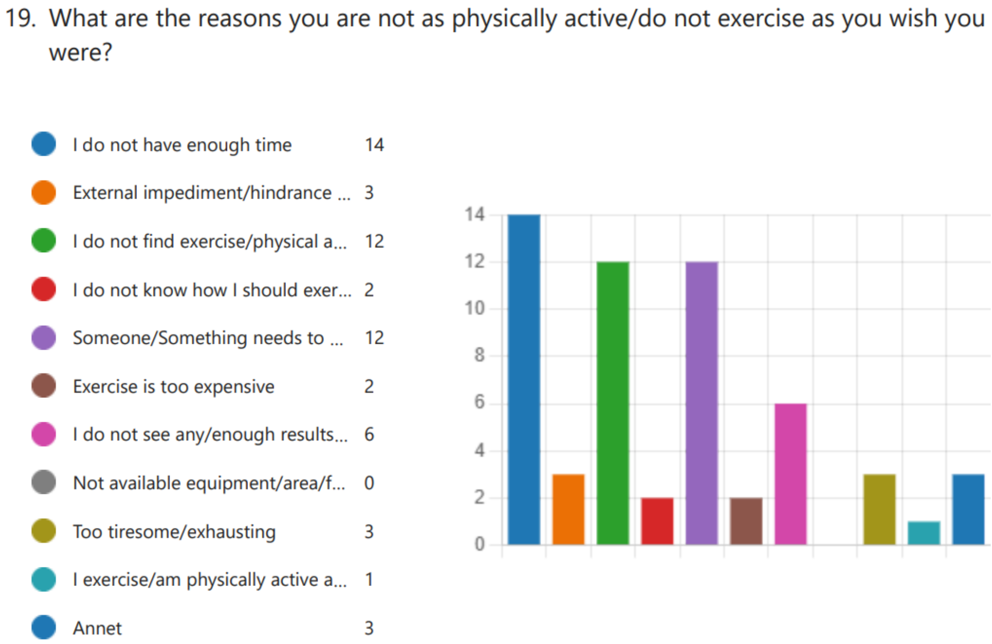

Figure 29.18: PrQ15 - What are the reasons you are not as physically active/do not exercise as you wish you were?

When asked what kind of exercise they did, when exercising, the test subjects mostly reported doing aerobic exercises like running, fast walking, and cycling (71%), with strength exercises (43%) and sports (43%) following. All other alternatives were selected by less than 15% of all test subjects. See Figure 29.19 for the actual results.

Figure 29.19: PrQ16 - When you exercise, what kind of exercise do you do?

In the pre-experiment questionnaire, the test subjects were also asked whether they go for walks in their spare time (PrQ17), and if they answered positively, they were asked if they preferred to walk in rural or urban areas or both (PrQ17.1). Figure 29.20 show that only 5% do not go for walks in their spare time, while 48% go for walks every week or more often, while the last 48% go for walks but less often.

As seen in Figure 29.21, about half of the test subjects report enjoying walking in both urban and rural areas, while 38% prefer rural areas.

Figure 29.20: PrQ17 - Do you go for walks/strolls/hikes in your spare time?

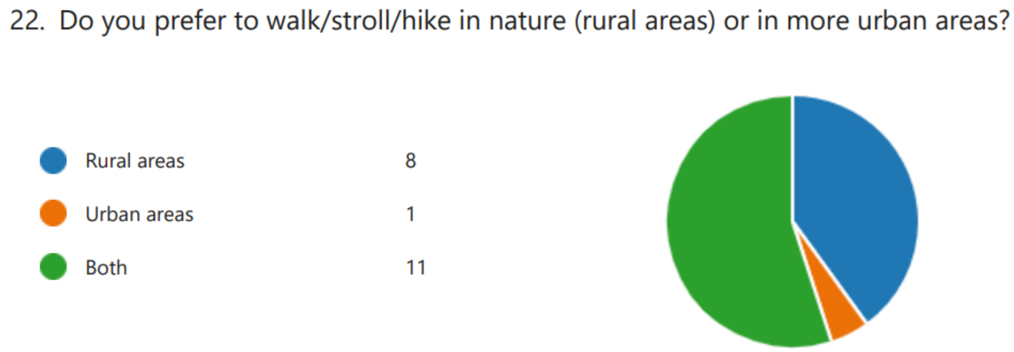

Figure 29.21: PrQ17.1 - Do you prefer to walk/stroll/hike in nature (rural areas) or in more urban areas?

Finally, in the post-experiment questionnaire, the test subjects were asked to report how long their play sessions were when playing Paint it green. Figure 29.22 shows the answers. The mean number of minutes per play session was 14 minutes, and the median was 15 minutes. The answers had a standard deviation of 7.6 minutes.

Figure 29.22: PoQ12 - Roughly, for how long (minutes) did you spend playing the game each play session?

29.3.2 Game usage data

Table 29.8 shows the two questions from the game usage data relevant to physical activity. The two questions detail how fast the players were moving while playing the game. Each reverse geocoding ping to the server was made with a 15-second time gap from the previous one. With each server ping providing the player's location in latitude and longitude, the distance traveled from the last server ping could easily be calculated.

Table 29.8: Game usage questions related to physical activity

ID	Question/Statement text
GU9	How fast did the players move while playing?
GU10	How fast did the players move while playing when not being stationary?

Thus, we had a pretty solid way of getting a grip on how far the players moved every 15 seconds, which is easily translated to a velocity in meters per second (m/s). The results should, however, not be unconditionally trusted as a measure of the players' speed since there could occur errors in the form of lost server packages, GPS sensor errors, and other noise, decreasing the validity of the data.

It is also worth looking at the player speed with all *0-meter pings* removed, meaning that all server pings coming from the exact or approximately same position as the previous ping are removed. It would be natural to believe that at least some players played the game while being stationary at their workplace or school. If one would like to know how fast the players were actually moving, this subset of server pings would be noteworthy to inspect.

Table 29.9: Game usage results related to physical activity

Description	Result
Total amount of server pings	8171
Approximate total play time	$34.05h$
Total amount of server pings with *0 pings* removed	5402
Approximate total play time with *0 pings* removed	$22.51h$
0 pings share of total amount of pings	34%
Mean player speed	$0.78m/s$
Mean player speed with *0 pings* removed	$1.17m/s$
Median player speed	$0.67m/s$
Median player speed with *0 pings* removed	$1.20m/s$

Table 29.9 shows that the average player speed while not being stationary is $1.17m/s$, which corresponds to $4.21km/h$. $4.21km/h$ can be regarded as walking speed. Also noteworthy is that 34% of all server pings and thus game usage came from the exact or approximate same location as the previous ping, indicating that about a third of the total game usage came from stationary players.

29.3.3 Observations and interviews

Table 29.10 shows the pre-determined questions from the interviews relevant to the theme physical activity.

Table 29.10: The pre-determined questions from the interview relevant to physical activity

ID	Question/Statement text
InQ6	Roughly, how much time (minutes) do you spend being physically active on a normal day?
InQ7	What do you think of combining gaming and exercise/physical activity?
InQ8	How intensely physically active did the game encourage you to be?
InQ9	Do you think this game could replace a regular exercise session for you? Why/Why not?
InQ10	Do you think this game could replace some other physical activity? Why/Why not?
InQ5	In the time when you were playing the game, what do you think you would have been doing if you did not play?

The answer to InQ6 is answered in Table 29.4.

During the observations, all four test subjects walked at typical walking speed. No one walked at a swift pace or engaged in running.

All four test subjects had positive attitudes towards combining gaming with physical activity and exercise. They thought it had the potential to make the exercise/physical activity more fun and more motivating.

Every test subject also felt like the game mainly encouraged them to walk. One of the test subjects stated that they had tried using the game while running but did not enjoy running while looking at the phone screen. Another test subject said, "*it could be efficient to jog between paint stations.*"

When asked if they thought the game could replace an exercise session, three out of four answered no, while one answered yes. The test subject who answered yes said that since the exercise they already did was mainly low intensity, a good walk could have replaced it. All four test subjects did, however, answer yes when asked if playing the game could replace another physical activity. One of them did comment that they were a little confused by the question, as they thought the game would supplement a walk rather than replace it.

When asked what they would have done instead in their time playing the game, had they not been playing, three out of four said that they still would have been out walking. However, all three test subjects also mentioned that they would not have walked as far as they would have when playing, as they believed the game motivated them to take some detours and thus walk longer. The last test subject said they would have been sedentary had they not been playing.

29.3.4 Summary of physical activity results

There were no statistically significant changes in reported physical activity before and during the experiment (p=0.2152), even though the mean and median values increased. However, there was a statistically significant change in daily steps taken before and during the experiment (p=0.0010) and an indication of a positive change in how satisfied the test subjects were with their physical activity levels (p=0.0688).

Running was almost never the physical activity used while playing the game, and almost none of the test subjects would like to use Paint it Green as a replacement for other exercises. However, a large majority state the possibility of using an exergame to be more physically active than they are today. Most test subjects like to go for walks in their spare time, and it was found that a typical play session with the game was about 15 minutes.

About a third of the total playtime during the experiment was done with the player being stationary. The average speed when playing the game and not being stationary was $1.17 m/s$, which naturally translates to walking.

The observations and interviews primarily support the findings from the questionnaires and game usage data. Most interviewees saw the game as favorable to their physical activity levels by making it more fun and extending their walks. However, it does not seem to be the case that the game encourages running or taking more walks.

29.4 Enjoyment

This section presents the result data related to enjoyment from the questionnaires, observations, and interviews. The section will begin with a reminder of all relevant questions from each data generation method before dwelling on the results.

29.4.1 Post-experiment questionnaire

Table 29.11 shows the related questions and statements from the post-experiment questionnaire for enjoyment.

Table 29.11: The questions and statements from the post-experiment questionnaire relevant to enjoyment

ID	**Question/Statement text**
PoQ13	I found the overall gameplay enjoyable
PoQ14	I enjoyed visiting and exploring the map parts (city districts)
PoQ15	I enjoyed exploding the small battling blobs
PoQ16	I enjoyed battling the large blobs
PoQ17	I enjoyed battling the armored blobs
PoQ18	Time felt like it went faster when playing the game
PoQ19	The story and overarching goal/purpose of the game was clear and understandable to me
PoQ20	I understood how to play the game after completing the tutorials
PoQ21	I liked the graphics of the map, minimap, character, blobs, animations, etc.
PoQ22	My goals were clearly defined when playing the game
PoQ23	I felt in control of my player avatar's movements
PoQ24	I liked the music and sound effects
PoQ25	The game's difficulty was
PoQ26	I found this feature the most fun/enjoyable
PoQ27	Were there any game features which you did not understand how to play/use? If yes, what features?
PoQ28	What about the game did you enjoy the most?
PoQ29	What about the game did you enjoy the least?
PoQ30	I played mostly (alone or with others)
PoQ31	I played the game mostly in (rural og urban areas)
PoQ32	I repeated the tutorial after finishing it on the initial play session

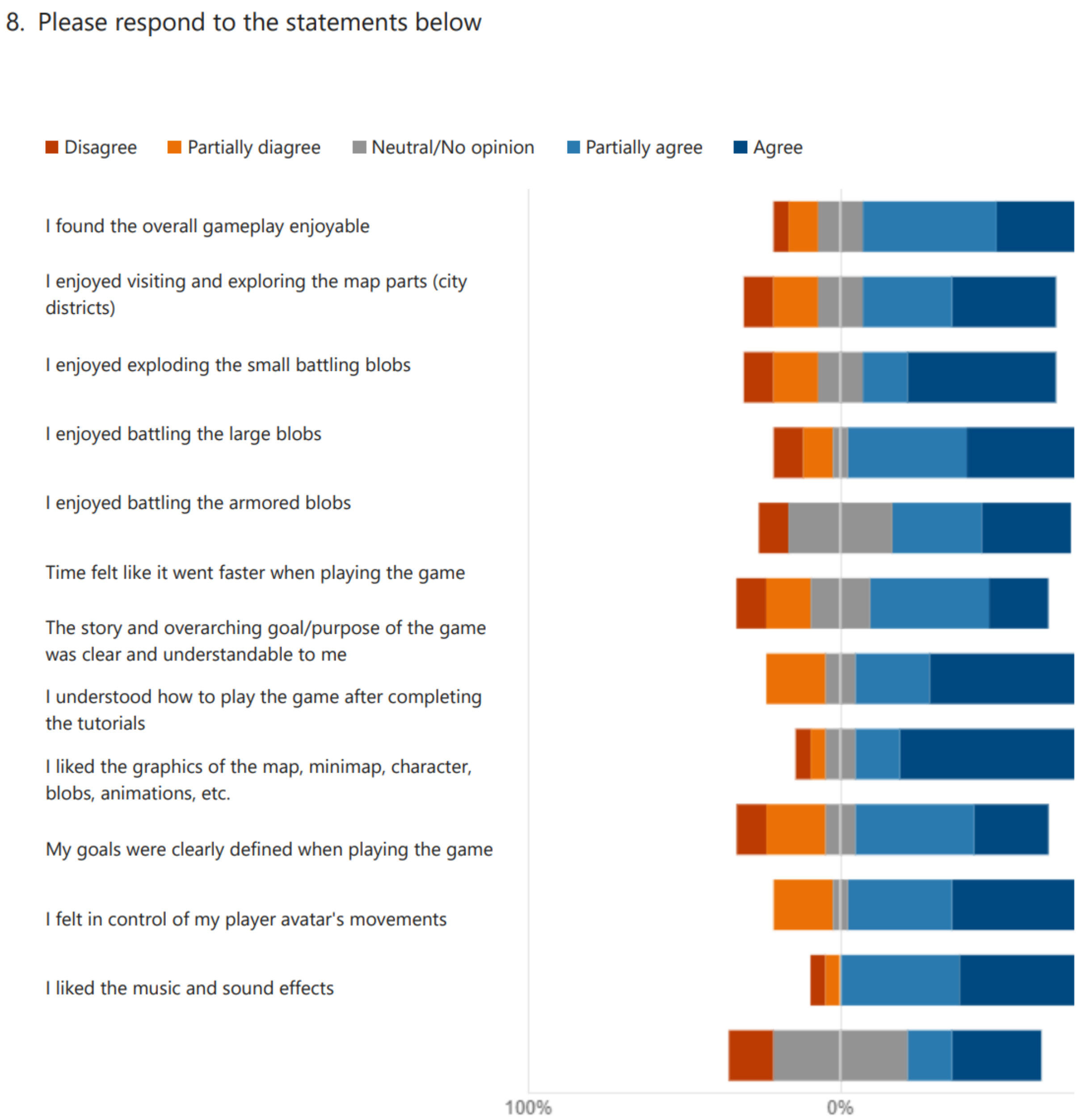

Figure 29.23: PoQ13 - PoQ24 - Likert enjoyment

Inspecting the statements with the Likert-answer format from Figure 29.23 some results are apparent and presented in Table 29.12. As previously, the alternatives *Agree* and *Partially agree*, and *Disagree* and *Partially disagree* will be merged, for better readability.

ID	Question text	Disagree	Neutral	Agree
PoQ13	I found the overall gameplay enjoyable	14%	14%	72%
PoQ14	I enjoyed visiting and exploring the map parts (city districts)	24%	14%	62%
PoQ15	I enjoyed exploding the small battling blobs	24%	14%	62%
PoQ16	I enjoyed battling the large blobs	19%	5%	76%
PoQ17	I enjoyed battling the armored blobs	10%	33%	57%
PoQ18	Time felt like it went faster when playing the game	24%	19%	57%
PoQ19	The story and overarching goal/purpose of the game was clear and understandable to me	19%	10%	71%
PoQ20	I understood how to play the game after completing the tutorials	10%	10%	81%
PoQ21	I liked the graphics of the map, minimap, character, blobs, animations, etc.	29%	10%	62%
PoQ22	My goals were clearly defined when playing the game	19%	5%	76%
PoQ23	I felt in control of my player avatar's movements	10%	0%	91%
PoQ24	I liked the music and sound effects	14%	43%	43%

Table 29.12: The answers to the statements about enjoyment in the post-experiment questionnaire.

Table 29.12 shows that a majority of the test subjects found the overall gameplay, as well as exploring city districts, enjoyable. Most also found the features enjoyable when asked about the enjoyability of battling or exploding the three blob types. Note that a significant portion of the respondents answered *Neutral/No opinion* when assessing battling armored blobs. The armored blobs do not start spawning in-game until the player reaches level 10 (see Table 23.1), which only eight of the registered players did (see Figure 29.27). Thus many respondents never tried battling an armored blob. A majority also reported agreeing with a feeling of time moving faster when playing.

A large majority reported understanding how to play the game and the story with the game's overarching goal. A clear majority also report feeling in control of the player avatar's in-game movements and that their in-game goals were clearly defined while playing.

A small majority reported enjoying the game's graphics, and a large minority reported liking the music and sound effects. In-game control options for turning off the music and sound effects were easily available to the players, which could have resulted in not many people listening to the music and sound effects very long. 43% answering with *Neutral/No opinion* supports this assumption.

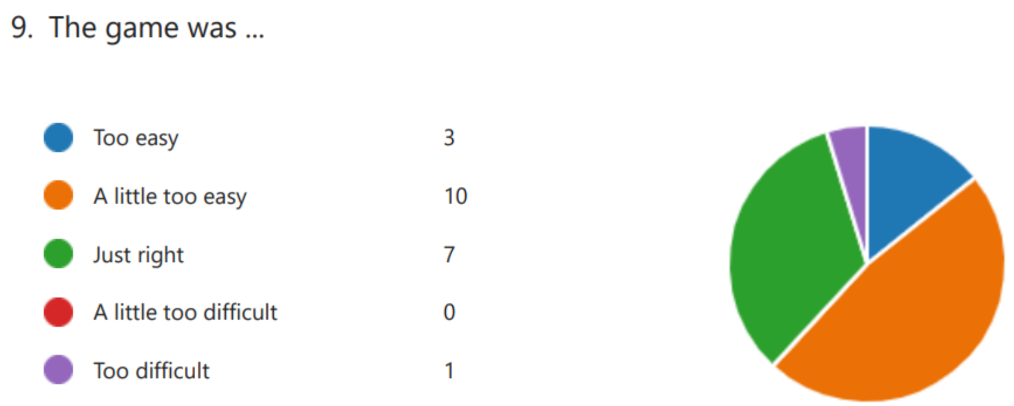

Figure 29.24: PoQ25 - Game difficulty

Figure 29.24 show that 62% thought the game was *too easy* or a *little too easy*, with 33% finding it *just right*. Only 1 test subject report the game as too difficult.

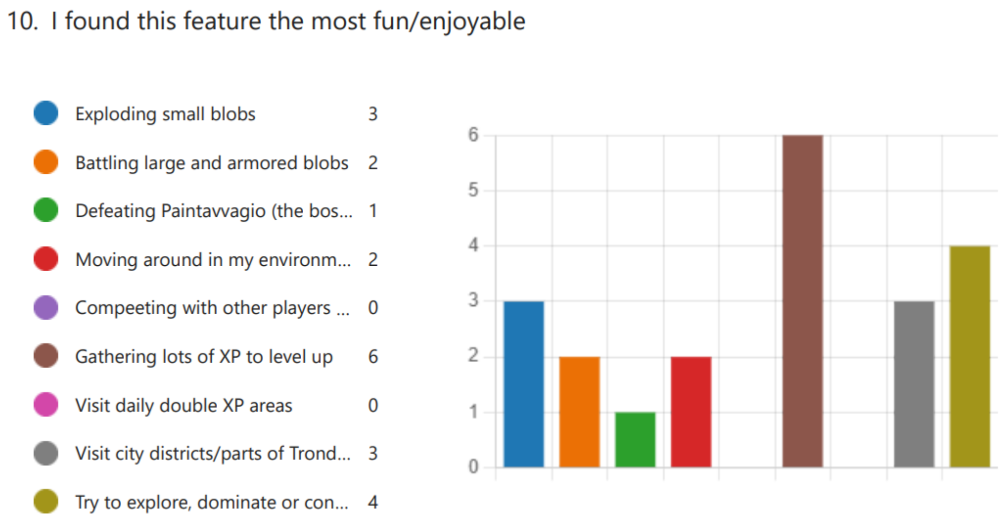

Figure 29.25: PoQ26 - Most enjoyable feature

Figure 29.25 shows the answers to which feature the test subjects found the most enjoyable. The answers are pretty evenly spread, but *Gathering lots of XP to level up* was the most selected option, with 29% finding it the most enjoyable. No test subject found visiting double XP areas or competing with other players on the leaderboards the most enjoyable.

The test subjects were also prompted to state whether there were any game features they did not understand how to play/use and, if yes, what features (PoQ27). 5 out of the 21 respondents answered this question, with 3 of them stating something related to the paint stations.

On what part of the game they enjoyed the most, with a free-text answer format (PoQ28), the answers varied a lot, with most compounding and highlighting several aspects. However, the most highlighted aspects of the game were the blobs and the exploration of Trondheim.

For the opposite question, that is what part of the game they enjoyed the least (PoQ29), the answers also varied a lot, making it difficult to interpret any clear patterns. Most of the answers were very specific about bugs or usability issues which is not too relevant for this chapter. The most visible repeating aspects were a lack of varied and new gameplay and having their phone active while playing and walking (not being able to have the game progress in the background). One test subject wrote *I disliked that I was so immersed in the game that I almost walked into a bus.*

All test subjects played the game mostly alone and in urban areas. Only 2 test subjects used the repeat tutorial feature, while the rest did not.

29.4.2 Observations and interviews

Table 29.13 shows the pre-determined questions from the interviews relevant to the theme of enjoyment.

Table 29.13: The pre-determined questions from the interview relevant to enjoyment

ID	Question/Statement text
InQ12	What do you think of the game?
InQ13	Did you feel in control of your actions while playing?
InQ14	For the most part, did you understand how to play the game?
InQ15	Was there anything you liked about the game? What was it?
InQ16	Was there anything you disliked about the game? What was it?
InQ17	Were you aware of your environment and surroundings while playing?
InQ18	Did any part of the game make you curious and wanting to learn more?
InQ19	Was there any part of the game which made you feel satisfied/pleased?
InQ20	What did you think about the graphics of the game?

During the observations, three out of four players wanted to color the map green, making it seem like making visual progress was something they enjoyed. All of the test subjects enjoyed interacting with the paint stations, one of them stating that the color change was satisfying. The test subjects varied quite a bit on whether they enjoyed battling blobs. One player avoided all blob battles, while two players engaged in battling all blobs they came across. The last player mainly battled the small blobs, stating that it "*felt satisfying squishing them.*"

During the interviews, all four test subjects said they enjoyed the game. The subjects said they enjoyed competing for leaderboard spots, earning XP, discovering new blob types, battling small blobs, and battling the boss, Paintavaggio. When asked what they did not like, answers included battling blobs, needing to have the game active on their phone to gather exploration points, and having to stop walking to battle blobs. Two test subjects did not enjoy the amount of text in the introductory tutorial. One test subject also wanted more variation in the gameplay.

When asked if they mostly understood how to interact with and play the game, two test subjects said yes, while two were unsure. One of the latter said that they thought the tutorial was too long and skipped it because of that, missing important information. The last one answered primarily positively but reported the same issue.

Half of the test subjects answered that they were always aware of their surroundings when playing, while the other half said they sometimes were not. Two out of four test subjects answered a decisive yes when asked if they felt they were in control of what happened in the game. The others were a little more uncertain, one of them mentioning that accidentally entering blob battles when trying to pan the camera was an issue. The other two mentioned that they did not always feel in control because of the large number of blobs spawning.

When asked if there was something in the game which made them *curious*, three out of four test subjects had an answer. Two of them said they were curious about the story, wondering what would happen with Paintavaggio. Two players were curious about what new features would become available at the next level, while another became curious about how to color the map. A similar question asked if there was something the test subjects felt was satisfying. Three out of four mentioned the paint stations. They also mentioned coloring the map, defeating the boss, and small blobs.

Lastly, when asked what they thought about the graphics in the game, all test subjects gave a somewhat lukewarm response. One test subject said it looked like "*something from the 2000s*", while another said it was not the prettiest game they had played, but not the ugliest either. One player criticized the small text size, while another felt the overall graphics were "just okay."

29.4.3 Summary of enjoyment results

Most of the answers from the test subjects have shown a positive inclination toward enjoyment. 72% found the overall gameplay enjoyable. Most of the test subjects report enjoying exploring the map and battling blobs, and agreeing to a feeling of time moving faster while playing the game.

Most test subjects understood the story and how to play the game. Most test subjects also felt in control of their actions and that their goals were clearly defined while playing.

Some test subjects report liking the graphics, music, and sound effects, and most also found the game too easy. Battling blobs and being encouraged to explore Trondheim were often highlighted as the test subject's favorite parts of the game. In contrast, a lack of features and varied gameplay was often highlighted as the test subject's least favorite part of the game. Most play sessions were done in urban areas, with the player alone.

Interacting with paint stations and battling blobs was often mentioned as satisfying and fun but also as frustrating and confusing. Having the story and certain features (like large and armored blob battling) be gradually available to the players as they leveled up was mentioned by several as something which made them curious and want to learn more. Gathering XP and leveling up was also the most selected favorite game feature.

29.5 Motivation

This section presents the result data related to enjoyment from the questionnaires, game usage data, observations, and interviews. The section will begin with a reminder of all relevant questions from each data generation method before dwelling on the results.

29.5.1 Post-experiment questionnaire

Table 29.11 shows the related questions and statements from the post-experiment questionnaire for motivation.

Table 29.14: The questions and statements from the post-experiment questionnaire relevant to motivation

ID	**Question/Statement text**
PoQ33	The level and XP system was motivating
PoQ34	The game motivated me to visit places/areas which I had not yet visited (often)
PoQ35	Seeing leaderboards and competing against friends and other players was motivating
PoQ36	Marking areas as explored, dominated, or conquered was motivating
PoQ37	Battling small, large and armored blobs was motivating
PoQ38	The story motivated me to finish the game and learn more
PoQ39	During the experiment, I found it hard to motivate myself to use the game

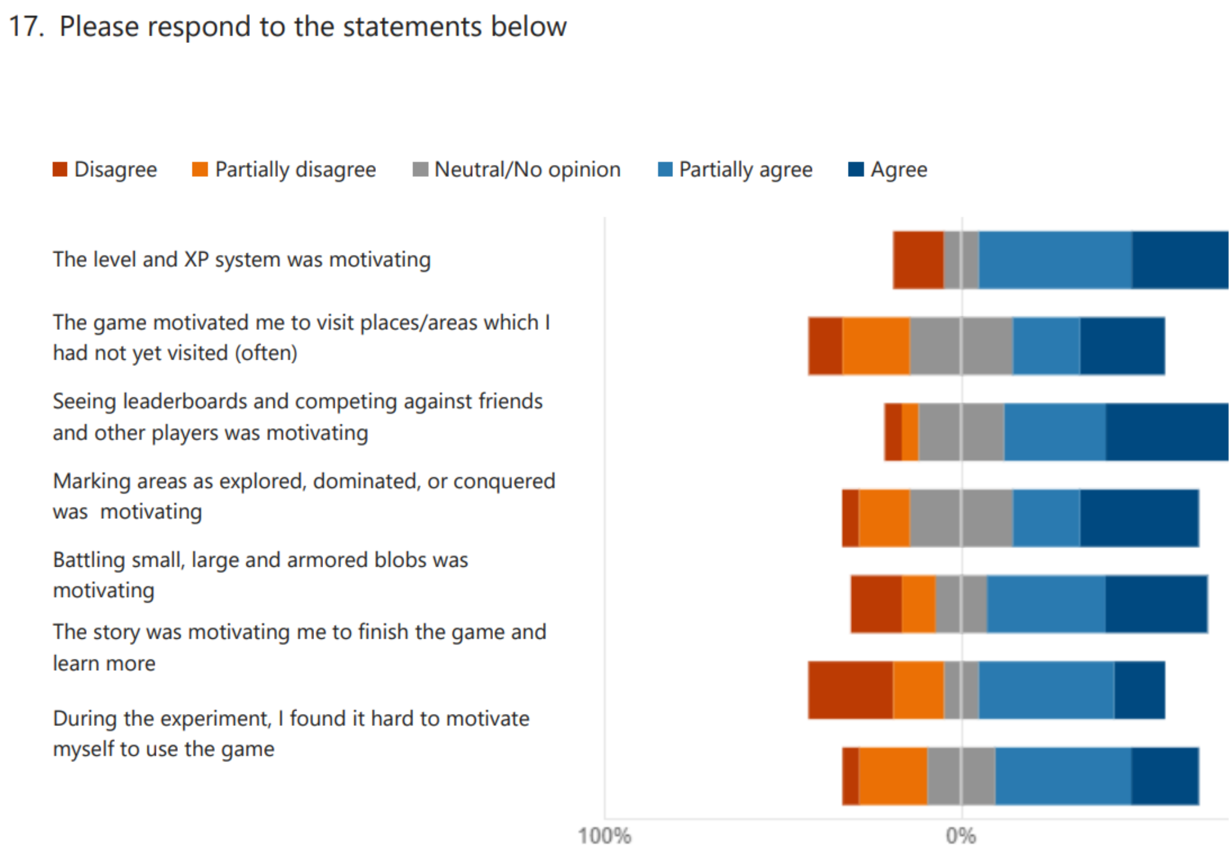

Figure 29.26: PoQ33 - PoQ39 - Likert motivation

ID	Question text	Disagree	Neutral	Agree
PoQ33	The level and XP system was motivating	14%	10%	75%
PoQ34	The game motivated me to visit places/areas which I had not yet visited (often)	29%	29%	43%
PoQ35	Seeing leaderboards and competing against friends and other players was motivating	10%	24%	67%
PoQ36	Marking areas as explored, dominated, or conquered was motivating	20%	29%	52%
PoQ37	Battling small, large and armored blobs was motivating	24%	14%	62%
PoQ38	The story motivated me to finish the game and learn more	38%	10%	52%
PoQ39	During the experiment, I found it hard to motivate myself to use the game	24%	19%	57%

Table 29.15: The answers to the statements about motivation in the post-experiment questionnaire.

Table 29.15 show that a large majority found the level and XP system and the social competitive aspect motivating. A minor majority also agreed that they became motivated by reaching new exploration levels in city districts, battling blobs, and progressing through the story. On whether the game motivated the players to visit new places in Trondheim, the answers are pretty evenly distributed but with more test subjects agreeing with being motivated.

Also noteworthy, a majority still agree with finding it hard to motivate themselves to use the game. Hence, even though many players were motivated by the game features, it often may not have been enough to start playing.

29.5.2 Game usage data

Table 29.11 shows the related questions and statements from the post-experiment questionnaire for motivation.

Table 29.16: Game usage questions related to motivation

ID	Question/Statement text
GU4	What levels did the players reach?
GU5	How far did the players progress in the story?
GU6	How much did the players use the paint stations?
GU7	How did the total usage of the game progress through the experiment?

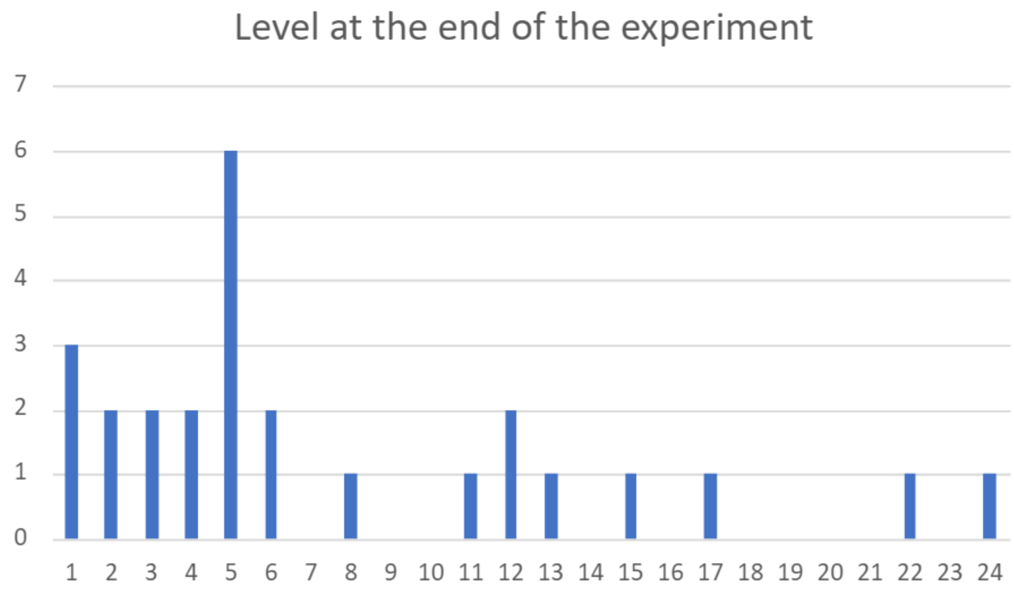

Figure 29.27: GU4 - What levels did the players reach?

GU4 details how much the players played the game by inspecting the levels reached (26 in total) at the experiment's end. All level thresholds were predefined with an amount of acquired XP as the only requirement for reaching the next level. See Table 23.5, Figure 23.3 and Figure 23.4 for these thresholds.

Figure 29.27 shows that most registered players reached level 6 or shorter. The mean level reached was 7.6, and the median was level five. As shown in the level thresholds table and figures, the XP requirements for reaching the later levels increase with higher levels, making it more cumbersome to reach the highest levels. However, the rewarded XP increases as stronger blobs providing more XP when defeated start spawning at higher levels, and other XP bonuses also increase. It may seem like most players never played the game that much, as only eight players reached level 10 or higher.

The total amount of acquired XP for all players was 1 967 250, which gives an average of 75 664 XP per registered player (or 93 679 XP if you only count the 21 players in the final data set).

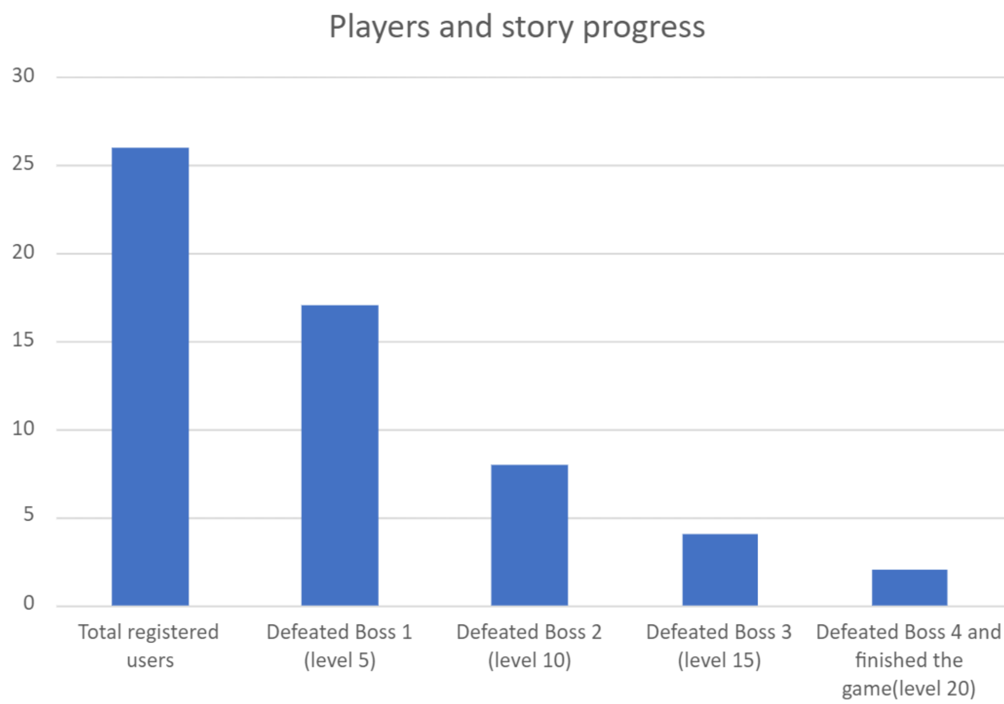

Figure 29.28: GU5 - How far did the players progress in the story?

Figure 29.28 shows a related result in how many players reached the different story events/milestones. As with level progression, there is a clear sinking trend in how far the players got in the story. Each milestone was marked with a boss fight with Paintavaggio, and the player got more of the story portrayed to them. New and stronger blobs also spawned as the player progressed. This tactic was purposefully utilized to excite the players' curiosity and motivate them to keep playing. However, this tactic did not seem effective as only two players completed the story by reaching level 20.

PoQ40 and PoQ41, which asked whether players finished the story and whether they kept playing after finishing the story, can also be answered by looking at these results.

GU6 - How much did the players use the paint stations?

During the experiment, 1 577 paint stations were clicked, meaning an average of 83 paint station clicks per day. This number gives an average of 60.7 total paint stations clicked, and 3.2 paint station clicks per registered player per day, counting all 26 registered players. If one only counts the 21 players in the final data set, the average number of total paint station clicks per player is 75.1 and 4 per player per day.

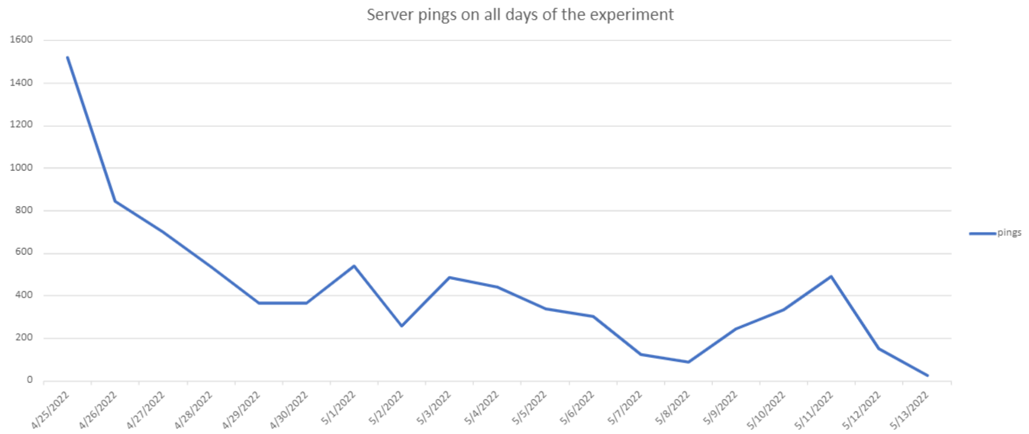

Figure 29.29: GU7 - How did the total usage of the game progress through the experiment?

Lastly, GU7 asks how the total playtime progressed through the experiment. In Figure 29.29 the number of server pings from all players per day of the experiment is shown. The general trend is that the activity was highest initially and then declined, with a few spikes here and there.

Running a straightforward linear regression on the number of server pings mapped to the experiment days, the slope of the resulting curve has a gradient of -43.4, which means that on average, the number of pings to the server decreased by a little over 40 pings. Since each ping roughly corresponds to 15 seconds of playtime, one can say that the average playtime for the game decreased by 11 minutes each day of the experiment, given the assumption that the decrease in playtime follows a linear pattern.

29.5.3 Observations and interviews

Table 29.17 shows the pre-determined questions from the interviews relevant to the theme motivation.

Table 29.17: The pre-determined questions from the interview relevant to motivation

ID	Question/Statement text
InQ21	While playing, what were your in-game goals?
InQ22	What, if anything, motivated you to reach those goals?
InQ23	Were the goals difficult to reach/achieve?
InQ24	Did you experience progress toward your goals while playing?
InQ25	Did you feel any skill progression, in that you got better at playing the game?
InQ26	Do you feel that the game motivated you to be physically active?

During the observations, it became clear that the test subjects had very different goals when playing. One played mainly without looking at their screen and was motivated by increasing their exploration status and coloring the map. Two others had walking between paint stations as their primary goal but later explained that it was because they thought it would increase their exploration status and color the city district map, which was not the case. The last player also walked between paint stations, but their primary goal was to level up, not increase their exploration progress. When asked in the interview what their main goals were and what made them want to achieve them when playing, the test subjects mostly gave answers that matched the observations. However, one test subject added that they felt being physically active was a goal in itself.

When asked if they felt that their goals were adequately challenging to reach, the answers were a little mixed. One answered no, as they did not know how to achieve their goal, which was coloring the map. Another, who had the same goal, said it varied between city districts, as some were more difficult to explore than others. One test subject said that fighting blobs and reaching paint stations were sufficiently challenging, but coloring the city was a little overwhelming. The last one deemed the difficulty level to be *okay*.

Three out of four answered that they perceived their skills to improve while playing, specifically mentioning blob combat. The last player answered that they felt they became a little better while playing, but that they felt *the low amount of ammunition while battling large blobs was frustrating*.

All players reported feeling that they made some progress while playing. Two test subjects were happy with their progression based on leveling, while one test subject did not care much for leveling but enjoyed progressing by coloring the map. The last player experienced some progress by leveling and finding new types of blobs but reported to be a little frustrated by not understanding how to color the map.

Lastly, the answers were slightly divided when asked if they felt that the game motivated them to be physically active. One person said that it made physical activity more fun, while another felt like that motivated them to walk as the game could not be played without moving. Two others repeated their answers to the previous question, specifying that they would still have been physically active but that the game encouraged them to walk a little further.

29.5.4 Summary of motivation results

Most test subjects found the game's level, XP system, and the social competitive aspect motivating. Furthermore, while other game features also were reported to be motivating, a majority still agreed to find it hard to motivate themselves to use the game.

Most of the test subjects never reached level 6 and thus never progressed very far in the story and never encountered the last type of blob. The game's total usage declined from the experiment's start, with a few activity spikes during the 19 days of game access.

The observations and interviews showed that playing the game in different ways with different goals was possible. All interviewees also stated that they experienced progress while playing the game.

29.6 Supplementary

This section presents the result data related to enjoyment from the questionnaires, game usage data, observations, and interviews. The section will begin with a reminder of all relevant questions from each data generation method before dwelling on the results.

29.6.1 Post-experiment questionnaire

Table 29.18 shows the related questions and statements from the post-experiment questionnaire for supplementary results.

Table 29.18: The questions and statements from the post-experiment questionnaire relevant to supplementary results

ID	Question/Statement text
PoQ40	I completed the story and defeated Paintavaggio
PoQ41	I played the game even after completing the story
PoQ42	Did you experience any technical problems? If yes, please describe the problems
PoQ43	Did any other external factors prevent you from playing the game as much as you would like to? (Such as illness, poor weather conditions, etc.) If yes, please describe the factors.
PoQ44	Did you cheat during the experiment? If yes, how and why did you cheat?
PoQ45	Do you have any last/departing comments?

PoQ40 and PoQ41 were answered in the previous section.

Technical issues

PoQ42 - Did you experience any technical problems? If yes, please describe the problems
Nine test subjects were reporting some technical problems. Most of them were related to the game freezing or other latency issues related to server communication or GPS tracking. There was also reporting of the bugs described earlier in Section 28.5.

External factors affecting the game usage

PoQ43 - Did any other external factors prevent you from playing the game as much as you would like to? (Such as illness, poor weather conditions, etc.) If yes, please describe the factors
Fourteen test subjects reported external factors negatively influencing how much they played the game. Rainy and otherwise unpleasant weather conditions (7), being extraordinarily busy due to exams, thesis writing, and other work (5), and being out of town (4) was the most frequently reported causes. Illness and inadequate phone battery were also mentioned.

See Figure 29.30 for the temperature and downfall in Trondheim during the experiment. The figure shows a decrease in temperature and an increase in downfall during the 19 days the experiment took place. Since the game encourages players to move around outside, it is fair to assume that these unpleasant weather conditions negatively influenced the total usage of the game for some players.

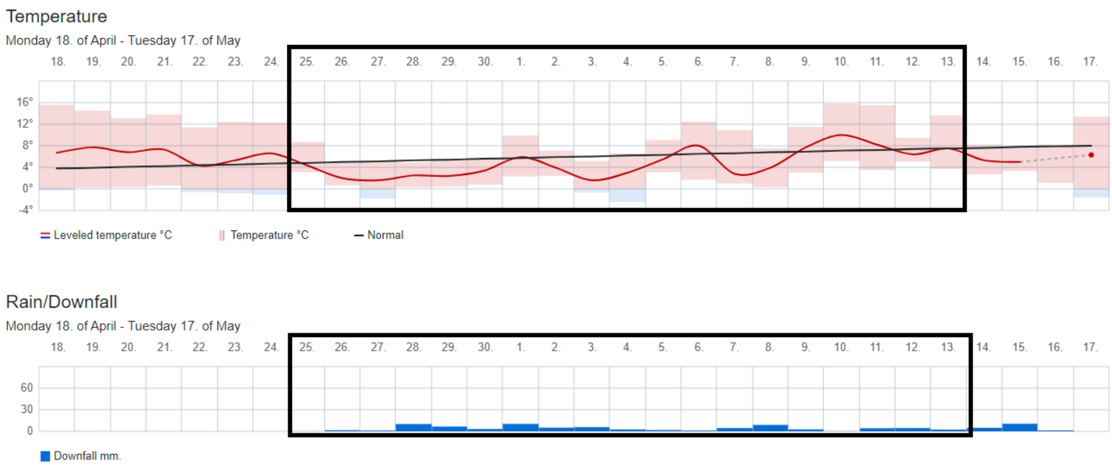

Figure 29.30: The weather in Trondheim during experiment. The 19 days of access to the game (25th of April - 13th of May) is marked within the black square

Cheating

PoQ44 - Did you cheat during the experiment? If yes, how and why did you cheat?
Five test subjects answered this question with some form of cheating. Three of them report playing on public transport such as buses or trains. Two test subjects also reported having some GPS trouble taking them over vast distances in-game, giving them much distance towards exploring new city districts and being able to tap new paint stations. The daily streak bug, as mentioned in Section 28.5, was also reported.

Even though there were some cheating or irregular activity, no test subjects or player data were excluded from the final data set. The cheating was minor in volume and thus probably did not affect the game usage much. In addition, since no e-mail addresses were directly linked to any of the registered users in the database, there was no direct way to communicate with an identified cheating player.

There were 26 registered players in total. From the post-experiment questionnaire, we know that only 21 played the game for 30 minutes or more, meaning that 5 of the 26 registered players' data was not included in the questionnaire results. Since it was purposefully (due to the players' privacy) made impossible to connect the registered users to the respondents in the questionnaires, it is not possible to exclude these five players from the data set. However, it is likely to believe that they have not contributed that much to the game usage data, as they never played the game for more than 30 minutes. There is, of course, the possibility of the game usage data not coming from the respondents from the questionnaire. If, for instance, a registered test subject were to send the game file to someone else who played a lot but was not a registered test subject in the experiment. However, this is not very likely as being part of the experiment was not an eminently exclusive opportunity for the test subjects, and there were no significant gains for the test subjects.

PoQ45 - Do you have any last/departing comments?
Eleven test subjects answered this question with some departing comments. Most of them were compliments on the game and wishes of luck for the rest of the projects. There were some requests for more features: a more thorough social aspect and a desire to be able to play passively without needing to have the phone and game active in the hand of the player.

29.6.2 Game usage data

Table 29.19 shows the related questions and statements from the post-experiment questionnaire for supplementary results.

Table 29.19: Game usage supplementary results

ID	Question/Statement text
GU1	How many player profiles were created during the experiment?
GU2	How much total time was spent playing the game by all players? (The server is pinged every 15 seconds)
GU3	What postal codes (city district) were used the most?
GU8	When during the day did the players play the most?

GU1 - How many player profiles were created during the experiment?
There were a total of 26 registered users in the database. However, only 21 of them were used in the questionnaire data set. See Section 29.6.1 for more details on this.

GU2 - How much total time was spent playing the game by all players? (The server is pinged every 15 seconds)
This question is answered in Table 29.9. A total of about 34 hours were played during the experiment.

GU3 - What postal codes (city district) were used the most? The postal codes (city district) with the most activity is presented in Table 29.20. The score is calculated like the score in the leaderboards by using meters traveled within the city district (m), minutes spent in the city district (t), and amount of unique addresses visited (u) totaled up for all players ($score = m/10 + t * 30 + u$).

Table 29.20: GU3 - The five postal codes which was used the most

Postal code	Area in Trondheim	Score
7034	Gløshaugen	13551.5
7050	Moholt Vest	12305.8
7030	Øya/Elgseter	9861.9
7051	Berg	7391.4
7011	Midtbyen Nordøst	6790.1

All the top five postal codes were in central areas of Trondheim, as can be seen in Figure 29.31. The top postal codes all have a high total score, but it decreases drastically when maneuvering out of the city center. There are 73 postal codes in Trondheim municipality. The server was pinged from 56 of those (77%). Taking the mean score of all postal codes gives 992.2. However, the median score is 75.5. The mean is much higher due to most of the city center's postal codes having a drastically higher score than the rest. The standard deviation was 2610.4.

It is, therefore, imminent that the game was primarily played in urban areas near the city center and was rarely used in more rural areas of Trondheim. These urban areas are also highly populated by students at NTNU, who also populate a large share of this project's test subjects.

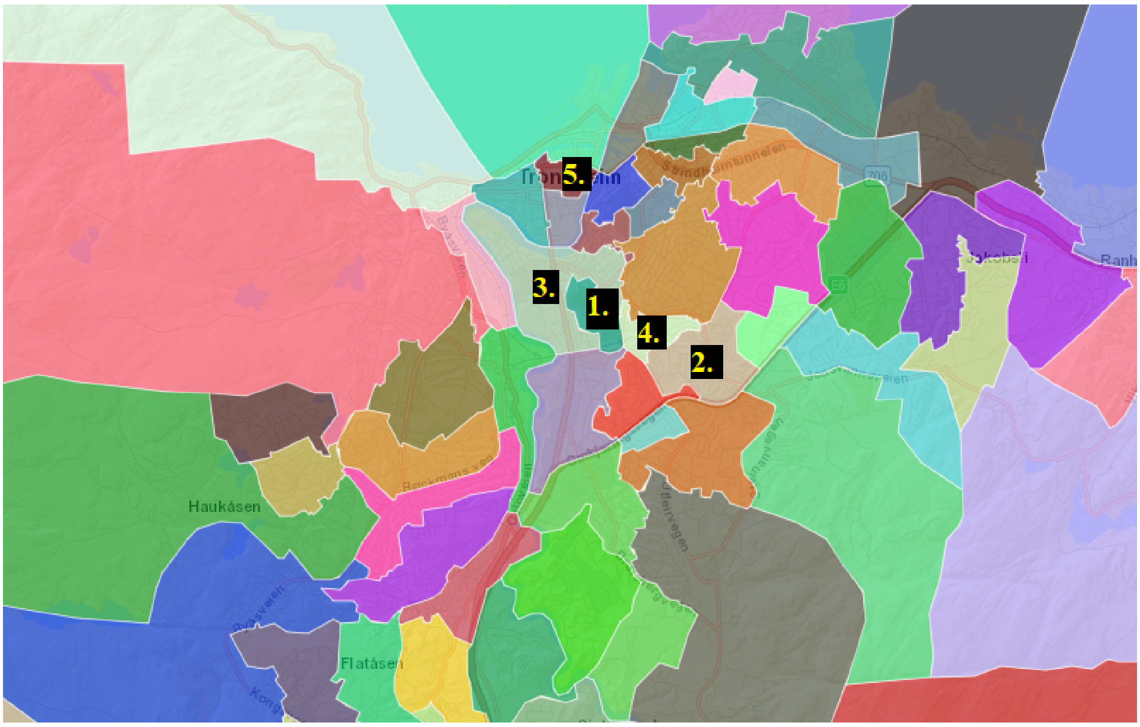

Figure 29.31: GU3 - What postal codes (city district) were used the most? Most of Trondheim municipality's postal codes. The top five most used postal codes in the game is marked with a number

GU8 - When during the day did the players play the most?

If one takes all pings to the server, removes the stamp for the date, minute, and second, and then sums up all pings, one can get an overview of when during the day people were active. Figure 29.32 shows this clock hour distribution. There is a local peak at noon and a global maximum in the afternoon/early evening. There is almost no activity at night and less during normal work/school hours (except for lunch hours) and late evening.

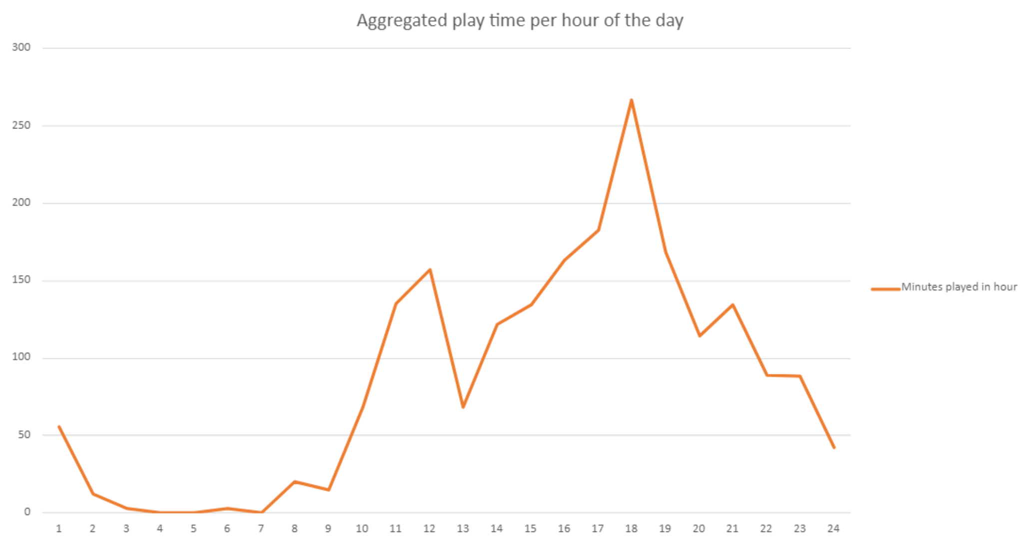

Figure 29.32: GU8 - When during the day did the players play the most?

29.6.3 Observations and interviews

Table 29.21 shows the pre-determined questions from the interviews relevant to supplementary results.

Table 29.21: The pre-determined questions from the interview relevant to supplementary results

ID	Question/Statement text
InQ27	Did you experience any technical difficulties or other complications while playing? If so, how did it affect your gaming experience?
InQ28	Is this a game you could imagine playing more of if it were further developed?
InQ29	Do you have any other ideas or feedback you would like to tell us?

During the observations, a few bugs were encountered. Two test subjects encountered battles they did not lose when they ran out of ammo (paint grenades or missiles). One test subject accidentally shrank the body of Paintavaggio during a boss battle, having to restart the game to get him back to standard size. During the interviews, when asked about any technical difficulties, one player added that there sometimes would spawn so many blobs that it made interacting with paint stations difficult without accidentally starting a battle. Another test subject mentioned trouble with the GPS sensor finding their correct position, which ruined their motivation to play. One last person experienced their profile suddenly being at a lower level, which they claimed was a little demotivating.

When asked if there were any features or improvements they would have added to enhance the game, they mentioned the following features:

- Being able to turn off the screen to track the position in the background.
- Scale the exploration status requirements better to city district size.
- More varied blobs and battles.
- Customization options to the player avatar.
- Make the camera stop changing position after battles.

Lastly, the test subjects were asked if they could imagine themselves playing the game more if it was further developed. Two test subjects answered yes, while one said they might have played it here and there but did not think they would have gotten addicted. The last person said they could have played it more if the game had more social features, like adding friends and having different teams for cooperation and competition.

29.6.4 Summary of supplementary results

There were some bugs and technical issues. It seems they influenced the affected players somewhat but did not spoil the experiment and generated data excessively. The game usage was also influenced by unpleasant weather conditions and the fact that it took place while many students in the test subject pool had their exams, worked on their thesis, or otherwise were busy. There was some cheating but not a substantial amount.

Several test subjects wanted more diverse features and requested a more thorough social aspect of the game. However, several test subjects also had positive attitudes toward using this exergame if it were further developed or to use another exergame to increase their physical activity levels.

There were 26 registered users in the user database, and 21 played for at least 30 minutes. All players played for roughly 34 hours in total, and the postal codes near the city center were the most active ones by far regarding game usage. The players mainly played during the late afternoon and lunch hours.

29.7 Summary

The experiment was populated rather diversely within the restrictions from Chapter 26 but had a majority of males in their mid 20's. Most test subjects like playing video games and prefer PC or console, but only about half of the 21 test subjects report playing video games for more than an hour on a normal day.

There was a statistically significant change in how many steps the test subjects took during and before the experiment. There was also a positive indication of a change in how much the test subjects wished they were more physically active. The test subjects took more steps and were more pleased with their physical activity levels during/after the experiment than before. However, there were no statistically significant findings when asking the test subjects to report how many minutes they spent being physically active. The game seems not to be a suitable replacement for *regular exercise*, but perhaps a means to make people walk longer or more often and thus help them be more physically active.

Typical play sessions were walks in urban areas for roughly 15 minutes, but players often played while being stationary. The test subject always played alone. When the test subjects played the game, it was seldom a *new* walk where they would otherwise be sedentary, but the play sessions could contribute to the players taking longer walks.

Most test subjects enjoyed the overall gameplay and reported feeling that time was moving faster than usual while playing. Fighting blobs, being encouraged to explore Trondheim, feeling in control of their in-game movements, and understanding how to play the game also got positive feedback from the test subjects. However, the graphics, music and sound effects, and game difficulty were not too successful.

Several test subjects wanted more features, diverse gameplay, and social features. The paint stations were reported to be both fun, satisfying and confusing, and several players felt curious to learn more about the story and game features as they got access to it by leveling up.

The level and XP system and the competitive leaderboards were reported as very motivating for the test subjects. Other game features were also reported as motivating for players, but a majority still reported struggling to motivate themselves to play the game. Most players did not progress very far through the story and never reached level six. The total game usage peaked at the beginning of the experiment and declined throughout the 19 days of game access.

It became apparent that there were different ways of playing the game. Players had different goals; some focused on battling and defeating blobs, while others focused on exploring the city and conquering city districts. At the same time, others were more oriented around the story or the leaderboards.

Some technical issues, bugs, and cheating were involved in the experiment. Unpleasant weather and test subjects being extraordinarily busy during the experiment probably contributed negatively to the total game usage. The game was played for about 34 hours in total, mainly during the late afternoon and lunch hours.

Most subjects were positive about using either another or this exergame, if it was further developed, to increase their physical activity levels.

Chapter 30

Analysis of Demographically Partitioned Results

This chapter splits the results into independent subgroups based on demographic traits to see if any noteworthy differences appear when comparing the two partitioned groups. Like in Chapter 29, there will be performed two-tailed t-tests and Mann-Whitney tests on the data in order to find any indications of ($p < 0.15$) or statistically significant differences ($p < 0.05$). Each partition will include a table with only the comparable questionnaire results with a p-value of 0.15 or less. Indications of differences are marked orange, and statistically significant changes are marked blue. P-values marked with an * are related to a t-test, while all other p-values in the tables are from Mann-Whitney tests.

Each partition consists of a pair of subgroups that are non-overlapping and exhaustive of the whole data set ($n = 21$) in the questionnaires. The subgroups include gamers vs. non-gamers, active vs. non-active, normal/healthy weight vs. overweight and obese, and males vs. females. Each pair of subgroups will be explicitly defined in its section.

30.1 Gamers vs. non-gamers

This section partitions the respondents into two groups called gamers and non-gamers. The gamers (G) are the respondents from the pre-experiment questionnaire who report playing video games for 30 minutes or more on a normal day ($n = 13$). The non-gamers (N-G) are the remaining respondents who thus report playing less than 30 minutes of video games on normal days ($n = 8$). Table 30.1 showcases the questions and statements from the post-experiment questionnaire where the p-value from a Mann-Whitney test or a t-test is < 0.15. The mean and median value is also stated. Like previously, the values from the Likert-formatted statements are mapped to a number from one to five. One corresponds to disagree, and five corresponds to agree, as shown in Table 29.1.

Table 30.1: Comparison of gamers (G) vs. non-gamers (N-G) test subject's answers to some questions and statements

ID	Statement/Question text	Sub-group	Mean	Median	p-value
PoQ6	The game helped motivate me to be physically active	G	2.69	3	0.1032
		N-G	3.63	4	
PoQ10	Using an exergame can make me more physically active than I am today	G	4.39	5	0.1470
		N-G	3.63	4	
PoQ21	I liked the graphics of the map, minimap, character, blobs, animations, etc.	G	3.08	3	0.0950
		N-G	4.13	4	

PoQ21 indicates that the non-gamers liked the graphics, animations, and other visuals better than the gamers. There is also an indication that the gamers are more favorable than the non-gamers to using *an exergame* to be more physically active. However, the opposite result is indicated when asked if Paint it Green helped motivate them to be physically active.

30.2 Active vs. non-active people

Another relevant partitioning divides the test subjects into active and non-active. Active (A) includes the test subjects who, in the pre-experiment questionnaire, reported to be physically active for 60 minutes or more on normal days ($n = 7$). Non-active (N-A) includes the remaining 14 who reported being physically active for less than 60 minutes on normal days ($n = 14$).

Table 30.2: Comparison of active (A) vs. non-active (N-A) test subject's answers to some questions and statements

ID	Statement/Question text	Sub-group	Mean	Median	p-value
PoQ3	During the experiment, how much time did you daily spend being physically active?	A	135.71	90	0.0404 *
		N-A	44.64	40	
PoQ5	I was physically active more often during the experiment than I was before	A	2.14	2	0.0404
		N-A	3.43	4	
PoQ10	Using an exergame can make me more physically active than I am today	A	3.14	4	0.0930
		N-A	4.57	5	
PoQ12	Roughly, for how long (minutes) did you spend playing the game each play session?	A	19.29	20	0.0253 *
		N-A	11.57	11	
PoQ13	I found the overall gameplay enjoyable	A	3	4	0.0672
		N-A	4.14	4	

Table 30.2 displays statistically significant differences and indications of differences between the active and non-active test subjects. The active, according to PoQ3, were still more physically active during the experiment than the non-actives. However, the non-active agree more with having a perceived positive change in their physical activity levels, meaning that they experienced a greater effect on how much time they spent physically active. An indication of the same is seen in PoQ10, where the test subjects respond to the potential an exergame can have on their physical activity levels. In contrast, the non-active group is more positive compared to the active.

In addition to being more physically active during the experiment, the active played longer sessions than the non-active but probably found the overall gameplay less enjoyable.

30.3 Normal/Healthy weight vs. over-weight and obese

Normal/Healthy weight people (N) were the test subjects who reported to have a body mass index (BMI) of between 18.5 and 24.9 before the experiment ($n = 12$). The overweight and obese are the ones who, in the pre-experiment questionnaire, reported their own BMI to be above 25 ($n = 9$).

Table 30.3: Comparison of Normalweight (N) vs. overweight and obese (O) test subject's answers to some questions and statements

ID	Statement/Question text	Sub-group	Mean	Median	p-value
PoQ9	I would like to use this game instead of traditional exercise in the future	N	2.5	2.5	0.466
		O	1.44	1	
PoQ22	My goals were clearly defined when playing the game	N	3.67	4	0.1032
		O	4.44	5	
PoQ38	The story was motivating me to finish the game and learn more	N	3.83	4	0.0070
		O	2	1	

Table 30.3 shows that N has a statistically significant more positive attitude towards using Paint it Green as a substitute for traditional exercise in the future, even though none of the subgroups are very eager about it. There is an indication that O saw their in-game goals as more clearly defined than N. Lastly, N seemed more motivated by the game's story than O.

30.4 Males vs. females

The last partitioning was made on genders. No test subjects reported having a non-binary gender identity or did not want to state their gender. The gender in this partitioning is based on the reported gender in the pre-experiment questionnaire. Males are denoted by M (n=15), and females are denoted by F (n=6).

Table 30.4: Comparison of males (M) vs. females (F) test subject's answers to some questions and statements

ID	Statement/Question text	Sub-group	Mean	Median	p-value
PoQ19	The story and overarching goal of the game was understandable to me	M	4.27	5	0.1096
		F	3.33	3.5	
PoQ39	During the experiment, I found it hard to motivate myself to use the game	M	3.73	4	0.1388
		F	2.83	3	

The males seem to have found the game's story more understandable than the females, and there is also an indication of the males agreeing more to finding it hard to motivate themselves to use the game.

30.5 Summary

This chapter split the results into independent subgroups based on demographic traits to see if any noteworthy differences appeared when comparing the two partitioned groups. T-tests and Mann-Whitney tests were performed on the data in order to find any indications of ($p < 0.15$) or statistically significant differences ($p < 0.05$). All p-values are two-tailed.

The tests showed that gamers were more critical than non-gamers towards some aspects of the game by not enjoying the graphics and animations. The gamers were also less motivated to be physically active by this game. However, they were more positive when considering whether *an exergame* could be used to become more physically active.

When comparing active and non-active test subjects, the active played for longer sessions and were still more physically active during the experiment than the non-active. However, the active group seemed to perceive less of an effect on their physical activity levels during the experiment than the non-active group. The non-active also seem to see a higher potential of exergames to make them more physically active than the active. The non-active also probably found the overall gameplay more enjoyable.

A partitioning of normal/healthy weight versus overweight and obese test subjects showed that the overweight and obese were less open to using this game instead of traditional exercise in the future and were less motivated by the game's story.

The last comparison between males and females showed that the males probably found it harder to motivate themselves to play the game during the experiment.

Chapter 31

Reliability and Validity

When doing research, not all data gathered will be as valid or reliable as desired. There are different reasons why the findings might not be too valid or reliable. This chapter will discuss some of the significant reasons why the data gathered in and for this project could be somewhat unreliable.

31.1 Game usage data

The game usage data is not the primary source of information to answer the research questions but will be used to complement and potentially weaken or strengthen any conclusions drawn. This section details two of the reasons game data could be inaccurate.

31.1.1 Quality of GPS data

The position determined by a mobile phone's GPS is not always accurate. Especially when moving in and out of buildings, the GPS' determined position could be off by long distances. While it usually accurately determines the player's position, discrepancies over a more extended period could lead to players performing noticeably better than they should on the leaderboards. Players performing better than they should have could lead to losing motivation, either from being constantly beaten by someone else or having no motivation to play as they are already on the top of their desired leaderboards. It might also influence what postal codes were most actively played in and how fast and far the players moved.

31.1.2 Cheating

Cheating could heavily affect players' enjoyment and motivation to play the game. As mentioned in Section 28.5, early in the experiment, a bug was discovered that let players collect the once-a-day streak XP-bonus in rapid succession. A player greatly misused the bug and reached a high level within the first few days of the experiment. Even though no other player reported being aware or negatively influenced by the cheating player's sudden level progress, this kind of cheating could heavily affect players' motivation to play the game further. Affecting player motivation could influence results, and the actual game usage data focuses on the story and level progression for all players.

Other cheating methods could include trying to manipulate location and game usage data sent to the server. Authentication tokens are required whenever sending data to the server to counter this. It could still be possible to perform some token manipulation attack, but we consider this as not very likely. See also Section 29.6.1 for some further reflections on cheating.

Furthermore, there very likely exist other ways of cheating the game which we are unaware of, which could influence the game usage data and the players' emotions related to the game.

31.1.3 Other bugs and updates

As stated in Section 28.5, during the experiment, several other bugs and gameplay issues were discovered, leading to two new versions of the game being sent to the test subjects with a recommendation to use the newest version. Some bugs could be annoying to test subjects, lowering their enjoyment and motivation for playing the game and thus impacting the data. Others might get fatigued having to update their game, leading to them playing an old, faulty version of the game, thus allowing for more severe bug and cheating issues.

31.2 Observer bias

Observer bias can be defined as any systematic discrepancy from the truth during observation and information recording for a study [169]. An example is medical images being reviewed by different people. One person might find an abnormality, while another might not find any. Different people might round measurements differently or interpret color-sensitive information differently.

General observer bias could affect the data taken from observations, as subjective judgment is integral to the observation. When observing the test subjects, there is great potential for variability between observers [169].

One type of observer bias is that people might behave differently than they would normally, simply by knowing that they are part of an experiment. This effect is commonly called the Hawthorne Effect [170]. While using the term "Hawthorne Effect" seems somewhat controversial, similar psychological phenomena could likely have affected test subjects [171]. The feeling of being observed could be present during the entire experiment. However, the feeling would likely be stronger during the observations, as we would be physically present and visible nearby, observing the test subject and taking notes.

31.3 Test subject sampling

Details on how the test subjects were recruited can be found in Chapter 26. This section will discuss reliability and validity issues from the test subject sampling.

Bias from knowing the observers: The test subjects were mainly recruited from our network of friends, colleagues, and classmates. Most of the final 21 test subjects know us personally. Thus, they could have been inclined to give feedback more favorably towards their perception of our research goal than they would, had they not known us personally, which could influence some of the data gathered in the experiment. The test subjects were encouraged to be honest when giving feedback to eliminate the possible bias.

Sample size: A sample size of 30 participants is recommended for statistical analysis to be reliable [1]. Our experiment is below that amount, which could lead to our data not being statistically reliable due to the small sample size.

Diversity: As mentioned in Section 29.2.1, there are certain dominating factors in the test subject sample. The test subjects are mainly between 24 and 25 years of age, male, with a standard or healthy weight class, and most like to play video games. Most subjects being from a specific group could mean that whatever results we find will not apply to the general population but just the group dominating the test sample.

Busy test subjects: As previously mentioned, the test subjects were recruited from our social networks. As a consequence, several test subjects were, like us, writing their master's theses or preparing for exams during the experiment period. In the post-experiment questionnaire, five out of 21 people answered that being very busy affected how much they were able to play the game. Three mentioned working on their exams/theses specifically, as seen in Section 29.6.1. While it might not have had the most significant effect, three people still equal to 14% of the test subject population. Since we know most of the test subjects personally, we also know that there are undoubtedly more test subjects than the three/five test subjects who are extraordinarily busy with their exams or master's thesis during the experiment.

31.4 Other influencing factors

Some final factors could affect the reliability and validity of the data. These will be discussed in this section.

The Pygmalion effect is a psychological event in which high expectations lead someone to perform better than they usually would [172]. As mentioned in the previous section, most test subjects know us personally. Knowing the observers could lead to the test subjects wanting to perform better than they usually would, as they might think that the observers had high expectations of them and their performance.

Demand characteristics refers to a phenomenon where test subjects form an idea of the purpose of an experiment and change their behavior to fit that idea [173]. Test subjects could potentially form an idea that the experiment wants them to be as physically active as possible and therefore be way more physically active than the exergame motivated them to be.

Weather conditions could affect people's motivation to go outside and play. As mentioned in Section 29.6.1, seven test subjects mentioned unpleasant weather as an external factor affecting how much they played the game. Affecting 33% of the test subject population could have affected the data.

31.5 Summary

This chapter reviewed some factors and aspects which could have affected the experiment data and thus reduced their reliability and validity. There are factors that both could boost and hinder the total usage and reported/observed effect of the game. Factors reviewed include cheating, in-game bugs, the Hawthorne Effect, test subject sampling, and weather conditions.

This project is limited in time, resources, test subject volume, and others. Readers of this thesis should thus be cautious when assessing the confidence of any conclusions or applying the conclusions to the general public.

Part VI

Discussion and Conclusion

This part concludes the master thesis. It discusses the findings from the previous parts before a conclusion is presented. Finally, further work is discussed concerning the thesis and future exergame research.

Chapter 32

Discussion

This chapter will discuss the research questions presented in Chapter 3.

32.1 Research Question 1 - What is the best way to create an effective, enjoyable, and motivating exergame?

To answer the research question, we mainly consider existing exergames, modern exergame development technology, research on the existing exergames, and survey results. However, we also consider the data from the experiment's questionnaires to deliver a more informed discussion.

32.1.1 Summary of existing exergames and research

It is beneficial to examine platforms, technologies, and exercise/physical activity usage for existing exergames to answer several research questions. We therefore recap the exergames review from earlier in this report. Three of the exergames utilize motion controls, and Wii Fit uses an external accessory, the Wii Balance Board. Beat Saber uses VR technology. Dance Dance Revolution uses either an accessory in the form of the dance mat or is built into an arcade cabinet. Just Dance can be played with either motion controllers, camera, or smartphone, depending on the platform. Two of the phone games utilize GPS technology, while the last one uses a variety of different sensors.

Research on Dance Dance Revolution pointed out mostly positive health effects [67; 66; 64; 65]. Research on the Wii Sports and the Wii Fit series has seen varying results, with some studies finding health benefits while others did not [75; 77; 76; 73; 71; 72]. Studies on Zombies, Run! found that narratives, tracking, and goal orientation motivated players to exercise, but the game had no significant effect on the test subjects' physical fitness [80; 81; 82]. Literature reviews on Pokémon Go reported that the game positively affected the players' physical, mental and social health and increased the number of daily steps taken [8; 84; 85; 174]. A study on Exermon found that 40% of test subjects experienced improved strength and exercised more than before when playing the game [87]. Research on Ring Fit Adventure found that interactive video game training can significantly improve lower extremity strength quality and that the game improved test subjects' time of running 1600m [90; 91]. A short study on Beat Saber found that the game can be considered a viable exercise form more engaging than treadmill running [92]. Studies on Just Dance also had varying results but found that playing could be just as effective as dancing with a dance instructor [95; 94].

32.1.2 RQ1-1: What platforms are most suitable for an exergame?

When combining the answers from the survey and the pre-experiment questionnaire, *most people report PC as their preferred platform*, consoles are the second most favorable platform, with mobile being third. The respondents had played a variety of exergames, with mobile exergames being the most popular. Based on the survey, it seems that the people who were not satisfied with their exercise frequency were more likely to have mobile as their preferred platform. Even though no statistical analysis has been done on the survey results, this pattern should be noted, as people who are not satisfied with how often they exercise are essential to the target group of this project. In addition, when partitioning the test subjects into gamers and non-gamers, *none of the gamers had mobile as their preferred platform.*

Making an unambiguous, conclusive answer to RQ1-1 is very difficult. People have different preferred video game platforms, and reach potential must also be considered. Preferring a platform over others does not mean that one only likes playing video games on that platform. It must be considered that a vast majority of survey and pre-experiment questionnaire respondents answered that they like playing video games. The survey results indicate that it is *possible to assume that people who enjoy video games are more likely to prefer PC or console, while people who do not might be more likely to prefer mobile.*

The reviewed studies do not provide a clear conclusion either but find favorable effects on Pokémon Go, Exermon, and Ring Fit Adventure, with varying effects on many other games. Pokémon Go also boasts massive download numbers, *showing that there are many potential exergame players for the mobile platform.* Games for other platforms have also sold well, especially for consoles.

The only emerging pattern is that the people who spend the most time playing video games are probably less likely to prefer a mobile unit as the platform for an exergame. In addition, there are few successful exergames available only for PC and even less research on their positive health effects.

32.1.3 RQ1-2: What technologies are mostly used in exergames?

Many different technologies are used in successful exergames. The most played exergame, Pokémon Go, is a location-based game for smartphones utilizing GPS technology. Location-aware games motivate players to use the real world as their game world. Pokémon Go also utilizes AR technology to simulate the player catching Pokémon in real life. Nintendo has seen great success with the motion controllers for their platforms, which were mimicked by their competitors but not to the same success. The Wii and Nintendo Switch use motion controllers to great success, as seen in the sales numbers of games like the Wii Sports series and Ring Fit Adventure. Beat Saber also utilizes motion controllers combined with VR technology. It is also possible to utilize other types of technologies. Gesture recognition is used by Just Dance on specific platforms, previously seen on Microsoft's Kinect, while Exermon utilizes different phone sensors.

Even though many technologies exist to create an exergame, the most successful ones have used GPS sensors or motion controllers.

32.1.4 RQ1-3: How can an exergame make the players more physically active?

Inspecting the most successful existing exergames, it is clear that there are many ways of making the player physically active while playing. We separate between exercise and physical activity. *Exercise includes physical activity, but not all physical activity is exercise.* Furthermore, there are four main types of exercise: aerobic, strength, flexibility, and balance. All four exercise types have seen uses in the reviewed exergames.

After considering what type of exercise or physical activity an exergame should focus on, one needs to think about how the player will perform said activity/exercise and have the game interact and give feedback to the player's movements. There are different ways to achieve this, which ties into the previous section about used technologies. Location-based games utilize a GPS sensor to detect where the player is moving. At the same time, the Wii Sports series uses motion controls to simulate actual sports, like swinging the controller to simulate hitting a ball with a racket in tennis. Other games, like Ring Fit Adventure and Dance Dance Revolution (the console version), use extra accessories to register the players' movement.

It must also be considered how to encourage the player to keep interacting with the game and thus stay active. First, the game must be enjoyable, which will be considered in the next section. The DualFlow framework considers two factors critical for the success of an exergame, attractiveness and effectiveness [3]. To create a successful exergame, one should try to reach flow for both factors, as the player will be invested in the game, and the exercise/activity will be effective. Research on Zombies, run! indicate that the narrative was found motivating by players, dissociating them for exertion efforts and reaching the flow state.

The existing exergames vary from light walking to high-intensity boxing to yoga sessions on a balance board. However, low to medium-intensity games such as Pokémon Go and Wii Sports have been the most commercially successful exergames. A research paper also recommended that exergames use large muscle groups and provide long-term motivations [97].

Different exergames exist for different reasons. Some focus on high-intensity exercise, while others focus on lower-intensity physical activity. Based on the factors reviewed in this section, we are inclined to believe that the latter has a higher chance of success. *Making a low-intensity exergame appeals to a broader audience*, which may include people who are not the most physically active and would like an easy and fun occasion to exercise or be physically active. The game should include long-term incentives to keep playing it instead of returning to their previous sedentary lifestyle, as the literature reports often is the case.

32.1.5 RQ1-4: How can an exergame be made enjoyable and motivating for a player?

As the previous section mentioned, an exergame must be enjoyable to play for it to be successful. The DualFlow framework recommends balancing the game's challenge with the player's skill to achieve to make it enjoyable.

The article *What Makes Things Fun to Learn* highlights three main characteristics of good computer games, *challenge*, *fantasy*, and *curiosity* [2]. In order to provide the right challenge, a game should provide a *clear goal* and an *uncertain outcome*. Fantasies should be intrinsic, presenting problems in terms of the fantasy world. Lastly, games should also appeal to both the player's *sensory curiosity*, to attract their attention or enhance the fantasy, and their *cognitive curiosity*, to motivate them to learn more and keep playing.

The GameFlow framework is based on the Flow model for an optimal experience and includes eight elements with criteria to achieve enjoyment [55]. A player must be able to *concentrate* on a game for it to be enjoyable, and *challenge* should match the player's skill level. Games should support the *player's skill* mastery and development, and players have to be given *control* over their actions. Games should have a comprehensible *goal*, and players should receive fitting *feedback* at appropriate times. Lastly, players should be able to be *immersed* in a game, and even though it might interrupt said immersion, *social interaction* can provide much enjoyment for players.

Scripting and emergence are two contrasting approaches to creating game environments. Scripting requires developers to handcraft events and player interactions. Emergence involves defining general rules, which lead to more freedom for players and diverse gameplay, but less creative controls for developers. The article concludes that neither of the approaches are ideal but that there needs to be a synthesis where both approaches are used in different parts of the game design [59]. There might be advantages to a scripted approach for story and game objectives. In contrast, for other parts of the game, an emergent approach could be advantageous to give the player more freedom and allow for more creative gameplay.

The facet which returns the most in all the reviewed game design papers is *challenge*. A game must provide an appropriate challenge level for the player to enjoy. If the game is too hard, they will become frustrated, and if it is too easy, they will feel apathy. *Clear goals* are also repeated, as the player needs to know the purpose of why they are playing to stay motivated.

Another aspect that should be considered when answering this research question is game genre. The respondents' favorite genres from the survey and pre-experiment questionnaire were *RPGs, strategy, and puzzle games.* A study recommends measuring the utility value of an exergame by how much the player likes the game genre [97]. Based on the survey and questionnaire, this would favor creating exergames in the strategy and RPG genre.

A third aspect that should be considered is game features, as different players enjoy different features. Implemented features should be based on the game design theories just discussed. Based on the post-experiment questionnaire, one of the most enjoyable features of Paint it Green was battling large blobs, which could indicate that players enjoy a challenging combat scenario where success is not guaranteed. Some of the most motivating features were acquiring XP and leveling up, and comparing their progress to others on the leaderboards. The latter indicates that *competitiveness against other players was motivating.* Features specifically requested for an improved version of Paint it Green included more fleshed-out social features and overall more varied gameplay. The most popular exergames: Pokémon Go, the Wii Sports series, and the Just Dance series, feature some multiplayer, either cooperative or competitive. Further, Wii Sports and Pokémon Go feature the possibility of battling or playing a match against AI opponents.

Based on all the findings, there seems to be a strong indication that *social features and multiplayer are motivating for players and a trend towards possible combat/match scenarios.*

32.2 Research Question 2 - To what degree are people interested in using exergames to increase their physical activity level?

32.2.1 Reflections and literature review

Does existing exergames have a positive effect on the physical activity of players?

After reviewing the studies on existing exergames, their results sometimes appear inconclusive and sometimes positive on providing players with health benefits. The players often seem to have positive takeaways from playing the game. However, there seems to be a *lack of long-term research on whether exergames can improve the lifestyle of many players to be less sedentary and more physically active as a routine or regular part of their everyday life, instead of just during an experiment to test an exergame's effect.* None of the reviewed experiments reported any long-term health benefits after an experiment or an exergame intervention. Any potential benefits occur while playing the game regularly.

Even perhaps the most successful exergame to this day, Pokémon Go, has a solid basis to state that the game does affect players' physical health *while playing the game regularly* [8]. After that, the imminent question is how to get people to keep playing an effective exergame for a very long time. This question is tentatively handled in the later research question reviews.

An alternative strategy to having exergames improve peoples' physical health is to make the games' positive effects overreach the period players actively play. This strategy attempts for the players to stay more physically active than before, even after having stopped playing the exergame regularly. However, this strategy is more related to the gamification of regular exercise and physical activity and transferring knowledge, attitudes, and habits on exercise and physical activity to the players, which is not really in the scope of this project or the project description for this thesis.

Do people want to use the exergames?

Even though one could create an exergame that has long-term positive effects on the players' physical activity levels, it is not the same as people wanting to or being interested in using it for this purpose. Undoubtedly, many people play exergames for other reasons than to exercise and be more physically active. In the systematic literature review of research on Pokémon Go, it was found that the *nostalgia factor played a significant role* in why players used the game so much [8]. Other motivating and enjoyable aspects of exergames can be just as significant of a reason to play the game as not to be sedentary.

Some players play exergames solely to exercise more or be more physically active. In contrast, others play the game for other reasons and see any possible health benefits as bonus perks to playing the game. Others do not care at all about their physical activity levels. Dwelling too deep into what reasons people have for using exergames is nonetheless not a worthwhile activity. The goal is to try to make an enjoyable and motivating exergame. Creating a successful exergame with long-term health benefits will benefit players whether that is their primary motivation or not.

Existing exergames's success

When assessing the examined exergames' success, the *low to medium-intensity games* such as Pokémon Go, Ingress, and Wii Sports have been the most commercially successful. (See Table 9.1) Even though commercial success in the form of sales and downloads is far from a precise measure of whether people were interested in using the game to be more physically active, exergames' success indicates how much people liked playing the game and thus being physically active.

Encouraging the players to be physically active with a slight increase in energy expenditure as in these low to medium intensity exergames seems more meaningful and effective than focusing on a specific sport or muscle group or solely on aerobic fitness.

32.2.2 Survey

The reader should remember that young urban students and working people disproportionately populated the survey respondents. The results indicate that about half of the respondents are interested in using a game to exercise and be physically active more often than they currently are. Most of the respondents do not exercise as much as they would like and like playing video games.

The survey found that strategy and puzzle games were the most popular game genres among the respondents, which creates a potential concern for the exergame genre. We deemed puzzle games not the most suitable for an exergame because it was hard to find a solid mapping between relevant physical exercise activities and in-game puzzles.

The respondents were also asked if they would be interested in using a game to help them reach their exercise and physical activity goals. Only 26% disagreed with wanting to use a game for this purpose. Thus, if an engaging exergame were to be implemented, there could be a potential to engage many people to reap its health benefits.

Another notable finding from the survey is that most respondents would like to be physically active and exercise more than they do today. Many people do not reach their goals due to a lack of time, exercise not being sufficiently motivating and fun, or requiring a nudge from an external agent. In addition, a few respondents reported spending much time on video games.

If one were only to inspect the respondents who are (partially) interested in using video games for exercise and physical activity, these respondents also like video games slightly more and exercise slightly less. The opposite pattern emerges when inspecting the people not interested in using video games for this purpose.

No eminently apparent target group is visible after performing the literature review and the survey. Exergames can have positive health benefits for children, teenagers, adults, and elders. From our overall assessment, the potential is neither staggeringly high nor low but substantial and worth further exploration.

32.2.3 Experiment findings

The experiment was also populated mainly by males in their mid-20s who liked playing video games. There were a total of 21 test subjects in the final data set for the experiment.

61% of the test subjects reported having played an exergame in the last 12 months, with Pokémon Go as the most selected one. 95% also agree (or partially agree) to, before the experiment, wanting to exercise more than they already do. Like in the survey, a lack of time was the most selected reason for not reaching their exercise and physical activity goals. Also, not finding exercise and physical activity fun or entertaining enough and needing someone or something to nudge them to exercise or be physically active was often stated as a reason.

After the experiment, *only 19% wanted to use Paint it Green instead of a traditional exercise in the future.* However, when asked if *an exergame* could be used to make them more physically active than they are today, *86% agreed.* The same indications are repeated in the findings from the interviews. Especially the test subjects that play video games for more than 30 minutes on a normal day and those who are physically active for less than 60 minutes on regular days seemed to agree with this potential for an exergame to make them more physically active than they are today.

During the interviews, the test subjects were asked if they could imagine themselves playing Paint it Green more if it were further developed. Two of the four test subjects answered unreservedly yes, while the last two answered conditionally yes, and requested specific features or changes that could have them play the game more in the future.

The game's usage declined from the start of the experiment. The game was played in total by all players for about 34 hours. There were 26 registered players, and 21 were included in the final data set as a limit of playing in total for at least 30 minutes was set. Also, a total of 31 people registered to be a part of the experiment, meaning ten registered people did not complete the experiment by filling out the post-experiment questionnaire or did not play for more than 30 minutes. *Less than half of the final 21 players reached past level 6*, and the total game activity mostly declined throughout the 19 days of the experiment.

The game usage illustrates that even though the interest in testing the game and being a part of the exergame experiment was substantial initially, most metrics for using the game declined. Of course, there are many influencing factors to why this would happen. For instance, the experiment occurred during a period when students were extraordinarily busy, the weather conditions were poor, and the fact that in these kinds of experiments, one should always expect some withdrawal from the start. The final quality of the implemented game also significantly affects how long and frequently the test subject played the game. Even still, there could be a point made that the test subjects in the experiment were not that interested in using the game to be more physically active than they were, as the game usage mostly declined throughout the experiment.

Many people wanted to try out the game and perhaps be more physically active, but the motivation faded as the experiment progressed. Perhaps due to the game not being quite *good enough*, due to external factors, or because the potential of exergaming improving people's physical activity levels is not that significant. However, the potential is still not deemed *negligible* since some statistically significant, positive results are discussed in the sections below.

32.3 Research Question 3 - What were the players' affective reactions to playing the exergame?

32.3.1 RQ3-1: What features or aspects of the exergame did the players enjoy the most?

When asked about overall enjoyment with the gameplay, *72% of the test subjects found it enjoyable.* Most of the test subjects enjoyed exploring the map and battling blobs and agreed that time felt like it was moving faster than usual while playing the game. Gathering XP, leveling up, blobs, and exploring Trondheim were the most highlighted favorite parts of the game.

Interacting with paint stations and battling blobs was deemed by several test subjects as satisfying and fun but also as sometimes frustrating and confusing. Most test subjects also reported understanding the story and how to play the game. They also mainly reported feeling in control of their actions and feeling their goals were clearly defined while playing.

Most test subjects also liked the game's graphics (including animations), although gamers were less favorable to the graphics than non-gamers. When looking at all 21 test subjects again, only 43% liked the music and sound effects. 43% also answered neutrally to whether they liked it or not. The high amount of neutrals may indicate that many test subjects turned off the music and sound effects early in the experiment.

Battling blobs

Even though a majority found defeating/exploding small blobs enjoyable (62%), several players reported the spawn rate for the small blobs as distractingly high. Players also reported their color being too similar to the in-game map's color. Both of these factors may have contributed to more test subjects not finding defeating/exploding small blobs as enjoyable (24%).

Especially battling the large blobs was seemingly enjoyable as 76% agreed with enjoying battling them. The large blob battle feature was introduced early but not from the beginning to the players. As the battle mode mechanic differed significantly from the previously known gameplay and was not present initially, it is possible that this new challenge also appealed to the players' curiosity. Large blob battling consisted of aiming and throwing paint grenades at the blob, which probably was recognized as similar to throwing pokeballs at Pokémon in Pokémon Go.

The battling of armored blobs was introduced at later levels, which many test subjects did not reach, which probably contributed to more respondents answering neutrally (33%) to finding it enjoyable.

The game's difficulty

62% of the test subjects deemed the game as too easy or a little too easy, with 33% finding it *just right*. As mentioned while discussing RQ1, the challenge of a game should be matched with a player's skill level to reach *flow*. Since only a third of the test subjects found the difficulty just right, the challenge level was probably set too low and may have induced apathy in some players since they were not sufficiently challenged while playing the game.

There were many global, constant, numerical thresholds for progressing in the game, like XP requirements per level, battle mode ammunition, XP rewards and multipliers, exploration status requirements, and more. Most of these game constants could easily be set to different values before the start of the experiment and thus have influenced the experienced challenge for the players. Most of these values were scaled by us when testing the game before any usability testing and the experiment itself. In hindsight, many game constants could and should have been adjusted before the experiment. We tried to balance the thresholds between enabling test subjects to complete the story and *get to try out the other features*, given the confiding 19-day experiment boundary, while not letting them try out and master all features within a few days or play sessions.

The game's difficulty also increased as the player progressed, with the exploration status requirements increased, blobs got tougher, and XP thresholds between levels increased. It would seem as if this difficulty progression and feature restraint based on levels, in total, *did not provide the proper challenge for the players*, as 62% found it too easy, and most test subjects never made it past level 6. As suggested in the DualFlow-framework, presented in Section 8.3, implementing a more adaptive difficulty should be considered to endeavor max DualFlow for the players [3].

32.3.2 RQ3-2: What were the most motivating features, and what features were used the most?

According to the test subjects, the most motivating feature was the *level* and *XP system*, which 75% agreed to find motivating. A large majority of the test subjects also agreed to be motivated by the social features of competing with other players on the leaderboards and battling blobs. However, the story and marking city districts as explored, dominated, and conquered were only motivating to 52%. Many test subjects also stated feeling progress in skill and goal progression during the experiment. The test subjects played the game differently and were often motivated by different in-game goals.

If one looks at the total game usage throughout the experiment, it declined from the first day with a few activity spikes here and there. Nevertheless, many players were motivated by some central features, and a majority still agreed with finding it hard to motivate themselves to use the game. Hence, even though many features of the game were indeed made motivating, they may often not have been enough to make the player start playing.

It should also be noted that the weather conditions during the experiment were quite unpleasant, with a drop in temperature and an increase in rain from the previous weeks. Paint it Green is centered around encouraging players to walk or run outside and explore their environment. Unpleasant weather conditions, in all probability, affected both the experienced motivation and enjoyment while playing. Several test subjects also explicitly write this in the questionnaire. In-game bugs and technical issues may also negatively affect players' emotions about playing the game.

As mentioned, more than half of the test subjects never progressed past level 6, and only two players completed the story (at level 20). The average players interacted with between three and four paint stations per day. The city districts (postal codes) near the city center were also substantially more actively played in than those further from the city center, which supports the finding of test subjects being less motivated by visiting and marking new city districts as explored, dominated, and conquered.

Even though it is impossible to get a complete overview of what features were used more or less than others, it may seem that the *complete story* and *exploring new places in Trondheim* were the least used. *Battling armored blob*s was probably also one of the less used features due to the armored blobs only starting to spawn from level 9.

32.3.3 RQ3-3: What demographics enjoyed and were motivated by the exergame the most?

First and foremost, one should remember that the experiment's demographics were dominated by males in their mid-20s who like playing video games. About half of the 21 test subjects were overweight, and about half played video games for an hour or more on regular days. The findings from the two sub-research questions above are therefore most applicable to young males who like video games, not the general public.

However, suppose one were to partition the test subjects into subgroups based on demographic traits. In that case, there are other findings on what demographics enjoyed and were motivated by the exergame the most.

Statistical analysis showed that *gamers were probably less enthusiastic than non-gamers* on some game features. The gamers liked the graphics and animations less than the non-gamers. The gamers were also less motivated to be physically active by the game during the experiment. However, when considering if *an exergame* could be used to make them more physically active, they were more positive than the non-gamers. There seems to be a pattern of gamers being more critical of the actual game they tested but may seem to have a more positive attitude toward using games to increase their physical activity levels.

If one were to partition the test subjects into physically active and non-active subgroups (based on reported physical activity levels from before the experiment), there was an indication of the *non-actives finding the overall gameplay more enjoyable than the active ones.* This result was also found in a study on the health and social impacts of playing Pokémon Go on various player groups [174].

Another partitioning was made between the test subject with a reported BMI category of normal/healthy weight compared to those with an overweight or obese BMI category. A relevant difference between the two subgroups was that the *overweight and obese were less motivated by the game's story than the normal/healthy weight.*

A last comparison between the male and female test subjects showed that the *males probably found it harder to motivate themselves to play the game during the experiment.*

32.4 Research Question 4: Does the developed exergame affect the players' physical activity levels?

32.4.1 RQ4-1: How did the players' physical activity levels change during the experiment?

There was *no statistically significant changes found in the reported physical activity levels.* However, the mean and median values increased, and the test subjects took more steps during the experiment than before. Also noteworthy is that there is an *indication that the test subjects were more satisfied with their physical activity levels* after the experiment than before. The perceived physical activity effect is thus noteworthy.

The physically active test subjects played the game for longer sessions and were still more physically active during the experiment than the non-active. However, the non-active seem to perceive more of a positive physical activity effect during the experiment than the active. The non-active also seem to see a higher potential of exergames to make them more physically active than the active.

Some evidence points to the game's positive effect on the test subjects' physical activity levels. The test subjects who were not very physically active before the experiment perceived a more significant effect on their physical activity levels and saw a larger potential in exergames influencing them even further.

32.4.2 RQ4-2: What type of physical activity did players perform while playing?

The activities performed while playing were *mainly walking and being stationary.* Running was rarely the physical activity used while playing the game, as only one test subject reported partially disagreeing with the statement *I mostly ran instead of walked while playing the game*, while the rest reported disagreeing. From the interviews, only one interviewee reported having tried running while playing the game. The calculated average player speed was considered walking speed, not including stationary pings.

About a third of the total playtime during the experiment was done with the player being stationary, which could mean players were opening and playing the game from home, school, or work. Several mechanics encouraged players to move around in their environment, like exploring city districts, blobs not spawning when the player was not moving, and others. These mechanics seemed to be somewhat effective.

A typical play session seems to last for roughly 15 minutes while walking alone in urban areas. It does not seem to be the case that the game encourages running or taking more walks than usual. Some test subjects report taking more walks than usual to play the game but perhaps extended some of the test subjects' walks by taking detours to reach paint stations, acquiring more XP, or visiting other city districts.

32.4.3 RQ4-3: Did people play the game instead of doing a sedentary activity, or did playtime replace other exercise?

From the questionnaires, the test subjects mostly disagree with playing the game instead of exercising but mostly agree with using *an exergame* to become more physically active.

An interviewed test subject who answered yes to thinking that the game could replace an exercise session said that since the exercise they already did was mainly low intensity, a good walk could have replaced it. All four interviewees did, however, answer yes when asked if playing the game could replace another physical activity. They saw the game positively influencing their physical activity levels by making it more fun and extending their walks.

A similar finding was reported in a study on Pokémon Go where a survey showed that the main reason for increased physical activity *was to go Pokémon hunting, make unnecessary detours, and choose walking, running, or biking instead of public transport* [174].

As stated in the previous sub-research question, it *does not seem to be the case that the game encourages running or taking more walks*. However, it may seem that Paint it Green made people *take more steps and extend their walks*, which is meaningful in this project.

Despite some evidence of the game producing more walks and encouraging running, the most pertinent finding is that the players *played the game on walks they would already be taking*, but perhaps extending them and thus making the test subjects less sedentary. Another important consideration is that the test subjects, especially the gamers of the test subjects, seemed optimistic about using an exergame to be more physically active. Paint it Green is a relatively small and short game developed by two Master's students with limited time and game development experience. A bigger, better, and more polished exergame could have had a more significant effect on the test subject's physical activity levels.

Chapter 33

Conclusion

This thesis continues the specialization project (TDT4501) conducted in autumn 2021.

The defined research goal of this project is to *Discover, analyze, develop and test a new exergame concept and prototype which motivates people to increase their physical activity levels.*

As discussed in Chapter 3, this project uses the goal question metric to reach the research goal. Thus, there is a set of research questions that need answering. The research questions were thoroughly reviewed in the discussion in the last chapter, and their conclusions will be presented later in this chapter.

The project began by examining the dominion of video games, physical activity, and exergames. We looked at game genres, game design theories, existing exergames, modern exergame development technologies, and performed a literature review on exergame research. All these aspects make up the thesis' prestudy. Several exergame concept ideas were formulated using the knowledge from the prestudy, where one was chosen and flourished into the final concept, Paint it Green. The concept encourages players to be physically active by using GPS sensors to walk or run around in their environment and painting Trondheim from gray to green by defeating evil paint monsters. It was implemented into a prototype which was tested in an experiment. The experiment consisted of a questionnaire at the start and end, observations and interviews in the middle, and 19 days of gameplay access for the test subjects. The results from the prestudy, questionnaires, interviews, observations, and game usage data provide answers to the research questions, which are presented below.

RQ1: What is the best way to create an effective, enjoyable, and motivating exergame? Developing an exergame can be done successfully on several platforms, but developing for *mobile units seems in total to be a good choice* of platform for reaching many people and motivating for a healthier lifestyle. Similarly, with other technology choices and accessories, there are several suitable choices, but GPS sensors or motion controllers have previously had success when utilized. Different suitable exercise types and actuating technologies can induce physical activity.

The physical activity intensity is an outstandingly vital aspect to consider when creating an exergame. When designing and adjusting the game to produce the correct difficulty and intensity for the players, the *DualFlow framework for exergames should be followed* [3]. Considering the prospects of a successful exergame, *low to medium-intensity physical activity could be preferable* to high-intensity physical activity. Focusing on low-intensity physical activity could increase player retention and long-term health benefits, over improved muscle strength or aerobic fitness, which seldom lasts after having stopped playing the game regularly.

In order to create an enjoyable and motivating exergame, *challenge* is an *integral aspect. Social features* also seem pretty important to exergame players. Choosing a game genre that potential exergame players like might be a good idea.

RQ2: To what degree are people interested in using exergames to increase their

physical activity level?
Exergames seem to produce positive health effects for players while they regularly play. However, long-term effects are mostly unsure or unknown. Exergame developers should thus keep *player retention* and *long-term play incentives* in mind.

People play exergames for different reasons and in different ways. However, the exergames that produce low to medium-intensity physical exercise seem more commercially successful than others. It seems somewhat evident that many people are unhappy with the exercise frequency and how often they are physically active. Also, the interest in combining gaming and physical activity by using a game to increase their physical activity levels seems large.

When reviewing our implemented exergame prototype, the results on interest for using the game for more exercise or physical activity seem not to be that encouraging. Paint it Green's implementation was limited by time and resources. Despite the mixed, prospective results of the prototype, the prospects of people wanting to use *an exergame* to be more physically active still seemed good. Despite a substantial initial engagement in using the game at the beginning of the experiment, *the test subject's motivation and game usage seemed to decline.*

People's interest in using exergames to increase their physical activity level seems *moderate*, as it were, neither considerably low nor high, but worthwhile further research and development efforts.

RQ3: What were the players' affective reactions from playing the exergame?
Most test subjects enjoyed the overall gameplay experience, but many found it *too easy.* The battling of blobs was often highlighted as an enjoyable feature. The most motivating features of the game were progression by leveling up and getting access to new features, as well as the social aspects of comparing one's exploration progress of a city district to others. However, the game's story and visiting new or distant parts of Trondheim were not as motivating.

The gamers in the test subject pool were more critical and less enthusiastic about the game than the non-gamers. However, the gamers also had a more positive attitude towards using exergames, in general, to be more physically active. *The test subjects who were more physically active before the experiment probably enjoyed the gameplay less than the non-actives.*

RQ4: Does the developed exergame affect the players' physical activity levels?
There was *no significant change in how much time the test subjects were physically active* before and during the experiment. However, there was an increase in how many daily steps the test subjects took and an indication of positive change in how satisfied they were with their physical activity levels.

The non-active test subjects seemed to get a more significant effect from the game and were more satisfied with their physical activity.

Although some played while stationary, the game was *mostly played while walking.* A typical play session lasted roughly 15 minutes while walking alone in urban areas. Playing the game is mostly not seen as a substitute for regular exercise but as a means to be somewhat more physically active by walking more. The game seems not to induce running or to take more walks but to extend the walks the test subjects already would take and thus increase how much time they would spend physically active and make people less sedentary.

Chapter 34

Further Work

This chapter includes an overview of the work that should be done to improve Paint it Green as an exergame and considerations for future exergame research.

34.1 Considerations for Paint it Green

While Paint it Green motivated players to walk further and a bit more, and the overall gameplay was found enjoyable, much work can be done to improve the prototype. The game could potentially have an even more significant impact if more features were added and issues found after the experiment were fixed.

One aspect which should be fixed is the game's tutorial. It should be shortened so that players do not lose interest and then skip it, and the game's goals should be conveyed simpler and better. The challenge level should be adjusted so the game is not perceived as too easy. Auto adaptive difficulty would also be a viable tactic for adjusting the game's difficulty. Test subjects reported a lack of features as their biggest issue with the game. Adding more features like new blob types and battle mechanics with varying difficulty levels could further motivate people to progress in the game by appealing to their curiosity while also addressing the challenge issue.

More work should be put into the social features of the game. The existing leaderboard functionality was positively regarded, and test subjects requested even more sophisticated social features. Adding features like adding players as friends and comparing level, story, and total exploration progress to specific players could increase players' enjoyment of the game. A feature allowing for cooperation with other players and not just competing with them should be considered. Achievements and customization features could provide even more situations where players might want to compare themselves to others.

Several players wanted the game to track their position still and update their progress when their phone was not active. Allowing the game to run as a background process could appeal more to players who want to play it passively while walking.

Some players were not motivated by battling blobs. Adding "blobs defeated" requirements to city district exploration could increase the motivation for fighting blobs but could also alienate those who just want to explore the city while the game passively tracks their progress.

Some of the functional requirements which were not implemented should be considered implemented. The paint meter functionality could add extra incentives to visiting paint stations. Daily quests or missions could also be considered to provide players with more short-term goals and increase player retention by motivating players to play daily.

The city district map view should also be extended to cover more than just Trondheim, at least some other cities. Some experimentation with AR technology for battling blobs should also be done.

Lastly, the game should be polished more. Load times should be decreased, cheating and security vulnerabilities should be mended, graphics should be improved, music and sound effects should be updated, and the leftover bugs should be fixed.

Implementing these proposed features and fixes would require significant time and resources. However, it is important to strive toward making Paint it Green a fully fleshed-out exergame and not just a prototype to test the concept's true potential. The new features and changes should preferably go through iterative and user-oriented testing to ensure the functionality functions properly and contributes to improved gameplay enjoyment and motivation to play the game.

34.2 Considerations for future exergame research

After reviewing many published research papers on exergames, there is an apparent lack of research on the long-term health effects. Most experiments have been limited to covering a couple of days or weeks. Suppose one is to grapple with common health issues related to a lack of physical activity. In that case, there needs, in our view, to be more research on how exergames can affect players' lifestyles to sustainably make their lives less sedentary.

Other compelling issues also lack an emerging conclusion. Issues like what demographic group have the greatest health benefits from exergaming, what game genres are most engaging for exergames, what type of physical activity is most suitable for an exergame, and if there is a game engine, platform, or framework which is better than others. There are some indications towards answering these issues, but we do not find the available research sufficient to confidently make any solid recommendations for future exergame research.

We also recommend further research and work on Paint it Green, too. The game showed potential, and a new experiment is recommended to further strengthen and control the findings. A potential new experiment should include a control group, more accurate monitoring, and game data storage to track player sessions and other individual usage data. In addition, a more extended time period for the experiment and a bigger, more randomized, and varied group of test subjects would be helpful. The control group should report their physical activity habits without having access to the game simultaneously with the test subjects with game access.

A bug-free, polished prototype with the features from above, available to both iOS and Android players, distributed in a more controlled manner than just sending a .apk-file would also be preferable.

34.3 Summary

We both still believe that exergaming is a worthwhile research area and that there is potential to increase many people's physical activity levels by playing games. Even though the potential is, in our assessment, not remarkably high, if an exergame could provide health benefits to some people, the efforts are meaningful.

We also believe Paint it Green could be further improved and tested after this project. Implementing new features, fixing bugs, and polishing the game might enhance the overall gameplay experience.

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Appendix A

Survey - Questions and Results

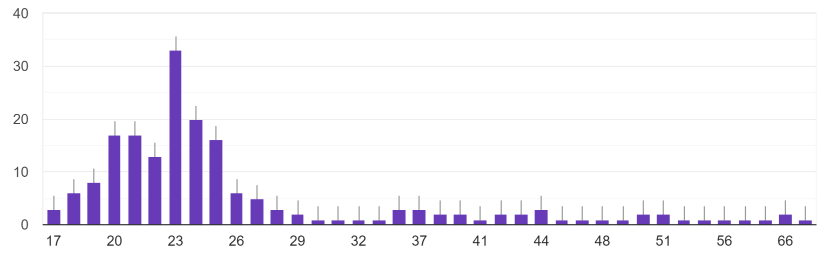
Due to the intended recipients of the survey primarily being Norwegian citizens, the questions and options are written in Norwegian. Here is a translation of the questions and options in the same order as they are presented below:

- How old are you? - Input a number
- What is the category which best describes your situation? - Options: Student, working, on benefits, etc.
- Where do you live now? - Options: Large city (50 000+), small city, settlement
- Housing status? - Options: Alone, with parents, in a collective, etc.
- Sex/Gender? - Options: Male, female, other gender identity, does not want to state
- Roughly how many times a week do you exercise (More intense activity than walking) - Input a number
- Roughly how many minutes on a regular day are you physically active? - Input a number
- I wish I was exercising more often than I am today. - Choose between disagree, partially disagree, neutral, partially agree and agree
- I wish I was more often physically active than I am today. - Choose between disagree, partially disagree, neutral, partially agree and agree
- What are the reasons that you do not exercise/are physically active as much as you would like? - Options: I do not have the time, external obstacle, I do not find it entertaining, other/free input, etc.
- Do you like video games? - Choose between disagree, partially disagree, neutral, partially agree and agree
- What platform do you prefer to play video games on? - Options: PC, console, mobile, I do not like to play video games
- About how much time do you spend on video games on a normal day? - Options: Less then 15 minutes, 15-30 minutes, 30-60 minutes, 1-2 hours, etc.
- What kind of games do you like to play? - Options: Strategy/Puzzle games, sports and racing, adventure, etc.
- What is important for you to like a game? - Options: Fun/Engaging gameplay, good graphics, music, other/free input, etc.

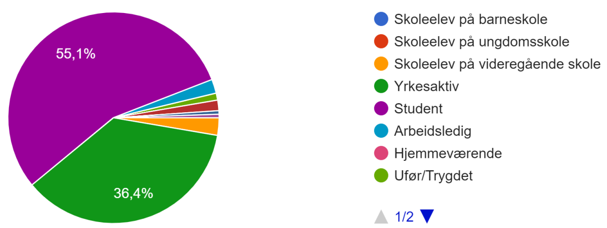
- Have you played any of these exergames in the last six months? - Options: I have not played any of these, Pokémon Go, Dance Dance Revolution, Wii sports/Wii sports resort, other/free input, etc.
- I am interested in using games to help me come closer to my exercise/physical activity goals. - Choose between disagree, partially disagree, neutral, partially agree and agree

Survey - results

Hvor gammel er du?
187 svar



Hva er stillingen som beskriver din nåværende situasjon best?
187 svar



Hvor bor du nå?
187 svar

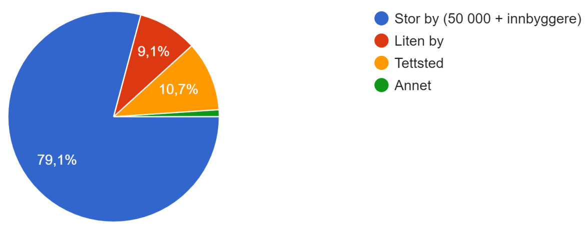
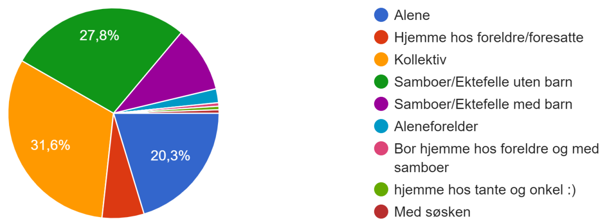


Figure A.1: The survey questions with answers

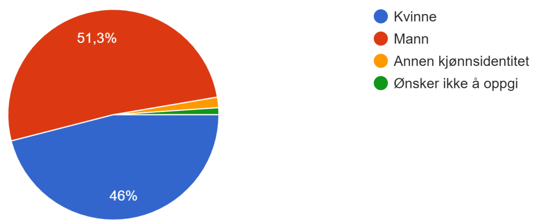
Bostatus

187 svar



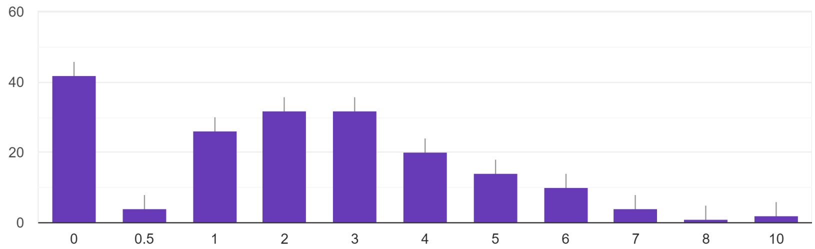
Kjønn

187 svar

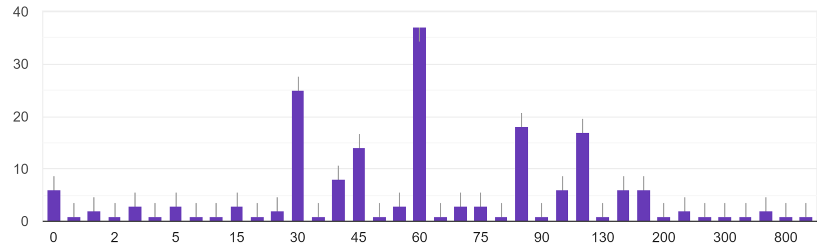


Omtrent hvor mange ganger i uka trener du? (Mer intens aktivitet enn gåing)

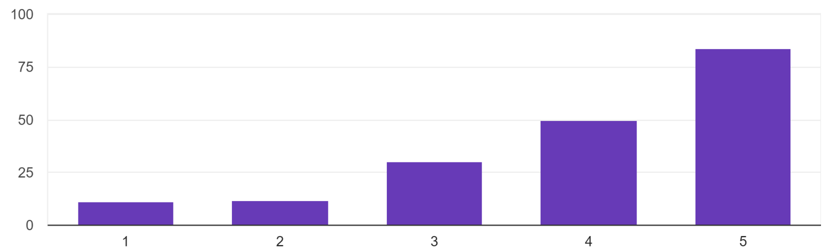
187 svar



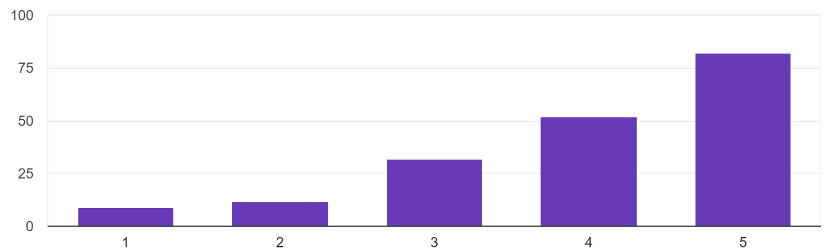
Gjennomsnittlig, omtrent hvor mange minutter er du i fysisk aktivitet på en vanlig dag? (Trening og lettere aktivitet som gåing)
187 svar



Jeg skulle ønske at jeg trente mer enn jeg gjør nå for tiden
187 svar

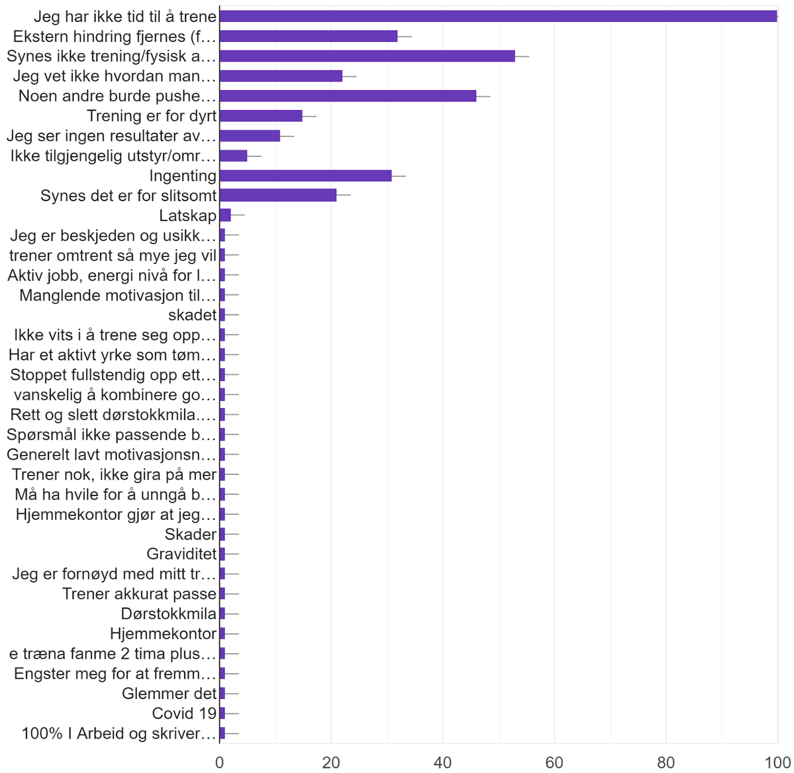


Jeg skulle ønske at jeg var oftere i fysisk aktivitet enn jeg er nå for tiden
187 svar



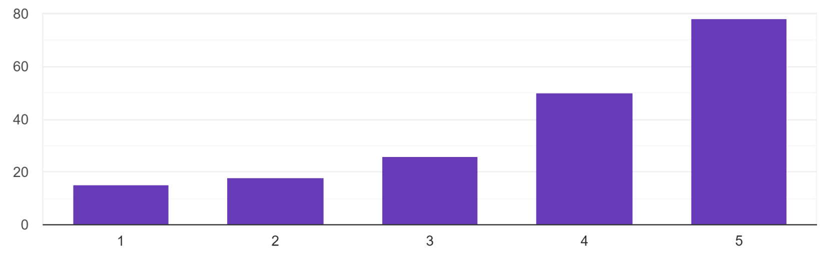
Hva er grunnene til at du ikke trener/er i fysisk aktivitet så mye som du vil?

187 svar



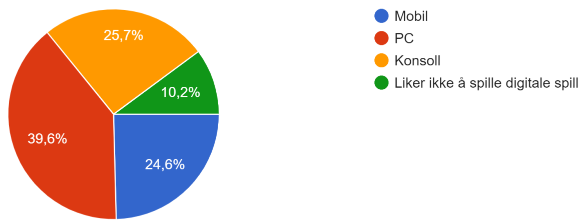
Liker du digitale spill? (mobil, PC, konsoll)

187 svar



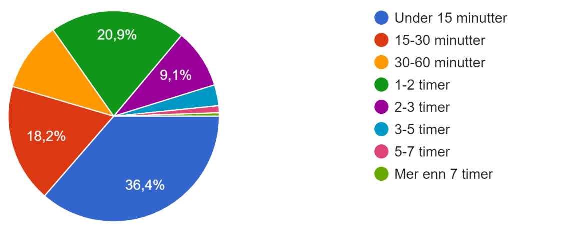
Hvilken plattform liker du best å spille på?

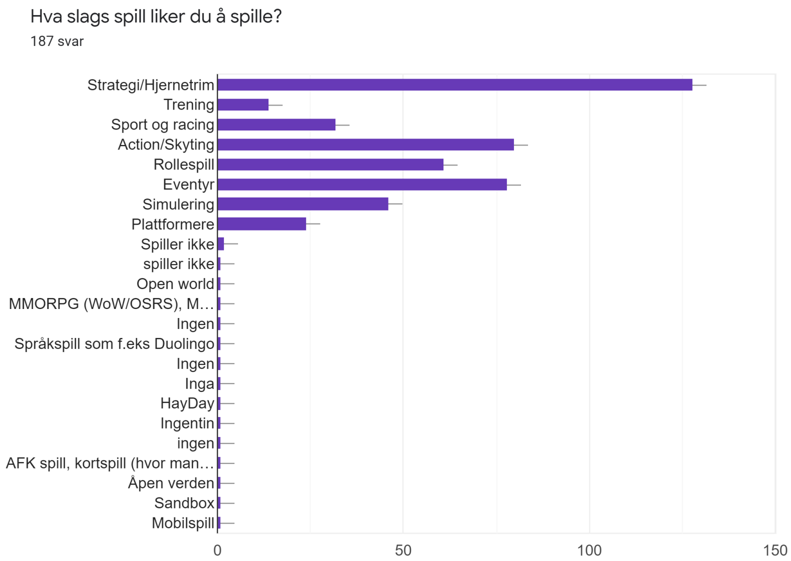
187 svar



Omtrent hvor mye tid bruker du på digital spilling i gjennomsnitt en vanlig dag?

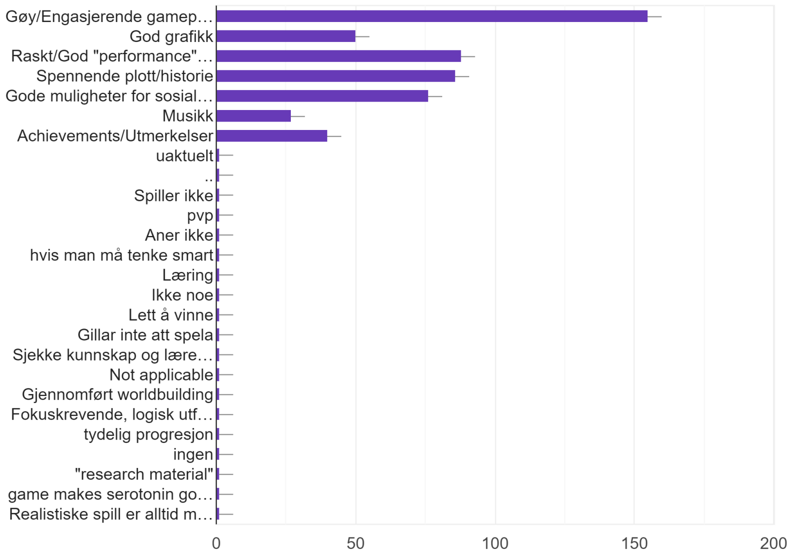
187 svar



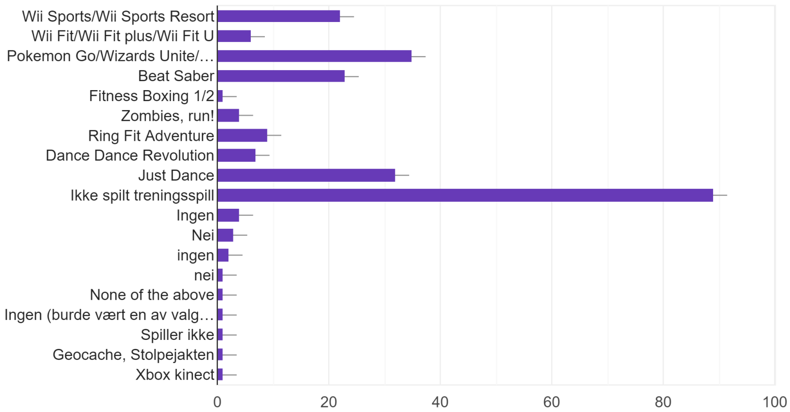

Hva slags spill liker du å spille?
187 svar
Strategi/Hjernetrim
Trening
Sport og racing
Action/Skyting
Rollespill
Eventyr
Simulering
Plattformere
Spiller ikke
spiller ikke
Open world
MMORPG (WoW/OSRS), M…
Ingen
Språkspill som f.eks Duolingo
Ingen
Inga
HayDay
Ingentin
ingen
AFK spill, kortspill (hvor man…
Åpen verden
Sandbox
Mobilspill
0
50
100
150

Hva er viktig for at du skal like et spill?

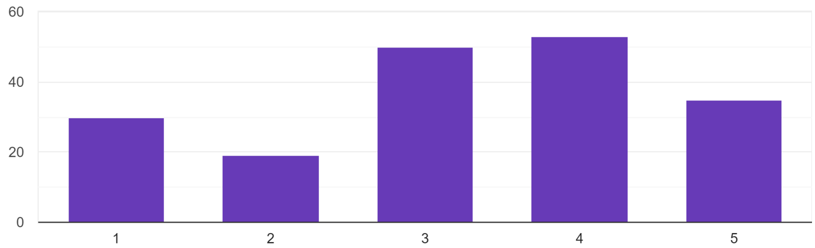
187 svar



Har du spilt noen av disse treningsspillene de siste 6 månedene?
187 svar



Jeg er interessert i å bruke spill til å komme nærmere målene mine om fysisk aktivitet/trening?
187 svar



Appendix B

Pre-Experiment Questionnaire

Paint it gray - Pre experiment questionaire

* Obligatorisk

Introduction + demographics

1. User ID *

   Enter the anonymous ID which was given to you at the start of the experiment

   ____

2. Age *

   ____

   Verdien må være et tall

3. Gender *

   ◯ Woman

   ◯ Man

   ◯ Non-binary

   ◯ Prefer not to say

4. How would you categorize your weight category (BMI)? *

- Underweight (BMI below 18.5)
- Normal/Healthy weight (BMI between 18.5 – 24.9)
- Overweight (BMI between 25.0 – 29.9)
- Obese (BMI above 30.0)

3/16/2022

Figure B.2: The pre-experiment questionnaire

Game/Gaming preferences and behaviour

5. I like playing video games (mobile, PC, console) *

- ◯ Agree
- ◯ Partially agree
- ◯ Neutral / No opinion
- ◯ Partially disagree
- ◯ Disagree

6. About how many hours do you play video games on a normal day? *

- ◯ Less than 15 minutes
- ◯ 15-30 minutes
- ◯ 30-60 minutes
- ◯ 1-2 hours
- ◯ 2-3 hours
- ◯ 3-5 hours
- ◯ 5-7 hours
- ◯ More than 7 hours

3/16/2022

Figure B.3: The pre-experiment questionnaire

7. What game genres do you prefer to play? *

- [ ] Strategy (Civilization, Starcraft)
- [ ] Puzzle (Candy crush, Tetris)
- [ ] Sport and racing (FIFA, Forza, Need for Speed)
- [ ] Action/Shooters (Fortnite, Call of Duty)
- [ ] RPGs (Skyrim, World of Warcraft, RuneScape)
- [ ] Adventure (Zelda, The Walking Dead)
- [ ] Simulators (X-Plane Flight simulator)
- [ ] Plattformers (Super Mario, Castlevania)
- [ ] Idle games (IDLE Capitalist, Cookie Clicker)
- [ ] Annet

8. What platform do you prefer? *

- ○ PC
- ○ Console
- ○ Mobile
- ○ Web browser
- ○ I do not like playing video games

3/16/2022

Figure B.4: The pre-experiment questionnaire

9. Have you tried playing an exergame in the last 12 months? *

Examples: Pokémon Go, Wii Sports, Beat Saber, Ring Fit Adventure, Dance Dance Revolution, etc.

- ◯ Yes, a lot
- ◯ Yes
- ◯ Yes, a little
- ◯ No

10. Which exergames have you played in the last 12 months? *

- ☐ Pokemon Go
- ☐ Wii Sports/Wii Sports Resort
- ☐ Wizards Unite!
- ☐ Ingress
- ☐ Beat Saber
- ☐ Dance Dance Revolution
- ☐ Fitness Boxing 1/2
- ☐ Ring Fit Adventure
- ☐ Zombies, run!
- ☐ Just Dance
- ☐ None
- ☐ __________

Annet

3/16/2022

Figure B.5: The pre-experiment questionnaire

Exercise and physical activity

11. How would you subjectively rate you physical fitness/shape *

- ◯ Poor
- ◯ Not very good
- ◯ Alright/Good enough
- ◯ Good
- ◯ Excellent

12. Roughly, how many times a week do you exercise? *

More intense physical activity than walking

Verdien må være et tall

13. Roughly, how much time (minutes) do you spend being physically active on a normal day? *

(Exercise and low intensity physical activity such as walking)

Verdien må være et tall

3/16/2022

Figure B.6: The pre-experiment questionnaire

14. I wish I were more physically active than I am today *
(Exercise and low intensity physical activity such as walking)

- ◯ Agree
- ◯ Partially agree
- ◯ Neutral/No opinion
- ◯ Partially disagree
- ◯ Disagree

15. I wish I exercised more than I do today *
More intense physical activity than walking

- ◯ Agree
- ◯ Partially agree
- ◯ Neutral/No opinion
- ◯ Partially disagree
- ◯ Disagree

3/16/2022

Figure B.7: The pre-experiment questionnaire

16. What are the reasons you are not as physically active/do not exercise as you wish you were? *

- ◯ I do not have enough time
- ◯ External impediment/hindrance is removed (physical/psychological illness, functional disability or equivalent)
- ◯ I do not find exercise/physical activity fun/entertaining enough
- ◯ I do not know how I should exercise/be physically active
- ◯ Someone/Something needs to push/nudge me to exercise/by physically active
- ◯ Exercise is too expensive
- ◯ I do not see any/enough results/progress
- ◯ Not available equipment/area/facilities for physical activity/exercise
- ◯ Too tiresome/exhausting
- ◯ I exercise/am physically active as much as I would like
- ◯ Annet

17. When you exercise, what kind of exercise do you do? *

- ☐ Aerobic exercise (running, fast walking, cycling, etc.)
- ☐ Strength exercise
- ☐ Balance exercise
- ☐ Flexibility exercise
- ☐ Sports
- ☐ I do not exercise
- ☐ Annet

3/16/2022

Figure B.8: The pre-experiment questionnaire

18. Do you go for walks/strolls/hikes in your spare time? *

◯ Yes, weekly or more often

◯ Yes, but less often

◯ No

19. Do you prefer to walk/stroll/hike in nature (rural areas) or in more urban areas? *

◯ Rural areas

◯ Urban areas

◯ Both

3/16/2022

Figure B.9: The pre-experiment questionnaire

Appendix C

Post-Experiment Questionnaire

Paint it green - Post-experiment questionaire

* Obligatorisk

Introduction

1. User ID *

   Enter the anonymous ID which was given to you at the start of the experiment

2. Did you test the game? (At least 30 minutes in total) *

   Some players experienced failures/bugs which prevented them from playing, or otherwise never tried playing the game. If you played the game in total for less than 30 minutes, you can not complete the form.

   ◯ Yes, I played the game in total for 30 or more minutes

   ◯ No, I played the game less than 30 minutes

3. What kind of mobile unit did you use to play the game? *

   (F.eks. Samsung Galaxy S10, Huawei P50, Google Pixel, etc.)

Physical activity

4. Roughly, during the experiment, how much time (minutes) did you spend being physically active on normal days? *

   Both with and without using the game. (Exercise and low intensity physical activity such as walking)

   Verdien må være et tall

5/10/2022

Figure C.2: The post-experiment questionnaire

5. Please respond to the statements below *

	Disagree	Partially disagree	Neutral/No opinion	Partially agree	Agree
During the experiment, I still wish I were more physically active than I was	○	○	○	○	○
I was physically active more often during the experiment than I was before	○	○	○	○	○
The game helped motivate me to be physically active	○	○	○	○	○
I mostly ran instead of walked while playing the game	○	○	○	○	○
I forgot/became unaware that I was being physically active while playing the game	○	○	○	○	○
I would like to use this game instead of traditional exercise in the future	○	○	○	○	○
Using an exergame can make me more physically active than I am today	○	○	○	○	○

5/10/2022

Figure C.3: The post-experiment questionnaire

6. Roughly how many steps do you take on average during the experiment (in the last weeks)? *

Please use your phones step counter logs. If this is not available, feel free to give your best estimate

- ◯ 0-3000
- ◯ 3 000-6 000
- ◯ 6 000-9 000
- ◯ 9 000-12 000
- ◯ 12 000-15 000
- ◯ 15 000+
- ◯ Don't know

7. Roughly, for how long (minutes) did you spend playing the game each play session? *

Answer in minutes

Verdien må være et tall

5/10/2022

Figure C.4: The post-experiment questionnaire

Enjoyment and game usage

5/10/2022

Figure C.5: The post-experiment questionnaire

8. Please respond to the statements below *

	Disagree	Partially diagree	Neutral/No opinion	Partially agree	Agree
I found the overall gameplay enjoyable	○	○	○	○	○
I enjoyed visiting and exploring the map parts (city districts)	○	○	○	○	○
I enjoyed exploding the small battling blobs	○	○	○	○	○
I enjoyed battling the large blobs	○	○	○	○	○
I enjoyed battling the armored blobs	○	○	○	○	○
Time felt like it went faster when playing the game	○	○	○	○	○
The story and overarching goal/purpose of the game was clear and understandable to me	○	○	○	○	○
I understood how to play the game after completing the tutorials	○	○	○	○	○
I liked the graphics of the map, minimap, character, blobs, animations, etc.	○	○	○	○	○
My goals were clearly defined when playing the game	○	○	○	○	○
I felt in control of my player avatar's movements	○	○	○	○	○
I liked the music and sound effects	○	○	○	○	○

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Figure C.6: The post-experiment questionnaire

9. The game was ... *

- ◯ Too easy
- ◯ A little too easy
- ◯ Just right
- ◯ A little too difficult
- ◯ Too difficult

10. I found this feature the most fun/enjoyable *

- ◯ Exploding small blobs
- ◯ Battling large and armored blobs
- ◯ Defeating Paintavvagio (the boss) and progressing through the story
- ◯ Moving around in my environment to explore map areas
- ◯ Compeeting with other players on the leaderboards
- ◯ Gathering lots of XP to level up
- ◯ Visit daily double XP areas
- ◯ Visit city districts/parts of Trondheim I otherwise would not visit
- ◯ Try to explore, dominate or concquer city districts (filling up the progress bars and making the map part more green)

11. Were there any game features which you did not understand how to play/use? If yes, what features?

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Figure C.7: The post-experiment questionnaire

12. What about the game did you enjoy the most? *

13. What about the game did you enjoy the least? *

14. I played mostly *

- ◯ By my self
- ◯ With others who also played the game
- ◯ With others who did not play the game

15. I played the game mostly in *

- ◯ rural areas (nature)
- ◯ urban areas (cities, housing areas)
- ◯ about the same of each

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Figure C.8: The post-experiment questionnaire

16. I repeated the tutorial after finishing it on the initital play session *

◯ Yes

◯ No

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Figure C.9: The post-experiment questionnaire

Motivation

17. Please respond to the statements below *

	Disagree	Partially disagree	Neutral/No opinion	Partially agree	Agree
The level and XP system was motivating	◯	◯	◯	◯	◯
The game motivated me to visit places/areas which I had not yet visited (often)	◯	◯	◯	◯	◯
Seeing leaderboards and competing against friends and other players was motivating	◯	◯	◯	◯	◯
Marking areas as explored, dominated, or conquered was motivating	◯	◯	◯	◯	◯
Battling small, large and armored blobs was motivating	◯	◯	◯	◯	◯
The story was motivating me to finish the game and learn more	◯	◯	◯	◯	◯
During the experiment, I found it hard to motivate myself to use the game	◯	◯	◯	◯	◯

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Figure C.10: The post-experiment questionnaire

Misc. statements

18. I completed the story and defeated Paintavvagio *

- ◯ Yes
- ◯ No

19. I played the game even after completing the story *

- ◯ Yes
- ◯ No

20. Did you experience any technical problems? If yes, please describe the problems

21. Did any other external factors prevent you from playing the game as much as you would like to? (Such as illness, poor weather conditions, etc.)
If yes, please describe the factors

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Figure C.11: The post-experiment questionnaire

22. Did you cheat during the experiment? If yes, how and why did you cheat?

23. Do you have any last/departing comments?

About the game, the experiment or anything else

5/10/2022

Figure C.12: The post-experiment questionnaire

Appendix D

Experiment Data Processing and Storage Agreement

Vil du delta i et forskningsprosjekt om terningspill?

Exergaming – Play to get fit - Samtykkeerklæring om databehandling

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke hvorvidt spill kan bidra til økt fysisk aktivitet. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva å delta innebærer.

Formål:

Dette prosjektet har som hensikt å undersøke hvordan spill kan brukes som en del av løsningen på problemet rundt økende inaktivitet i dagens samfunn. Prosjektet vil gjøre dette gjennom utvikling av et spill som inkluderer fysisk aktivitet, et slikt spill omtales som et exergame. For å teste om spillet har ønskelig påvirkning på brukernes fysiske aktivitet vil det bli gjennomført en testperiode, det er denne testen du vil bli spurt om å ta del i. Forskningsprosjektet er en masteroppgave ved NTNU og en del av forskningsprogrammet Game Technology For Health (GT4H) som et bidrag til NTNUs forskning på exergaming.

Ansvar for prosjektet:

Norges teknisk-naturvitenskapelige universitet (NTNU) ved Institutt for Datateknologi og Informatikk (IDI) er ansvarlig for prosjektet. Veileder og hovedansvarlig for prosjektet er Alf Inge Wang. Forsøket vil bli gjennomført av studentene Haakon Gunleiksrud og Tobias Ingebrigt Ørstad.

Hvorfor blir du spurt om å delta:

Du har tidligere meldt interesse om å delta i prosjektet til oss. Utvalget til dette prosjektet er ikke spesialisert. Hvem som helst kan få være med på prosjektet så lenge de er over 18 år og myndig. I prosjektet ønsker vi å se på en variert gruppe mennesker innen bestående av folk med både høyt og lavt aktivitetsnivå. Men den primære målgruppen for prosjektet er mennesker som i varierende grad ønsker å være mer fysisk aktive enn de er i dag. Det er ønskelig å se på hvordan din motivasjon til å være fysisk aktiv påvirkes av bruk av spillet over en tidsperiode.

Hva innebærer det å delta:

Velger å delta, innebærer det at du vil få tilgang på å installere spillet på din mobiltelefon. Spillet vil så være tilgjengelig for deg i 3 uker, hvor du spiller spillet så mye du selv ønsker, på eget initiativ i løpet av prosjektperioden. Før og etter denne perioden vil du fylle ut et spørreskjema. Noen av spørsmålene i disse to spørreskjemaene vil være like, men ikke alle. Hvert spørreskjema vil ta deg ca. 10-15 minutter å fylle ut. Spørsmålene vil dreie seg om hvordan du opplevde å bruke spillet, samt vaner rundt fysisk aktivitet.

Du kan bli spurt om å delta på intervju og observasjon. Det er frivillig å delta på intervju og observasjon. Et intervju og en observasjon vil bli utført for å oppdage tanker, følelser, problemer eller annet som oppstår rundt bruk av spillet og som ikke kommer frem fra spørreundersøkelsene. Under intervju vil det bli gjort lydopptak. Det kan også bli tatt bilder, men da vil det ikke bli tatt bilder av ansikter slik at det ikke blir personidentifiserende.

Det er frivillig å delta:

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

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger:

Vi vil kun bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket. All data som vil bli samlet inn vil kun være tilgjengelig for de to studentene i prosjektgruppen og for veilederen. Dette vil bli sikret ved at alle opplysninger vil bli kryptert på NTNU sine servere. I tillegg til dette vil personopplysninger, som navnet og kontaktopplysningene dine vil bli erstattet med en kode som lagres på en egen navneliste adskilt fra øvrige data. Din epostadresse vil kun bli brukt til å sende ut nødvendig informasjon til deg, som inkluderer spillet og spørreskjemaer.

Du vil ikke kunne gjenkjennes i publikasjonen, det vil kun publiseres oppsummeringer av- og ulike sammenhenger mellom flere av testdeltakerenes svar på spørreskjemaene og data knyttet til hvordan og hvor mye man har beveget seg ved hjelp av spillet. Eksempler kan være gjennomsnitts- og behandlet anonymisert data, samt anonymiserte kommentarer fra spillsesjon og intervju. Leverandør av spørreskjemaer vil være Microsoft Forms.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet:

Opplysningene anonymiseres eller slettes når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 7. juni 2022. Ved denne datoen vil også dine personopplysninger og kobling til koden brukt i prosjektet bli slettet.

Dine rettigheter:

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

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

Figure D.2: The data processing and storage agreement, agreed upon by all test subjects in the experiment

Hva gir oss rett til å behandle personopplysninger om deg:

Vi behandler opplysninger om deg basert på ditt samtykke.

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

Hvor kan jeg finne ut mer:

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

- NTNU: Alf Inge Wang på epost alf.inge.wang@ntnu.no
- Student: Haakon Gunleiksrud på epost haakogun@stud.ntnu.no
- Student: Tobias Ingebrigt Ørstad på epost tobias.i.orstad@ntnu.no
- Vårt personvernombud: Thomas Helgesen på epost thomas.helgesen@ntnu.no

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

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

Med vennlig hilsen Alf Inge Wang (Veileder), Haakon Gunleiksrud og Tobias Ingebrigt Ørstad (Studenter)

Samtykkeerklæring:

Jeg har mottatt og forstått informasjon om prosjektet Exergaming - Play to get fit, og har fått anledning til å stille spørsmål. Jeg samtykker til:

☐ å delta i testperiode av aktuelt spill

☐ å delta i observasjon

☐ å delta i intervju

☐ å delta i spørreskjema før og etter testperiode

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

(Signatur av prosjektdeltager, dato og sted)

Figure D.3: The data processing and storage agreement, agreed upon by all test subjects in the experiment

Appendix E

Approved NSD Application

NORSK SENTER FOR FORSKNINGSDATA

Meldeskjema

Referansenummer

164112

Hvilke personopplysninger skal du behandle?

- Navn (også ved signatur/samtykke)
- E-postadresse, IP-adresse eller annen nettidentifikator
- Lydopptak av personer
- Gps eller andre lokaliseringsdata (elektroniske spor)
- Helseopplysninger

Prosjektinformasjon

Prosjekttittel

Exergames - Play to get fit

Prosjektbeskrivelse

Dette prosjektet skal undersøke hvordan spill kan brukes til å gjøre folk mer fysisk aktive og gi dem bedre fysisk helse. Inaktivitet og en stillesittende livsstil er et vedvarende problem for folkehelsa i Norge. Prosjektet vil gjøre dette gjennom utvikling av en spillprototype spill som krever fysisk aktivitet for å spille det (exergame). For å finne ut av om spillet har noen effekt på spillernes fysiske aktivitet vil det bli gjennomført et eksperiment på bruk av spillet.

Begrunn behovet for å behandle personopplysningene

Vi trenger brukernes e-postadresse for å distribuere spill-prototypen og spørreskjemaene for å samle inn data. Brukerens navn vil brukes når testdeltagerne skriver under på samtykkeskjema/informasjonsskriv. Lokasjonsdata vil brukes av applikasjonen, da spillet er lokasjonsbasert og bruker lokasjonsdata til sentral spillfunksjonalitet. Ingen lokasjonsdata vil være direkte koblet mot navn, men kun en tilfeldig generert bruker-ID. Personopplysninger vil lagres separat fra annen data (koblingsnøkkel).

Ekstern finansiering

Type prosjekt

Studentprosjekt, masterstudium

Kontaktinformasjon, student

Haakon Gunleiksrud, haakongunleiksrud@gmail.com, tlf: 95407576

Behandlingsansvar

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

Skal behandlingsansvaret deles med andre institusjoner (felles behandlingsansvarlige)?

Nei

Utvalg 1

Beskriv utvalget

Personer som vil øke tidsbruk på trening/fysisk aktivitet og som vil forbedre sin fysiske helse. De skal gjennomføre et eksperiment (spilltest) og svare på to undersøkelser knyttet til dette eksperimentet, men ikke delta på observasjon/intervuer.

Rekruttering eller trekking av utvalget

Rekruttering skjer i eget nettverk.

Alder

18 - 70

Inngår det voksne (18 år +) i utvalget som ikke kan samtykke selv?

Nei

Personopplysninger for utvalg 1

- Navn (også ved signatur/samtykke)
- E-postadresse, IP-adresse eller annen nettidentifikator
- Gps eller andre lokaliseringsdata (elektroniske spor)
- Helseopplysninger

Hvordan samler du inn data fra utvalg 1?

Elektronisk spørreskjema

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (art. 6 nr. 1 bokstav a)

Grunnlag for å behandle særlige kategorier av personopplysninger

Uttrykkelig samtykke (art. 9 nr. 2 bokstav a)

Redegjør for valget av behandlingsgrunnlag

Elektronisk spørreskjema

Figure E.2: The approved research project application sent to the Norwegian Center for research Data (NSD)

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (art. 6 nr. 1 bokstav a)

Grunnlag for å behandle særlige kategorier av personopplysninger

Uttrykkelig samtykke (art. 9 nr. 2 bokstav a)

Redegjør for valget av behandlingsgrunnlag

Informasjon for utvalg 1

Informerer du utvalget om behandlingen av opplysningene?

Ja

Hvordan?

Skriftlig informasjon (papir eller elektronisk)

Utvalg 2

Beskriv utvalget

Personer som vil øke tidsbruk på trening/fysisk aktivitet og som vil forbedre sin fysiske helse. De skal gjennomføre et eksperiment (spilltest) og svare på to undersøkelser knyttet til dette eksperimentet, og delta på observasjon/intervuer.

Rekruttering eller trekking av utvalget

Rekrutteres i eget nettverk.

Alder

18 - 70

Inngår det voksne (18 år +) i utvalget som ikke kan samtykke selv?

Nei

Personopplysninger for utvalg 2

- Navn (også ved signatur/samtykke)
- E-postadresse, IP-adresse eller annen nettidentifikator
- Lydopptak av personer
- Gps eller andre lokaliseringsdata (elektroniske spor)
- Helseopplysninger

Hvordan samler du inn data fra utvalg 2?

Personlig intervju

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (art. 6 nr. 1 bokstav a)

Figure E.3: The approved research project application sent to the Norwegian Center for research Data (NSD)

Grunnlag for å behandle særlige kategorier av personopplysninger

Uttrykkelig samtykke (art. 9 nr. 2 bokstav a)

Redegjør for valget av behandlingsgrunnlag

Elektronisk spørreskjema

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (art. 6 nr. 1 bokstav a)

Grunnlag for å behandle særlige kategorier av personopplysninger

Uttrykkelig samtykke (art. 9 nr. 2 bokstav a)

Redegjør for valget av behandlingsgrunnlag

Annet

Beskriv

Observasjon under gjennomføring av en spilløkt. Her vil vi se på hvordan personene gjennomfører en spilløkt og notere for å evaluere hvor brukervennlig/fungerende spillet er.

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (art. 6 nr. 1 bokstav a)

Grunnlag for å behandle særlige kategorier av personopplysninger

Uttrykkelig samtykke (art. 9 nr. 2 bokstav a)

Redegjør for valget av behandlingsgrunnlag

Elektronisk spørreskjema

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (art. 6 nr. 1 bokstav a)

Grunnlag for å behandle særlige kategorier av personopplysninger

Uttrykkelig samtykke (art. 9 nr. 2 bokstav a)

Redegjør for valget av behandlingsgrunnlag

Informasjon for utvalg 2

Informerer du utvalget om behandlingen av opplysningene?

Ja

Hvordan?

Skriftlig informasjon (papir eller elektronisk)

Figure E.4: The approved research project application sent to the Norwegian Center for research Data (NSD)

Tredjepersoner

Skal du behandle personopplysninger om tredjepersoner?

Nei

Dokumentasjon

Hvordan dokumenteres samtykkene?

- Manuelt (papir)

Hvordan kan samtykket trekkes tilbake?

Siden personene er i masterstudentenes eget nettverk kan de enkelt ta kontakt via f.eks sosiale medier, telefon eller mail for å trekke tilbake samtykket.

Hvordan kan de registrerte få innsyn, rettet eller slettet opplysninger om seg selv?

Siden personene er i masterstudentenes eget nettverk kan de enkelt ta kontakt via f.eks sosiale medier, telefon eller mail for å trekke tilbake samtykket.

Totalt antall registrerte i prosjektet

1-99

Tillatelser

Skal du innhente følgende godkjenninger eller tillatelser for prosjektet?

Behandling

Hvor behandles opplysningene?

- Maskinvare tilhørende behandlingsansvarlig institusjon
- Ekstern tjeneste eller nettverk (databehandler)

Hvem behandler/har tilgang til opplysningene?

- Student (studentprosjekt)
- Prosjektansvarlig
- Databehandler

Hvilken databehandler har tilgang til opplysningene?

Forms i Office 365 (Kjører innenfor NTNU's SharePoint)

Tilgjengeliggjøres opplysningene utenfor EU/EØS til en tredjestat eller internasjonal organisasjon?

Figure E.5: The approved research project application sent to the Norwegian Center for research Data (NSD)

Nei

Sikkerhet

Oppbevares personopplysningene atskilt fra øvrige data (koblingsnøkkel)?

Ja

Hvilke tekniske og fysiske tiltak sikrer personopplysningene?

- Opplysningene anonymiseres fortløpende
- Opplysningene krypteres under lagring
- Opplysningene krypteres under forsendelse
- Endringslogg
- Flerfaktorautentisering
- Adgangsbegrensning

Varighet

Prosjektperiode

15.03.2022 - 07.06.2022

Skal data med personopplysninger oppbevares utover prosjektperioden?

Nei, data vil bli oppbevart uten personopplysninger (anonymisering)

Hvilke anonymiseringstiltak vil bli foretatt?

- Koblingsnøkkelen slettes
- Personidentifiserbare opplysninger fjernes, omskrives eller grovkategoriseres
- Lyd- eller bildeopptak slettes

Vil de registrerte kunne identifiseres (direkte eller indirekte) i oppgave/avhandling/øvrige publikasjoner fra prosjektet?

Nei

Tilleggsopplysninger

Figure E.6: The approved research project application sent to the Norwegian Center for research Data (NSD)

Appendix F

Complete Observation Report

F.0.1 Observation 1

Test participant data

- Age: 24
- Gender: Female
- Exercise sessions per week: 3
- Physical activity amount per day (minutes): 30
- Likes playing video games: Yes, but doesn't play that much.
- Average time playing video games per day (minutes): 30
- Has played an exergame in the last 12 months: Yes, Beat Saber.

Observation details

The test subject starts the observation by taking a look at the the map view. She finds out that she is missing some time to reach a new exploration status in a neighboring city district, so she starts walking towards it. On the way she does not fight any blobs, but actively follows the city district status screen. She also frequently looks at the leaderboards.

"I like being on the top of the leaderboards".

She says the usually wonders how she is doing compared to other players. When playing she explains that she usually likes listening to an audiobook while she plays, not looking that much on her phone while she plays. She usually just checks which city district she is currently in.

While walking she repeats that her goal is to reach dominated exploration status on the Øya/Elgseter city district. She still does not fight any of the spawning blobws, and she says that she does not feel a need to fight them after she reached level 20 (where the story ends). Her overarching goal is to get as many city districts as possible green on the map. She tries to walk places where she has not walked before to get more unique addresses visited in the current city district. She explains that on a normal walk she would have continued towards the city centre, as she had not played that much there, but as the observation was past the halfway point she started to head back to where we started. She adds that she likes clicking the paint stations.

"It is satisfying to make the gray buckets green."

As we re-enter the Gløshaugen city district she comments that she has already reached conquered status there.

"When I have reached conquered status I don't feel like there is a point in playing here."

She therefore ends the observation at that point.

F.0.2 Observation 2

Test participant data

- Age: 48
- Gender: Male
- Exercise sessions per week: 0-1
- Physical activity amount per day (minutes): 30-60 min
- Likes playing video games: Might like simple games.
- Average time playing video games per day (minutes): Close to 0.
- Has played an exergame in the last 12 months: No.

The test subject opens the game and starts off with a message telling him he has a streak of 4 days. He then taps a paint station that is withing range. While walking he stops to battle all blobs that spawns.

"I'm bad enough at the game that I need to stop to battle the enemies."

He opens the city district status screen and says that he does not really keep a track of the status for different city districts. He does like seeing where he has been though. He checks the leaderboards here and there but says that he is more focused on being in the game and battling blobs than the overarching mission of coloring the map. As a result it does not matter much where he is walking. He is mainly motivated by leveling up.

"When you are about to level up it is hard to stop playing."

He discovers a bug while playing, he is unable to leave the battle scene. He comments that he has not really discovered many bugs while playing. He continues to battle blobs, and says that he thinks the difficulty level is okay for the armored blobs, as he wins some battles but loses others. While walking he also interacts with all paint stations that are close, and takes detours to reach areas with a lot of paint stations. Heading back to where the observation started he wants to take another detour to reach some more paint stations. Just before the observation is over he levels up, which he seems quite satisfied about.

F.0.3 Observation 3

Test participant data

- Age: 23
- Gender: Female
- Exercise sessions per week: 2
- Physical activity amount per day (minutes): 45
- Likes playing video games: Yes.
- Average time playing video games per day (minutes): 120
- Has played an exergame in the last 12 months: Yes, several.

The test subject starts the observation by looking at the map. She has several city districts colored yellow, but none of the green. She says she is motivated by trying to color the map. She checks the leaderboards, and comments that she likes being able to see her own position, even when shes not in the top five. She checks the additional map information to get more information about what the colors mean. She points out that she would have been listening to music if it was a normal play session. While walking she taps the small blobs to defeat them, she says they are satisfying to defeat.

"The smaller blobs are quicker to defeat compared to the large ones, the large ones take to much effort. It also feels like I am squishing them, which is fun."

She still battles a big blob here and there. She comments that she does not like that the camera changes position after a battle is done, saying it makes her a bit disoriented. While she is walking her overall goal is getting to different paint stations. She believes that she needs to interact with the paint stations to increase her exploration status, something which indicates that she has not quite understood how to increase her own exploration status. She comments that she would have liked to see a clock while playing, but realizes that she can drag the header bar of her phone down to see the phone's clock. While playing she also mentions that it is hard to know where the border between different city districts are, she also says she would like a range indicator around her to know when she is in range of paint stations. She opens the city district status again, thinking that unique addresses mean paint stations. While walking there a large amount of blobs spawning, while trying to rotate the camera she clicks one of the blobs by accident. Before ending the observation she reaches level 10, and defeats the second boss on first try.

F.0.4 Observation 4

Test participant data

- Age: 20
- Gender: Male
- Exercise sessions per week: 0
- Physical activity amount per day (minutes): 30
- Likes playing video games: Yes
- Average time playing video games per day (minutes): 300
- Has played an exergame in the last 12 months: No

The test subject starts of the observation by tapping the small blobs that have spawned close to him. He then starts walking towards a cluster of nearby paint stations. While interacting with the paint stations he reaches level 5 and starts battling the first boss. He discovers a bug where the boss is more tiny than intended, but restarts the game and defeats the boss on the first try. Before and after defeating the boss it is noted that he reads all the dialogue presented to him.

After defeating the boss he continues to walk after paint stations, claiming that he wants to complete the local city district. This indicates that he has misunderstood how to increase his own exploration status, falsely believing that paint stations help increase his city district progress. While playing he does not check the current city district status or leaderboards even once. He does stop to fight the newly discovered large blobs however. He starts of by losing to almost all of them, but by the end of the observation he is able to defeat many of them. He comments that he thinks there is a little too many blobs spawning. After taking the last of the nearby paint stations he feels like his play session is complete.

Appendix G

All Game Dialogue

Table G.1: Intro

Scenario	Intro
Who?	Brushy
When?	At the start of the game
Sentences	• Hello, my name is Brushy, and your name is [player username]. Welcome to Trondheim! • Trondheim is not what it used to be. The EVIL Paintavaggio has overtaken the city and painted it boring gray and infested it with paint blobs. Can you help defeat him and bring colors back to the city? • I would love to do this myself of course, but I am just an expositional 2D character with no agency or abilities, so it's gonna have to be you [player name]. It's all up to you! • Let's get crackin, shall we? • **Animation happens** • This is our city, Trondheim. Here you can move around and interact with paint stations along your way. You see those green buckets here and there around you on the map? • By approaching and tapping on a paint station you can get a small amount of exploration points (XP), which will aid you on your journey to defeat Paintavaggio. Death be upon him! • When you explore Trondheim, you will also meet Paintavaggio's EVIL paint blobs. • Try defeating as many of them as you can to lower his power and acquire more XP. Start battling blobs by tapping on the slimy buggers! • As you gain more exploration points, you will level up, and grow stronger. At some point you will be ready to take on Paintavaggio himself! • But beware, the EVIL blobs also get stronger, the more exploration points you aquire! • Now let's check out the map of Trondheim! Press that button in the top left corner!

Table G.2: Tutorial

Scenario	Tutorial
Who?	Brushy
When?	After the player has finished the intro and pressed the map button
Sentences	• This is a map of Trondheim and its colors. You see the different parts of the city and what colors they currently have. I like to call each part of the map a city district. • All the city districts have, as you can see, been painted boring gray by Paintavaggio. But by visiting and exploring each city district, you can give them color and eventually repaint them green! YAAAY! • Right now you can see that the area you are currently in has a bright yellow color. This means you have visited that city district today. City districts which have a darker shade of yellow means you have visited them before, but not today. • When you finally explore a city district, it will become a beautiful green! • But what does explore mean? Try pressing the part of the map you are currently in! • **Player has to tap the current city district on the map** • Here, you see an overview of your progress towards exploring the city district you just tapped on. To fully explore the district you need to fill all of these three green bars! It's a difficult task but I know that a nice can of paint like you can make it! • It might sound daunting, but I feel you are just the right can for the job, [player name]! • By pressing the leaderboard button you can compare yourself to other paint cans fighting Paintavaggio in uhhmm, parallel universes, or something.. • Anyways, you can only check out the leaderboards for city districts you have visited at least once. So let's get crackin! I mean, erhm, exploring!

Table G.3: Small Blob Tutorial

Scenario	Small Blob Tutorial
Who?	Brushy
When?	First time a small blob spawns
Sentences	• "This is one of Paintavaggio's EVIL blobs! This one is not very dangerous, although I don't like them at all, nasty blobses! • Try tapping it to defeat it!

Table G.4: Large Blob Tutorial

Scenario	Large Blob Tutorial
Who?	Brushy
When?	First time entering combat with a large blob
Sentences	• Now this is a Large blob, they are a little more tough than the small blobs you have been fighting this far. Very nasty! • To defeat it you need to hit it with a yellow paint grenade or two! Try throwing it at him! Beware though, you have a very limited amount of grenades, so make them count!

Table G.5: Armored Blob Tutorial

Scenario	Armored Blob Tutorial
Who?	Brushy
When?	First time entering combat with an armored blob
Sentences	• Oh boy, I see you have gotten in a fight with an armored, spiky blob! These are the scariest blobs of Paintavaggio's EVIL blob army. • They have strong, rotating shields to defend themselves. Of course they have shields... It's never easy, is it? • To defeat them you need to shoot green paint rockets past their shields. • Try swiping up, down, left or right to send a paint rocket at them! • But watch out. Bigger blobs are more difficult to defeat! And remember that you still have a limited amount of paint rockets!

Table G.6: First Paintavaggio encounter

Scenario	First Paintavaggio encounter
Who?	Brushy & Paintavaggio
When?	After player reaches level 5
Sentences	• Brushy: "Oh no, he's here!" • Brushy: "If I had inner organs, my stomach would surely be twisting and turning in agonizing anticipation of this coming boss battle. Oh boy!" **Paintavaggio shows up in world scene.** • Paintavaggio: "Someone has been interfering with my plan. Are you the one who has been ruining my beautiful gray paint and defeated my NOT EVIL blobs?" • Paintavaggio: "And who are you? Someone who thinks they are better than me? Well, I'll show you." **Paintavaggio starts following the player in the world scene** **Player clicks him to initiate battle** • Paintavaggio: "What I'm about to do to you, you stubborn, annoying little paint can, I'm gonna enjoy it, very, very much." **If the player loses** • Paintavaggio: "I guess my paint was thicker than yours in the end" **If the player wins** • Paintavaggio: "You got me this time! But I'll be back, and next time I will be much stronger and have new features as abilities!" • Brushy: "Great job [player name], you showed him who's the boss around here! You and me! We're the bosses. Right? • Yeah, that's right! You are my best friend! It's true! It's not bullshit. You are my best friend. You aare! • Anyways, like he said, that is probably not the last time you'll see him, so you should probably get back to farming some more exploration points and getting stronger for your next encounter with him!"

Table G.7: Second Paintavaggio encounter

Scenario	Second Paintavaggio encounter
Who?	Brushy & Paintavaggio
When?	After player reaches level 10
Sentences	• Brushy: "Oh crap, he's back!" • Brushy: "Lock up your lids, he's gonna hit it and quit it!" **Paintavaggio shows up in world scene.** • Paintavaggio: "So you are still focused on ruining everything for me? You realize you are just a bully. And like my father, Bucky, always told me: Bullies always lose in the end." • Paintavaggio: "He also said something about life and chockolates, but I don't remember what it was. Not that it matters. Get ready for trouble, and make it double." • Paintavaggio: "Let's battle!" **Paintavaggio starts following the player in the world scene** **Player clicks him to initiate battle** • Paintavaggio: "You Could Not Live With Your Own Failure, And Where Did That Bring You? Back To Me" **If the player loses** • Paintavaggio: "Haha, told you you would lose. You incompetent paint nugget! Luckily for me, you can't attempt to beat me again, right? Right?" **If the player wins** • Paintavaggio: "Again? It's almost like the game is rigged against me! I will get you some time! This is not over!" • Brushy: "Great, you got him again [player name]! Keep at it, and we can perhaps defeat him for good!"

Table G.8: Third Paintavaggio encounter

Scenario	Third Paintavaggio encounter
Who?	Brushy & Paintavaggio
When?	After player reaches level 15
Sentences	• Brushy: "Oh snap, he's here again! This bucket of nuggets is very consistent, oh boy!" **Paintavaggio shows up in world scene.** • Paintavaggio: "I hope your main motivation for harrassing me is more than just some imaginary exploration points in some stupid game!" • Paintavaggio: "What are you trying to achieve here? You think I am the bad guy? have you ever considered taking a look in the mirror, if you even have one of those where you come from?" **Paintavaggio starts following the player in the world scene** **Player clicks him to initiate battle** • Paintavaggio: "Do your worst... " **If the player loses** • Paintavaggio: "When are you gonna learn, I am inevitable!" **If the player wins** • Paintavaggio: "I hope you step on Legos every day! Not that I know what those are...! Next time we fight, I will crush you!" • Brushy: "I feel like we are starting to approach the end. Great work [player name], we can do this!"

Table G.9: Fourth and final Paintavaggio encounter

Scenario	Fourth and final Paintavaggio encounter
Who?	Brushy & Paintavaggio
When?	After player reaches level 20
Sentences	• Brushy: “It’s time, this is gonna be the final battle, I feel it!” • Brushy: “I can feel Pantavaggio is even bigger and stronger now. But we have to do this. Certainty of death! Small chances of success. What are we waiting for?” **Paintavaggio shows up in world scene.** • Paintavaggio: “I hope it’s worth it, whatever it is you’re doing.. I am going to stop you, even if it’s the last thing I do!” • Paintavaggio: “It’s time for you to explode like a waterbaloon filled with too much paint! An overfilled paintballoon! Haha” **Paintavaggio starts following the player in the world scene** **Player clicks him to initiate battle** • Paintavaggio: “Fun Isn’t Something One Considers When Balancing the world. But This... Does Put A Smile On My Bucket” **If the player loses** • Paintavaggio: ”You Should Have Gone For The Head.” **If the player wins** • Paintavaggio: “Oh no! You got me, again. Who could have predicted this? • Paintavaggio: “My beautiful dream of removing all green paint from Trondheim is no more.“ • Paintavaggio: “Trondheim will never be gray again. Which is my favorite color, by the way” • Paintavaggio: “I hope you’re happy with what you have done. We are quite alike you and I. I am just prettier and have superior character motivations.” • Brushy: “Congratulations, you defeated Paintavaggio, you beat the game! Everything is over!” **The player character is about to speak for the first time** • Player: “No..., I am not done yet.. We are done when I say we are done!. I will not stop until every single part of the map is colored green. No blob will be left alive.. I will get all of them.” • Player: “And not just the armored blobs, but the large blobs and the small blobs too! The blobs are like animals. And I’ll slaughter them like animals! I hate them!” • Brushy: [player name], what are you doing! It’s over! Stop this madness! **The player avatar changes to an evil face** • Player: “No, this is where the fun begins!”

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Paint it Green - Master's Thesis

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